you will enjoy a life full of service to those in trouble, you will be remunerated according to your deserts, you will always be able to look ahead with something still to do, something still to learn, something still to be discovered.

And now at the end of your novitiate, at the beginning of your real career, it is my pleasure to join with your faculty and your medical friends and to welcome you as fellow members to our profession.

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A RESEARCH DELUSION[1]

WITH the administrative heads of many of our educational institutions demanding a doctorate of every member of the permanent staff, as it is supposed to be a prerogative for research, and the issuing of a list of titles published each year by their staff, the urge for so-called research, namely, a list of titles, goes madly on. In fact publication sometimes becomes a sort of self-defense, for the absence of any titles over a brief period of years stamps one either as lacking the ability of doing research or inefficient. Likewise, such a policy has permeated the staff, so that their interest is centered in output rather than in quality. This is just another characteristic symptom of megalomania, so prevalent in our day in most lines of endeavor. I think that on an occasion of this kind a brief period can be profitably spent in analyzing the present tendency in research in order that we may have a better understanding of what actually constitutes research.

Research consists of more than the mere accumulation and publication of facts. Research in its highest aspect is something creative, akin to the well-known masterpieces of art, music and literature. A masterpiece is the product of the artist's mind, in that any one using the same oils and paints could not create a similar picture. The same creative urge is shown in music and literature. It is true that the scientist can not create any new material thing, but neither does the painter use anything in the way of materials other than those available to any one. However, the master scientist can so arrange his materials and facts that they represent a fundamental contribution to science as a painting does in art. As in art a masterpiece may go unnoticed for years, so in science the true value and significance of a contribution may escape attention for decades, but once its proper value is ascertained it persists for ages.

[1] Address of the past president of the Nebraska Academy of Science, Fremont, Nebraska, April 27, 1928.

It is rather disconcerting to listen to classical music and to realize suddenly that the melody transposed and in quickened tempo forms the basis of the latest jazz hit. The same feeling comes over one after reading an article to find that, although some new data are added, it is just a transposed rendition of some old familiar contribution. As in the arts, music and literature there are too many imitative and not enough creative minds. It is impossible for us all to become creative scientists, but we should at least strive towards this goal.

The English cleric who recently suggested that all active research be abandoned, for a period of ten years, had in mind, I think, that too much work was being repeated and the period of inactivity would bring us to a realization of the futility of doing research without an adequate understanding of what has previously been accomplished. An analysis by a master in his field of all existing data in his specialty would advance research much faster than the addition of more data during this period. As a merchant takes stock once a year and balances his accounts to see what progress has been made, so should we take stock at intervals of all the endeavors in our special field of science. A carefully digested inventory of the investigations in our field can not but lead to research of a higher standard. Not only do we fail to digest properly the publications of previous workers, but we are so intent on the mere collection of data that we do not take the time to weigh our data in their broad relationships.

It is true that from an economic standpoint the collection of new facts has yielded large returns, but soon, unless some precautions are inaugurated, having been so thoroughly sold on the benefits of scientific endeavors, the public will expect the impossible. Have the contributions of science to the progress and development of civilization made us a better and more cultured people? Scientific discoveries have no doubt given us more leisure than the world has ever known before. Are we producing any great works of art, music or literature in our times as the result of this leisure?

Perhaps at this point it might be well to review the history of science and attempt to determine how fundamental discoveries were brought to fruition. It is well known how the philosophical theories of Aristotle permeated the thought of Europe for centuries. While many of Aristotle's observations are sound, his deductive reasoning on natural phenomena probably more than any other factor held in abeyance the adoption of the experimental or inductive methods in science. Galilei, on the other hand, after much thought propounded his theory of falling bodies and

was able to prove experimentally that his deductions were correct. The discoveries of Newton, Faraday and others are very striking in that they propounded fundamental laws on what would now be considered very meager data. I am inclined to believe that their profound knowledge of mathematics was a great aid in arriving at the conclusions they did with so little data. Darwin, however, went to the opposite extreme and amassed a large amount of data over a long period of years before he announced his theory of the origin of species. One could cite numerous examples of the thought that was given to the interpretation of data before it was offered for publication.

The present tendency is to accumulate a superabundance of facts and data and devote too little time and effort in the proper correlation and interpretation of them. It is high time that we do relatively more thinking and less investigating if we are to maintain the high standards which have been set up for us by the past masters of science.

How are we to attain the goal of creative research? This question can not be answered any more easily than one can explain the production of a masterpiece in art, music or literature. However, it is possible to discuss some of the avenues which might lead to creative research. I am sure that when we began our careers in the sciences we were prompted to do so either through curiosity, humanitarianism, personal vanity, imitation or some such motive. Whatever this urge might have been originally, without it I doubt if any of us would spend the energy we do in research. In more ways than one this incentive is like a mirage, always in the distance, but for some reason or other we are never quite able to catch up with it. This failure to catch and hold a creative thought is partly due to the fact that we are not real dreamers or good philosophers. We are so busy collecting facts that we fail to give them much thought. Have you ever analyzed where your ideas originate? You will frequently find that it is during moments of relaxation, when the problems demanding your working energy are farthest from your thoughts. It is seldom that the most constructive thinking is done while busily engaged in the laboratory. More relaxation and reflection would be much more advantageous in solving problems than the mere collection of more data. With relaxation and reflection our subconscious mind might function and flash to us in an instant the clues which we were vainly groping for while in the laboratory.

Even if we ourselves fail to do creative research we can stimulate the rising generation of scientists to hunger for the goal and in this fashion make our contribution to the advancement of science. It should be the chief aim of the teacher in his contact with students to direct and stimulate them to thinking, rather than to fill their minds with masses of unrelated facts, which are always available, providing they have been taught where to find them. Convenient and accessible libraries should be built up, even at the expense of the laboratory, and students taught to use books constantly, as they would indispensable methods in the laboratory. Our graduate students for the most part have access to too much work and thought evading equipment. It is really surprising what can be done in the way of substantial research without costly apparatus. It is only necessary to refer back to the old masters of science to substantiate this statement.

Let us therefore stop deluding ourselves. The aim of research is not solely the accumulation of facts for immediate publication, so that we may in vainglory point to our output for the year. We must strive to do more constructive thinking and especially give our minds an opportunity to function through proper relaxation. We shall not advance fundamental science if we are simply busy collecting data. With more constructive thinking on our problems there would be fewer but better publications, an era without doubt we should all sincerely welcome.

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RECENT DEVELOPMENTS IN QUANTUM MECHANICS[1]

THE fundamental fact for quantum physics which has emerged from experimental investigations in the field is a double duality of wave and particle concepts. The wave theory of light, firmly grounded by the wave explanations of interference and diffraction and by Maxwell's electromagnetic theory of light waves, is now recognized as giving but one aspect of the nature of radiation. The corpuscular aspect of radiation is revealed in the photoelectric effect and in the Compton effect. In these effects Planck's constant appears as a universal constant which connects the wave and particle modes of description of the same radiation.

The radiation which functions as a wave disturbance of frequency ν waves per unit time, and as having a wave number of σ waves per unit length, when interference and diffraction phenomena are being discussed, also functions as a mechanical corpuscle of definite energy, E, and momentum, P, when effects like the photoelectric and Compton effects are considered. The connection between the quantities, ν, σ,

[1] Based on a lecture delivered on July 19, 1928, before the summer school for engineering teachers of the Society for the Promotion of Engineering Education at the Massachusetts Institute of Technology, Cambridge.