GENERAL SCIENCE

Making the Creative Scientist

Four major factors go into the making of a creative scientist: intelligence, motivation, training and hard work. The thrill of discovery is one of his rewards.

By DR. GLENN T. SEABORG
Chairman, U.S. Atomic Energy Commission

Address given at the awards banquet of the 20th Annual Science Talent Search in Washington, D. C., March 6.

➤ IT IS AN HONOR and an opportunity to be asked to speak at this twentieth Science Talent Search dinner. The honor is in being in such distinguished company—including the young and the not-so-young. The opportunity is that of congratulating these forty young men and women whom we honor here tonight on their achievements in science.

Our congratulations go also to the Westinghouse Educational Foundation, to SCIENCE SERVICE, and to the Science Clubs of America which for twenty years have made possible this exciting challenge to our high school students to explore the world of science and technology.

Twenty years is the span of time generally credited to the long sleep of the legendary Rip Van Winkle. When Rip came back to his village, the things that puzzled him most were the political and social changes. There had been a revolution. A new kind of money was being used. The townspeople talked about a Congress. There was a new nation in the world—the United States of America.

Important things also were happening in science at that time. A dozen elements, including hydrogen and oxygen, were discovered. But it would have been ridiculous for the author, Washington Irving, to have Rip Van Winkle and the villagers talk about hydrogen and oxygen. There was little science in America then and even in the countries where these discoveries were made, there was no public interest in science.

Imagine how different it would be if we had a modern version of Rip Van Winkle. Suppose some person had cut himself off completely from our world twenty years ago and returned in time to look at the exhibits of these young people that we saw here over the weekend. He, like old Rip, would be bewildered. While there have been great political changes in the past two decades, a modern Rip Van Winkle doubtless would be puzzled most by the knowing talk of space vehicles, of nuclear power plants, of transistors and of the many uses of radioisotopes in our daily lives.

It is this explosive rate of scientific and technological advance and its importance to our society that sets the background for what I wish to discuss with you: "The creative scientist: his role and his training."

First, let us try to define a "creative scientist." He is a dedicated person of great natural intelligence who has been trained thoroughly and is hard at work on the frontiers of science. He is searching for new facts or new and better explanations of the natural phenomena he sees around him.

He is doing important work—fundamental research. There may be no immediate practical use for his discoveries. When the big particle accelerator, the bevatron, was being planned at the Berkeley Laboratory that now bears his name, the late E. O. Lawrence was asked what he expected to get from this large atom smasher. His reply was, in effect: "If we knew that, there would be no need to build it."

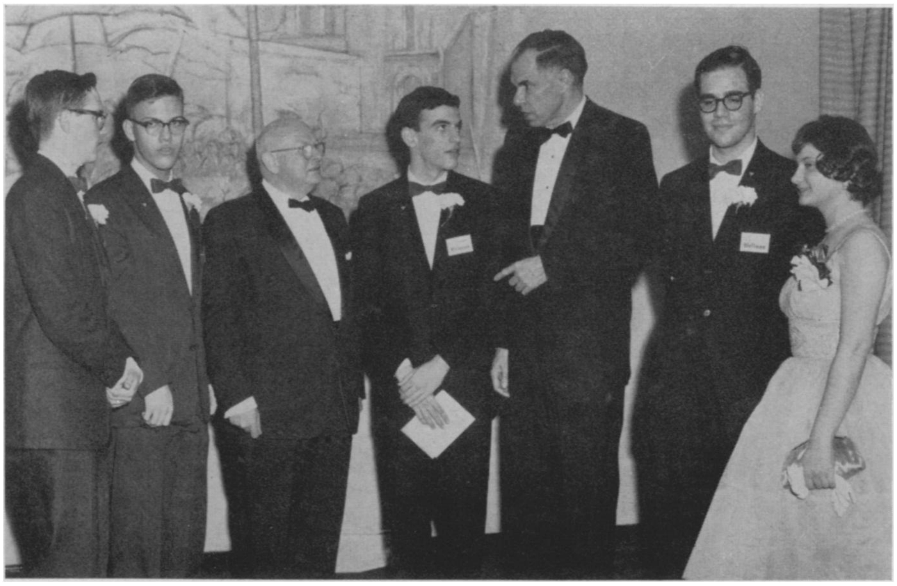
Never Greater Need

Never was there a greater need for creative scientists and for fundamental research than now. Our energy resources must quadruple by the end of the 20th century. Nuclear power must be developed. The possibilities of solar power and the controlled release of energy in thermonuclear reactions must be explored vigorously. Great discoveries in geology, oceanography, metallurgy and in synthetic materials must be made if our wants are to be met in the face of diminishing supplies of rich pockets of raw materials. The grave problem of water use must be solved. New advances in public health, in the treatment of mental diseases, in care of the aged and in all branches of medicine are required.

For the rest of this century, the United States will be called upon to use extraordinary political and technical skill to aid the development of new and lagging countries toward economic and political stability and to guide the evolution of a stable inter-

Introducing Dr. Seaborg

➤ *THE LAST two decades have been extraordinary times for many reasons, besides the rise of appreciation of science in war and peace and the discovery of young scientists like the winners of the Science Talent Search. The years since 1940 have been an era of elemental discovery such as never happened before and never will again. Tick off the new elements, transuranium elements found from 1940 onwards: Elements all heavier than uranium No. 92. 93 neptunium; 94 plutonium; 95 americium; 96 curium; 97 berkelium; 98 californium; 99 einsteinium; 100 fermium; 101 mendelevium; and 102 which is yet to be named. The great scientist who discovered or participated in the manufacture and discovery of the last nine of the most recent and heaviest chemical building blocks of the universe is our speaker tonight at the 20th Science Talent Search. He is Dr. Glenn T. Seaborg, Nobelist, who has just become chairman of the Atomic Energy Commission to which President Kennedy called him from the chancellorship of the University of California at Berkeley.*



WINNERS—of Westinghouse scholarships are congratulated by Dr. Watson Davis, director of SCIENCE SERVICE, *and Dr. Glenn T. Seaborg, chairman, U. S. Atomic Energy Commission. Left to right are: Edward Charles Jones, William Milton Adkins III, Dr. Davis, Daniel Ellis Kleinman, Dr. Seaborg, Joshua Wallman (top winner) and Harriet Jane Fell.*

national order. No one can foretell exactly what form these developments will take. One thing is certain. There must be a continuing flow of new knowledge from the creative scientists for other scientists and engineers to convert to practical technology which will be increasingly important in the solution of national and international problems.

Four major factors go into the make-up of a creative scientist. They are: intelligence, motivation, training and a willingness to work hard.

Many great advances of science have been made by men of the highest intelligence. No man of meager intellect could have done what was done by Rutherford, Bohr, Einstein, Lawrence, and others of equal stature. This does not mean, however, that one has to be a genius. The great bulk of scientific discoveries were made by men of better-than-average intelligence but who were by no means in the genius category.

There is plenty of interesting and exciting work to be done by well-trained scientists who may not happen to be Enrico Fermis or John von Neumanns. In fact, much of the effectiveness of great men like them is due to the many lesser scientists who tried out their suggestions, investigated their findings or produced new data for them to consider.

Set a High Goal

To you young people here in this room and within the sound of my voice, I say: Set a high goal of achievement and be steadfast in your resolve to do everything possible to reach that goal. This leads us to motivation.

I believe every person has a deep psychological need to feel that what he is doing is of some importance, aside from the money he is paid for doing it. The scientist has the satisfaction of this need built into his life, and this gives zest and motivation to his efforts over an indefinite period of time.

Most scientists decided to embark on careers in science before they entered college. This was true in my own case. It was my teacher in chemistry and physics in the David Starr Jordan High School at Los Angeles, California, who generated the initial spark that propelled me into a scientific career. It is a tribute to the all too thin ranks of good secondary science teachers of today that the forty winners here tonight and the many who competed with them have shown an early interest in science.

The training of a creative scientist can be divided into two major steps: High school and undergraduate college study, and, from three to seven years of graduate and postgraduate work.

New science builds on the past. The scientist of today stands on the shoulders of those who went before him. Systematic and intensive research of the past few decades has produced an enormous accumulation of facts, hypotheses and theories that today crowd our libraries. The rate of accumulation increases yearly as new fields of inquiry are opened up.

The chief purpose of high school and undergraduate science is to present the student, in a highly compressed form, the huge output of previous scientists. He should absorb the codified knowledge of science and acquire an understanding of the unifying principles and natural laws that form the basis of the codification. When the student gets his bachelor's degree, he should have accurate concepts of the general features of the sciences and be able to relate new information he will acquire in the future to what he has learned.

The task of the good teacher is to organize and present this vast accumulation concisely and effectively, making judicious selection from the mass of available material. The teaching must be flexible so that new advances, particularly when important discoveries are made, can be integrated with previous knowledge.

It is unfortunate that many of our high school science courses have not been brought up to date. Too often, when changes were made, it has been simply adding new material without relating it to the old. Part of the trouble stems from the poor salaries, inferior community status and misguided accreditation requirements that have made a career in high school teaching unattractive to qualified professional scientists.

Improvement is under way. There is renewed interest of universities, professional societies, industry, private foundations and government agencies—including the one it is now my privilege to head, the Atomic Energy Commission—in the plight of the high schools.

This interest has taken the form of summer institutes for retraining of teachers, writing projects to revise course outlines and textbooks, special programs and courses on television, new films, and publication of a wealth of material in paperback form.

New programs supported by the National Science Foundation, such as the Physical Sciences Study Committee for Physics, bid fair to revolutionize secondary science teaching. Similar groups are at work in the fields of chemistry, mathematics and biology—all on a cooperative basis with university scientists, school administrators and high school teachers participating.

I urge every school board, every school administration and every interested citizen to get acquainted with these new programs and consider how their school system might benefit from them.

In general, the undergraduate colleges face the same problems which are compounded by the enormous increase in the number of students that looms ahead in next decade.

A word about the colleges: March and April are months of anxiety for thousands of high school seniors all over the country. They have taken the various tests, filed their applications and now wait to hear if they will be accepted by the college of their choice.

You will be well advised to choose the best college within your scholastic and economic ability to attend. It is not necessary to go to a large university with a famous staff to get good undergraduate training in

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science. Many of the smaller high-quality liberal arts colleges have made impressive records in preparing those majoring in science for entry into the graduate schools.

The second major step in the making of a creative scientist is his training in methods of carrying on scientific investigation. There are exceptions but generally we must rely on the discipline of our graduate schools to convert the trained intelligence of the undergraduate to the creative intelligence of the research scientist.

The doctor's degree is the symbol of the successful completion of this conversion. In basic science—and to an increasing extent in all science and engineering—the Ph.D. or Sc.D. degree is the rule rather than the exception for positions of mature responsibility.

In the graduate school, the student is put in a laboratory under the supervision of a master scientist. The candidate for the Ph.D. must do a piece of original scientific investigation on a problem that may be quite difficult and of considerable importance in his field.

This is where he learns experimental techniques; how to set up a meaningful experiment; how to extract correct answers from the data he collects; the importance of letting an unexpected result lead to new conclusions or to new experiments.

Graduate research is a rigorous, demanding experience that makes an enormous change in the scientific effectiveness of the doctoral candidate. At many institutions, the research interests of the teaching scientist are very advanced and are likely to be in a frontier area far beyond the material currently appearing in undergraduate textbooks.

The professor also is stimulated greatly by the student. The latter comes to the problem with a different educational background and is eager to work hard to find out what the experiments will reveal. This fresh outlook usually makes valuable contributions to the research being pursued

We can be proud of the graduate schools of our great universities. They meet the qualifications of excellence. They train virtually all of our great creative scientists. They tackle the big problems, especially in fundamental research. The fact that more than forty living Americans hold the Nobel Prize in chemistry, physics or medicine attests the productive work of our graduate schools of science.

The serious problem is that these fine schools are small in size and in number. It is urgent that they be strengthened, that their number be increased, that the educational and research processes be better integrated, and that ways be found to extend the creative stimulation of graduate education into more of the laboratories in which fundamental research is done. This problem was the subject of a special report to the White House made by a Panel of the President's Science Advisory Committee. I had the honor of serving as chairman of that Panel.

This brings me to my last point—work, plain old-fashioned hard work. This matter of hard work runs counter to the modern trend toward shorter work weeks and more leisure time. I recognize the importance of these developments in society generally but I cannot feel that the 35-hour week has much relevance for a creative scientist.

The greater effort expected of the scientist seldom is extracted against his will. Most scientists are able to get the kind of jobs that allow them to do work they genuinely love. They do not work simply because it is necessary to work to live. The intellectual satisfactions, the thrill of discovery, the sense of worthwhile effort are rich rewards and strong stimuli to sustained effort.

Scientists as a group definitely are not clock-watchers. The large majority of my personal acquaintances work in laboratories where the doors are never locked and where lights frequently burn late into the night.

I hope this outline of what is required to become a creative scientist will not discourage any who may hear or read what is said here. If I may judge from my experience in talking with young people, many of you lack self-confidence and are somewhat hesitant about visualizing yourself as potentially an important scientist. Others wonder how they will finance their years of study. To this group I would say three things:

First—One does not have to make a final decision in high school or even in the first two years of college. By the time you are a college junior, you can make a choice with a clearer knowledge of your interests, ambitions and abilities.

Second—If you set your course in one of the sciences, the number of scholarships for undergraduate work is increasing and there are several ways to meet the cost of the years of graduate study. Many fellowships are available. Teaching and research appointments are fairly common. Often a graduate student can meet most, if not all, of his expenses through some combination of these.

Third—If you decide that your talents will be used best in a non-scientific field, I assure you that the effort you have put in science subjects will not be wasted. Science plays such an important role in our lives that the work of nearly every professional person is carried on better when he has some fundamental understanding of the nature of science.

Science Changes the World

In the world of today, people in all walks of life and all occupations—even the housewife and mother—see their daily tasks undergo continual change because of the rapid advance of science and technology. To be an effective breadwinner and citizen of today and tomorrow, it is necessary to extend your understanding of science.

You may now ask: If one has the qualifications you have outlined and does the things you say are necessary, will he be a great scientist? There is no scientific answer to that question. It is hard to put a finger on what is the key to success. In science, as in other professions, the human factor is important.

One cannot explain why one scientist wins high recognition and another of equal promise does not. But one can say that, whatever may be the degree of achievement, the satisfactions of a career in science are deep and lasting.

We live in an age in which, for better or worse, the influence of science is revolutionary. It is part of our culture, shaping every aspect of our lives and our institutions.

We can no more ignore it than the men of the Middle Ages could ignore the feudal system. Properly nurtured and manned with adequate numbers of trained people, science can provide marvelous tools for the solution of many of the grave problems of our physical and social world.

The mishandling or ignoring of science can lead us to disastrous consequences. I take great hope and comfort in the fact that enterprises such as this science talent search augur well for the future use of science in the United States.

• Science News Letter, 79:170 March 18, 1961