Intimations of Disaster:

Glenn Seaborg, the Scientific Process, and the Origin of the "Cold Fusion War"

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Almost seven years ago in an issue of *Infinite Energy* (#15/16, July-November 1997), we discussed some of the material that follows. But in 2004, with the U.S. Department of Energy's impending review of the past fifteen years of evidence for low-energy nuclear reactions (a.k.a. "cold fusion"), it is an appropriate time to review—in a fresh light—a most critical turning point in the saga of cold fusion. In an episode which occurred in the spring of 1989, we find the seeds of the disastrous DOE response to cold fusion. Upon further investigation, I later found that the false premises that gave rise to the "Cold Fusion War" were evident as far back as 1964.

The events in question occurred only three weeks after March 23, 1989, when Drs. Martin Fleischmann and Stanley Pons made their startling announcement at the University of Utah of excess heat production and low-energy nuclear reactions. Nobel laureate Glenn T. Seaborg had been called in to brief President George H.W. Bush (the father of today's U.S. President George W. Bush). Days before Seaborg spoke to the first President Bush, there had been a very enthusiastically received talk by Dr. Pons before the American Chemical Society Meeting in Dallas, Texas (April 12, 1989).

Even though the jury was certainly still out on the evidence for or against "cold fusion," Seaborg, *through some as-yet-to-be-revealed process* (though he certainly had conducted no experiments), had determined that cold fusion was not what it was claimed to be. On April 14, 1989 Seaborg told President Bush that *"it is not due to nuclear fusion."* Thus was launched a sham investigation, biased from the outset by this Nobel luminary's words to the U.S. President, who had taken office only a few months earlier. Of course, Seaborg had ample time between 1989 and when he passed away (in 1999) to investigate what was even in 1992 quite mountainous evidence that had been compiled for low-energy nuclear reactions and excess energy production. During his life, Seaborg did not advise any U.S. President, nor any other official to our knowledge, that the case *against* cold fusion, which he helped set in motion, should be re-examined. In fact, we now know from Seaborg back in 1997 that he was still unrepentant and biased. We discovered this extremely revealing account of Glenn Seaborg's actions in the spring of 1989, which appeared in an issue of *Skeptical Inquirer*, November/December 1997, as part of "The Elemental Man: An Interview with Glenn T. Seaborg":

Glenn Seaborg briefing President George Bush on "cold fusion" at the White House on April 14, 1989. Photo courtesy of the Ernest Orlando Lawrence Berkeley National Laboratory.

SI: During the early stages of the cold fusion furor, President Bush asked you to come to the White House and give him your views on the matter. What happened? What did you tell him?

Seaborg: In April 1989, I was called back to Washington to brief George Bush on "cold fusion," the totally unexpected phenomenon that University of Utah scientists announced they had discovered by the simple process of electrolysis of heavy water. A couple of days earlier, the purported co-discoverer of "cold fusion," University of Utah electrochemist Stanley Pons, spoke to an enthusiastic standing-room-only audience of chemists at the semi-annual meeting of the American Chemical Society in Dallas. His talk had attracted so much attention that, apparently, the news had reached the White House. After briefing White House Chief of Staff John Sununu, I went into the Oval Office to brief President Bush on April 14, 1989.

I told him about my role in the discovery of the radioactive iodine that had been used a couple of days earlier to treat his wife, Barbara, and said that a similar treatment with radioactive iodine had effected a miraculous cure for my mother, who was suffering from the same condition as Barbara. The president facetiously said that Barbara is now radioactive and she is not allowed to kiss their dog as long as this condition prevails, but he implied that it didn't seem that this prohibition included himself—the president.

I then went on and described briefly the situation with respect to cold fusion. ***I indicated that this is not a valid observation—that is, that it is not due to nuclear fusion—but, on the other hand, it must be investigated.*** *The president seemed very interested and convinced by my assessment, and encouraged us very much to go ahead with an investigation.* [*Infinite Energy's* emphasis]

I might add that the panel I recommended to study the purported "cold fusion" process was created and about six months later came out with a report disputing the validity of the observation, pretty much in line with the view I adopted in my briefing of the president. Also it is interesting to note that President Bush himself, two years later, in May 1991, benefitted from treatment with the same radioactive iodine (iodine-131).

—(End of the *Skeptical Inquirer* interview section)—

Of course the panel that Seaborg recommended ended up with the negative view put forth by Seaborg on Day One. How could it have done otherwise? Just consider who was on the panel in leading roles. First we had Seaborg's close colleague, Prof. John Huizenga, then of the University of Rochester, the panel's driving force, who later wrote his version of cold fusion history (*Cold Fusion: The Scientific Fiasco of the Century*, 1992). In Huizenga's book, we find confirmation of Seaborg's negativity on April 14, 1989, but not until the *SI* interview did we have such stark words from Seaborg himself.

Robert O. Hunter, Jr., a hot fusion man, was at the time the Director of DOE's Office of Energy Research. It was he who called upon Seaborg to come to Washington, according to Huizenga. On the morning of April 14, Seaborg briefed Admiral Watkins, then DOE Secretary, and later John Sununu, then President Bush's top advisor.

By Huizenga's own statements, Huizenga was opposed to moves to have a cold fusion investigation. He wrote in his book: ***"My initial feeling was that the whole cold fusion episode would be short-lived and that it would be wise to delay appointing such a panel.*** *However, the persuasive manner of both Seaborg and Schoettler and the ongoing press reports on cold fusion convinced me that such a panel was necessary and timely from the Department of Energy's point of view for reasons to be discussed in the next chapter."* [*Infinite Energy's* emphasis]

Huizenga and Seaborg had already determined that the Utah results were unimportant, according to Huizenga in his book and elsewhere, because ". . .cold fusion should not be possible according to current nuclear theory, which is supported by a large body of experimental data."

But that was not the end of the bigotry on the DOE panel. We have this account by Gary Taubes (in *Bad Science*, 1993) from Dr. William Happer, a Princeton hot fusioneer: "Happer had decided upon hearing of cold fusion that it was probably wrong. In fact, a *Scientific American* reporter had called him a few days after the announcement, and Happer had harangued him for over an hour on the various aspects of fusion—its physics, the fatal effects of neutrons—that made cold fusion so implausible. 'The thing I didn't have the nerve to do was say that *just by looking at these guys on television, it was obvious that they were incompetent boobs*.'" [Infinite Energy's emphasis] In 2004, Happer remains convinced that he was correct from the start, and he is still eager to have LENR science killed with the same bureaucratic scam that was used in 1989: "But if you put together a credible committee, you can try to put the issue to bed for some time. It will come back. The believers never stop believing," according to Happer (quoted by Toni Feder in *Physics Today*, April 2004).

So much for the "impartiality" of the DOE cold fusion panel of 1989. Let us hope that the evaluation committee in 2004 will merit our confidence. And so much for the reputation of Glenn Seaborg, who helped initiate the disgraceful behavior of DOE over the past fifteen years—its refusal, at every turn until recently, to reconsider its highly flawed cold fusion report of November 1989. During his life, Seaborg did nothing to make amends. History should remember him for that. For now, one of his other tangible legacies is having his name permanently affixed to element number 106, seaborgium.

A Stroll Down Memory Lane: 1964

Because I happen to be an inveterate packrat, I tend to collect old scientific literature, magazines, and other paraphernalia, which others might long-ago have shredded, but which I imagine might eventually be useful. And on occasion, one piece of pack-ratted scientific memorabilia percolates to the top of a pile and sends a message across the sands of time. So it was for a small pamphlet that I saved from my high school years—from 1964, to be precise. It was published by the U.S. Atomic Energy Commission (AEC), that era's precursor of today's DOE. It features an address by Glenn T. Seaborg, who was then AEC Chairman, to the 14th National Science Fair International (NSFI) at Albuquerque, New Mexico in 1963. Seaborg's talk, "The Creative Scientist: His Training & His Role," is so quaint (note, for example, the gender bias in the title) and pregnant with intimations about future scientific history, that I consider it to be a useful accompaniment to this commentary. We reprint it in its entirety. Enjoy!

Notable about Seaborg's lecture is its tiresome blandness and repetition of bureaucratic-sounding nostrums about how the young people he is addressing should view their prospective careers in science and engineering. Note especially: Seaborg gives no obvious challenge whatsoever to the students to find something truly *new*, something really revolutionary, or—heaven forefend—something fundamentally *wrong* with existing theories of nature. The implication is clear, and even spelled out in its deification of certain "genius" scientists: "Furthermore, much of the potential of a Fermi or a Von Neumann would be lost were there not many other scientists to try out their suggestions or to turn up new phenomena and new data for them to study and consider." The not-so-subliminal message is clear: "You are likely to be drones in the house (hive?) of science, whose work is to be evaluated and *used* by these superior kings and queens, who disdain getting their hands dirty in your sort of pedestrian experimentation. Esteemed theorists will consider, accept, or reject, the value of *your* work. Boy or girl, know your place."

I regret to say that had I been in the audience listening to Seaborg in 1963, I might then have been in awe of this great messenger of supposed wisdom about the process of science. I would not then have been sensitive to the implicit distortions being served up. Seaborg airily offered this canard: "The time lag between the discovery of a fundamentally new scientific principle and its application in engineering or medicine is now very short." This is utter nonsense; it is blather. It pertains only to some new kind of technoid gadgetry based on accepted principles that engineers and marketers may disgorge, not to the fruits of "fundamentally new scientific principles." In fact, those "fundamentally new scientific principles" that are allowed admission to the cathedral of official science are so rare as to be virtually non-existent these days. And as we have seen, thanks to the likes of Seaborg, substantial evidence for low-energy nuclear reaction phenomena and excess heat have been side-tracked for at least fifteen years—and perhaps the farce will go on much longer. (An unbiased DOE review of LENR is by no means assured.) At the same time, all manner of experimentally untethered, nonsensical theory in physics is bandied about and rewarded as received cosmic wisdom.

At another point Seaborg told the students, "In his search he knows that in the final analysis his success as a scientist is measured against the criteria of nature—rather than the judgments of persons." That was another con-job from Seaborg. That statement may be true and self-evident as far as Science, the abstract, ideal process may go, but it is most certainly not the *real experience* of pioneering scientists these days. The work of frontier scientists now faces immediate scorn and ridicule by the rash judgements of "persons"—persons such as Seaborg or Huizenga, who tell the President of the United States and then the world that a new scientific finding is not such-and-such, based on totally anti-scientific *a priorisms* ("It simply can't be true. . .etc., etc."). This is another sad howler from Seaborg: "A scientist who is correct can prove he is correct, and by a proper marshalling of experimental evidence can convince his colleagues regardless of their superior reputation, seniority, or rank." Oh, sure, just serve up a a few hundred bullet-proof papers on LENR and the Scientific Establishment will roll right over! Evidence with revolutionary implications means *nothing* to the hide-bound theorists of today.

Then comes blatant propaganda about how, "By intensive study of the organizing law the new scientist may understand immediately many hundreds of individual facts which were quite mysterious to the past generation of scientists." That's it, man, just memorize those "laws" and you have the whole shebang in hand, the world of scientific "facts" at your fingertips! Implied, of course, is that those "laws" can't be wrong, because, after all, from them can be derived "facts." Get it? After such nonsense, a disastrous, false assertion popped out of Seaborg's mouth, which a quarter century later would come to characterize perfectly the idiotic rationale for launching the War Against Cold Fusion: "New mathematical techniques may also make it possible to explain or quickly derive numerous experimental facts which could only be understood at the expense of great labor by previous students." *Mathematically derive an experimental fact?* Isn't that how LENR phenomena were so resoundingly dismissed by Seaborg *et al.*—by mathematical calculation from sacrosanct "laws," purporting to show that certain experiments *had* to be the result of error?

Seaborg tells us how it should be with graduate students: "He learns how to set up a meaningful experiment and how to extract correct answers from the data he collects. He learns the importance of letting the unexpected result lead him to new conclusions or at least to new experiments." Of course, Seaborg can't possibly be talking about truly anomalous, "law"-violating results that could lead to "new conclusions." He emphasizes "correct answers," which in his lexicon cannot be allowed to appear to violate those laws. He then describes a hypothetical graduate student. One who recalls the early history of the LENR field may immediately think of Nigel Packham, a doctoral student under Professor John Bockris at Texas A&M University during 1989-1990 and afterward, who through hard work found irrefutable tritium evolution in cold fusion cells. That is the kind of research that should merit a Nobel Prize, at least. But, not so fast. Seaborg describes an open-minded graduate student: "With this fresh outlook it frequently happens that he contributes greatly to the success of the research and may transform it into an advance far greater than might reasonably have been expected at the initial stages of the work." Yes, that is precisely what Packham did under Bockris, except that Packham was "rewarded" by being called a likely fraud-perpetrator in a slanderous article by Gary Taubes in *Science* magazine, which spanned five pages of that still unrepentant journal in June 1990. So, it did not work out for Packham in 1990 as Seaborg had suggested it would back in 1963. Packham was driven out of the field and has been working in the U.S. space program doing human factors biophysical research.

With these now all-too-evident intimations of the disaster for science that would later emerge in the Cold Fusion War, it is perhaps a blessing for him that Seaborg is not around to see the consequence of his acts: the inexcusable delay in recognizing that a new window on physics and chemistry had opened, one with a huge technological potential. But the eventual blossoming of that initially small sprout of scientific discovery that Seaborg so incompetently sought to abolish could not be stopped. "Law"-defying experiments in LENR continue and become an ever larger threat to what Seaborg thought he knew about science. We can agree with at least one of Seaborg's 1963 truisms, although not in the way he intended it: "Science is self-correcting in that spurious results will sooner or later be unmasked by new experiments or the attempted verification of previous conclusions." The unmasking that is occurring is the crushing correction that experiments are delivering to the fraudulent "previous conclusion" of Seaborg and Huizenga that there was nothing to investigate in the cold fusion claims.

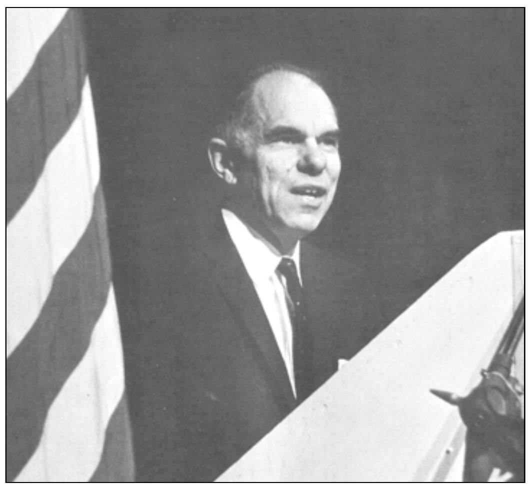
The Creative Scientist: His Training and His Role

Glenn T. Seaborg

Address delivered to the 14th National Science Fair International in Albuquerque, New Mexico, 1963.

It was only a century or two ago that modern science became an organized study of natural phenomena deduced from experimental evidence. Since that time applied science and invention have influenced the life of the individual, the development of industry, the evolution of political societies, and the course of history. In the past few decades we have seen a great increase in the impact of science on our society owing to a new factor which was not previously present. This new factor is the systematic and intensive accumulation of new scientific knowledge—the result of basic or fundamental scientific research.

We now know that the search for new knowledge, if not restricted to subjects of foreseeable and immediate practical importance, results in an unexpected increase in our understanding of physical or biological phenomena. These increases, in turn, give rise to far-reaching practical applications which could not have been anticipated from the original basic research. Our scientific knowledge and technology are advancing at an explosive rate. The time lag between the discovery of a fundamentally new scientific principle and its application in engineering or medicine is now very short, and these rapid developments are changing the lives of all of us in many ways which we only dimly perceive.



Dr. Seaborg as he delivered the address in 1963.

Brainpower: A Precious National Resource

Because of our inescapable dependence on modern science and technology we must regard trained brainpower as a precious natural resource. The extent to which we discover exceptional intellectual talent, encourage and develop it, and provide conditions for its effective flowering will be a measure of our success in meeting the truly challenging problems which technology and population growth are posing for us in the remainder of this troubled twentieth century.

I refer broadly to two types of trained brainpower. One is represented by the professional scientist or engineer, the other by the educated person in other fields who has mastered enough of the meaning and content of modern science to make valid judgments on the many questions raised by the influence of science on his field, whether it be law, medicine, politics, military affairs, industrial management, or some other field.

It is fitting, therefore, that considerable attention be paid to the early identification of intellectual talent. Tonight we are gathered to participate in one attempt at the identification of boys and girls who have exceptional aptitude for a creative and productive career in science. We are here to honor young men and women who have demonstrated by their conception and execution of some science project that they have a strong motivation and exceptional promise for a scientific education.

I think it is quite proper that we pause on regular occasions to acknowledge the intellectual, esthetic, and idealistic aspirations of our young people and encourage them by recognizing their academic excellence. Not unnaturally, a young person is influenced to seek goals which are recognized and respected. If praise is reserved only for athletic prowess or monetary success, who can blame him if he seeks these even if it means sacrificing a great potential in some other field. Perhaps some of you may have seen the Lichty cartoon of a month ago in which a father admonished his son: "The future is wide open for a science graduate, Otis! But he can do still better if he can hit over .300 and catch fly balls!"

So, I am most happy to extend my personal congratulations to these young men and women. It would be extraordinary indeed if all of you should develop into brilliant scientists of international reputation. I would be the last to lay the heavy burden of such an expectation on your shoulders. It would also be extraordinary if any of you failed to contribute in some way and in some pursuit, which none of us can predict here tonight, much more than an average share of intellectual achievement.

I would like now to mention briefly a few important steps in the education of a scientist, and a few attractive features of the life of a research scientist.

Research Is Important Work

The work of a research scientist is of great interest and importance. Often it is difficult to relate his work to matters of dollars and cents but in the value system of the scientist the subject he has under study—whether this be the origin of the solar system, the biochemical basis of heredity, or the nature of a meson—is of great significance.

I believe that most people have a deep psychological need to feel that what they are doing is of some importance. The scientist feels the satisfaction of this need, and this gives drive and zest to his efforts. This is particularly true if, from time to time, his efforts are rewarded by the thrill of discovery. In his search he knows that in the final analysis his success as a scientist is measured against the criteria of nature—rather than the judgments of persons. Science is self-correcting in that spurious results will sooner or later be unmasked by new experiments or the attempted verification of previous conclusions. Hence it can more readily establish truth and confound error than other more abstract fields of study. A scientist who is correct can prove he is correct, and by a proper marshalling of experimental evidence can convince his colleagues regardless of their superior reputation, seniority, or rank.

Scientific research is a stimulating activity requiring constant assimilation of new facts, theories, and techniques. This feature appeals to many gifted persons who would be stifled by the repetitive, dulling routine of many other occupations. A career in scientific research has many deep intellectual satisfactions which appeal strongly to the person of superior natural abilities. Let us turn now to a consideration of how an interested young person may make a career in this exciting field.

Science is an organized body of knowledge and a method of extending or revising that body of knowledge by observation, hypothesis formation, and experiment. The training of a scientist is a two-step process—the mastery of a body of knowledge developed by previous workers and the mastery of a technique for extending that knowledge. I sometimes liken the role of the scientist to that of a mountain climber who with great care and exertion achieves some great prominence from which he is able to perceive immediately and clearly new vistas which are hidden from the sight of those down in the valley below even though many of those in the valley may have better eyesight.

Mastering Existing Knowledge of Science

New science builds on the work of the past. The scientist of today stands on the shoulders of the giants of yesterday. Therefore, the first task of any serious aspirant toward a career in science is to master the recorded history of the past. The task of the effective teacher is to organize and present that history concisely and effectively. Our libraries are so filled with an enormous accumulation of facts, hypotheses, and theories that the complete mastery of any science or even one major branch of a single science is a quite impossible task. Hence there must be a judicious selection of material—a judgment concerning the relative importance of various fields of study at various stages of the educational ladder, and a continuing judgment concerning the relative importance of facts, laws and correlations.

We are greatly helped in this effort by the great unity of much of science because of the fundamental laws or generalizations underlying all natural phenomena. In physics and chemistry, for example, we are enormously aided by the laws of thermodynamics, the laws of conservation of momentum and energy. We are also aided by the circumstance that many decades of past work in science may become logical and clear once some satisfactory organizing law or theory is evolved.

By intensive study of the organizing law the new scientist may understand immediately many hundreds of individual facts which were quite mysterious to the past generation of scientists. New mathematical techniques may also make it possible to explain or quickly derive numerous experimental facts which could only be understood at the expense of great labor by previous students. Therefore, it is the purpose of high school and undergraduate education in science to teach with the utmost economy of effort the organizing principles which may unlock for the student the important heritage of the past. Because the relative importance of facts is subject to rapid obsolescence, the goal is not to teach facts alone, but a system of understanding facts so that the new knowledge can later be absorbed.

Needed: Better High School Courses

There is no ideal way to teach high school or college science courses and we may expect a variety of approaches without a clear choice among them as to effectiveness. Nevertheless, whatever approach is tried must be subject to change in content to accommodate the material to new advances in science, particularly advances occasioned by important discoveries. Unfortunately, our high school courses have not changed too much over the years and such changes as have been made until very recently are mostly in the way of accretion of new material without significant deletion of the old.

Another problem in science education is the need for still more able and dedicated teachers. Poor salaries, the inadequate community status accorded to teachers, and misguided accreditation requirements have repelled many qualified professional scientists from a career in high school science teaching. Adequate preparation in his subject matter is essential to a good teacher, and normally a high school course in chemistry should, where at all possible, be taught by a teacher with a college degree in chemistry, and a high school course in biology by a teacher with a degree in zoology or biology. Such a person can usually better evaluate new developments in the field and effectively interpret them to young people. Yet it is a rare high school indeed that has such a professionally trained science teacher. New attitudes toward teacher salaries and recruitment would assist in improving this critical situation. It is fortunate that our country nevertheless has many able and dedicated high school science teachers who are willing to make the necessary sacrifices.

One encouraging development of the past few years is the renewed interest of the universities, the professional scientific societies, the private foundations, and many governmental agencies—particularly the National Science Foundation—in the plight of the high schools. This interest has taken the form of summer institutes for the retraining of teachers, writing projects to revise outdated course outlines, textbooks and laboratory manuals, the preparation of films, TV programs and TV courses, and the publication of a wealth of new explanatory and authoritative scientific material in paperback form. School board members, school administrators, and interested citizens who are acquainted with these programs find them a new and very effective means of developing adequate science teaching in their school systems.

Earlier Courses Provide Background

One of the chief purposes of high school science and undergraduate college science is to present the huge output of previous scientists to the student in a compressed form. They must give the student a meaningful, accurate, unified body of knowledge so that the general features of the sciences may be correctly perceived, so that new information to be acquired in the future can be related to the old and so that important features requiring further study can be recognized.

Graduate Schools Teach Research Methods

We turn now to the next step in the making of a scientist, namely, his training in the methods of carrying on scientific investigation. The principal centers for this type of instruction are the graduate schools of our great universities. The graduate holding a bachelor's degree in science has a good knowledge of his field, is able to perform a variety of laboratory tasks and may, with on-the-job training, develop into a creative research scientist. But as a general rule we rely on the rigorous training of our graduate schools to convert the trained intelligence of the holder of a bachelor's degree into the creative intelligence of the research scientist. The Ph.D. degree is the symbol of this creative intelligence.

The chief instructional technique of the graduate school is to put the student in the laboratory under the supervision of a master scientist to do a piece of original scientific investigation on a problem of considerable importance and difficulty. Here he learns a variety of experimental techniques. He learns the importance of asking big questions. He learns how to set up a meaningful experiment and how to extract correct answers from the data he collects. He learns the importance of letting the unexpected result lead him to new conclusions or at least to new experiments.

Graduate research is a rigorous, demanding experience which makes an enormous change in the scientific effectiveness of the candidate. At the better institutions the research interests of the professor are very advanced and are likely to be in a frontier area far beyond the material currently appearing in undergraduate textbooks. The professor is also greatly stimulated by the student. The student is usually brilliant, comes to the problem with a rather different educational background from that of his professor, and is eager to work hard to find out what the experiments will reveal. With this fresh outlook it frequently happens that he contributes greatly to the success of the research and may transform it into an advance far greater than might reasonably have been expected at the initial stages of the work.

America's Graduate Schools Are Excellent

The American people can regard with great pride the graduate schools of our great universities. They meet all the qualifications of excellence. They train virtually all of our great creative scientists. The scientific research done under the student-professor symbolic working arrangement adds a major fraction to our truly important new knowledge.

I could cite many, many examples of this. The selection of any scientific problem involves a judgment concerning what is worth investigation. In the first-rank graduate schools it is the big problems which are attacked. It is free research. The fact that over forty living Americans hold the Nobel Prize in chemistry, physics, or medicine attests to the excellence of our graduate schools of science. Unfortunately, in today's world there is not a sufficient number of such schools. A study made by the President's Science Advisory Committee in 1960 included recommendations that it be our national science policy to strengthen these existing schools, to increase their number, and to work out ways to extend the mutual creative stimulation of graduate education and research into more of the laboratories in which our fundamental research is done.

It is important that the standard of excellence of our top-rate universities be maintained and extended to more institutions. In the extension of scientific knowledge excellence is crucial. There is an enormous difference between pretty good and the very best. A system of scientific training and research institutions which can produce and support a few Enrico Fermis or John Von Neumanns or Ernest Lawrences will be profoundly more effective than one which fails to do so.

Graduate Study Decisions May Be Deferred

A potential young scientist listening to these words may be hesitant to embark on such a foreboding and rigorous course of training. Therefore, a few words of comfort may be in order. Your decision whether or not to consider graduate training in science can be deferred to the middle or later years of your undergraduate college career. By then your decision will be based on a clearer knowledge of your abilities, interests, and intellectual performance. Should you then decide that your talents and interests lie in other directions there is a strong likelihood that the science courses which you studied will nevertheless form a significant part of your total education.

While graduate training usually takes from three to five years, the extra expense attached to this period can be greatly lessened by the many teaching and research appointments and fellowships which are available. In many fields the student can expect to pay all his living and school expenses from such appointments.

A further comment that I should make is that there is plenty of room in scientific research for those who are not in the genius category. All Ph.D.s of course are better than average in intelligence, but few of them indeed approach the manifestly superior intelligence of Enrico Fermi or John Von Neumann. There is a large volume of work which needs to be done and which can be done very well by the trained scientist of more modest endowments. Furthermore, much of the potential of a Fermi or a Von Neumann would be lost were there not many other scientists to try out their suggestions or to turn up new phenomena and new data for them to study and consider.

Research Utilizes Many Talents

Creative research calls for a combination of qualities, only one of which is superior intelligence. It is difficult to specify the combination of characteristics which may be of crucial importance for success in solving a specified scientific problem. Perhaps an intuition or a "feel" derived from lengthy experience with certain types of phenomena, perhaps special knowledge of a new instrumental technique, perhaps a natural manual dexterity in some important type of laboratory manipulation, perhaps an unreasonable stubbornness in seeking a better explanation of some phenomena which others have passed by as "explained" may be the key to a fruitful series of developments.

I should find it difficult to explain the secret of the effectiveness of the many able scientists I know or the relative ineffectiveness of others who seemed at the beginning to hold out great promise. Maybe it's just plain hard work, because, without downright hard work, there can be no success in a scientific career. All the productive scientists have been "smart" it is true, but the ways in which they have been "smart" have differed greatly. And, as I have said, they are all dedicated hard workers.

In the near future we shall hope to see a great expansion in our colleges and universities including our graduate schools of science and engineering. We should see an expansion of research activities adjacent to university campuses and in university-related institutes as the importance of our scientific education and research to our national growth is fully realized. We should also see a more vigorous and understanding support of uncommitted research in industrial and governmental as well as university laboratories, with the realization that such research over a period of years will result in faster discovery of radically new developments.

Engineer's Role Equally Important

Today, new discoveries in the nature of matter, the structure and the electrical and magnetic properties of materials, etc. are rapidly reduced to engineering application. Although I have not emphasized the role of the engineer, this is equally important in today's and tomorrow's society. To apply the results of scientific research rapidly and surely the engineer must have a sound and sophisticated knowledge of science and an adaptability which in general will be achieved only under a thoroughly revised engineering curriculum including some graduate training.

Nonscientists Must Understand Science

Turning to the education of the nonscientist there is a necessity of including a course or courses that will insure a better understanding of science as part of the general high school and college or university undergraduate curriculum. We live in an age in which, for better or worse, the influence of science is pervasive and revolutionary. It is a part of our culture which is shaping nearly every aspect of our lives and our institutions. We can no more ignore it than the man of the middle ages could ignore the Christian church or the feudal system. Properly nurtured and employed, science can provide us with marvelous tools for the solution of many of the weighty problems of our physical and social world.

The promise of the future lies in the hands of the dedicated and the educated. A most significant part of that promise lies in the field of science. I would invite the earnest young men and women who are prepared to study and work hard to join in the exciting and rewarding profession of science and the scientist.

Contestants at the 14th National Science Fair International in 1963, photographed while their nuclear-related exhibits were being judged.