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SELECTION AND TRAINING OF STUDENTS FOR INDUSTRIAL RESEARCH[1]

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IN selecting college graduates for industrial research, certain qualities are sought. Not all these qualities are the product of college training, but many of them might be. The purpose of this discussion is to inquire whether colleges could contribute more to this total training.

The qualities which are needed for success in industrial research may be classed in four groups. They are, in order of importance, character, aptitude for research, attitude toward work and knowledge.

CHARACTER

Character is the most important qualification. It is rated first in the hiring and retaining of personnel. I shall not try to define character; the many virtues which it comprises include self-discipline, courage and tolerance, all of which are needed in industrial research. It also includes honesty and generosity. Honesty is more than the negative virtue of not telling lies. Positive honesty is the quality that enables you to say of a man, "I always know just where to find him." It is the basis of true friendship and teamwork, and hence is an essential requirement in a cooperating group. The honesty of research workers, however, must be even greater than this. They not only must not deceive others but must not deceive themselves, for the greatest scientific sin is wishful interpretation of data. It is more common than is generally realized, and is so serious that it can reduce a research worker's value to the vanishing point. The man who is more anxious to prove that he is right

[1] Vice-presidential address before the Section for Physics, American Association for the Advancement of Science, Cleveland, 1944.

than to find the truth will nearly always arrive at a conclusion in accordance with his wishes. His observational values will be shaded, without intentional deceit, to agree with preconceived ideas, and he may even see things that are not there. A deeply grooved habit of scientific honesty, of facing the facts impartially, is more important than knowledge to a research worker.

Generosity, an old-fashioned virtue, is also necessary in the modern research laboratory. It is essential for cooperation, without which a laboratory to-day is primitive. Cooperation is a two-way flow; one can not expect to receive it without giving it freely and generously. It is important that this spirit prevail throughout the group, for one or two ungenerous men can poison the mutual confidence in a laboratory. Jealousy and greed and suspicion are weeds that grow easily, while cooperation is a delicate flower. Sometimes it is possible to isolate a single individual of exceptional qualifications and treat him as a prima donna, but only a genius is of much value as a prima donna. As a rule, no laboratory can afford to hire men who lack the generous spirit of cooperation.

If this analysis is correct, and character is the most important qualification of research workers, then it should be a prime objective of any educational system. Is it, in fact, the prime objective of our colleges to-day? I think all colleges would answer "Yes" to this question, but would have to admit that only a very small fraction of educational effort is devoted to it, because of lack of an accepted method of character training. Admittedly it is the most difficult as well as the most important of educational tasks. But when have universities shrunk from a task because it is difficult?

I am making this plea in the belief that what is needed is emphasis. War has taught us that tasks which seem impossible can be accomplished if given sufficient priority. Although this problem is being studied fundamentally by psychologists, and a better understanding of it may be hoped for eventually, we could, in the meantime, make greater use of what psychology has already taught. We know that character is neither inherited nor taught by precept, but is the product of self-discipline under the stimulus of environment. In earlier days the predominant environment was the home; to-day it is the school. For better or worse, we are "molded to manhood" under the influence of teachers and fellow students. Therefore, I plead for more consideration of character in the selection of faculty and students. Hard as it is to judge character, if we put it first as an entrance requirement, a much better job of selection could be done. To-day industrial laboratories put more emphasis on character in the selection of personnel than colleges do. It should be the other way around, since the college has the greater influence in molding men. Why not expend as much effort toward finding out whether applicants for admission have desirable character, as in scholarship tests? Some one may object that this is undemocratic, but it is not any more so than refusing entrance to the scholastically unfit. And education's method of raising the standard of scholarship by denying privilege to the unfit, is likely to succeed also in raising the standard of character by denying privilege to the ethically or morally unfit.

APTITUDE

Next to character, ability is the quality that is looked for in research men. For scientific work this means, of course, scientific ability or aptitude for research; its absence does not necessarily indicate lack of ability in other lines. The inborn aptitudes needed for research include imagination, analytical power and curiosity.

Imagination, the power to visualize situations and foresee possible consequences, is a prime requisite for pioneer research work. Without it a man can solve only the problems which are given him. He may be a useful man in a laboratory, but will seldom make discoveries. As a result, he is likely to be dissatisfied with his accomplishments in research, especially if he possesses other abilities, such, for example, as would make him a successful engineer or business man.

The power of analysis often is identified with ability. It is the power to size up a situation. By virtue of this gift the physicist is a problem-solver. Without it a man draws a wrong conclusion, or no conclusion at all, from every experiment. His advancement will be slow and he is likely to be dissatisfied, if he has skills that would enable him to excel in some other profession.

Curiosity is the most important research quality, in the opinion of one of the greatest pioneers of industrial research, Dr. W. R. Whitney. It is the quality that motivates research-for-the-fun-of-it. Nature is full of interesting problems to one who is endowed with this quality. If, in addition, such a one possesses the ability and character needed to make his research efforts bring satisfaction, and if, then, he is paid a salary for doing the thing he likes best to do, he is properly placed. I personally believe that every man has some useful ability or skill which gives him this kind of pleasure, and that each one could be properly placed.

The university's function in regard to ability is guidance. This is recognized by all colleges, and advice and placement are considered part of their responsibility. But it should be a much larger part, if the relationship between correct placement and happiness is as intimate as I have indicated. By placement I mean finding the right kind of activity rather

than getting a job. Few young men know what they want to do. They enter college with the question, "What have you?" The function of broad education is to show them what treasures of activity life holds; and to give them opportunity to try these different activities and find which ones gives them satisfaction. The time is short and the range of subjects is long. A correct placement can be found in four years only with the help of sympathetic and alert guidance from teachers, to see that undue time is not wasted in following false trails. More is involved than mere loss of time; for if a certain line of training has been followed to the degree stage, and then is found unsatisfactory, it is very difficult to make a change. The man feels impelled to follow a career that "makes use of his education."

I have purposely emphasized the importance of activity, rather than mere learning, as a goal in education. Much has been written about the treasures of knowledge—science, history, literature, philosophy—that a college should offer, in all of which I concur. But coincident with learning about these things, there should go the assessment of one's ability to contribute to them. The greatest satisfactions in life come from accomplishment, and such accomplishment is possible only in the line of one's greatest aptitude. Should not, then, the greatest emphasis in education be on learning *to do* by experiment—trying one's wings, so to speak? The broad college curriculum is ideally adapted to help each man determine what to do, provided sufficient emphasis is given to this objective. This is the first step toward correct placement. When men reach the professional-training stage, a second task devolves upon the university to advise and "screen" them, lest they choose wrongly because of ignorance, or from false standards, rating salary considerations above aptitude and congeniality. More careful screening at this level would be a great service to industry and could save many human tragedies.

ATTITUDES

While aptitude can only be recognized, attitudes can be taught, and, next to character, they constitute the most important product of education. This is no new doctrine; the greatest Teacher of all time taught that "As a man thinketh in his heart, so is he." Industry to-day is more interested in what a man thinks in his heart, that is, in his attitudes toward his work and his subject and his fellow men, than in what he knows. If he loves his work, so that days are too short, and has a passionate desire to know, which drives him to read and study, he will soon outstrip the most erudite pedant. This is especially true in the field of research. University training at best is too brief to provide more than a small fraction of the knowledge that is needed to make a good research man. The rest must be acquired during his career by continuous study. The opportunities are ample: books, fellow workers, up-to-date magazines and frequently study classes, sometimes sponsored by management but often organized and conducted by fellow workers. In emphasizing this self-education, I do not mean to underestimate the value of university training. The university has the task of imparting these attitudes which make self-education possible, and grooving them deeply so that they will endure. But it should not be forgotten that the *attitude* is the real goal of the training.

With this analysis every teacher and administrator will unquestionably agree. But most will also agree that attainment of this objective falls far short of the goal. The criticism does not apply to graduate schools, which on the whole, are doing an excellent job of imparting correct attitudes. Their success may be attributed partly to small classes, allowing personal contact with teachers; but mainly, I think, to the influence of fellow graduate students, who, having caught these attitudes from good teachers in the first instance, transmit them from class to class by infection.

It is this factor of student influence which also accounts for the relatively poor attitude toward work and study in most undergraduate schools. The "spirit" of a college is a living thing, which persists, transmitted from class to class, through decades and even centuries. Its persistence is one of the great factors in education, for the influence of fellow students is a more potent educational force than books or teachers. It is, on the whole, a healthy influence; but it is not often a scholarly influence. I believe that this attitude, caught from fellow students, spells the principal handicap in research work of the B.S. graduate compared to the man who has done graduate work. It is not so much the additional knowledge obtained in advanced graduate study as the changed attitude toward study that enables the one to advance without limit, while the other often reaches an early ceiling. Could this be changed? Could the *desire for knowledge* be attained at the undergraduate level?

There are other attitudes, toward work and play and friendship and tolerance, which the research worker needs, that also are products of group influence. Character, too, is molded by this influence. How can this all-powerful group spirit be controlled and molded? I shall suggest only one method, the method that works in industrial laboratories, namely, leaven. The beginning must be small—a qualified teacher with two students, then four, then eight, expanding only as fast as new members can be infected with the spirit of the group. Such a group might start within the walls of an established college, and as it grew could eventually become strong enough to leaven the whole college. It is a slow process, but the stakes are high. It might be worth trying.

KNOWLEDGE

Last and least of these four qualifications comes knowledge. But it is last only because of the high valuation of the other three, not because it is unimportant. The obtaining of new knowledge is the chief aim of research, and the accumulated knowledge of the past is its working capital. Moreover, the pursuit of knowledge furnishes the training ground on which the qualities of character and attitude are forged.

Science faculties to-day are giving a great deal of thought to the question: "What kind of knowledge is required for industrial research?" I shall attempt to answer this question.

From the standpoint of the laboratory with a long-range research program, the answer is: First and most important, fundamentals—as broad a range as possible. The reason for this is that the research man must be prepared to tackle more than one kind of problem. Research horizons expand, giving birth to new projects and making those of yesterday obsolete. In addition to this broad training, a man must master some one subject and become an expert in it, as part of his training, but *it matters little what that subject is*. For example, men trained in physical chemistry have made excellent physicists, and have become expert in such fields as high frequency electronics within a few months. Similarly, specialization in nuclear physics is a satisfactory training for industrial physics, provided it is combined with broad fundamental training.

For short-range research projects, the requirements are different. Here a man is hired to solve a particular problem or work on a particular type of development, with less emphasis on long-range usefulness. The requirements in this case are *training and expert knowledge in this particular field.* Broad fundamental training still is desired, however. The difference, therefore, is essentially only in the subject chosen for specialization; in the case of preparation for short-range research, the subject should be one for which there is a current demand.

SUMMARY

To summarize, I have tried to suggest that knowledge, valuable as it is, is not considered the most important qualification for industrial research. Character, aptitude and attitudes are more important. Should they not be rated so in the college educational program? Aptitude, though it can not be trained, can and should be screened by the college more than is done to-day, to avoid the lifelong disappointments of misplacement. Character and attitudes actually are molded by college influences, for better or worse, and therefore are products of college life and are the responsibilities of the college, just as much as scholarship. The fact that the molding influence is the student body, more than the faculty, makes the problem different from that of scholarship, and a different method must be found for dealing with it. Could a method be found if sought with sufficient effort? To-day we give it low priority, devoting only a small fraction of college effort to it. Why?

A STIMULUS-EXPECTANCY NEED-CATHEXIS PSYCHOLOGY[1]

By Professor EDWARD CHACE TOLMAN
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AT the time I sent in the peculiar title of this paper obviously I was suffering from mental obfuscation. However, in the intervening four or five months my mind has had time, I hope, to clear. In fact, I now seem actually to have discovered what the paper is to be about and to have invented a quite normal title for it, to wit: "The Contribution of Rats to Human Psychology."

In other words, what I really want to talk about is the simple, though somewhat hackneyed, subject of the contribution of rat experiments to the understanding of human behavior. It would seem that the ultimate goal of all psychologists (even of rat psychologists) is the explanation of the behavior of human beings. It appears further, however, that those of you, among us, who have concentrated primarily on human beings have become increasingly aware (as the psychologists of thirty or even twenty years ago were not) that human behavior takes place only in social contexts. You human-oriented psychologists have begun reading (and perhaps even *inventing*) bits of anthropology and sociology. As a result, you have finally become convinced that men are not born, like Athena, full-grown and all armored but, rather, as naked babes who begin acquiring their armor at their mothers' breasts, in the alarms and excursions of toilet training and in the give and take of sibling rivalries.

Now this has produced a real revolution in all our thinking—even in that of us rat psychologists. But, unfortunately, it seems also to have led to some tendency (or perhaps I am merely over-sensitive) on the part of you human psychologists now to look

[1] Address of the vice-president of Section I, American Association for the Advancement of Science, Cleveland, Ohio, September 12, 1944.