THE NEXT HUNDRED YEARS . . . III

by HARRISON BROWN, JAMES BONNER AND JOHN WEIR

This article has been extracted from the book, The Next Hundred Years: Man's Natural and Technological Resources, *by Harrison Brown, James Bonner, and John Weir, published this month.* Dr. Brown is professor of geochemistry at Caltech; Dr. Bonner, professor of biology; Dr. Weir, professor of psychology.*

This extract, the last in a series of three, has been drawn largely from Dr. Weir's evaluation of our technical manpower sources.

IN OUR ANALYSIS thus far of the material, energy, and food resources of the world, from the purely technological point of view the future of mankind seems secure, if we exclude the possibility of a world catastrophe. There is an almost infinite supply of raw materials and of energy in the granite of the earth's crust, and we have sufficient knowledge of the technology of agriculture and of food production to support a world population of several times our present one. In principle, we may think of the problem of food and material resources in terms of energy. If we can produce sufficient quantities of energy and expend it properly in the production of food and materials, we can meet the demands we foresee for the future.

Our only remaining problem, then, is how to add this energy to the system. Obviously, someone must do it. But this is by no means a simple matter—much skill, knowledge, and equipment is required, and additional skill and knowledge are needed to build the equipment. So, in effect, we may be limited in the amount of energy we can expend, or in the rate at which we can expend it, by the availability of this knowledge and skill—that is, by the availability of technical brainpower, of trained scientists and engineers.

At the present time the United States is the most complex industrialized society in the world. Since it offers almost unlimited educational opportunities of many different kinds, as well as great freedom of educational and vocational choice, an analysis of technical brainpower resources in America will provide us with a good example of the problems of supply and demand for engineers and scientists in a free economy.

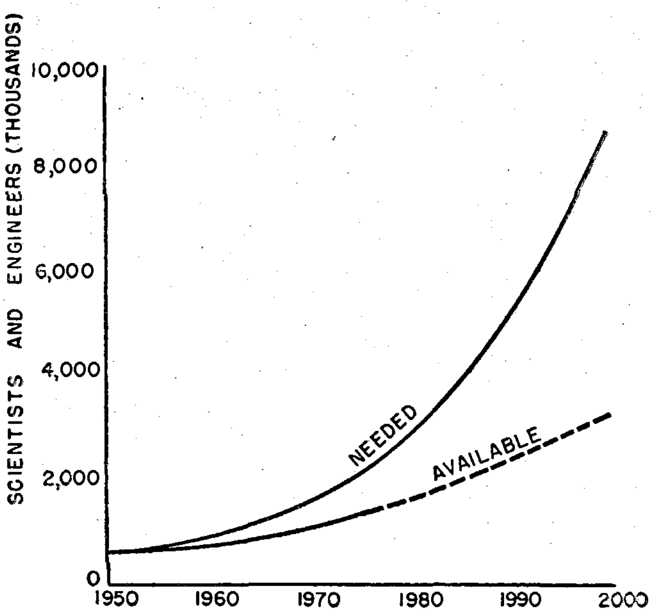
Scientists and engineers have been in short supply in the United States for several years—a shortage which is growing more acute and to which no immediate end is in sight. So critical has it become that industrial organizations are curtailing research and development activities because of a lack of available trained men. It takes many years to train an engineer and even more to develop a professional scientist. Even if we were to double enrollments in technical colleges immediately, it would be five to ten years before an appreciable effect would be felt in the field or in the research laboratory.

When we attempt to calculate the future supply of technical manpower, we are immediately faced with the problem of definition. What is a technician?

For our purposes, it will be satisfactory to confine our discussion to those scientists and engineers who have obtained bachelor's degrees in their respective fields. This group comprises the bulk of trained technical manpower in the United States; and a bachelor's degree in science or engineering provides a reasonably uniform criterion for professional competence.

In 1920 somewhat less than 3 percent of all 22-year-olds were college graduates. By 1930 this percentage doubled to almost 6 per cent. In 1940 it reached 8 percent, and by 1950, 11 percent. The rate of increase has slowed down in recent years, but it is predicted that by 1970 a plateau will be reached and that about 17 percent of all 22-year-olds in any one year will have earned college degrees.

For the past several decades the proportion of the graduates of any particular year that obtains degrees in engineering and science has remained around 18 to 22 percent. Within this group of technical graduates,



Projected technical manpower needs.

however, only about two-thirds of the engineers and one-third of the scientists continue in their respective fields.

On the basis of these varied figures, we obtain the curve above. It shows the total number of scientists and engineers with bachelor's degrees in the working population, and is adjusted for losses due to death and for retirement at 65. It gives us our expected available supply of working engineers and scientists of this level of competence from now to the year 2000, and it forecasts that we will have about 1,700,000 engineers and scientists in the working population by 1980—and about 3,300,000 by the year 2000.

We have, then, our estimate of future supply. What will be the future demand?

During the past half-century, the percentage of laborers and unskilled workers in the American labor force has been steadily decreasing while the percentage of semiskilled and professional workers has been steadily on the rise. The greater part of the increase in the proportion of professional workers is due primarily to increased numbers of scientists and engineers. At the beginning of the twentieth century there were about 1800 persons in the United States for each working scientist or engineer. By 1950, the ratio was about 300 to 1. By 1980, if these trends continue, we will need 1 scientist or engineer to every 90 persons; and by the year 2000, we will need 1 to every 40. When we compare this estimate of demand with the curve of supply, we may conclude that we will need over twice as many scientists and engineers as we will have available in the year 2000.

What are our ultimate potential resources of trained men? If we were able to change these past trends, could we increase the number of scientists and engineers produced each year? If so, by how many?

This is in part a question of the efficiency with which we can develop the potential engineers and scientists among our young people of school age. If we are efficient in this matter, then every American youth who possesses the abilities, traits, and characteristics required of successful scientists and engineers, and who wishes to enter these fields, will do so and will develop his potential abilities to their fullest extent.

As we are limiting our considerations here to engineers and scientists who have obtained bachelor's degrees from college or university, we can readily assess how well we are doing in the education of our young people by studying college enrollment and graduation figures.

For example, let us take a random sample of 100 American youths and follow them through their educational careers. All of them will enter the first grade, since in America everyone goes to school. Eighty will begin the ninth grade, 60 the eleventh grade, and 59 will graduate from high school. Twenty of them will go on to college, from which 13 will graduate—3 in engineering and science. (Only about one-third of our high school graduates go on to college. Of these, slightly more than one-half obtain their bachelor's degrees.)

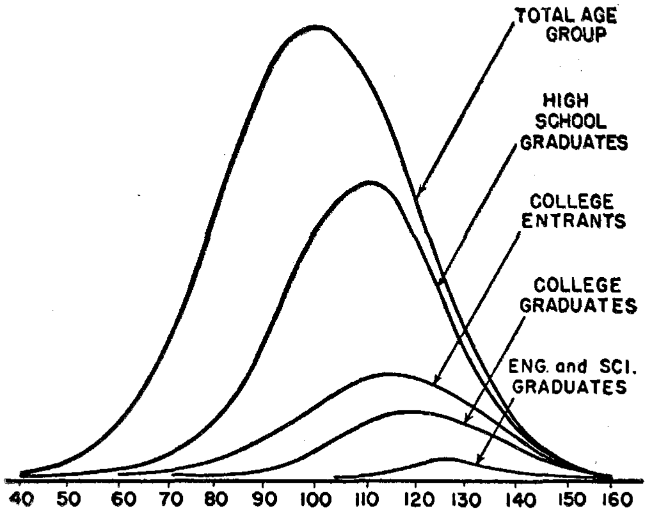
These figures, which are typical of recent decades, give some indication of the attrition among American young people as they progress up through various levels of educational achievement. But they do not tell the whole story, for one may quite appropriately ask: Should *all* high school graduates go to college? Or, should *all* those who enter college obtain bachelor's degrees?

Intellectual manpower

The scholastic requirements set by our colleges and universities demand a minimum level of intellectual ability, so we must consider our output of intellectual manpower in terms of the available supply of potential graduates. We must concern ourselves with different levels of intellectual ability and judge how successful we are in helping each individual develop to his maximum potential.

The chart on page 24 shows the distribution of intellectual ability among certain groups of American young people. The numbers on the horizontal scale represent scores on the Army General Classification Test. These scores are measures of intellectual ability and are roughly equivalent to Intelligence Quotients. The height of the curve above any scale score represents the relative frequency of occurrence of individuals with that degree of intellectual capacity. The large curve represents the distribution of intellectual ability within an entire age group in the United States. The next smaller curve represents the distribution of intellectual ability in that portion of the total group that graduates from high school. Next is shown the distribution of ability of the portion that enters college, then of the portion that graduates from college, and finally, of graduates from college with degrees in engineering or science.

These curves show quite clearly the importance of higher levels of intellectual ability for higher educational achievement. While the average intellectual capacity for the entire group is 100, it is 110 for high



Distribution of intellectual ability.

school graduates, 115 for college entrants, and 120 for college graduates.

But these curves also indicate that there must be important factors in addition to intellectual ability that determine success or failure in college. For, on one hand, some young people scoring as low as 90 obtain college degrees, while on the other hand, at the extremely high-ability end of the curve (those with scale scores of 140 and above) we see that only two out of three obtain college degrees.

These curves indicate rather dramatically that we fall far short of developing to the fullest our intellectual resources within the United States. If we assume, for example, that a score of 110 represents a reasonable minimum of intellectual ability necessary for college-level work, then we can conclude that we lose two-thirds of our potential college graduates. We lose, by the mere fact that they don't go to college, one-half of the very capable, and one-third of the exceptionally talented.

Here, then, is one domain in which we might seek to increase our output of intellectual and technical manpower. If we could increase the efficiency of our educational procedures by eliminating this wasted potential brainpower, we could achieve an important reduction in our current technical-manpower shortage.

The more important influences which lead to success or failure in the making of a scientist or engineer fall readily into three groups—early identification, encouragement, and training.

Clearly, the earlier we can identify the embryo scientist or engineer the better, for we are then in a position to provide him with optimum intellectual and emotional opportunities and encouragement.

There are some indications at the present time that occupational choice within broad fields is determined to a very significant extent by psychological and cultural influences such as the parents' occupations, the socio-economic status of the family, positions of birth order among siblings, the attitudes of the parents toward intellectual knowledge, and the parents' own educational attainments.

We are just beginning to understand the manner in which these influences work. As we gain more understanding, we will be able to identify the embryo scientist or engineer at a much earlier age than is now possible.

The second group of problems centers around the encouragement of the budding scientist or engineer. Of importance here is his motivation for continued study and education. About half of the extremely high-ability students who fail to go on to college do so because they simply have no interest in higher education. Often the young student's rejection of intellectual achievement is a result of attitudes toward intellectual knowledge held by his parents and his peers. And certainly, with the great variety of social and cultural activities that are provided in American secondary schools today, distractions by competing interests and activities sorely test the student's motivation for intellectual work.

At both the elementary-school level and the high-school level, the manner in which science and mathematics are taught, and the enthusiasm and understanding of the teacher often have tremendous influences in awakening the spark of curiosity in young students. Too often, unfortunately, teaching procedures and course requirements deaden any interest the young student may have brought to the subject. In a recent study, the Educational Testing Service observed 60 mathematics teachers at the elementary-and secondary-school level. It was found that only 10 were competent to teach mathematics. The remaining 50 were judged to be confused, often dissatisfied, and unable to teach the subject except in a dull mechanical way.

Vocational counseling

Next, there is the matter of sound educational and vocational guidance and counseling. A student of high-school age is usually quite ignorant of the skills, abilities, interests, and personality traits which are necessary in order to be successful in a particular adult occupation. This is especially true for the professional occupations. Yet only rarely can a young student gain any first-hand experience as a scientist or engineer until very late in his college career. And so he must rely on the advice and guidance of others in making his vocational choice.

Often he must begin this reliance in the 10th or 11th grade in high school, at which time he must choose to study the mathematics and science courses that are required for admission to a technical school. He is much more likely to choose an occupation that will properly match his abilities, interests, and values if he has the opportunity to consider all possibilities in the course of discussions with trained counselors.

Still another influence that relates to the encouragement of potential scientists and engineers concerns financial support. In recent years about 40 percent of high school graduates who were clearly capable of doing college work did not go on to college because of lack of adequate finances. This is today recognized across the country as a loss of technical manpower that can be decreased by immediate and direct action. As a result, the funds available for scholarship purposes have recently been increasing rapidly, especially in technical schools. They have come from school funds, from industry, and from state and federal programs. The time is approaching when any qualified and deserving high school graduate who wishes to enter a technical field will not be blocked by lack of funds—whether he be merely capable, outstanding, or extremely gifted.

Teacher shortage

The third group of factors which affect losses in the production of engineers and scientists relates to training or education. We are faced also with the fact that high school science and mathematics teachers are in short supply. For example, we needed about 7900 new mathematics and science teachers in 1954-55. Only 3800 actually completed training in the same period. Of this number, only 2100 entered teaching in the fall—filling about one-fourth of the total need.

This attrition is easily explained. If the young teacher is well trained in his subject, he can begin his career in industry at an initial salary 25 to 50 percent greater than the initial school salary. After five years in industry, he can expect to earn as much as he might be getting after 14 years in teaching. A qualified scientist must indeed be a dedicated teacher to resist such an attraction.

Thus, the overall effect of these different influences on high school science and mathematics teaching is to lower the quality of teaching and to make instruction in science and mathematics less available just at the time when our industrial growth demands more scientists and engineers.

There is no serious shortage of teaching staff in higher education—at least up to the present time. Higher pay scales, greater prestige, and opportunity to pursue individual research interests have so far proved sufficient to attract qualified scientists and engineers into university teaching. We can, however, increase our efficiency in the production of scientists and engineers at the college level by critically evaluating our admissions procedures and course requirements.

One can certainly question whether it is really necessary to take 22 years to develop a scientist or engineer to the bachelor's-degree level. Might it be feasible to push back the age at which college-level teaching is begun from 18 to perhaps 16 or 15? Are 12 years of elementary and secondary education necessary before the student is qualified to begin what we now regard as a college career? There is strong evidence that the answer is no.

We also need to take a more critical look at our college course requirements. There have been almost no attempts to study the performance by college alumni in their productive careers and to find out how college performance and college course requirements prepare the student for later life. We have little validation of our college teaching procedures. There are probably many undergraduate courses currently required of all students that make no useful contribution to the students' skill or knowledge—either professionally, socially, or culturally.

We have discussed a few of the major factors which currently limit the production of scientists and engineers in the United States. Some of the problems are quite obvious, and solutions to them appear simple and straightforward, although difficult to achieve. For example, the shortage of science and mathematics teachers in the high schools would be eased if teacher pay scales were raised to the industrial level.

Solutions to other problems are not so clear. It will take years of intensive research before we will be able to enumerate all the important factors which contribute to the early identification of scientists and engineers, or before we understand thoroughly the nature of creative thought. It will take imagination, effort, and money to reduce these sources of waste to insignificance. However, if all these obstacles could be removed—and it seems theoretically possible to do so—then we would have a working force in which each individual would have achieved the highest educational level commensurate with his intellectual capacity.

Clearly, we would greatly increase the number of college graduates produced each year. As a matter of fact, we would have graduated about 75,000 scientists and engineers each year for the last two years, instead of the 45,000 we actually did produce.

Why not women?

We can also increase our production of scientists and engineers in quite another way. Among working college-graduate engineers and scientists in the United States, only 1 percent of the engineers and 11 percent of the scientists are women. Does this have to be? No student of human behavior has as yet convincingly isolated any difference between the sexes that would forever preclude women from becoming competent in these fields.

In Russia today, where 50 per cent of professional workers and at least 20 percent of engineers are women, we have a clear demonstration that women can successfully enter these fields. If technical occupations were to be made available and attractive to women, then we might almost double again the number of scientists and engineers produced in America each year.