nutrition. What are the concentrations and relations of metals in the green cell conducive to the largest synthesis of sugar permitted by other factors in the environment? Evidence on this point is being developed.

Increasingly, the workers in animal and plant nutrition are finding common interests in their researches on minute factors in cell metabolism. We are beginning to appreciate that the plant does not synthesize vitamins or their precursors merely as a philanthropic act for the benefit of the animal. These substances first of all may have a function in the plant itself. Likewise, many inorganic elements, including at least several of the micro-nutrient elements, are indispensable to plant and animal alike. But the qualitative or quantitative requirements are not always coincident. Investigators are now asking how the environmental factors influencing the composition of the plant are related to its value as a food for animals; in other words, how do climate and soil and fertilizer practice affect nutritional quality? The old problem of iodine deficiency in the animal is too familiar to warrant discussion, save to remark that in recent experiments in Berkeley with several types of plants it has not been possible to show so far that iodine is an essential element for the growth of crop plants, within the limits of technique now available. An interesting example of a differential requirement for plant and animal is that of the cobalt-deficiency disease of sheep and cattle extensively studied in New Zealand and Australia. The cobalt deficiency in certain soils did not prevent pasture plants from growing, but the animals suffered for lack of cobalt in the ration. Apparently deficiency of copper for the needs of animal nutrition may also occur in various regions. Manganese deficiencies require further study.

On the other hand, there exists the possibility that the plant might absorb special mineral constituents of the soil in such amounts as to produce a toxic food stuff. One instance of this kind has been carefully investigated by the United States Department of Agriculture, the South Dakota Agricultural Experiment Station and other research agencies. Some species of plants growing on selenium-containing soils absorb so much of this element that the plant becomes severely toxic to the animal. It is an interesting aspect of plant physiology that ability to accumulate selenium from the same soil medium varies strikingly among different species of plants. We also note that plants may absorb fluorine, arsenic, and other toxic elements, if they are naturally present in, or added to the soil.

The whole subject of soil and plant interrelations in its bearing on problems of animal nutrition has been deemed of sufficient importance to warrant its inclusion as a major research objective by one of the Department of Agriculture's new laboratories. The field is ready to be explored, but only long and patient cooperative research on the part of plant and animal physiologists, soil chemists, and probably plant breeders, can determine the extent of existing quality deficiencies in crops and the feasibility of modifying the quality by commercially practicable procedures. Broad generalizations on this aspect of micro-nutrients are not admissable on the basis of present information.

# SCIENCE IN GENERAL EDUCATION AT THE COLLEGE LEVEL[1]

By Dr. LLOYD W. TAYLOR
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A few years ago the writer was examining the portraits of Sir Isaac Newton in the British Museum. The museum keeps a file of negatives of portraits that are in the greatest demand. In response to an inquiry whether that file included any of Newton, the attendant replied: "Oh, no, sir. We 'as 'em of the fymous men, sir, but not 'im, sir!"

Instances are not lacking of a similar obtuseness on this side of the Atlantic as to the importance of the sciences. It is true that until fairly recent years sciences in American education were riding a strong wave of popular approval which originated in the last quarter of the nineteenth century. But lately there has been a reaction and the trend is now in the opposite direction. This is being reflected in shrinking registrations in all the high-school sciences on a scale which is positively catastrophic. In colleges the corresponding ebb is being stemmed by the science requirement. But pressure is accumulating toward the elimination of that requirement and the contraction of the sciences in the program of higher liberal education will ultimately be the more pronounced in consequence of its deferment.

Two years ago the American Association for the Advancement of Science set up a special committee to try to identify the problems involved in adapting the sciences to the requirements of general education at the college level. Though this paper is in considerable measure an outgrowth of that study, it is in no sense a report of the committee. Some of its subtopics did

[1] Invited paper, given before the American Science Teachers' Association at its meeting at Columbus, Ohio, on December 28, 1939.

not come before the committee at all and others doubtless express sentiments upon which the committee would not be willing to go on record, or from which it might even dissent. The committee is accordingly hereby absolved from responsibility for any deductions drawn, though free use will be made of some of its statistical studies.

"Pearls before swine" is the defense reaction sometimes elicited from teachers who hear of diminution in student favor toward their subjects. But let us hear some reactions that are presumably more carefully considered. Of more than 1,000 college teachers of science[2] who expressed an opinion, more than two thirds felt that their offerings were justifiably less than completely acceptable to students whose interest in the subject was not primarily professional. They felt that general courses in science were being aimed primarily at the minority who were later to specialize, and were disregarding the best interests of the non-specialist majority.

Many things could be said on the bearing of this state of affairs on the downward trend of the sciences in the educational scheme and on what should be done about it, not so much to save the sciences as to save the educational scheme, but this is not the occasion. Some are not convinced that there is any danger of the sciences being eliminated from the general educational program. They possess a facile optimism that the sciences will remain in the education system because society can not exist without science. This is a *non sequitur*. Rightly or wrongly, disillusionment with the laboratory is in the air. Let the facile optimist read only a little history or look around him at contemporary events to see the excesses to which popular disillusionment will carry a mass movement.

In the course of its investigation the committee received replies from college and university teachers of science to another question: "What do you believe are the most significant contributions which a study of (your science) should make to those students who are not to specialize in it?" More than 80 per cent. felt that one of the most important contributions was to develop the ability to think critically. All the rest, except 3 per cent., believed this to be of some importance, though they did not accord it so high a place. This is an interesting response in several respects. For one thing, development of the ability to think critically seems to have been considered the *most* important contribution that the sciences can make to general education, for none of the suggested alternative answers received as large a vote as this and there was no significant trend in the supplementary answers. It is perhaps natural that the physical sciences (physics, chemistry, mathematics) were somewhat more categorical on this point than the others, critical thinking being given first place by an 84 per cent. vote in the physical sciences and a 76 per cent. vote in the others. This seems to accord the palm to the non-physical sciences for the more critical thinking about critical thinking.

This remark is made with some measure of seriousness. The ability to think critically has been the central quest of the educational process ever since education came to be one of the significant cultural values. Unquestionably, the educational process as a whole aids greatly in the development of this desirable trait, but there seems to be a great deal of question about the superiority of any one subject over another in this respect. There is little evidence to indicate that men of science are able to think any more critically about such issues as the complicated political situation in the world at large to-day than are men of equal training in other fields. Let us not forget that two generations ago a virtual monopoly on training in the ability to think critically was declared by the ancient languages. In those days the attempt to develop critical thinking was called "formal discipline." When the bubble of formal discipline was pricked by modern educational psychology, the classics experienced a major loss in prestige, much to the impoverishment of the educational world. The sciences will do well to try to avoid a similar debacle, but they have already gone far toward committing themselves to a parallel educational theory.

Considerable unanimity was reached also on another point. Seventy-four per cent. of those answering the same question, namely, as to the most significant contributions which the study of their respective sciences should make to non-specialists, attributed great importance to making students familiar with the facts, principles and concepts of the science in question. All except 2 per cent. of those remaining felt that this possessed some importance, though they did not accord it as high a place as did the 74 per cent. The importance of subject-matter would seem to be a much more secure position to take than to urge the preeminence of science as training in critical thinking. One can not help connecting the favorable attitude toward the critical thinking question with the large agreement, already commented upon, that our general courses are not as well designed as they might be to meet the requirements of non-specialists. That a good training in subject-matter does promote ability to think critically *about that subject* can scarcely be gainsaid. May not the uneasiness which so many felt about the value of the subject-matter itself have led them to seize upon the critical thinking doctrine to bolster up a waning faith in their present classroom procedures?

This interpretation receives some support in the answers given to another question. Seventy-six per

[2] Statistics compiled by L. M. Heil and P. E. Schaefer, research assistants to the committee.

cent. considered very important the clarification of a point of view for teachers concerning the place of science in general education. Less than 5 per cent. considered it of no importance. It seems fairly obvious that this question would not have been answered that way unless some need were being felt for such clarification. The expression of this need is perhaps the most heartening element in all the labors of the Committee on the Improvement of Science in General Education. One might almost say that the whole, somewhat cumbersome, undertaking could be justified on the basis of that one answer alone. It disposes, at least for the sciences, of an assertion often made that education at the college level is completely in the hands of the ultra-conservatives.[3]

But while conservatives in higher education are not entirely unchallenged, they hold the balance of power. They are, for the most part, men who, primarily subject-matter specialists, as are substantially all who are engaged in college and university teaching, seem to have allowed a natural preoccupation with subject-matter to divert them from problems of how most effectively to administer instruction in such subject-matter. In some cases the preoccupation has been with research; in others, with the training of specialists in their own or allied fields, a very different undertaking than the problem of fitting one's subject into a matrix of general education. Many of these men seem not at all to sense the change in the teaching problem which has been brought about by the great mass movement toward higher education that has occurred in this country during the last fifty years.

One of the committee's observations should be taken to heart by any group of scientists. It is to the effect that the great majority of the "experiments" now under way in the teaching of science at the college level make no provision whatever for controls or any other means of checking the validity of the results. Analogous experiments in the teachers' subject-matter fields would be instantly rejected as yielding no information. Allowance must be made, of course, for the human element in education. Perfectly valid educational objectives do not always lend themselves to scientific approach, and, even more often, the tests of their attainment can not be administered until the student has been out of college for twenty years and even then not by conventional examinations. Teaching, even the teaching of science, is more of an art than a science and will always remain so. But even after all this has been realized, almost any one would be impressed by the almost complete absence of control on the teaching experiments constituting the long list presented to the committee. Many teachers, especially in colleges, do not realize the extent to which techniques have been developed in recent years, capable of measuring with considerable accuracy the degree to which such aims as can be made explicit are achieved by teaching. Many teaching experiments are fading out in futility solely for lack of the application of perfectly feasible tests by which the results could be demonstrated to others.

During its deliberations the committee found itself facing repeatedly the desirability of the establishment of a central clearing house to which teaching problems in the sciences could be brought for bibliographical aid and for information as to unpublished current ventures in other quarters. Such a bureau could reduce duplication of effort, suggest areas which seemed to be unexplored and in general help to organize and vitalize a phase of science teaching which sadly needs cooperative assistance. The present list of teaching experiments could constitute one of the points of departure for such a bureau. While broadcast publication of that list might do more harm than good, the bureau could put it at the disposal of those who were demonstrably in a position to profit by its use. Another type of working material which the committee would add to the assets of such a bureau would be the bibliography, compiled for the use of the committee, consisting at present of some 600 entries, about half of them annotated. The present indication is that the function of a central clearing house of this nature can be performed by some one of several appropriate agencies already in existence. Arrangements to that end are already under way and when completed will be announced.

There are those who deprecate any suggestion that the mode of presentation of the sciences should be changed to adapt them to the changing requirements of higher education. This attitude seems to be taken partly because the individual is not convinced that the sciences have anything to gain by such a change, and partly through a fear that academic standards will be jeopardized by such a change. Both of these objections are understandable and merit a candid reply.

First, let it be realized that any suggested reformulation of science instruction applies only to a limited portion of the science student body. Only terminal first-year courses are under discussion. We are considering solely the requirements of students for whom the general course will constitute the only experience in that field. Whatever revision in the conduct of pre-professional courses may be appropriate is no concern of the present inquiry. We are dealing only with the reformulation of science instruction for the pur-

[3] See, for example, Constance Warren's new book, "A New Design for Women's Education" (Frederick A. Stokes Company, 1940). The following quotation supports this thesis (page 263): "The medieval cap and gown is not only picturesque, it is too often dangerously symbolic. . . . (College) teaching is the one profession which has never felt the obligation to be abreast of the times."

poses of general education. That is, however, no small undertaking. Thanks partly to the science requirement, it involves the majority of students in the liberal arts.

Second, there is no implication that the science courses, as reformulated for this group of students, should be on an intellectual plane that is one whit lower than that upon which the conventional courses are pitched. On the contrary, any error that is made in judging this level should be on the side of the arts science courses requiring more rather than less ability and application on the part of the student than the pre-professional science courses. An amazing wall of resistance has been built up against experimentation in this field on the assumption that any such venture is necessarily in the direction of relaxation of intellectual standards. The damaging part of that assumption lies in the fact that so many teachers who have ventured into this field have themselves apparently had the same feeling, with the inevitable result that the courses which they have evolved have been open to serious criticism on the basis of their superficiality. Teachers who have taken this position have done a major disservice to the cause which they have been attempting to serve. It should be quite clear that, at a time when any effort in this direction, however meritorious, is bound to come under fire from the conservative element, they have given their critics the best possible ground for the most devastating form of criticism. I can see no escape from the conclusion that mere prudence, if no other factor, must result in pitching any modification of the traditional science courses on a plane well worthy of the mettle of the best students. Any attempt which is based on an assumption that the general level of ability of those who are not expecting to continue with the subject is less than that of those who are, is doomed to ultimate failure.

A third difficulty is perhaps a subhead of the second. It is the feeling that to convert the conventional general course in science to one adapted to general education, about all that needs to be done is to omit some of the more technical material. The whole sorry scheme of starred paragraphs in text-books is an outgrowth of this misapprehension. It should scarcely be necessary to remark that this is attacking the problem at precisely the wrong end. Our students are human beings, candidates for *general* education, before they are engineers or physicists or zoologists, candidates for *professional education*. If the preparation of either is to be the more extensive, it should be that of the candidate for *general* education, with starred paragraphs in *his* text-book to limit it to the narrower requirements of the specialist. It would probably be more discriminating, however, to recognize that each group has its peculiar requirements, and that any attempt to overlap the two, at least without supplementary separate instruction, is certain to prejudice the interests of one group or the other.

This brings us to the main point: What really is the central objective of the sciences as curricular elements in general education? One of the implications of the foregoing paragraph was that science courses for general education should be more extensive than they are usually found to be; that they should give more attention than they now do to the requirements of general education at the college level. It is entirely fair to require any one who subscribes to this assertion to justify it. There is some ground for a contention that the sciences have done very well by themselves through staying in their own technological back yard. Why worry about what the neighbors think? Let us continue (so we are urged) the strategy that has been so productive up to the present. This "isolationist" point of view is very old. Consequently the opinions of many men, both in and out of the sciences, are available on the issue thereby raised. I shall make use of these wherever it seems appropriate.

We live in what is frequently termed the scientific era. General education rightfully looks to the sciences to show why this is a correct characterization and what such a characterization implies. Unless the sciences live up to this responsibility, society will lose sight of the real place of science in the social order. Lord Acton once said:[4]

> There may be, perhaps, a score or two dozen decisive and characteristic views that govern the world, and that every man should master in order to understand his age.

Lord Acton would surely have included a comprehension of the scientific method as one of these views, the one which takes a place of precedence in understanding the present age. Yet how much real comprehension of it does the average educated man possess? R. E. Lee answered the question four years ago in this way:[5]

> In spite of the fact that science has tinged every aspect of the world, the attitude of the man who lives on Main Street toward scientific knowledge is highly capricious and varied. In one breath he proclaims the pure scientist as a highbrow and an impractical theorist; in another he anathematizes him for disturbing the social order and blasphemously undermining his religious beliefs; but at the mention of a name like Edison, he conjures up a sort of superman, before whom he falls in a sort of coma of veneration. At one moment this resident accepts unquestioningly a knowledge he does not fully understand, yet at another he is thrown into a hysteria by the challenge of one of its basic conceptions. Such contradictory mental attitudes may be traced not infrequently to the failure of

[4] Quoted by President Conant. President's Report, p. 10, March 1, 1937.

[5] "Man the Universe Builder," p. 37, Williams and Wilkins, 1935.

individuals to grasp the real *meaning* of science. To be *appreciative* of the merits of science is something more than to be merely *impressed* by its achievements.

One may agree with Lee and yet not concede that it is the proper function of the *sciences* to provide this element of comprehension of the scientific method. There are those who maintain that interpretation of science is the function of philosophy rather than of science itself. This has been tried, however, and found wanting, partly on account of lack of an adequate knowledge, on the part of philosophers, of subject-matter in the fields which they were attempting to interpret, though I suspect that this is not the deepest seat of the trouble. In any case this condition is destined to become worse instead of better as the sciences steadily become more complex. It is growing clear that the interpretive responsibility must be discharged by the sciences themselves if it is to have any chance of being done well. Frederick Barry says:[6]

> The ultimate establishment of more liberal elementary courses in science can not be avoided. It is necessary to our purpose that the humanistic liberalization of scientific studies be powerfully advocated and actively encouraged and at once; for the obvious reason that we must depend on the scientists to devise our basic cultural courses in science.

H. D. Gideonse, formerly of Chicago, recently appointed to the presidency of Brooklyn College, remarked a year ago:[7]

> Science as usually taught to liberal arts students emphasizes results rather than methods, and tries to teach techniques rather than to give insight into and understanding of, the scientific habit of thought. What is needed, however, is not a dose of metaphysics, but a truly humanistic teaching of science.

We will all admit that we are at present very inadequately trained to make the contribution which Gideonse suggests. We in the colleges are primarily subject-matter specialists and only secondarily educators. This has in large measure been brought about by the adoption of the Ph.D. fetish in higher education, together with the narrowness of the qualifications that graduate schools have established for the doctorate. With the best will in the world, even in the case of one who resolutely puts behind him all conscious consideration of professional recognition and advancement, it is very difficult to give the same heartiness of effort to the non-specialist majority that is spontaneously lavished on the specialist minority. To overcome this tendency will require a pronounced about-face by college teachers of science, but it must be overcome, and our curricular offerings be enriched, if the sciences are to continue as a major factor in the scheme of general education. President Emeritus Neilson has recently said:[8]

> Especially in the natural sciences is it the case that the temptation to early and intense specialization has produced a specialist capable of training other specialists, but ill adapted to educating youth between seventeen and twenty-two.

It is still possible for the doubter to demand a bill of particulars. What is the nature of the humanistic element that is thus to be injected into our science teaching? How can it be acquired and transmitted? These, too, are fair questions, but the statute of limitations confines me to a woefully inadequate answer. One could scarcely do justice to the subject in less than a whole address or, better, yet, a whole book. But briefly, of several possible approaches to this problem, the one that impresses me as the most promising is, while retaining substantially the present arrangement of general courses in the sciences and the basic alignment of subject-matter in each course, to place that subject-matter in a setting of the history of its development. In my extremity, let me once more invoke the statements of others on this point.

President Conant recently said:[9]

> Much of the significance of accumulated knowledge lies in an understanding of the process by which it was accumulated.

Ernst Mach once said:[10]

> The historical investigation of the development of a science is most needful, lest the principles treasured up in it become a system of half-understood prescripts or, worse, a system of prejudices. Historical investigation not only promotes the understanding of that which now is, but also brings new possibilities before us by showing that which exists to be in great measure *conventional* and *accidental*. From the higher point of view at which different paths of thought converge, we may look about us with freer powers of vision and discover routes before unknown.

A. S. Adams asked five years ago:[11]

> Can we not lead the student to a greater appreciation of the significance of science by acquainting him with the toilsome thought that has gone into the discovery and confirmation of the scientific facts that we accept so readily? . . . In order to have real meaning, the student's growth in the knowledge of a science must bear some relation to the growth of the science itself.

Wilhelm Ostwald once remarked:[12]

> While by the present methods of teaching, a knowledge of science in its present state of advancement is imparted very successfully, eminent and far-sighted men have re-

[6] "The Scientific Habit of Thought," p. 321, Columbia University Press, 1927.
[7] *Bul. Am. Assn. Univ. Profs.*, 24: 376, 1938.
[8] *Bul. Am. Assn. Univ. Profs.*, 25: 591, 1939.
[9] *Bul. Assn. Am. Colls.*, 23: 43, 1937.
[10] "The Science of Mechanics," p. 225, Open Court, 1907.
[11] *Am. Phys. Teacher*, 3: 62, 1935.
[12] Quoted in preface to F. Cajori, "A History of Physics," Macmillan, 1929.

peatedly been obliged to point out a defect which too often attaches to the present scientific education of our youth. It is the absence of the historical sense and the lack of knowledge of the great researches upon which the edifice of science rests.

It should not be invidious to point out that the historical approach is especially appropriate to the teaching of physics and astronomy. It fell to the lot of these sciences to meet the full impact of authoritarianism in the sixteenth and seventeenth centuries. They thus became the focus of the various points of view which converge into the scientific method. But the pattern of thought thereby established became general only because the other sciences moved into their appointed places. The heritage of physics and astronomy belongs as much to biologists and chemists and geologists as to physicists and astronomers. The recognition and exploitation of this heritage is a resource which is being sadly neglected.

One final point: In urging the appropriateness of more emphasis on the historical element in science instruction, I am not suggesting a substitution of the *history* of science for the *study* of science itself. On the contrary, such a venture, to be successful, must hew pretty much to the conventional line of subject-matter already in vogue. But the stage should be set with historical wings and backdrops. As subtopics are taken up in the usual order, the story of their development will shed a new light, not only on their present significance as scientific concepts, but on how they contributed to the birth of the sciences and to the dawning of the scientific era. When the subject is developed in this way, the time involved is not at all proportional to the extra ground covered, since in the main the process consists of rearranging, from another point of view, material already involved or implied in the traditional science courses.

Neither do I take the position that the historical approach is the *only* way in which the sciences can adapt themselves to the requirements of general education which are pressing in on us with ever greater and quite proper insistence. I am sure that there are other ways. But, to me, it seems the solution lying most readily at hand and which can be exploited to the best effect. But whether that method or some other is adopted, a heavy responsibility rests upon college and university teachers of science to adapt their offerings, in one way or another, to the changing requirements of a rapidly evolving educational pattern. The American mass movement toward higher education has no parallel. We have no precedents to guide us. But we shall be wise, perhaps with the wisdom of self-preservation, if we recognize this new responsibility and marshall all our resources to meet it.

# SCIENTIFIC EVENTS

## CONFERENCES IN BIOCHEMISTRY AT THE UNIVERSITY OF CHICAGO

A GROUP of lecture-conferences in biochemistry, dealing with endocrinology, physiology and the chemistry of vitamins and enzymes, to be held under the auspices of the department of biochemistry of the University of Chicago on June 25, 26 and 27, and on July 9, 10, 15, 16 and 17, has been announced by Dr. E. M. K. Geiling, professor of pharmacology and chairman of the department.

Visiting professors at the summer quarter of the university will conduct the meetings. Among the speakers will be Dr. C. N. H. Long, Sterling professor of physiological chemistry of the School of Medicine of Yale University; Dr. E. A. Doisy, professor of biological chemistry of the St. Louis University School of Medicine, and Professor James B. Sumner, professor of biochemistry of Cornell University Medical College.

The program of the series is as follows:

June 25, 26, 27, Professor Long: Effects of Hypophysectomy and Anterior Pituitary Extracts on Metabolism; Effect of Adrenalectomy and the Adrenal Cortical Hormones on the Metabolism of Carbohydrates and Proteins, and the Interrelationship of the Pancreas, Adrenal Cortex and Anterior Pituitary Cortex as Exemplified by the Study of Experimental and Clinical Diabetes Mellitus.

July 9, 10, Professor Doisy: Vitamin K: Assay, Purification and Isolation; Vitamin K: Constitution of Vitamins $K_1$ and $K_2$ and Related Compounds Having Vitamin K Potency.

July 15, 16, 17, Professor Sumner: Development of Present-day Ideas as to the Chemical Nature of Enzymes; the Properties, Preparation and Chemical Nature of Catalase, and Recent Progress in Enzyme Research.

All conferences will be held in Eckhart Hall from 7 to 9 P.M.

## HONORARY DEGREES CONFERRED BY NEW YORK UNIVERSITY

HONORARY degrees were conferred by New York University on the occasion of its hundred and eighth commencement exercises on June 5 on Dr. N. B. Van Etten, of New York City, president of the American Medical Association; on Dr. John Philip Hogan, president of the American Society of Civil Engineers; on Dr. Gano Dunn, president of the J. G. White Corporation, New York City, and on Dr. Frank Aydelotte, who recently retired as president of Swarthmore College to become head of the Institute for Advanced Study at Princeton, N. J. The candidates were presented to Chancellor Harry Woodburn Chase by the secretary of the university, Harold O. Voorhis. The citations follow: