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GRADUATE WORK IN SCIENCE, PAST, PRESENT AND FUTURE[1]

By Dean F. K. RICHTMYER

CORNELL UNIVERSITY

IT is generally agreed, even by casual observers, that the world seems to be passing rapidly from one era of its history into another. We of 1936 are, of course, too close to the stirring events of this decade to be able to evaluate their true significance. That task must be left to the historian of several generations hence. We are conscious, however, of the fact that momentous changes are taking place before our very eyes, in almost every phase of human society.

Those governments of the world in which revolutions have not yet occurred are undergoing an evolution so rapid that it may almost be called "revolution." It is only a few short years ago that a great war was fought "to make the world safe for democracy." But now, to our regret, the question "Is democracy safe for the world?" is being raised by persons to some of whom at least, whatever we may think of their philosophy, we must credit sincere motives.

Sometimes in our more pessimistic moods we are inclined to wonder whether our whole economic structure is not breaking down. We see rapidly changing social relations among individuals and among groups of individuals, whether the grouping be on economic or geographical lines. Even religion, usually the most stable component of society, is experiencing transitions as fundamental as they are subtle.

What are to be the characteristics of this new era

[1] Presented upon the occasion of the celebration of the twenty-fifth anniversary of the founding of the Graduate School of the Ohio State University, Columbus, Ohio, May 22, 1936.

into which we seem to be entering so precipitously, we find it difficult to forecast. Not in recent times has the future been so beclouded. Nevertheless, the educator, with obligations almost unique among those of his professional colleagues, must try as best he may so to order our present educational system and its underlying philosophy as to give to the youth of this generation adequate training for leadership in the next. The task is not easy; but it must be faced if our schools, colleges and universities are to render the service that society has a right to expect of them. It is therefore peculiarly appropriate that the Ohio State University, in celebrating the twenty-fifth anniversary of the founding of its Graduate School, should be considering plans for the future, in addition to looking backward at a quarter of a century of rich and satisfying accomplishment.

Dean McPherson has asked me to discuss the next twenty-five years of graduate work in the sciences. In some respects, graduate work in the sciences differs from graduate work in the humanities, but there are many more points of similarity than of difference. Furthermore, graduate work, taken in its entirety, is merely a part of our whole educational system, which extends in unbroken line from kindergarten, up through high school and college to research and scholarly work by the faculty. It is impossible to discuss one segment of that system apart from the others. I am inclined to the opinion that education has suffered from too many water-tight compartments that have separated the several subjects of the curriculum from each other; have separated high school from college; and this from graduate and faculty research. We see some of these compartments breaking down. They should all disappear.

Centering our attention, however, on graduate work in the sciences in its relation to higher education, we find a suitable starting point for our discussion in the question: What is the fundamental objective of our colleges and universities? One oft-quoted statement has it that they serve "to disseminate existing knowledge and to create new knowledge." But it has always seemed to me that any educational philosophy based on this as a statement of purpose leaves much to be desired. It places far too much emphasis on knowledge as such; as if the acquisition of knowledge either by the individual or even by the race is an end in itself. It is the ability to use knowledge and to enjoy its possession for cultural and other similar purposes that gives knowledge its real value. No; the dissemination of existing knowledge and the creation of new knowledge—that is to say, teaching and research—are not ultimate objectives; they are functions, serving a deeper purpose. It is the purpose of our institutions of higher education to train men and women, using the word "train" in the broadest possible sense. It is to this thought that I wish to devote major emphasis.

Conventionally, we classify the academic activities of our colleges, universities and technical school under three heads—undergraduate work, graduate work and faculty research. This classification, however, serves the purposes of organization and administration far more than of function. For reasons so old that they have long since been forgotten, the so-called undergraduate courses occupy four years. But for the five or six per cent. of undergraduates who enter upon graduate work, the transition from the one to the other involves no real discontinuity of either method or purpose. And the relations between graduate work and faculty research are so intimate as to be almost axiomatic. Graduate work reaches its culmination in the research problem, whether for the master's degree or the doctor's degree. Real research problems can not be assigned, much less directed, out of a book. They must come, and their direction must spring, out of active programs of research carried on by the faculty. In a very real sense graduate students and faculty are collaborators in a great and challenging enterprise—"the creation of new knowledge." But the real end to be sought is the training which the graduate student receives through his intimate, almost daily, contacts with the professor. The quest for the undiscovered laws of nature, compellingly fascinating as that quest is, after all is only a by-product—albeit an important one.

Accordingly, the formula for the further improvement of graduate work in the sciences would seem to be relatively simple—at least so far as a *statement* of the formula is concerned. Maintain as a graduate faculty a capable, enthusiastic group of scholars. Give them adequate opportunities—that is, both time and facilities—for carrying on research. Surround them with a relatively small number of carefully selected, well-trained graduate students—and in very large part the future will care for itself. It might seem that little more need be said about the next twenty-five years of graduate work—in either the sciences or the humanities.

The underlying principles of this formula are indeed basic, not only in graduate work, but in undergraduate work; in the high school; even in the kindergarten. The success or failure of any of the institutions of modern society depends in very large part on personnel. As applied to education, the formula is as old as education itself, and has been stated hundreds of times and in various ways.

But this formula, like mere knowledge transmitted from teacher to student, is of no use unless it can be applied. And it is in the application of the formula

that certain guiding principles and philosophies are requisite. A knowledge of the fact that the tensile strength of steel is 60,000 pounds per square inch is imperative in bridge building. But that knowledge alone will not enable the novice to design and construct a bridge.

Let it be admitted that our institutions of higher education need the services of the best minds the country can produce. Let it be assumed that those in whose hands lie the destinies of these institutions have at their disposal funds adequate to secure such services—a utopian assumption that is as far from realization as mankind is from perfection. Let us grant that the ultimate goal of education is the training of young men and women for positions of responsibility extending all the way from Greek archeology to animal husbandry. There still must be formulated, and with the changing times even reformulated, certain basic principles to guide administrators in the selection of faculties, and faculties and administrative officers jointly in carrying on their work. And we must remember that in the last analysis an institution is judged by the caliber of its faculty.

So, granted all this, what then?

Plans for the future are best made by starting from the present, with the past as a background of experience. How has graduate work in the sciences reached its present stage of development? What are the successes and the shortcomings of our present system? What changes, in either administration, procedure or underlying philosophy, should we be prepared to make in the future?

Graduate work in the sciences is of relatively recent origin in American institutions of higher education. The American college dates from colonial, indeed rather early colonial, times. Before the Revolution there were ten or a dozen colleges, lineal descendants of Oxford and Cambridge, devoted mainly to the training of ministers for the church. One half of the graduates of Harvard in its first century of existence entered the ministry. The charter of William and Mary states it as a prime object that the Church of Virginia be provided with a seminary to train ministers of the gospel. In a very real sense, therefore, these early colleges were professional schools. Their curricula were comprised largely of Greek, Latin, some mathematics, logic, philosophy and divinity. Their presidents were usually ministers. Their resources were very small. The annual budget of Yale in the early seventeen hundreds was of the order of 300 pounds. Nevertheless, these colonial institutions performed a great service, if for no other reason than that they laid the foundations of our college and university system.

An abrupt change came with the Revolution. Not only was the work seriously interrupted, for a quarter of a century, but new obligations and new opportunities appropriate to the new country came into being. By 1800 the type of institution that characterized the first half of the nineteenth century was well crystallized. Looking back with the perspective of a century, this institution seems to have differed very little from its colonial progenitor. The curriculum, rigidly fixed for all students, still consisted of Latin, Greek, mathematics, logic, philosophy, with the addition of a very little "natural philosophy" and history. Intellectual discipline and culture were the primary objectives. Professional training declined. Some one, in the middle of the century, referred to the American college as an institution which served to give to the sons of the well-to-do something the only purpose of which was to distinguish them from their less fortunate contemporaries.

Nevertheless, the colleges grew both in number and in student enrolment. By 1850 there were 234 collegiate institutions, with 1,600 teachers, 27,000 students and an annual income from all sources of $2,000,000. Well toward half of these institutions were professional schools—theology, law, medicine.

The conservatism of these colleges was in strange contrast with the restless progressivism of the new country, and by the middle of the century we note that, among many others, two shortcomings were recognized.

First, the fixed curriculum provided no opportunity and little incentive for study beyond the conventional four years—with the result that those few students who became interested in advanced work were forced to go to European institutions. This proved later to be a blessing in disguise.

Second, there was dissatisfaction with the type of training which the fixed curriculum gave. It overemphasized disciplinary and cultural values. It did not recognize the needs of the country for education along more practical lines. Moreover, the increase in knowledge, particularly in the sciences, forced into the fixed curriculum many new subjects, with the result that the four years of study became more and more superficial.

The changes which were to be made in the last half of the nineteenth century were foreshadowed by the plan adopted by the University of Virginia at its founding in 1825. The prescribed curriculum was to be abolished, and a free elective system substituted therefor. Specialization was to be encouraged, and training for particular vocations was to be introduced. In one form or another these suggestions were tried, half-heartedly, by a few other colleges, but without success. It seems to have been true then, as now, that there is no legislative body more ultra conservative than a college or university faculty!

The evolution of the modern American university began shortly after the Civil War. In its development we recognize, among others, two influences which are particularly germane to our present discussion.

First, as noted above, many young Americans, to continue their education, went to the European universities, particularly to those of Germany, where they found a freedom and an insistence on research and productive scholarship almost unknown in America. Returning to America, many of these young men joined the faculties of our colleges and universities, and, fresh from the inspiration of their European experience, by both precept and example gradually enlarged academic view-points, broadened the curriculum and in effect introduced our present system of graduate work and research. A statistical study of the academic backgrounds of professors who are now retiring from our faculties shows that many of them took their Ph.D.'s in Europe. While they represented, collectively, all branches of learning, there was special attention paid to the sciences.

The second influence has been a very powerful one —so powerful in fact as to dominate, even to control, our whole system of education. The introduction of electric power and the telephone; the rapid increase in facilities for transportation; the opening up of the rich agricultural west; the increased utilization of our vast natural resources—all emphasized, indeed made critical, the need for men, and ultimately women, with special training not only for the professions but for positions in industry. The extent to which our colleges and universities responded is indicated by the growth which has taken place since, say, 1880. In that year, there were 600 college students per million of inhabitants, and of these, eight—a vanishingly small number—were graduate students. In 1930 there were 7,500 college students per million of inhabitants —an increase of more than twelve fold over 1880; and 380 graduate students per million of inhabitants— an increase of nearly fifty fold. The first Ph.D. given in the United States was granted by Yale in 1861. The University of Pennsylvania followed in 1870; Harvard in 1873; and Columbia in 1875. According to Walton C. John[2] 44 Ph.D.'s were granted in America in 1876. At the present time the number exceeds 2,600 per year.

Since our colleges and universities, particularly our graduate schools, have grown so rapidly in response to the needs of industry, technology and the professions, it is perhaps but natural that these needs should permeate to every nook and corner of our whole system of education. If I were to select one adjective that more completely than any other characterizes modern education, it would be the adjective "utilitarian." Graduates of high schools are supposed to have been inadequately educated unless they are prepared at once to enter some business or trade; and, wisely or unwisely, the curriculum has been shaped to that end. Students enter college, not merely in the professional courses, but in colleges of liberal arts and sciences as well, with the definite, almost sole, objective of securing a preparation for a life work. And this same objective motivates most of those who continue on into graduate work. This applies equally to the student of English, who goes into teaching or professional writing; to the student of chemistry, who goes into industrial chemistry; and to the student of geology, who goes searching for oil. Not only are many of the courses, both graduate and undergraduate, deliberately designed with this end in view, but universities have officially recognized their assumed obligations by organizing placement bureaus to secure positions for young graduates.

In short, the American university of 1935 is almost the complete opposite of the college of the first half of the nineteenth century. The latter emphasized culture and mental discipline almost to the exclusion of the so-called "practical" objectives. The former emphasize practical training with far less relative attention to culture and mental discipline. The pendulum has reached the other end of its swing.

Now, of course no one would for a moment recommend that we discard the developments of the past half century, even if those developments have been mushroom-like, and return to the college of 1850, with its narrow, fixed curriculum and its almost complete indifference to the practical needs of the current civilization. The exceedingly complex structure of modern society demands men with highly specialized training, to build our bridges and power plants; to levy our taxes and to man our courts; to organize and direct our industries; and to invent new things to be used as necessities, conveniences and luxuries for an increasingly voracious public. Only the colleges and technical schools can supply men with such training. As knowledge has increased, the extent of specialization required has increased. The length of time which a student must devote to his studies has increased. And thus the graduate school has been called on more and more to provide what in almost every subject amounts to professional training.

Nevertheless, the modern university lacks something which the earlier college, in spite of its many shortcomings, did emphasize. For example, it is debatable whether long, concentrated study in a very narrow field is the best training even for the embryo specialist. A few months ago during an all-day trip in a chair-car I chanced to get in conversation with a traveling companion, who was manager of a large real estate busi-

[2] Bulletin No. 20, 1934, U. S. Department of Interior.

ness in a mid-western city. He told me that one of his duties was each year after commencement to engage for his company a number of high-school graduates, to run errands, collect rents and ultimately to develop into more responsible positions. His criterion for probable future success was four good years of high-school Latin. This he regarded as far more important than the specialized training provided by the commercial courses in high school. "Latin," said he, "is a sieve. Only the better minds get through. Also," he continued, "Latin provides a disciplinary training, which is as real as it is difficult to analyze." This real estate dealer was looking for a mind; not for an automaton.

However, it was the emphasis on culture or more properly speaking on non-utilitarian objectives, inherent in the colleges of a century ago, to which I particularly refer. Whether the Latin and Greek and rhetoric characteristic of that period constitute the *sine qua non* of culture is not the point. One of the most uncultured men I know is a Shakespearian scholar. A mechanical engineer of my acquaintance would instantly be classed as a cultured gentleman in any group. I do not know an acceptable definition of culture; nor am I very much concerned about it. But what I am concerned about is the fact that while our colleges and graduate schools have developed to a point of high efficiency the technique of training men and women how to earn a living, they have grossly neglected the technique of training men and women how to live.

But, it may be asked, what has all this to do with the next twenty-five years of graduate work in the sciences? Graduate students, and their faculty colleagues, will continue to be concerned with finding new methods for splitting atoms; with bridging the gap between animate and inanimate matter; with elucidating the many puzzling problems of vital processes; with peering into still further depths of space by, perhaps, 400-inch telescopes. For the most part these investigators, both old and young, will be motivated by a desire to study the phenomena of nature; not by any hope of personal gain, even remote, as a result of these researches. Could anything be farther from "utilitarian"?

The answer, I think, is to be found in repeating our statement that the primary function of any university is to train men. These young graduate students, embryo scientists, are being trained for careers. Some will go into industry; some to government laboratories; some will continue in universities, where they will train the next generation of scientists. But wherever they go, they are, in their graduate work, laying the foundations of a career, just as truly as if they had been studying medicine or law or engineering, instead of physics or biology or astronomy. The fact that they enter science for the love of it is no distinguishing feature. So does the *real* professional man, if he makes a success of his profession. I have never built a bridge. But I can well understand that the bridge designer gets as much joy and satisfaction over seeing the bridge he has built, as I do when I have discovered some hitherto unknown relationship among physical phenomena. The fact that the bridge builder's monthly check may be ten times my own doesn't in the slightest alter the argument.

We should, of course, continue to strive unceasingly for better faculties, better facilities, enlarged opportunities for carrying on scientific research in our universities, and thereby the better to train young men and women for careers in science. But when we have given them our best we have succeeded, sordid though the expression may be, merely in teaching them to earn a living. I am bold enough to predict that this business of *earning* a living, essential though it is, will be somewhat less important in this new era ahead of us than it has been in the past half-century. Living outside of one's profession; taking a deeper interest in the trends of human society; trying to understand the many puzzling problems which are ever before the race; accepting one's responsibilities as a world citizen; drinking deeper of the great enrichments of life—these will play a larger part in the future than they have in the past. We will do our young scientists an ill service, if, in our enthusiastic emphasis on a scientific career we detract their attention completely from this business of living. A scientist who knows only his science is as narrow as an engineer who knows only his bridges; or as a classicist who knows only his Greek. The world can never make progress if it is made up of narrow men.

With a few notable exceptions, scientists as a group have not been very active in extra-scientific affairs. This is to be regretted. For not only has science been almost solely responsible for moulding, for better or for worse, the material aspects of present-day civilization, which in turn have influenced so profoundly our whole social complex; but science is unique in the extent to which it recognizes no international boundaries. There is a voluntary and very effective cooperation and, more important, a kind of camaraderie among scientists of all nationalities that our leaders in world affairs could do well to study. One recognizes, of course, that it is far easier to discuss objectively data on cosmic rays than the problems of the tariff or the limitation of armament. And one would not for a moment imply that scientists could solve problems, where statesmen have failed. Nevertheless, I believe that the scientists can render service in ad-

dition to discovering new phenomena to serve as bases for new gadgets and new inventions. That he has not done so is, again, due in part at least to the fact that his training has been rather narrowly specialized.

In short, of the many problems which will have to be faced in organizing and administering graduate work in science in the next twenty-five years, I believe that none is more important than that of finding ways and means of impressing upon the embryo scientist the fact that he has both obligations and opportunities outside of his professional field—a remark that is probably applicable to every branch of higher education.

How is this to be accomplished? I wish I had wisdom enough and experience enough to answer the question—or even to make constructive suggestions as to lines of approach to the solution.

I am quite sure that no formal changes in the conduct and administration of graduate work will be in the slightest degree effective. It matters not whether it takes two years or four years to get a Ph.D.; nor whether the direction of the work of a graduate student be in the hands of one faculty member or ten; nor whether the thesis occupies one fourth or three fourths of the entire period of study. I am equally sure that the addition of required, liberalizing courses would be of no avail; would be a step in the wrong direction. We should reduce, rather than increase, the *formal* requirements for a degree. What is needed is the development of an attitude of mind. Preaching, in the guise of instruction, would almost certainly produce an adverse reaction.

Nor will this problem be solved by any one man or group of men; nor in a day or a year or a decade. It has required a half-century to bring the technique of graduate instruction to its present point of effectiveness in the training of specialists. It will require another half-century to perfect methods of extending that training along the lines I have indicated. The methods to be employed must be as subtle as is the problem itself.

Perhaps, however, I might presume to make a couple of suggestions.

I return again to the question of the graduate faculty. So long as the faculty is interested only in the training of specialists, only specialists will be trained. If we would turn out young doctors of philosophy with broader interests, we must have faculties made up of men with broader interests. For it is generally agreed that the personal influence which a faculty, mainly in indirect ways, exerts upon its student body is more potent than the instruction which it gives. To build up such faculties is the task of administrators. The task will require careful selection in the filling of new positions; much time; and, above all, the backing, even demands, of public opinion. Our utilitarian colleges evolved in a utilitarian age. Colleges which emphasize both utility and culture will be found only in a society which places culture on a par with utility. This comparatively young country of ours is still a long way from that goal. To lead the public in that direction is both the opportunity and the obligation of university administrators, faculties and alumni—a task in which the alumnus who has his Ph.D. in science may, if he will, play a prominent part.

This brings me to the second suggestion—still farther from any hope of early realization. I have emphasized the desirability of the scientist's acquiring a deeper interest in, and a better understanding of, the various extra-scientific problems of the day. Conversely, I hope the time may come when the general public will have a better understanding of, and perhaps a keener interest in, research in pure science. To-day there is, I fear, much mutual misunderstanding. The scientist, engaged as he is in non-profit-making pursuits, finds it difficult to understand why the people of this country are willing to spend a couple of billion dollars per year for cigars, cigarettes and tobacco, chewing gum and the like, while the total budget of all our collegiate institutions, support for research included as a very small fraction thereof, is only a little over a quarter of that sum. He himself finds the search for new knowledge so fascinating that he is frequently hurt when the public fails to share his enthusiasm or even laughs good-naturedly at it. A large part of the public, however, with so many of its non-working hours occupied with the sports-page of the evening paper, the current movies in town and with radio-jazz providing the background for what little thinking there is, fails to see why any red-blooded man should want to spend his time with test-tubes, microscopes and galvanometers. (I perhaps err in mentioning the last-named instrument, for probably "the public" has never heard of it!) There is recognition of what is *called* science, but this recognition is mainly lip-service, and in any event is confined largely to applied science—really engineering development—which produces new radios, television, faster automobiles and airplanes, and the like. These commercial products of applied science are what the public *sees*. Behind them, the public hears much about the industrial research laboratory—frequently referred to as houses of magic, and the workers therein as magicians. We all like to see a clever magician do his tricks; pull rabbits out of empty hats. But, having no faith in the spontaneous generation of rabbits, we know that the magician somehow got the rabbit into the hat without our seeing it. It is *that* cleverness that we admire and applaud. If these exceedingly capable industrial scientists and engineers are able to pull scientific rabbits out of hats,

it is because somehow the rabbits were placed there in advance. For this the pure scientist, working behind the scenes, is in large part responsible. The public sees only the play; not the author and the backstage force.

It should not be difficult to find ways and means of educating the public to understand the contributions that pure science makes to world progress. Indeed, various agencies are already working toward this end—newspapers, periodicals, occasionally radio, for example. The public is reasonably responsive to anything which has a utilitarian end. When it becomes generally understood that to expand industry we must have applied science; to have applied science we must have pure science; then pure science will receive increased recognition, and perhaps more adequate support.

But—a utilitarian argument again! Are scientists ready to admit that the only justification for maintaining laboratories for work in pure science is that out of those laboratories may come a few discoveries that may ultimately find industrial applications? I am sure that scientists themselves do not believe so. While they are usually gratified when a scientific discovery does become "useful," as the man-of-the-street uses the term, it is not for that purpose that they carry on research. They believe that science —a knowledge of the universe around us and its laws —should interest the average citizen; that in the scheme of modern society science, pure science, should have a place at least on a par with art and music and poetry. The pictures on the wall do not make the house warmer in winter. Yet it is a poor room indeed that does not have them.

But what are scientists themselves doing to urge this view-point? And who will do it, if not the scientists?

I believe that graduate schools can very greatly extend their services during the next twenty-five years by broadening their own horizons beyond the utilitarian specialization characteristic of the past half-century. By means of that subtle thing called "atmosphere," and in various other ways they can see to it that "doctor of philosophy" means something more than a badge of professional proficiency; and that the holders thereof are men and women who recognize and accept their obligation to help make this a better world in which to live.

OBITUARY

CHARLES E. JOHNSON

IN the untimely passing of Professor Charles E. Johnson on June 6, at the age of fifty-six years, the field of zoology sustains a very real loss.

Born in Oslo, Norway, on April 24, 1880, he came to this country with his parents at the age of two, the family settling near the town of Warren, Minn., on the east side of the Red River Valley. Their arrival was about contemporaneous with the disappearance from that region of the last herd of bison, but Dr. Johnson used to relate how their whitened skulls dotted the prairie for many years afterwards.

After graduating from Warren High School, he attended the University of Minnesota, taking his A.B. in 1906, A.M. in 1907 and Ph.D. in 1912. For brief periods he worked with Dr. Minot at Harvard and with Dr. B. M. Allen at Wisconsin. During this period of university study, he made frequent long trips into the wild, among others a journey to the west coast in 1907, traveling on foot across Vancouver Island. He also took the first motion pictures of animal life in the Superior National Forest during the summers of 1912–1915, as photographer of the James Ford Bell expedition, which films are now in the Museum of the University of Minnesota. He was an expert woodsman, known as a crack shot with the rifle, and in addition a member of the university championship strong man team.

In 1914 he married Miss Jane Wood. After teaching at Minnesota from 1912 to 1918, and at Kansas from 1919 to 1923, he went to the New York State College of Forestry and in 1926 became director of the Roosevelt Wild Life Station at that school. In this capacity he supervised and edited a series of publications on the animal life of New York State which are unsurpassed in the quality and extent of the work which they represent.

Author of about forty contributions to zoology, in his earlier days he published outstanding work on the pharyngeal derivatives of the turtle, but in later years he abandoned embryological and anatomical studies for the field of vertebrate ecology. His papers on the beaver in the Adirondacks and the muskrat in New York are regarded as classics in their field. Throughout his entire life he was a passionate student of wild life, and any excursion into the country was for him an occasion for study and observation.

In photography he found his chief hobby and diversion, producing work which was often accepted for public exhibition. As teacher and scientist, his chief personal qualities were painstaking thoroughness and honesty. In a day when the field of education has become debauched by so much of fad and folly, he was almost unique in his adherence to high academic standards and sound scientific principles. He had no use for opportunism or expediency in any form, and