Quatrefages has shown in the case of the *Teredo,* as did formerly Prevost and Dumas with other animals, that more than one spermatozoon is requisite to fertilize an ovule. This has likewise been clearly proved by Newport, who adds the important fact, established by numerous experiments, that, when a very small number of spermatozoa are applied to the ova of *Batrachians,* they are only partially impregnated, and the embryo is never fully developed; . . . With respect to plants, nearly the same results were obtained by Kölreuter and Gärtner. . . . The pollen-grains of *Mirabilis* are extraordinarily large, and the ovarium contains only a single ovule; and these circumstances led Naudin[3] to make the following interesting experiment: a flower was fertilized by three grains and succeeded perfectly; twelve flowers were fertilized by two grains, and seventeen flowers by a single grain, and of these one flower alone in each lot perfected its seed, and it deserves especial notice that the plants produced by these two seeds never attained their proper dimensions, and bore flowers of remarkably small size. From these facts we clearly see that the quantity of the peculiar formative matter which is contained within the spermatozoa and pollen-grains is an all-important element in the act of fertilization, not only in the full development of the seed, but in the vigour of the plant produced from such seed.

The following is Mendel's own story of his experiment:[4]

Because of my eye trouble, I was unable last year to undertake further hybridization experiments. Only one experiment appeared to me so important that I could not make up my mind to postpone it to some later date. It deals with the view of Naudin and Darwin that a single pollen-grain is not sufficient for an adequate fertilization of an egg. As experimental plant I used *Mirabilis Jalappa,* as did Naudin; the result of my experiment, however, is an entirely different one. I obtained from fertilization with single pollen-grains eighteen well-developed seeds and from them as many plants, ten of which are already in bloom. The majority of these plants are just as fully developed as those derived from free self-pollination.

A few specimens, however, have until now lagged somewhat in growth, but to judge from the success of the others, the reason can only be found in the circumstance that all pollen-grains do not possess the same faculty to fertilize; and, furthermore, that in these particular experiments the competition of other pollen-grains was excluded. Where several compete, we may assume that always the strongest succeeds in alone effectuating the fertilization. However, I intend to repeat these experiments; also one should be able by an experiment to ascertain directly whether in *Mirabilis* it is possible for two or more pollen-grains to participate in the fertilization of one egg. According to Naudin at least three would be required!

TAGE U. H. ELLINGER
U. S. DEPARTMENT OF AGRICULTURE
GRADUATE SCHOOL

[2] Charles Darwin, "Animals and Plants under Domestication," Vol. 2, Chapter 27, pp. 435–436, 1868.

[3] M. Ch. Naudin, "Nouvelles recherches sur l'hybridité dans les végétaux," *Nouvelles Archives du Museum d'Histoire Naturelle,* Paris, Vol. 1, pp. 35–37, 1865.

[4] Excerpt from a letter written by Gregor Mendel to Carl Nägeli, dated July 3, 1870. (Translation from German.)

FACILITATE HUMAN ENDEAVOR THROUGH COLLEGE TRAINING IN SCIENTIFIC METHOD

DR. ANTON J. CARLSON makes several points in his statement about Dr. Cattell's service to science[1] that need a lot more emphasis: (1) "Scientific method should be applied to all fields of human endeavor; (2) education (even in the sciences) is largely memory conditioned by traditions and faith rather than by the exercise of reason based on understanding; (3) human curiosity, human want and human pain are potent spurs; (4) keep your mouth shut and your pen dry till you know the facts."

Most of us will agree with the good doctor "that all men should have a good workable knowledge of scientific method," but he would be the first to point out, I am sure, that thus far the percentage of men who could thus qualify would be very small indeed.

The scientific attitude or viewpoint is comparatively rare, my observation forces me to say. The responsibility for this rests, in part, on our schools and colleges —or on what Dr. Carlson calls "the 'Quiz Kid' ideal of *what* rarely proceeding to the *evidence* and the factual *why.*"

To capitalize on human curiosity, instead of stifling it as happens so often in our schools now, I suggest that our colleges offer a full year's course in "Scientific Methods," and that such a course be required of all freshmen.

The accompanying outline covers the essentials of such a course, I submit, because it is basic, fundamental, broad in scope and provides orientation through the active participation of leaders in the various fields of endeavor. It is my thought that every college student should get an idea (1) of the mechanics of thinking, analysis or research, both technical and market; (2) of what is being done in research in biology, chemistry. geography, physics, marketing, etc.; (3) of statistics, semantics, logic; (4) of personal aptitudes; (5) and that he should learn when to keep his mouth shut.

A Tentative Outline of a Year's Course in "Scientific Method":

(1) Spirit and basic principles of scientific inquiry (2).
(2) Current research activities, needs, opportunities (4).
(3) Isolation and statement of problems (1).
(4) Technical and market research methods, public opinion polls (6).

[1] SCIENCE, 99: 2565, 158, 159.

(5) Sources of research material (1).
(6) Readings in literature of research.
(7) Orientation in the various sciences and fields of endeavor (9).
(8) Aptitude tests and personal problems (2).
(9) Elementary principles of statistical methods (4).
(10) Semantics (4).
(11) Logic—with particular reference to fallacies (2).
(12) Presentation of research reports (1).

Obviously, such a course could not be handled by any one instructor; it should be handled by the leaders or best speakers in the various fields. One of the by-products of this would be considerable vocational orientation or guidance.

The numbers in parenthesis cover, tentatively, the number of weeks' study that I would devote to each of the various general topics.

This course is not presented as a panacea or cure-all—but it can help do some of the things that James McKeen Cattell fought for for over fifty years—and which Dr. Carlson advocates to-day—extend the use of scientific methods.

K. C. RICHMOND

CHICAGO, ILL.

STARRING SUBJECTS IN "AMERICAN MEN OF SCIENCE"

IN view of the long service rendered by J. McKeen Cattell to science in our country it would seem appropriate to devote considerable space to his life work in SCIENCE. I would be especially interested in a discussion of the advantages of starring men in "American Men of Science." It seems to me that it is very important for the progress of science that the achievements of those working in this field should become known more widely and more reliably than is now customary.

If the methods adopted by J. McKeen Cattell can be replaced by better ones it is highly important that this should be done. I realize that it is very difficult to find methods of procedure which will be generally acceptable, but this does not seem to be a sufficient reason for not considering the possibility of improvement. I have heard many favorable comments on the success of J. McKeen Cattell along this line, and it seems to me that we could honor him mostly by considering the possibility of improvements of his methods.

G. A. MILLER

SCIENTIFIC BOOKS

WILLARD GIBBS

Willard Gibbs. By MURIEL RUKEYSER. xi + 465 pp. New York: Doubleday, Doran and Company, Inc. $3.50.

I HAVE always found it hard to write about Willard Gibbs. Neither my brief biographical sketch in the Dictionary of American Biography nor my Gibbs Lecture before the American Mathematical Society seems to me quite satisfactory. It may be a significant fact that in the forty years since his death none of his pupils, colleagues or friends have written so extensively about him as an English science writer, J. G. Crowther, or a native poet, Miss Rukeyser, whose whole background seems very remote from that of Gibbs.

There are two excellent biographical notices of Willard Gibbs. The one first published is by H. A. Bumstead, his pupil and colleague for the last decade of his life; it prints fifteen pages at the head of the first volume of "The Scientific Papers of Willard Gibbs." The second is by C. S. Hastings, who was his pupil during the first year of tenure of his professorship of mathematical physics, and who, except for a brief period of service away from Yale, was his colleague until the time of his death; it fills about twenty pages of volume 6 of the "Biographical Memoirs" of the National Academy of Sciences. These two notices represent Gibbs as I knew him better than I can; they deserve the most careful study by all who would know him as he appeared to his contemporaries, old or young.

The sixty-five pages Crowther devotes to Gibbs leave me rather cold. They constitute an interpretation rather than a biography, and much of the interpretation seems very dubious. The start is from: "The problem of Gibbs is the discovery of the explanations of his simultaneous greatness and obscurity, the nature of his own work, the influence of his personal psychology and social environment, and the social history of the United States."

One who sets himself such a task can hardly do otherwise than mold objective facts to his subjective philosophies. So far as I can see, Gibbs never suffered obscurity in matters that really counted—professor at 32, subject of Maxwell's praise at 35, elected to the National Academy at 40, called to Johns Hopkins a year later, recipient of the Rumford Medal within another year, he seems not at all to have suffered the fate of Gregor Mendel or Hermann Grassmann.

Later Crowther writes: "Is it possible that Maxwell's intelligibility was a reward for social conscience, and that Gibbs's unintelligibility was a penalty for the belief that he had no duty to ensure that his discoveries were understood and used?"

As to intelligibility or unintelligibility let me say that in the days when I was teaching Maxwell's electromagnetic theory and Gibb's thermodynamics I cer-