general understanding of science. And so it is, as I have said, only natural that we of the Academy should in recent years have had an increasing concern with educational matters. In recent years, and especially in recent months, there has been another reason for acute interest in problems relating to the more abundant recruitment of scientists and the better training of young scientists for future scientific careers—partially, I regret to say, because we compare our situation with the situation in Russia. It has recently been pointed out that although, according to reasonably reliable figures, only 4 per cent of the high-school students in the United States study physics for one year, all secondary-school students in Russia study physics for five years. Those same figures indicate that only 7 per cent of American secondary-school students study chemistry for one year, whereas in Russia all study chemistry for four years. And so it goes. It has also been found that in 1928 there were but 26 schools for science and technology in Russia, whereas in 1954 the number had increased to 153. But I, for one, wish that we had sufficient confidence in our own destiny and ideals to shape our culture without the stimulus of fear. We could, in analyzing our own situation, easily find that in 1900 approximately 50 per cent of the high-school students in our country were studying algebra, but only 24 per cent in 1955; that in 1900, 25 per cent of the high-school students were studying geometry but in 1955 only 11 per cent; in 1900, 19 per cent of our high-school students were studying physics, but only 4 per cent in 1955. I cannot vouch for the validity of these figures, but they are indicators of a growing disregard for science in our educational system, at a time when it is becoming more difficult adequately to present scientific knowledge so that the general population may have a better understanding of the bases of our modern culture. It would, I think, in this time of ideological conflict be tragic if we the pioneers and idealists were to be considered by the world merely seekers for an easy way to material satisfactions. And so, in deciding how we, this afternoon, might consider the place of science in education, it seemed to us desirable to bring together a group of wise men who have thought much about the place of science in education in its broader ramifications. So I was pleased to find that we could persuade not only our fellow members George Corner and Joel Hildebrand but also our friends Henry Moe, Clarence Faust, and Arthur Adams to discuss with us their ideas regarding the place of science in the totality of our educational system. In order to have some historical background for our thinking, we have asked Mr. Corner to begin the discussions of this afternoon.

MR. CORNER: Mr. President, Ladies and Gentlemen: Standing upon this platform, one is always impressed by the resemblance of our auditorium to a great church or basilica. With its apse, its transepts, its pulpit, and its bench for the elders, it is indeed a temple of science. When my discourse is finished, you may think that I have succumbed unduly to the architectural mood of this place and have delivered a sermon instead of a scientific address. You may say that I come here with a preconceived faith—that I utter a few dogmatic statements, embellish them with none-too-relevant illustrations, and conclude with a pious exhortation. What is more, I shall give you a text for the day, lifted from its context in the Scriptures and somewhat altered in its connotation. This is something not infrequently done by us preachers. My text, brethren, is from the Ninety-fourth Psalm: “He who teacheth man knowledge, shall not he know?”
These words express in condensed form the question which I believe was in the mind of our presiding elder, Mr. Bronk, when he arranged today’s symposium. The title “Science in Education” calls for a discussion of the scientific investigator’s opportunity—and duty—to participate in, and even to lead, the work of education. Can we expect to have sound education without the inspiration of men who are seeking to know, through their own research, the universe in which mankind dwells and the nature of man’s body and mind? What do we stand to lose if education rests only upon what is already known? What may we hope to gain if teaching is planned by those who are themselves striving to learn new facts and to organize them into new concepts?

These questions I am asked to discuss from the historical point of view. Let me simplify this huge assignment by defining our major terms. For today’s purpose I define “science” as the effort to understand the physical universe and its living inhabitants; “education,” as preparation for effective living. At the beginning of history there was no distinction between science and education thus defined. When an African tribesman takes his little boy to the riverside and says, “Look, there’s a crocodile, he bites,” this is natural history, a branch of science; when the father adds, “Therefore keep out of the reach of such creatures,” that makes it education. For each of us, in the short time we had in the cradle when we could play with our toes and touch new objects with our fingers, before parents and pedagogues began to educate us, science and education were indistinguishable. Successful teachers know that at any age the most effective education is that which lets the pupil find things out for himself—which keeps alive in his work the innate zest for exploration. This to me is axiomatic; it is the preconceived faith on which my homily is based.

The history of the interplay of science and education, as human living has become even more complex, has been a long series of swings of the pendulum. At certain periods, in certain cultures, under the shifting effects of social change, religious belief, political stress, there have been times when the knowledge and experience that are stored in tradition, in books, and in tablets of the law loomed so large that education looked only backward, sought only to teach the understanding and use of remembered facts, of old dogmas, of time-honored codes. At other times scientific curiosity has taken the lead, often with drastic effects upon the outlook and methods of the educator.

In discussing these changes, I shall be on safer ground if I do not try to go too far back. Without a profound knowledge of ancient culture it is impossible to perceive the relations of discovery and teaching in long-past times. If we had fuller records of the second, third, and fourth millennia before Christ, who can say how many alternations of Dark Ages and Renaissances and periods of Enlightenment would be discernible? We can see the Greeks more clearly. They generally managed to achieve balance in intellectual affairs. Aristotle, at least, seems to have combined in supreme degree the functions of teacher and investigator. The Hellenistic and later periods until the eleventh and twelfth centuries A.D. were, on the contrary, dominated by traditional pedagogy. Coming to a time about which I can claim some little firsthand knowledge, in the Middle Ages, say from the twelfth to the fifteenth century, when the European universities were being founded, there was a dearth of science,
what there was being chiefly mathematics and theoretical astronomy in the Arabic
tradition. In philology, on the other hand, a considerable advance was being made
by the scholars who were bringing the Arabic scientific literature over into Latin,
much as scholars in Greek literature were to influence the true Renaissance a few
centuries later. A recent historian, Crane Brinton, bids us remember that "the
transition from the scholar, indeed from the scholastic, to the scientist was no
miraculous revolution . . . the modern scientist took over from his scholarly pre-
decessors all those slowly learned habits of mind and work so necessary to natural
science, patience, accuracy, the hard-won accumulation of mathematics and logic,
the great community of men and women devoted to the cultivation of the mind."
These philologists, translators, and commentators upon the Arabic and Greek texts
were not scientists in our sense, but they were research men in their own way, and
their enormous influence upon education is sufficient evidence that research is the
leaven of scholarship.

Even before A.D. 1500 there were stirrings of scientific curiosity evinced by direct
observation of nature and by experiment. Anatomists were beginning to dissect
the human body again, and alchemy was on its way to becoming chemistry. While
it would therefore be incorrect to say that there was no independent research in
natural science and no influence of research on teaching before, say, 1540, certain it
is that the sixteenth century saw a sharp change. There is a story, probably
apocryphal but symbolically apt, of a dramatic scene at the University of Paris
about the year 1535. The great professor Jacobus Sylvius was in the high rostrum of
the anatomy theater, expounding a book of Galen, with a barber surgeon below him
at the cadaver exposing the successive organs as they were discussed. A brash
student, the young Andreas Vesalius, was so upset by the prosector's ignorance that
he stepped to the front, took the knife away from the demonstrator, and proceeded
with the dissection himself. In that act were packed all the seeds of modern
scientific education: the discarding of mere intellectual authority, the exaltation of
first-hand knowledge, and the idea of learning to do by doing, which called for prac-
tical teaching in student laboratories.

That there was a change became evident to the learned world by the publication
in one year (1543) of the Fabrica corporis humani of Vesalius and the De revolutiomi-
bus orbium coelestium of Copernicus. Our current era of original scientific investiga-
tion had definitely begun.

The great upsurge of natural science in the seventeenth and eighteenth centuries
was partly within and partly outside the universities. Mathematics and theoretical
astronomy had been academic sciences since the founding of the earliest universities
in the twelfth century. Human anatomy and botany, being important to medicine,
were taught academically, and practical work in those sciences therefore could
develop to some extent in the universities. Anatomy was demonstrated on the
cadaver: many of the universities established botanical gardens. Other sciences
grew up, in the main, outside the academic walls. Microscopic biology was notably
the hobby of ingenious private students. Sciences requiring laboratories did not,
genally speaking, domesticate themselves in educational institutions, scarcely even
chemistry, close as it was to botany and pharmacy. Only four of the seventeenth-
century universities are known to have had chemical laboratories, namely, Giessen,
Leyden, Oxford, and Altdorf. Those seventeenth-century scientists who were
professors—Galileo, Torricelli, Malpighi, Isaac Newton—mostly carried out their investigations in their own homes or at the expense of a patron. Outside the universities some scientists, like Harvey, supported themselves by practicing medicine, or, like Leeuwenhoek, by business. Huygens, Baglivi, and van Helmont inherited or married money. The didactic universities were simply unprepared to provide opportunities and equipment for innovators of this type. The foundation of regius professorships in France and England did not take care of this situation. A few specially created institutes, for example, the Collège de France and Gresham College in London, provided institutional centers for scientific discussion, though with very little laboratory equipment. Francis Bacon’s Utopia (in the New Atlantis, 1652) was to have a research institute with a scientific staff and fully equipped laboratories.

It was in the learned academies of Europe that something approaching Bacon’s dream was actually realized. At the Accademia del Cimento, founded in 1657 Leopold de Medici provided a distinguished group of scientists, who experimented in common, with the necessary equipment and defrayed their expenses. Borelli, Stensen, and Francesco Redi were all on the roster of this institution, which operated for six years. Under Louis XIV the enlightened statesman Colbert set up in 1666 the French Académie des Sciences, whose members included Huyghens, Mariotte, Cassini, and Olaus Römer. Here there were laboratory equipment and considerable freedom of investigation. Various similar institutes on a smaller scale were begun in Italy, France, Germany, and Scandinavia; they had checkered careers, each in its own way, but the tradition thus created can be traced continuously to our own time, through the Senckenbergisches Institut in Frankfurt, the modern German and French research institutes, and those of Britain and America.

There were other academies of science, of which the Royal Society of London is the most eminent example, which did not have laboratories of their own but encouraged research as much as the others, and on the whole more durably, by providing for the exchange of information through meetings, correspondence, and publications. Thus in the seventeenth and eighteenth centuries a whole chain of national and local academies and societies, extending all over Europe and, by the end of the eighteenth century, even to America, supported the growth of science by direct observation and experiment rather than by scholastic speculation, at a time when most universities were failing to do so except by their anatomical theaters and botanical gardens.

The universities, indeed, in these same centuries became largely stagnant. In one and another of the leading European nations they suffered variously from loss of freedom through governmental or ecclesiastical control or from the conservatism and indifference of the ruling classes. Their failure to teach, much less to investigate, the new sciences, led here and there to the creation of professorships in the academies of science. The first course in practical laboratory chemistry was founded in 1752 at St. Petersburg in the Russian Academy of Sciences. In Britain there were independent schools of science, such as William Hunter’s famous anatomy schools, in London and also in some of the secondary schools of the Quakers and other dissenting sects, where such men as Priestley and Dalton were active.

Yet all these methods of teaching scientific subjects and promoting new research, put together, could never provide sufficient means for educating the youth of the
new scientific age. The European world had now attained almost complete divorce of scientific inquiry from education. Under these conditions it was education that deteriorated, for in no other field is it more true that what does not go forward goes backward. For a picture of education at its lowest ebb I turn to an English source. The description I am about to read is all the more poignant coming from a land we know so well. For local reasons, the reform of general education by the reunion of teaching and scientific research was postponed longer there than on the Continent; thus the process of degradation had time to go even further. It was as late as 1870 that Thomas H. Huxley could write as follows in his address "Liberal Education":

[In the English primary schools] a child learns

1. To read, write and cypher, more or less well; but in a very large proportion of cases not so well as to take pleasure in reading, or to be able to write the commonest letter properly.
2. A quantity of dogmatic theology, of which the child, nine times out of ten, understands next to nothing.
3. Mixed up with this ... a few of the broadest and simplest principles of morality....
4. A good deal of Jewish history and Syrian geography, and perhaps a little something about English history and the geography of the child’s own country. But I doubt if there is a primary school in England in which hangs a map of the hundred in which the village lies, so that the children may be practically taught by it what a map means.

Huxley goes on to the secondary schools and says that they taught a little more reading and writing ... but it is a rare thing to find a boy of the middle or upper class who can read aloud decently, or who can put his thoughts on paper in clear or grammatical ... English. The “cyphering” of the lower schools expands into elementary mathematics ... a little algebra, a little Euclid. But I doubt if one boy in five hundred has ever heard the explanation of a rule of arithmetic, or knows his Euclid otherwise than by rote.

Of theology ... the middle class schoolboy gets rather less than poorer children... his ideas when he leaves school are of the most shadowy and vague character, and associated with painful expressions of the weary hours spent in learning collects and catechism by heart.

Modern geography, modern history, modern literature; the English language as a language; the whole circle of the sciences, physical, moral, and social, are even more ignored in the higher than in the lower schools. Up to within a few years back, a boy might have passed through any one of the great public schools with the greatest distinction and credit, and might never so much as heard of any of the subjects I have just mentioned. He might never have heard that the earth goes round the sun; that England underwent a great revolution in 1688, and France another in 1789; that there once lived certain notable men called Chaucer, Shakespeare, Milton, Voltaire, Goethe, Schiller. The first might be a German and the last an Englishman for anything he could tell you to the contrary. As for science, the only idea the word would suggest to him would be dexterity in boxing.

As a witness to the state of the old universities, Huxley quotes the rector of Lincoln College, Oxford, Mark Pattison, writing in 1868:

"The colleges no longer promote the researches of sciences, or direct professional study. Here and there college walls may shelter an occasional student, but not in larger proportion than may be found in private life. Elementary teaching of youths under twenty is now the only function performed by the University and almost the only object of college endowments. Colleges were homes for the life-study of the highest and most abstruse parts of knowledge.
They have become boarding schools in which the elements of the learned languages are taught to youths." . . .

Now [says Huxley] let us pause to consider this wonderful state of affairs; for the time will come when Englishmen will quote it as the stock example of the stolid stupidity of their ancestors in the nineteenth century.

I hasten to say that I am one American among many who has seen the results of the reform of which Huxley was a leading spokesman. I have worked at Oxford and at University College, London; visited Harrow, Charterhouse, and Radley with informed guides; and talked over the work of the rural country schools with a schoolmaster kinsman of my wife. It is not to be claimed that the present sound state of education in England was achieved by the scientists alone. Huxley had among his contemporaries John Henry Newman, Benjamin Jowett, and Thomas Arnold; but who will say that without the scientists it would have been accomplished at all?

The reunion of research and teaching in the European universities began, effectively, with the foundation of the University of Göttingen in 1734. There the professors were expected not only to teach but to engage in scientific research, and they were provided with instruments and books. By about 1830 all the German universities were organized in a similar way, and the combination of research with teaching was an established feature of nineteenth-century German educational life.

It is not necessary here to set forth the advantages that accrue from having scientific education at the university level conducted by men who are themselves creative scientists, and at lower levels by men at least who are influenced by the research spirit. It is enough to say that a zest for exploration is the best incentive to work; direct observation develops both originality and precision; the planning of experiment, with its necessary formulation of hypothesis, check, recheck, and reformulation, teaches the laws of scientific evidence, and the attack upon the unknown is a profound antidote to dogmatic thinking. It is no marvel that the German universities of the nineteenth century were the foremost scientific centers in the world. Nor is it necessary to remind you here that the teaching of science and to a large extent also that of history, philology, and philosophy in the American universities stems from nineteenth-century Germany, having been brought over by the scholars who went to that country in the latter half of the last century and spread by the example of the Johns Hopkins, founded in 1876. That the teachers of science should also be investigators is an ideal largely achieved in our universities and in many colleges. It will be a bad day for American education if ever inadequate endowments, competition from industry, political interference, or any other cause divorces research from teaching in the universities.

It is obvious that the benefits of this union have not reached all the way to the secondary schools. Much worry has been expressed of late about the state of science teaching in the high schools, and various methods of improving the situation are being tried. I am frankly riding a private hobby when I say that none of these suggestions goes to the root of the trouble. The fact is that we do not expect enough of the high-school student. Science is too often presented as an easygoing popular introduction to a subject that is considered too difficult to be taken seriously by the young. High-school students can reach a higher level of intellectual discipline than such courses imply; they do it in mathematics and history. Any-
body who has heard an English boy choir sing, or watched a well-coached American
high-school team play football, knows what teen-agers can do when their best
efforts are called out by trained leaders. I have myself seen high-school pupils
under ambitious teachers of biology work in field and laboratory as well as college
students. High-school science ought to mean more than casual natural history or
the most elementary chemical experiments. I believe that the high schools ought
to teach science at the level now set by first-year college courses, so that the colleges
and universities could begin at a more advanced point than at present. When
sound work is expected of the pupils, the teachers will have to be good, and they
will have higher prestige. They may not do research in their high-school laborato-
ries, but they will be the kind of men and women, like our best college teachers
now, who feel the inspiration that comes from research in the universities. Better
salaries for the teachers are of course desirable, refresher courses and summer institu-
tutes are good, but these teachers need more than that; they need a sense of educa-
tional challenge and responsibility and prestige.

To return to our main theme, scientific investigators have in the last seventy-five
years taken a leading part in setting the pace of advanced education in the United
States, and they continue to do so. But history has not only its major revolutions
but also its minor oscillations. The merger of experimental science with university
education was to a certain extent reversed after the beginning of the twentieth
century. There came to be more and more research in nonacademic institutions,
that is to say, in government departments such as those of agriculture and public
health, in certain technical industries, and in independent research laboratories like
those of the Carnegie Institution and the Rockefeller Institute. Since the first
World War, and especially since the second, this tendency has increased. A very
high proportion of our trained investigators are now outside teaching institutions,
and many able men never in their lives exert influence upon educational programs as
teachers or executives. The harm is lessened, of course, by a good deal of migra-
tion from the nonacademic research centers to universities. The Rockefeller Insti-
tute, for example, in its nonteaching days sent out dozens of men into high teaching
posts, largely, of course, in medical schools. Occasionally men return from govern-
ment or industry to university professorships. But the separation into two groups
has, on the whole, been widening.

As of today, however, it seems that the pendulum is beginning to swing the other
way again. Research institutes once characteristically separate from the academic
world are opening their doors to students. The National Bureau of Standards and
other government research organizations have asked the Academy–Research Coun-
cil to help them find a group of postgraduate fellows. One of the largest industries
is sending picked young men back to a university for a year of general studies.
The Rockefeller Institute, which fifty-three years ago asked itself whether it should
offer instruction in the medical sciences and decided in the negative, has now begun
a program which makes it into a university school of biological and medical science.

Science and education at their respective extremes of specialization of course have
different aims and techniques. Talents differ so much that there are investigators
who cannot teach and teachers who cannot investigate—some, indeed, who cannot
even appreciate the ideals and methods of science. But at their core the discovery
of knowledge and the training of young people for effective living are so closely
linked that they must not be allowed to grow apart from one another.
There are those who fear that the scientific investigator, allegedly cold of heart, devoid of respect for the intangibles of human nature, insensitive to the poetry of life, cannot be intrusted with the training of youth. If there are any such in this audience, let us read a statement of the educational ideals of a man who, more ardently perhaps than any other, fought to increase the influence of science upon education in England and America. In that same essay from which I quoted earlier, Thomas Huxley wrote:

That man [I think] has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that, as a mechanism, it is capable of, whose intellect is a clear, cold logic engine, with all its parts of equal strength, and in smooth running order; ready, like a steam engine, to be turned to any kind of work, and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of Nature and of the laws of her operations; one who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience; who has learned to love all beauty, whether of Nature or of art, to hate all vileness, and to respect others as himself. Such an one and no other, I conceive, has had a liberal education; for he is, as completely as a man can be, in harmony with Nature.

If this is the ideal of a liberal education, you will agree that it cannot be achieved unless our best young men and women are enabled to seek the truths of nature and the laws of her operations in the laboratories of experimental science, side by side with men of skill and experience in the unending search for knowledge. "He who teacheth man knowledge, shall not he know?"

The author is indebted to Dr. John B. Blake, Assistant Historian of the Rockefeller Institute for Medical Research, for the use in advance of publication of an article, "Scientific Institutions since the Renaissance: Their Role in Medical Research," Proceedings of the American Philosophical Society, vol. 101, pp. 31–62, February, 1957.

Mr. Bronk: Thank you very much, Mr. Corner. Our next speaker is a remarkable man, with a remarkable range of intellectual interests, who as Secretary General of the Guggenheim Foundation has had a remarkable opportunity to study the qualities of men and institutions which make for great teaching and significant investigation. Mr. Moe.

Mr. Moe: Members of the Academy, and Fellow Guests: I wish I were here to report a series of experiments or even to argue a legal case, proceeding from precedent to precedent, from authority to authority, to a reasoned conclusion—or anything relatively simple like that. As it is, I can only give you my opinions; and I might as well say at the outset that I do not think much of my naked opinions. It is for this reason that you will find me trying to clothe them, even more than Mr. Corner has just done, with evidence from history.

During fifty days spent in the Middle East last autumn, I learned a lesson from history germane to the subject that your president has asked me to discuss here: "Science as Part of General Culture." I had been given what the Navy calls a "roving commission" to find out what I could about the state of higher education