

Whither GRADUATE EDUCATION

The following article was presented as an invited address on March 2, 1963, at the Southwest Meeting of the American Physical Society, which was held jointly with the Sociedad Mexicana de Fisica at the William Marsh Rice University in Houston, Texas.

By *L. V. Berkner*

THE past two years have seen the rise of a vigorous discussion concerning the extent and adequacy of graduate education in the United States. As physicists and engineers, we cannot ignore this discussion in its broad implications, since the natural sciences and the emergent engineering and technology are at the focus of the discussion—advanced training in physics and engineering is at the central line of that focus. This public discussion arises in response to the

growth of very powerful social, economic, scientific, and educational forces—all of increasing intensity. Moreover, the emergence of new and powerful technologies out of our successful progress in science is further enhancing the community forces that react back upon us and our activities as scientists.

What is the nature and extent of the present discussion?

At the top of the list is the report of the President's Science Advisory Committee that calls for doubling of graduate effort in the immediate future. To quote Jerry Wiesner: "The central thesis of the Committee's first report is the need in this present decade for more individuals of graduate training. The role of the inventor with limited education, no matter how inspired, has diminished; on-the-job training is now a poor substitute for advanced formal education, and today the requisite background in fundamentals cannot be crowded into the undergraduate curriculum. The panel concluded that impending shortages of talented, highly trained scientists and engineers threaten successful fulfillment of vital national commitments." Likewise, our national problems in graduate education have been explored and discussed by several congressional committees.

Numerous committees of the National Academy of Sciences, after mature study, have pointed sharply to lack of opportunity in graduate scholarship as the source of serious blind spots in our national scientific programs.

The President, himself, recently has on more than one occasion emphasized the need for more adequate graduate opportunity.

But discussion of the problem is not confined to this national level; at the state level, where political leaders



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are closer to the needs of their communities, the discussion is even more intense.

Here in Texas, both candidates for governor in the last election emphasized the need for graduate opportunity as a major political objective, and Governor Connally gave the matter major attention in his inaugural address, and in his first official actions.

Governor Brown of California is directing an effort toward development of major graduate schools at La Jolla, Santa Barbara, and Davis (Sacramento), with associated advanced research facilities. Governor Hatfield of Oregon has stimulated, and is now studying, a report of a special committee involving a major Graduate Center of Research and Education in Portland. Stimulated by the growth of science-oriented industry in Minneapolis-St. Paul from nothing to \$700-million annually in a decade, the Upper-Midwest Research Committee under J. Cameron Thomson is creating a new center for graduate opportunity on the Minneapolis-Madison axis. The Ford Foundation and the three universities in Kansas are studying the problem of graduate opportunity there. The new governor of Ohio has assigned to our colleague, Warren Chase, the post of secretary of commerce and development, with instructions to stimulate graduate opportunity in Ohio at any cost. The city of Detroit, in cooperation with Wayne State University, is leveling the central area of the city to enlarge the University at the graduate level and develop basic and applied research activities.

A committee of citizens is studying the graduate problem as it relates to Chicago's economy. Governor Rockefeller has announced a new science center in the Albany-Schenectady-Troy area to stimulate graduate activity in related universities. Boston has announced a 30-million-dollar publicly financed laboratory to augment its already superb educational and scientific apparatus. New York is advancing its Sterling-Forest Scientific Center in cooperation with the universities in New York City. Governor Bryant has appointed a select committee to examine the requirements of advanced education to bolster Florida's lagging economy.

What does all of this, and other intense activity toward advanced educational and scientific goals, mean in our American scene? Is it merely the shallow effort of a few promoters or politicians to make a fast buck out of science for themselves or their communities? Or, instead, is it the manifestation of a deep national disorder for which we, as scientists, engineers, and science-educators, bear the central responsibility for action? I think it clearly to be the latter—evidence of a major national revolution as a consequence of the technology arising from the science of our day with no alternative but to look for aid from that same science and the innovation that flows from it.

Let us remind ourselves briefly of the social factors that force political leaders to focus their attention on science and the underpinning of graduate education required to support it.

The application of health and medicine has produced a population explosion—a population phenomenon that

has been critically examined by our colleague, Harrison Brown, in *The Challenge of Man's Future* (Viking, New York, 1954). American population is expanding about two percent per year with a doubling time of less than 40 years. So at the end of this century, scarcely four decades hence, our population will approach four hundred million. As a consequence of this population explosion, 3.8 million new young workers from the high schools will become available to our labor force each year in the immediate future.

At the same time, through the application of scientific methods and an advanced technology, farming has emerged in three decades as a fully industrialized activity out of the traditional and prehistoric peasant pattern of the ages. Today, small farms by the thousands are being reorganized into large and economically viable production units requiring great capital and factory methods. Already, ninety percent of the production comes from forty-five percent of the farms; thus the

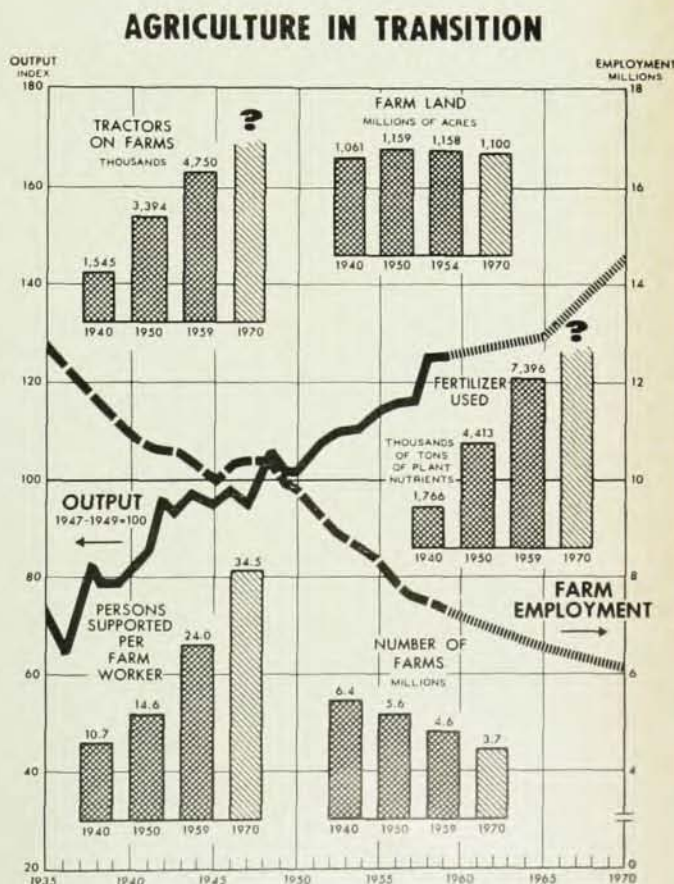


Fig. 1. Although farm output is rising under the influence of new applications of science, the farm population is falling as workers move from rural to urban areas. (Courtesy National Industrial Conference Board)

farm population of the US, according to the Census Bureau, dropped 2.6 million, or 37 percent, in the single decade 1950-1960.

We must endeavor to visualize what these numbers actually mean to most of our nation. Here, in Texas, a formerly rural state, our population is growing 25 percent each decade and in 1960 was classified 75 percent urban and 25 percent rural with 63 percent contained in the state's standard metropolitan areas. Of the 254 counties of Texas, all but 89 *diminished* in population in each of the last three decades; of these 89 counties, 58 had less than ten percent increase in any decade, and essentially all of the new and migrant farm population has concentrated in 31 counties, which are the standard metropolitan areas. These figures are typical of most of the states of our nation.

As a consequence, we are witnessing an explosion of American cities. The farms and small towns depending on farm income are being depleted of manpower. Essentially, all the new and migrant population is massing in the cities, so in the past decade our 100 or so American metropolitan areas have expanded immensely. From 1950 to 1960, according to the Census Bureau, in contrast to the 37-percent decrease of farm population, the number of manufacturing workers rose 21 percent. So our 100 great cities are increasing about 4 million annually, or an average increase for each ranging between 30 000 and 60 000 each year.

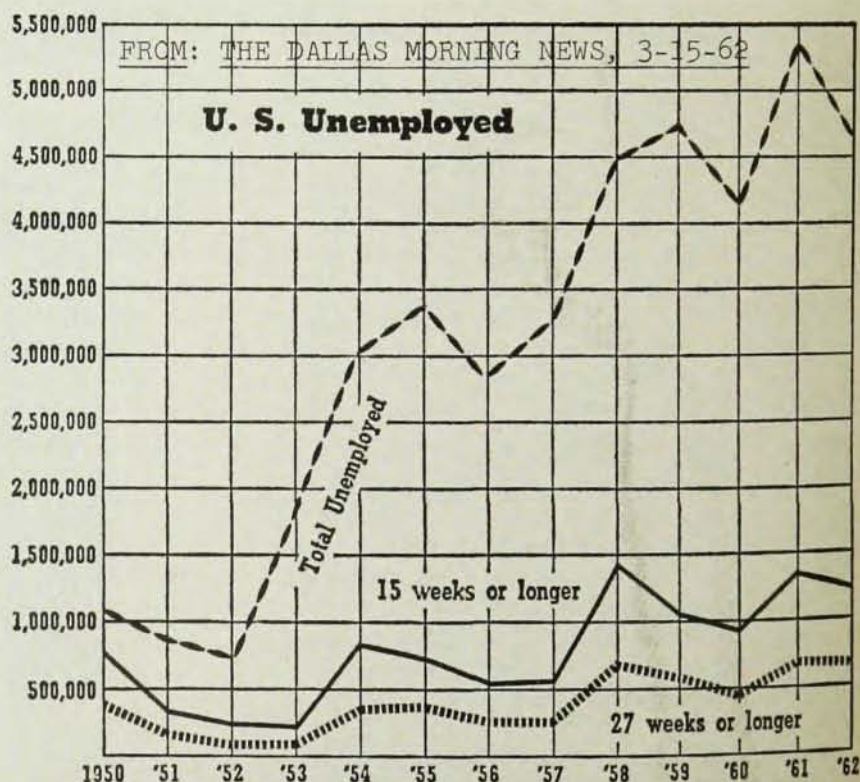
The population explosion of our cities is not merely confined to the industrialized East or North or Far

West. Metropolitan growth is far more apparent in those states that were traditionally agricultural. The migration from the farms and from resource industries enhances the urbanization in what we have remembered as the open areas of the nation. Moreover, the climatic advantages of the South and Southwest further emphasize the effect, with a typical Southwestern city like Dallas going from 600 000 to 1 million in scarcely more than a decade; Houston rose from 800 000 to 1.2 million in the same time.

In the stable manufacturing industries, scientific methods with emergent and improved technology have enhanced productivity, so fewer workers are required for an enlarged production—the much-discussed problem of automation. So with industrialization of farming and automation of stable industry, added to an exploding population, unemployment has steadily risen from two million to five million over the past decade—in the face of the rise of the gross national product to the unprecedented level of \$555 billion in the last year.

These are the social facts that force our political leaders to ask: How can each of our one hundred great metropolitan areas usefully employ an additional 50 000 men and women each year? These facts underlie the powerful social forces that cause our political leaders to turn to science, and to the innovation out of the derived technology, for sources of new industry, new opportunities for employment, and new products and services that nature can be forced to yield. The elaboration of fundamental knowledge has suddenly acquired

Fig. 2. The number of unemployed workers has more than doubled in the last decade.



an economic motivation, in addition to the traditional social and intellectual motivations.

Why do political leaders believe that science can yield a new level of national stability in this changing world? As physicists and engineers, we are acutely aware of the tremendous power acquired by the progressive science of our century.

Where the old Maxwellian science could mathematize technology, the science of our century can now revolutionize it. For the science of today gives man a growing command and control of the very particles of matter and energy of which the universe is composed. The depth of this control was demonstrated by the exigencies of the war, which showed that the science of today, when applied consistently to any technology, can revolutionize that technology—can produce quite new and far more functional technologies to replace the primitive technologies inherited from the ages. So the mid-century has seen the beginnings of an altogether new technological revolution whose power is orders of magnitude beyond what has been seen before.

Our leaders reason that with a science that can yield technologies that produce energy from controlled disintegration of matter, that give explosives 100-million times previous capabilities, that extend vision hundreds of miles, that yield vehicle velocities 1000 times greater than before, that permit travel to the planets—that science can be the foundation of a totally new economy when applied generally to the daily environment of our citizens.

Already the growth of science-derived industries is brilliantly apparent as a new phenomenon since the mid-century. In one rapidly growing metropolitan area that we have studied, essentially all the new industry and employment of the 1950-60 era was science-derived industry. This pointed demonstration, repeated in a dozen metropolitan centers, is no longer ignored by our leaders.

But to capture the innovation to be derived from today's science, we must have men in sufficient numbers who are trained to command the boundaries of scientific knowledge. Consequently, the knowledge of the PhD-trained scientist and engineer is at the core of the new science-derived industry. In the same metropolitan area mentioned above, our studies show that in 1950 perhaps 100 PhD-trained scientists and engineers were employed. There was essentially no science-oriented industry, the economy being related to oil and agriculture. As elsewhere, the PhD in 1950 was an academic curiosity, useful to this society only in a professorial and academic role.

By the early 1960's, employment of PhD's in this Dallas-Fort Worth area had risen to more than 1000, of which only about 200 were in the universities. One third of the total industry is now science-oriented industry. One third of the employment of the entire metropolitan area, and probably most of the new employment since 1950, depends on technology emergent from recently elaborated science. One PhD is now required for each 115 workers in these science-oriented

MORE JOBS AT HIGHER SKILLS

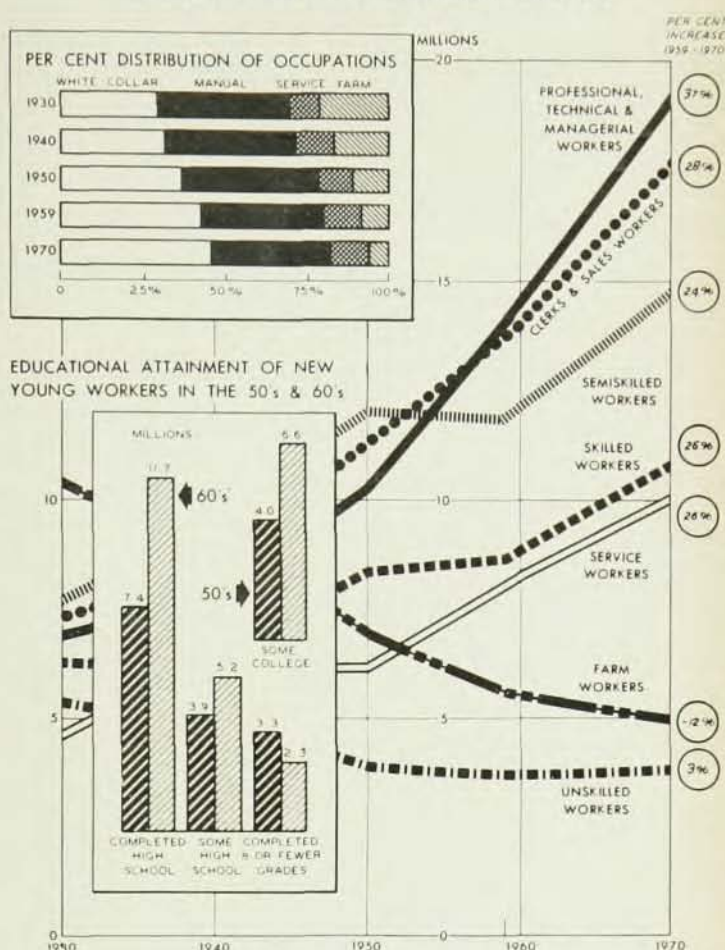


Fig. 3. The number of trained workers employed in professional and technical fields and in management has doubled since the end of World War II. (Courtesy National Industrial Conference Board)

industries. The existing industries estimate their need for additional PhD's will increase to not less than 1600 by 1970. This does not recognize new industry that will emerge during the decade—industry not yet in being. So one can estimate that by 1970 the demand for PhD's in this one metropolitan area will be more nearly 2500, or an increase averaging about 200 per year.

When we multiply this one experience by 100 American metropolitan areas, we can see the intensity of the problem.

Of course, corresponding demands for higher skills become apparent at every level of education. The statistics of the last decade show this clearly.

For each PhD we can employ five to ten engineers at the bachelor's level, and for each such engineer, we can use ten to fifteen skilled workers. But the creation of new industry, new products and devices, new methods and applications from the new technology arises

strikingly apparent. For instance, in 1950 about five percent of PhD degrees were earned by students from abroad; in 1960 this number had increased to fifteen percent. So the apparent five percent annual increase of PhD graduates is illusory, with the rate of earned PhD degrees by graduate students of American origin in the sciences hardly increasing at all. The flattening of the curve since 1959 appears to be an approaching saturation of the small number of universities responsible for the main output of PhD graduates. At the same time, as we have already seen, the need for such graduands has increased by a quantum jump since 1950 with the onset of the technological revolution.

Let us look at the regional distribution of opportunity for doctoral training.

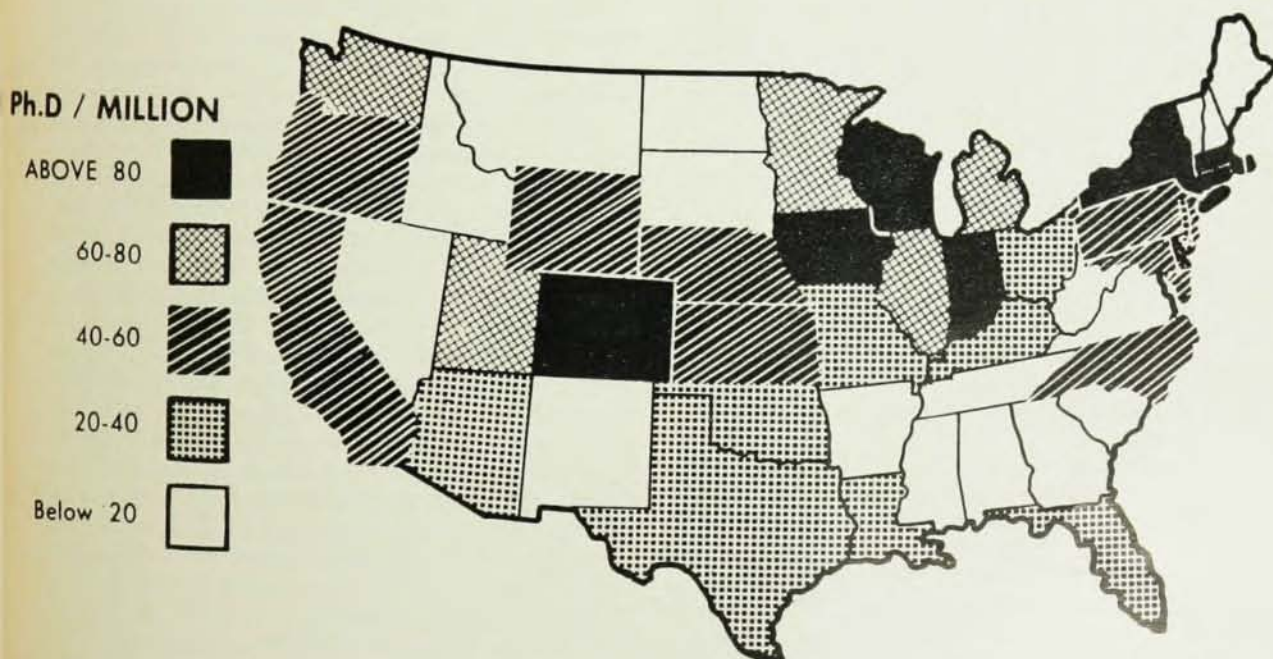
In 1959, for example, 9400 doctoral degrees of various kinds (including education and divinity and excepting medicine and law) were earned in the United States. Two thirds of these degrees were granted in ten states which have forty percent of the US population. The concentration in the Northeast, Upper Mid-West, and Far West is apparent.

The concentration of graduate activity per unit population is a more significant measure. Here I remind you that the level of *undergraduate* activity is almost uni-

form from state to state over the whole nation. At the graduate level, the picture is radically different. The ten states producing about two thirds of our PhD graduands have an average rate of more than 85 doctoral degrees granted per million of population (excluding medicine and law). They are:

	<i>PhD's annually per million state population</i>
Massachusetts	140
Connecticut	121
Wisconsin	95
Iowa	90
New York	89
Indiana	88
Illinois	74
Minnesota	70
Michigan	62
California	59

Here we must destroy the widely believed myth that students everywhere travel to the great centers of learning which serve the whole nation. Of course some



NOTE: Figures 5 to 8 and certain material included in this text are taken from a more extensive paper published by the author in the *Journal of the Franklin Institute*, and due credit is hereby acknowledged.—L. V. B.

Fig. 6. Intensity of doctoral activity (1958-59), a state-by-state comparison of the numbers of new PhD's per unit population.

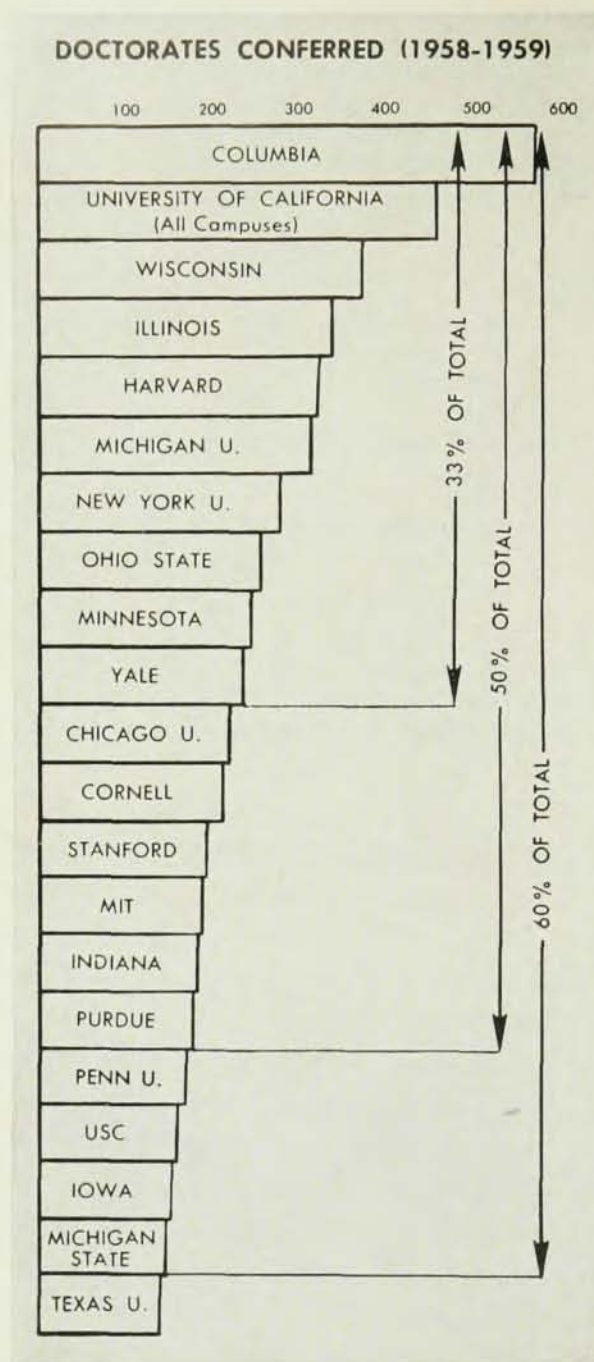


Fig. 7. The leading universities in the United States (in terms of numbers of doctoral degrees granted). Together, these institutions produced approximately two thirds of the nation's PhD's in 1958-59.

does not mean that they necessarily attend the nearest graduate school; but it does mean that the presence of the graduate school has a powerful effect on community and individual attitudes and motivations.

About two thirds of all doctoral degrees were granted by twenty leading universities, eighteen of which are in the ten leading states. Without question, these ten states, and twenty leading universities completely dominate US graduate education. If we add Ohio and Pennsylvania, the twelve states, with half of the US population and all of the twenty leading universities, produce more than three fourths of all US doctoral graduates (though Ohio and Pennsylvania average only 42 PhD's annually per million population). The remaining 38 states with the other half of the population, produce only one fourth of the US doctoral graduates at a rate of a little more than thirty PhD's annually per million population.

Without question, Americans must take off their hats to the leadership of these twenty great American universities which represent not just the core, but almost the whole of significant American graduate effort. To these we must add a few smaller universities such as Caltech, Rice, and Princeton, whose unquestioned excellence by any standard of international comparison has contributed immeasurably to the quality of our doctoral training.

The contrast among metropolitan areas is even more striking. Compare Boston, having 600 PhD's annually, or San Francisco with 500, or Los Angeles or Detroit having 300, or Minneapolis-St. Paul having 250, with Houston, New Orleans, or Oklahoma City having 40, or Dallas-Fort Worth having six, or Phoenix with none. Or compare a rural university like Cornell at Ithaca having 225, or Illinois at Urbana having 350, with the only substantial graduate university in the South or Southwest, Texas at Austin, having about 150. These contrasts may be bitter, but they are too critical to ignore in the face of the oncoming technological revolution. We simply must face the facts realistically.

Even more critical is the failure of great new graduate schools to emerge in the past two decades. In 1920, some ten graduate schools produced two thirds of our PhD graduates. In 1940 this number had increased to twenty universities producing two thirds of the doctoral degrees. Now, more than two decades later, the number is still twenty universities dominating the scene. At the very moment our national situation demands a radical enlargement of graduate education, the emergence of new great graduate universities has come to a dead halt.

do; and, of course, all such centers have a national, even international, character. Without doubt, they are the leaders! But fewer than ten percent of PhD graduates go more than 500 miles from their homes to pursue their graduate studies. Moreover, in the leading states (in the graduate sense), from ten to fifteen high-school graduates per thousand go to the PhD, while in the states lagging in graduate opportunity, only five per thousand achieve the degree. *The central point is that students do not go to graduate school in large numbers unless a substantial graduate school is near them!* This

I submit that this situation calls for a complete, critical, and objective reappraisal of our activities in support of graduate education. Let us try for a moment to see what has gone wrong.

Let us look first at university size. Among the top twenty graduate universities, i.e., those that produce two thirds of our doctorates, the number of doctorates granted per year ranges from some 600 at Columbia to about 200 at Michigan State. The big schools, like Columbia and Berkeley, are perhaps near maximum reasonable size because of organizational management problems.

Universities granting fewer than 150 doctorates per year, with two or three outstanding exceptions, tend to be strongly undergraduate-oriented, with graduate education taking second place.

Typically, any of the big twenty will have thirty to fifty percent of their student body in the graduate school; while, typically, any of our other universities rarely exceeds ten percent of graduate students. This fact reflects powerful implications with respect to teaching load, research opportunity, and faculty frustration.

Moreover, the top twenty are not only the largest, but by many are also considered among the best. So the optimum size for an excellent graduate university designed best to serve the needs of the community seems to fall between Harvard with 325, and MIT with 200 doctorates granted per year—let's say 250 on an average.

Since our objective should be about 100 doctorates annually per million population, how many good graduate universities do we need? For the whole United States with 190 million population, this means one for each two-and-one-half million, or some 75 good, substantial graduate schools. This is a lot more than twenty. Even then, our population will have risen to 250 million by the time we can do much about it, and then we will need 100.

How many good graduate universities producing more than 200 PhD's annually do we need in a typically changing region like the Southwest? With its 20 million people, we should have at least ten, and by the time we could build them up, we will need twenty. We can note here with some satisfaction that there are now twenty graduate universities in the Southwest giving some doctoral training. So the task at hand is to build these universities to adequate graduate size and, at the same time, to generate first-rate graduate quality to serve their community needs in this technological age. If this job can be done, then every great metropolitan area in the Southwest would be served.

Well, you may say, do you propose to generate a bunch of mere PhD factories? I remind you that the numbers we are considering are relatively small. Our present output of PhD's is only 650 in physics, 800 in engineering, 1200 in chemistry, 1000 in biology, and a handful in mathematics. Less than half of the total of 10 000 PhD degrees annually relate in any way to the fields of natural science and technology. The immediate need is to multiply this output by four or five.

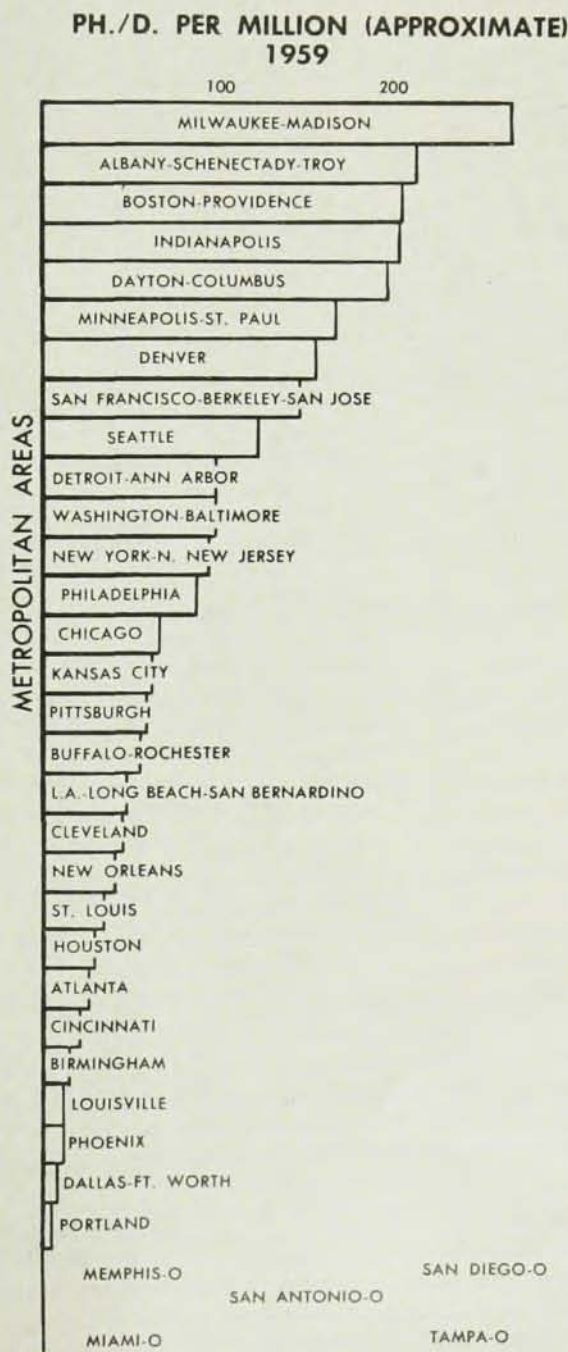


Fig. 8. A comparison of the most heavily populated metropolitan areas of the United States in terms of the numbers of new PhD's produced per million residents.

On the other hand, we can reliably estimate that more than 75 000 high-school graduands annually exceed the median level of IQ and creativity indices for individuals now receiving the PhD.* So to talk of exhausting the supply of qualified individuals is nonsense. The job is to enlarge opportunity for their training, and to identify these students to motivate and to support them. Since the median level of existing PhD's is so low in comparison with the supply, there is plenty of room for improvement.

Others may ask: Do you suggest that scholarship should be tied solely to crass commercial or military objectives? Should not the case for advanced education be made in terms of purely scholarly goals and the advancement of man's artistic and spiritual growth? Are you not degrading academic aspirations by relating advanced study to man's material welfare?

No one can question the intellectual search for truth as a major objective in the advance of the human spirit; of man's grasp for the expression of beauty, compassion, and dignity. Certainly the foundation of knowledge must always have as a major objective man's comprehension of his total environment—his entire adaptation to it.

But as man's knowledge has increased, that knowledge has modified his environment. That modification has come, at first slowly, and then since the mid-century, explosively. Man's changing social environment, out of the new knowledge of our century, has diverted his major needs for more labor in traditional production of food and resources, and their conversion into basic necessities for existence; at the same time, medical science has produced a population explosion.

So at the mid-century, our society finds itself plunged into a new social environment to which it must suddenly readjust. That readjustment requires a far greater emphasis on education at the boundaries of knowledge. Social adaptation to the new technological environment has become dependent upon leaders of thought, in much greater numbers, who collectively command and advance the whole range of academic attainment for human enlightenment and benefit.

Seen in this light, there is no conflict between the academic goals of man's spiritual and his material advancement. I would merely assert that the goals of knowledge now embrace both spiritual and material goals unambiguously; neither can be ignored if our society is to remain healthy. Where before, the scholarly pursuits were insulated from man's daily activities, and influenced them only obliquely, today we find that the new social environment puts scholarship at the very focus of man's whole future welfare.

As a consequence, in a decade the university has moved from the wings of the stage to the floodlights. Now in the full glare of society and its needs, the spec-

tators are no longer disposed to accept a fumbling, amateur, and immature performance.

What, then, is the academic response to this challenge?

As might be expected, it comes primarily from our academic leaders—the big twenty that are the foundation of American graduate education.

On one hand, they have created intellectual centers like Brookhaven and the Radiation Laboratory at Berkeley, where faculties and advanced students of many universities can join together in challenging nature to its limits. Postdoctoral research associates are developed in relatively large numbers to return to the universities in advanced areas of science. Out of this stimulation, their own universities have grown mightily in stature.

On the other hand, following the stimulation of President Hancher of Iowa, the Big Ten and Chicago have formally broken down interuniversity lines at the graduate level to permit free and easy interchange of faculty and graduate students. Their objective is to provide, collectively, access to the limits of all human knowledge.

Some great universities in our metropolitan areas are, with the cooperation of industry, making a determined effort to provide graduate opportunity to graduate scientists and engineers on a part-time basis. Certainly the individual motivation and maturity of the participants is great; and, where successful, offers a short-cut in augmentation of the ranks of advanced science and technology.

These are bold experiments of a quality designed to meet the challenge of our times. These are the actions of universities which already are doing their part to meet the social needs of today. *The key to the question: "Whither graduate education in America today?" lies in the response of Universities numbers 21 to 75.* Whether they can comprehend and evaluate the challenge; whether they can create the leadership; whether they can take their place with the big 20, will doubtless determine whether our nation can achieve an optimum adaptation to the revolutionary social changes of our time.

In closing, I recall the words of the philosopher, Alfred North Whitehead:

"When one considers in its length and in its breadth the importance of this question of the education of a nation's young, the broken lives, the defeated hopes, the national failures, which result from the frivolous inertia with which it is treated, it is difficult to restrain within oneself a savage rage. In the conditions of modern life the rule is absolute: the race which does not value trained intelligence is doomed. Not all your heroism, not all your social charm, not all your wit, not all your victories on land or at sea, can move back the finger of fate. Today we maintain ourselves. Tomorrow science will have moved forward yet one more step, and there will be no appeal from the judgment which will then be pronounced on the uneducated."

* See Lindsey R. Harmon, "High School Backgrounds of Science Doctorates", *Science* (March 10, 1961), Vol. 133, Table 11, p. 686.