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CONTENTS

Success in Science: DR. A. S. HITCHCOCK 141
The Relation of the Restricted to the General Theory of Relativity: PROFESSOR W. F. G. SWANN 145
A Year of Progress for Organized Museums: LAURENCE VAIL COLEMAN 148
Jay Backus Woodworth 150
Scientific Events:
An International Pharmaceutical Conference; The Proposed Sanctuary for Wild Animals in South Africa; The German Chemical Industry; Federal Funds for Scientific Research in Agriculture; Ramsay Memorial Fellowships 151
Scientific Notes and News 153
University and Educational Notes 156
Discussion and Correspondence:
The Nomenclature of the Vitamines: DR. CASIMIR FUNK. *The Politeness of American Botanists:* DR. J. H. KEMPTON, PROFESSOR CLIFFORD H. FARR. *Evolution and the Bible:* PRESIDENT ALBERT F. WOODS, E. T. BREWSTER 157
Scientific Books:
Lippmann's History of the Beet: DR. C. A. BROWNE 159
Scientific Apparatus and Laboratory Methods:
Mounting and Exhibiting Relief Models: ARCH R. ADDINGTON. *A Duplex Vacuum Gauge:* DR. RALPH C. HARTSOUGH 160
Special Articles:
A Rot of the Smyrna Fig in California: PANOS D. CALDIS 161
The Royal Society of Canada 162
The Western Psychological Association 163
The Metric Association 164
Science News x

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SUCCESS IN SCIENCE[1]

MANY books have been written on success. How to be a successful salesman, how to be a successful author, how to be a successful this, that and the other. Very appealing are rules by which those who have not may hope to join the ranks of those who have. The higher the so-called civilization of a race or nation the greater the average desire of its individuals to get more than they have, to become more than they are.

In the strict sense success is the accomplishment of the attempted, but in the humanistic sense the thing attempted is taken into consideration. A criminal may be successful in committing a crime, or the miser may be successful in amassing treasure. But the generally accepted meaning of the expression, a successful man, includes something more than mere accomplishment. The accomplishment must be thought worth while by society. In our own civilization success has come to mean rather more than keeping ourselves and our families provided with the usual physical necessities of life, even though this may require a considerable degree of efficiency. The average man desires bodily comforts and makes an effort to obtain them. Having obtained them his efforts are confined in the main to maintaining his position. In a broad way we may say that the average man is satisfied to maintain himself and his family in average conditions for the society in which he moves. Such a man is successful in the sense that he has not failed; but the expression, a successful man, brings to mind accomplishment greater than that of maintaining the *status quo*. It is clear that a small portion of society is impelled by some inner force to go beyond the average and attempt to accomplish many things that are not required to satisfy physical wants.

We find at once that we are dealing with what are generally known as spiritual things. We are satisfying a spiritual rather than a physical or bodily need. The progress of the race is directly connected with this force. The reward obtained from material success is the joy of possession; the reward from spiritual success is the joy of achievement. The unthinking may assume that the successful man of business, the financial giant, is pushed on solely by his desire to possess material things. Far more probable is it that he is impelled by a desire to do

[1] Abridged from the address of the retiring president of the Washington Alumni Chapter of Phi Kappa Phi, May 12, 1925.

things. True, he may covet power, but the great constructive genius of the financial, political or religious world is certainly moved by a desire for more than material reward.

We all know how this joy of achievement emerges in all walks of life, distinguishing the exceptionally advanced from the mediocre. The artist obtains satisfaction from a picture well painted; the writer from an article well composed; the goldsmith from a vase well executed. The Great Teacher had spoken to the woman at the well, his disciples were hungry and asked him to eat. He answered, "I have meat to eat that ye know not of. My meat is to do the will of him that sent me and to accomplish his work." Here we have an example of spiritual power transcending bodily desires. In a degree this power is being manifested in all who accomplish results. There is a direct connection between success and the development of the will to do for the sake of doing. The successful man loves his work. Some men fail because they lack this mainspring of action. Others fail because the opportunity for expression is lacking; they are round pegs in square holes.

Scientists are an exceptional group, as the members have entered the group from choice. The artisan may be an engraver because his father was one before him. The business man may be the president of a bank because by accident he became a clerk in the institution when a boy.

The scientist has nearly always entered his group after an examination of conditions. He is usually, at least in this generation, a college graduate and hence is already in a selected class. Financial returns from scientific pursuits offer little attraction when compared with the possible rewards in commercial lines, and hence play little part in the selection of science as a calling. The percentage of successes among scientists is very high because of the free choice of that vocation. A man does best that which he likes. In speaking of high percentage we have in mind a comparison between scientific pursuits and other lines of activity, and by success we have in mind the average opinion of those who can appreciate accomplishment in the branch of human endeavor under consideration. Not all men adapted to scientific work become scientists, but those who have had the opportunity to choose science start out with a favorable handicap.

In estimating the percentages of success we should confine the term scientist to the research workers, to those who are engaged at least a part of their time in original investigation. A professor of science may be a successful teacher, even a great teacher, but most of us, I think, would not class these workers as scientists on this ground alone. The man who does research work does so in nearly all cases because he wants to. He can not carry on research without a rather extended period of preliminary training. We have, then, a class of trained workers with a love for and a desire to do the work they are doing. Success, at least in a moderate degree, follows as a matter of course. The characteristics which make for success are possessed by all of us to a greater or less degree. It is the fortuitous coincidence of a maximum development of several of these characteristics in one individual that produces the truly great scientist, an occurrence whose rarity follows from the laws of chance.

Success evidently depends upon two sets of things, ability and training. The successful man must be born with the first, but he can acquire the second.

The scientist's natural ability, imparted to him by his ancestors, includes many qualities necessary for success in other lines of human endeavor, such as physical soundness, and particularly the will to do. An outstanding characteristic of the exceptionally great scientist is his ability to correlate facts. From a mass of facts he distinguishes those that are related, those that are significant, those that open the door to further knowledge.

There are three stages in a research problem: first, establishing the facts; second, coordinating and correlating the facts in an orderly and coherent solution; third, publishing the results. Industry, patience and attention to detail are well recognized as necessary in establishing facts. It has been said that genius is the infinite capacity for taking pains. This is true, yet we all know that this is not enough. Most of us who have had experience in teaching are familiar with the occasional student who wishes to do original scientific work, but fails because he has no judgment as to relative values. All facts are equally important to him. He has energy and patience, and digs up a multitude of facts but does not know what to do with them. He has no skill in selection and coordination and fails to appreciate that facts are important chiefly as they can be related. Such students are not adapted to take up constructive work because they have no capacity for constructive thinking.

The scientific worker must divest himself of prejudice, and an important part of his training is to learn how to approach an investigation in a spirit of open-mindedness. The scientific attitude is not natural with most of us and must be brought about by a rather rigid system of training. I have shown in another place[2] that parental authority and school dis-

[2] "Remarks on the scientific attitude," SCIENCE, 59: 476, 1924.

cipline are opposed to the development of the scientific attitude, since in the main the child is taught to respect authority and to think as others think. Early training is very persistent and it is not easy to throw off the effects of early influences, but unless we do we can not succeed in a search for truth. It is well for the scientist to examine his own mental machinery at intervals during the investigation of a problem to see that it is running smoothly and according to plan.

Some men show great ability in the first part of the problem, the investigation and establishing of facts, but fail to carry through to the end. Interest is stimulated by discovering new things, but this interest lags in the drudgery of assembling the facts for permanent record. Some brilliant men fail to attain success in proportion to their brilliancy, because they can not hold themselves to the task of preparing and publishing results. A worker owes it to science and to his colleagues that he complete his investigations by presenting a carefully prepared résumé for record. The scientist's ability is judged in part by his publications. Some men, knowing this, hasten to place on record a large number of papers without much regard to the quality. Scientific work can not be hurried and the scientific world can not be misled by a voluminous output of printed matter if this is lacking in quality. There is another class whose standard is so high that the problem set is difficult to work out to completion by the average investigator. One of this class may work for years, even for a lifetime, delaying publication until every possible ramification is explored and every detail completed. Such a one may be doing work of the highest excellence, but has failed sufficiently to take into consideration the element of time. His results do not become available until published, and his delay withholds the essentials from the scientific world unnecessarily long. In some cases excellent work is lost because the worker has passed off the stage before completing his record by publication, and seldom are his notes sufficiently complete to permit publication by another. Our advice to this class would be to bring together a coherent part of the work and publish the results within a reasonable time.

Another class holds back the publication of important work through over-caution or timidity, because of a few minor deficiencies, which have little bearing on the conclusions. The worker should pass careful judgment on the bearing of the missing data, but the element of time should be given due weight. Our advice here would be to round out results and publish, stating frankly the deficiencies.

Our model for a well-balanced judgment on the relation of time and publication is the example of Darwin and his 20 years' investigation leading up to the publication of his epoch-making "Origin of Species," a masterpiece from the gathering of the data, through the correlation of the facts, to recording of the results. If he had published too soon, his work would have been ineffective. There was required the coordination of a great mass of detail, and the results could not be presented in installments. On the other hand, to have waited until all data could be gathered and incorporated would have delayed publication indefinitely. There is in effect a maximum in the curve of effectiveness in such matters. The law of diminishing returns is applicable. It is a mark of greatness to be able to estimate properly when the maximum has been reached.

We have passed in review those who have the will to work but lack the capacity, and those who have both the will and the capacity. We may pause a moment to mention a small class who have the capacity but lack the will. They are always going to do something. The alleged reason for the paucity of published results is the necessity for clearing up doubtful points which are never cleared up or for performing further experiments that are never performed. For such there is no hope, for the scientific spirit is wanting. Others may have produced meritorious work in their younger days but grow contented and for a while at least live upon the reputation of their earlier successes. For these there is some hope, as the scientific spirit is present but not functioning, and they may be galvanized into action by sufficient pressure from without.

The true scientist is rather cautious in his assertions concerning scientific facts and theories. His statements are modified by ifs, ands and buts. The teacher is prone to fall into the pedagogic custom of bolstering his prestige by making categorical statements. It requires a certain amount of courage to state to a student, "I do not know," or to shake his faith by calling attention to the limitations of our knowledge. The inexperienced teacher of science may not know whether he ought to know the answer to a certain question or whether the answer is not fully known to science. We may well be suspicious of the scientist who is uniformly definite in his answers to his students and may have ground for greater faith in the one who frankly modifies his answers with reservations. Personally, I have more confidence in a physician who sometimes admits that he is puzzled than I do in the one who always knows everything. Why should a physician know more about his subject than I do about my specialty? I am faced with puzzles all the time.

When we review our knowledge we may well be astonished how much of it is an approximation or is based on probability. What is the ratio of the side to the diagonal of a square? We do not know—that is to say, we do not know exactly. It is as 1 to the square root of 2. As our system of notation is not adapted to determine exactly the square root of 2 our answer can never be exact. What is the ratio of the diameter to the circumference of a circle? We can never know this exactly. We can show that the answer lies within certain limits and by laborious processes we may reduce these limits, but never can we reduce them to zero. We wish to know the length of a certain line. We measure it, that is, compare it with a known standard of length. We measure carefully and repeatedly, but our results do not agree. We can never know the exact length of the line. The best we can do is to obtain a most probable length and state that this result is probably true within certain limits of probable error. We are confronted with this situation in all our scientific research in so far as it involves physical measurements. In fact, the only cases in which we can express physical relations with exactness is in the realm of spiritual things. We can assert with certainty that the whole is equal to the sum of all its parts, but we are unable to demonstrate this by actual measurements.

Turning abruptly to another aspect of our subject, how much and how soon should a scientist specialize? When a student starts out with the intention of doing research, that is, original investigation, he finds himself within an immense globe of knowledge. He wishes to add knowledge, to crystallize the known from the unknown by accretion at the periphery. He must make his way through the great mass of the known in order to reach the boundary which separates this from the unknown. He may make his way more quickly by cutting a straight narrow path to the surface. But in this case his additions can be over a surface no larger than the cross-section of his path. The wider the path the better equipped is he for research. How wide should the path be for maximum efficiency?

That the scientist should specialize is generally admitted, and I shall not present proofs. But how soon should one specialize? Since I am not developing this subject as a major theme, I will merely give my opinion. I believe every intelligent worker should have a general education, that he should have the opportunity of coming in contact with all the great branches of knowledge and of human endeavor. Assuming that he is free to develop along normal lines and is not forced by financial necessity to modify an optimum plan, the student should diversify his learning until he feels a special interest in certain branches. In a general way he should follow his inclinations. In the university he may include the branches which are especially attractive, but should not yet confine himself to any narrow specialty. What is usually called specialization in his studies would normally take rather definite shape at the beginning of his post-graduate work. If he has developed a liking for scientific research he would concentrate more and more on a particular science. Finally he may attain eminence in a very restricted field of a single branch of science. However, I believe the best results are obtained by maintaining an intelligent contact with a much broader field than the one in which he specializes. There are two important reasons for this. First, the specialist should be in a position to adapt to his own use in his specialty all relevant knowledge developed in other lines. This he can not do unless he keeps in touch, at least in a general way, with discoveries in all branches. Second, man does not live by bread alone, that is to say, there is mental enjoyment and stimulation in following the work of others, and these momentary vacations react on his efficiency in his own line. The contact with general knowledge must be continuous even though more and more general as the years go by, otherwise breaks will occur which the specialist never has time to bridge. I would say, then, develop first a broad general knowledge, then specialize, but maintain contact with developments in other lines.

Assuming that the research worker has laid a broad foundation and has chosen a field in which to specialize he becomes familiar with the known in that field and finally attacks the unknown. Assuming that he has normal health and is not subjected to diverting pressure from unusual family or social distractions, his efficiency in research increases in geometrical ratio. His physical and mental endurance begins to wane in middle life, but his curve of scientific output continues to ascend for some time because of his accumulating knowledge and experience, and the maximum of the curve is reached only when there is a marked falling off of his strength due to advancing age. When is a scientist old? So long as his mind is directed forward, so long as his past achievements are to him incidental, so long as he is thinking of what he is going to do instead of what he has done, he is young. When he begins to emphasize those things that have been accomplished, when his mind is facing the past instead of the future, he is getting old. Some men get old at an early age.

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