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THE FUNCTIONS OF A UNIVERSITY LABORATORY[1]

ON an occasion like the present, when we are gathered to congratulate this university upon the addition which it has just made to the existing equipment of the world for the prosecution of scientific studies, it seems appropriate, and it may not be entirely superfluous, to spend a little time in inquiry what it is that scientific laboratories have done for mankind during their comparatively brief past; to ask also how we may make them still more serviceable in the years which are to come.

It is not so very many years ago that a speaker upon this subject might have deemed it necessary to prove to his hearers (if he could) that laboratories were of service to the public and that they ought to be established and maintained. I am very glad that this is no longer necessary; that I may assume with confidence your acquiescence in the belief that scientific studies have been justified by their results. And I am very glad also that these results, great as they are, have, as yet, nothing like finality about them. To say that the natural sciences are still very imperfect and capable of vast improvements is only another way of saying that they are alive. Those of us who are devoted to their service have especial reason for joy in the fact that there is still so much to be done that we see no prospect of this service becoming unnecessary in our time or in that of our successors for many generations.

When one speaks of the beneficial results

[1] Address on the occasion of the opening of the Carnegie Science Building at Acadia University, Wolfville, N. S., October 21, 1909.

of scientific studies, it is only natural that the first things which arise in the mind should be the concrete things—the great practical benefits which have become so much a part of our lives that we wonder how our ancestors could have been comfortable without them. We think of all that the engineers have done for us with steam and electricity; and we remember that all the modern industrial applications of electricity had their origin in Faraday's laboratory; that wireless telegraphy, which has added to the security of all those who go down to the sea in ships, was born in the laboratory of Hertz. In our admiration of the great achievements of genius we do not forget the humbler services of lesser men who have attended to the details; who have made improvements here and there; and who, in the aggregate, have contributed incalculably to the results which we see all about us. But laboratories have done more than to provide opportunities for discoveries great and small, which are afterward put to the practical service of mankind. In them has been trained the great army of experts who keep the machinery of our industrial civilization running, and upon whose skill and knowledge we depend every day more than we know for safety, prosperity and comfort. This educational function of laboratories is of the greatest importance from whatever point of view we regard the subject, and we shall have occasion again to consider it more in detail.

It is not only in the domain of engineering (which is mainly applied physics) that we see these great, tangible results. Chemistry and biology are in no way behind their sister science in the direct benefits which they have conferred upon us. We have only to think of the enormous improvements which the study of chemistry has made possible in manufactures, in metallurgy and in many other branches of industry, to recognize what chemistry has done for the world. And in addition to such services, chemistry has powerfully assisted biology in the magnificent contributions which have been made to the cause of human health and security within the past two or three decades. Even a partial enumeration of these advances is convincing. Antiseptic surgery, the germ theory of infectious diseases, antitoxins, methods of stamping out such plagues as malaria and yellow-fever, the lessening of infant mortality—can any one compute how much sorrow and suffering have been prevented by these discoveries? And without laboratories and without men trained in laboratories, we should have had none of them.

All these things are obvious enough; even the "man in the street" is not in much doubt about them. But is there anything beyond this, anything less tangible and therefore more difficult to state and to perceive, anything higher and nobler than these concrete practical services? We should not, I think, find such entire unanimity in answer to this question as we encounter with regard to the so-called practical results of the sciences. Many people who have not thought much about the matter and some people who have thought much, but whose work and sympathies lie in other directions, would still be inclined to define science as "useful knowledge" with a very narrow signification of the word useful. To such persons, the sciences find their sole excuse for existence in their practical applications; if they look with amused tolerance upon the enthusiasm of spectacled professors over a discovery in pure science, it is only because they have come to realize that, in the course of time, even the most unpromising discovery may have important practical applications. Of course we have no monopoly of such unsatisfactory supporters; the

philistine is a thorn in the flesh of artists and moralists—especially the patronizing philistine. But I am inclined to think that men of science have more than their just share of that sort of thing; that, in other words, the number of people who can appreciate (if only dimly) the idea of art for art's sake is far greater than the number of those who can understand why science should be cultivated irrespective of its possible applications.

On the other hand, the professed followers of pure science regard the "useful" consequences of their work as a mere by-product—and one which must not be allowed to usurp the chief place in their hopes and plans. In fact, they are sometimes accused (and with some show of justice) of leaning too far in the other direction and despising everything that is practical. This undoubtedly is a wrong attitude and a very short-sighted one; no one who takes an unprejudiced view of the matter can doubt that, apart from their general beneficial effects, the applications of science have a most favorable reaction upon the progress of purely scientific studies. Not only does the prospect of useful technical results bring to scientific studies much greater support and financial aid than they would otherwise enjoy, but the progress of technology always assists in many ways the science with which it is most closely connected—by the development of instruments and appliances upon a commercial scale, by the purely scientific problems which are suggested in the course of the development of the applications, and by the stimulus which comes from the activity of large numbers of earnest men in closely related lines of work. Many things are easy to us to-day which would have caused Faraday infinite trouble and labor, just because the electrical engineers have been busy in producing such cheap and convenient instruments and appliances.

I can not leave this phase of the subject, however, without attempting to offer an excuse for the somewhat intolerant attitude which the student of pure science sometimes assumes toward his brother who deals only with its useful applications. Almost every successful man of science is constantly tempted to engage in technical work of some kind. Invitations come to him which mean an opportunity to do work which is obviously useful to the world. He knows that the material rewards for such work are usually much greater than for purely scientific achievements and he usually needs money as much as other people. He knows too that in all probability he will gain much more general commendation and applause along with the money; for the contemporary fame of even a very distinguished scholar is limited to a surprisingly small circle of people. At a recent academic celebration the degree of doctor of laws was conferred upon a number of prominent and well-known men; honorary degrees in letters and in science were also conferred, and a wise and observant spectator said afterward that the recipients of these latter degrees must have been distinguished scholars, for he had never heard of any of them before.

Well, our man of science knows these things and he is sorely tempted; but he also knows that if he yields he must give up the better part of his scientific work; he knows that there are ten men willing to take up the popular and profitable task for every one who is content to devote his time and energy to the other. So he resists the temptation; and if it helps him and comforts him to regard the part which he has chosen as the better part, as a little more honorable and dignified and worthy than the one which he has refused, we can hardly wish to deny him that consolation.

But is he right in his action? Is the ideal for which he is giving up money and possible fame one which is worthy of the sacrifice? Is there anything in science beyond its more obvious utilities? To put the question in another way, has this new laboratory and others like it throughout the world any other legitimate function than the training of technical experts and the making of discoveries which may be useful in a direct material way? I hope you will agree with me that it does have other functions to perform and that they are higher and more important than those we have been discussing.

As before, these activities are manifested chiefly in two directions—in the education of youth and in the discovery of new truth; in teaching and in research. Only in this case, we mean by teaching not simply the training of an expert for a particular task, the fashioning of a cog to be slipped into its proper place in the industrial machine, but the fostering and bringing a little nearer to perfection of a human mind and of all its powers, intellectual, esthetic, moral.

Can the study of the sciences do these things for us or any of them, and can we perhaps conclude that they are especially well adapted to perform certain parts of this task of general development of mind and character?

I must admit at once that, to the great majority of students, the esthetic aspect of science makes a very small appeal. In fact it is supposed by many people to be entirely lacking. Every one who has seriously studied one of the physical or natural sciences, however, knows that it is there, and that it is indeed one of the greatest incentives and rewards for such study. A great scientific theory with its component parts accurately adjusted to each other in due proportion and subordination, with great complexity of detail blended into the grandeur of perfect simplicity; such a structure makes upon the mind which is fitted to enjoy it an impression of beauty which is quite comparable with that which is produced by a French cathedral, a play of Shakespeare or a symphony of Beethoven. But it must be admitted that the ability to enjoy this kind of art is rarer and perhaps requires a longer apprenticeship than the appreciation of literature or music or painting. We must, of course, take into account that it is the fashion to pretend to like music and pictures even if one does not really enjoy them, while, on the other hand, there is, fortunately, no temptation to feign a liking for scientific pursuits. But when all such allowances are made, I think there can be little doubt that the number of people who find esthetic stimulus in music, for example, is much greater, and that the number who find it in literature is enormously greater, than the number who can see the beauty of science.

When we turn to the consideration of the more purely intellectual faculties we shall not, I believe, find the sciences at a disadvantage in comparison with other subjects used for the disciplinary training of young men and women. In the opinion of many people they possess indeed a certain superiority which especially fits them to serve some of the most important ends of education. Is there any justification for such an opinion? I think we must recognize, in the first place, that the experimental sciences possess a certain advantage in the relatively great simplicity of their subject matter. They are complicated enough—even physics, the simplest of all is quite sufficiently intricate—to give one all the work he wants in disentangling their puzzles. But the puzzles *are* disentangled and one definite and certain result

after another is arrived at. The problems we have to deal with are simple in comparison with those with which the historian, for example, has to struggle, at least if he attempts anything like the degree of completeness in his solution which we habitually attain. And just because we have attempted a relatively modest task, it has been done with a finish and degree of completeness which makes it particularly suitable to serve as a model of right thinking and as a means of training the minds of young people in the methods of attacking greater difficulties. Easy exercises in careful observation, right inductions, logical deductions, in which the result is definite and known, and a straying step can be detected at any point of the path—these do not make a bad beginning in the process of training the young mind to use its intellectual faculties to the best advantage.

I have called this process easy, and yet, as we all know, students do not regard it as altogether a path of roses; in fact they are usually of the opinion that economics or sociology is easier than (for example) physics. Now I am quite ready to admit that a process of close, accurate, careful thinking is never *very* easy; but if a man is to be well educated he must have training in such processes, and I am contending that it is possible in the experimental sciences, on account of their relative simplicity, to lead men along such paths and to guide and check their progress with a degree of precision that is too difficult even to be attempted in subjects of study which deal with more complex bodies of facts. They therefore seldom attempt it, and the student finds them easy; but he has missed a very vital part of education if he has not been through this particular mill.

I have been regarding scientific studies from the disciplinary point of view, as valuable to the individual student, especially if his after life is to be devoted to something else than science, because they supply him with a standard of careful and exact thinking to which he may approximate as closely as he can in the more complicated affairs of life. I think we may find some justification for this view of the place of scientific studies in the education of the individual, by a little consideration of the position which such studies have occupied in the history of the general development of thought since they have become conspicuous factors in that development. Nobody can doubt that their direct influence has been very great; and it is not at all certain that their indirect effect upon the attitude and methods of scholars in other fields of study has not been nearly or quite as great. We all know that philologians, historians, moralists, even some literary critics, have a very different point of view and very different methods of work from their predecessors of three hundred years ago. They think more of facts and less of words; they are more cautious in reaching conclusions and in defining the probability of the correctness of their results; they are more careful to guard against being prejudiced by external circumstances and implications; they get as near to first-hand evidence as they can. A great many of them are proud of using a "scientific" method and most of them habitually give the name of science to their subjects of study.

Now I am far from assuming that the so-called scientific method is, in its details, an entirely new invention; it is, after all, only applied common-sense and men have been using it in practical affairs since before the dawn of history. But its use as a definite, conscious, consistent policy, the recognition of its value and of its limitations, the perfection of its application, these, I believe, we do owe mainly to the

initiative of the students of the experimental sciences; and that the rest of the world of scholars owes much to their example. Here again I must make a qualification lest I should be misunderstood. I do not wish to imply that the essential priority which is thus claimed for the experimental sciences is due to any superior wisdom on the part of its students; on the contrary, I believe that it was the comparative simplicity of the task they had before them which enabled them to teach the world how more difficult problems are to be solved when their time comes. And I wish to draw your attention to the parallel between this general process and the place which I have been claiming for scientific studies in the education of the individual student. If we are right in believing that the study of the experimental sciences is mainly responsible for this particular step forward in the intellectual development of mankind, then we must conclude that this is a greater, a higher, a more vital service than the invention of trolley-cars, the production of cheap dye-stuffs, or even the suppression of yellow fever. And if scientific studies are peculiarly adapted to the purpose of leading young men into the paths of careful, sensible, fearless, original thinking then these new laboratories of yours have a much higher educational function to perform than merely to produce engineers or technical chemists or practising physicians.

And now we come to a still more vital question; how about the young man's morals? Have scientific studies any ethical effect, and if so is it in the right direction or the wrong one? The problem is a specific one and so we may leave to one side the ancient question as to how much knowledge has to do with conduct. It may be that perfect knowledge of good and evil would inevitably result in the choice of the good and that the will would, under such ideal conditions, be the servant of the intellect. But we know, alas! that perfect knowledge of good and evil is no more the attribute of any human mind than perfect knowledge of scientific truth; and we see too many instances in which a man knows and approves the better path and yet follows the worse, to be able to believe that morality is a matter of knowledge alone. It is plain, however, that sound knowledge and intellectual judgment must in general be antecedent to the deliberate choice of virtue; and that some training of the will itself is possible; if it be led to choose the good and the true habitually in lesser things, it is more likely to react nobly in times of stress and difficulty. These are doubtless minor functions in the domain of morals, but they are very necessary ones; and I think it may be successfully maintained that the natural sciences are strong allies of the forces which are fighting on the side of virtue in the great battle of good and evil.

Let the truth be proclaimed though the heavens fall, has been and must continue to be the fundamental principle of real science. At times in the past it has seemed to many that the heavens were falling—but they have not fallen; on the contrary, they have acquired a new glory which our eyes had not before seen. The medieval church thought quite honestly that Galileo, if he were allowed to go on, might wreck the universe at least for those who believed him. But how different has been the real result of his labors and of the work of those astronomers who have followed after him. For us it is true, with a depth and intensity which David could not have known, that "the heavens declare the glory of God; and the firmament sheweth his handiwork."

So in the middle of the nineteenth cen-

tury there were many who believed that, if the theories of Darwin were allowed to prevail, we should see religion and morality involved in one common ruin. But we all know now that this has not happened; that, on the contrary, the doctrine of evolution has furnished us with new and valuable criteria for judging conduct; that it has given us additional reasons for hating sin and a rational basis for charity toward the sinner. And as a comment on the fears of those who in those times of storm and stress thought that science was the enemy of religion I may quote the concluding sentence of the address of the president of the British Association for the Advancement of Science, at the meeting in Winnipeg last summer, just fifty years after the publication of Darwin's great work:

> As we conquer peak after peak we see in front of us regions full of interest and beauty but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks which will yield to those who ascend them still wider prospects, and deepen the feeling, the truth of which is emphasized by every advance in science, that "great are the works of the Lord."

We may, I am sure, dismiss from our minds the last lingering fear that the pursuit of science tends toward irreligion or immorality. We may go still further and with confidence deny the more common belief that physical science is unmoral, that it has no concern with ethical questions. On the contrary, its whole attitude and most fundamental enthusiasms are thoroughly permeated by the great ethical principles. No one who studies science aright can fail to recognize this fact; and no one who has taught the principles of any science to young men, and who has watched their after development, can doubt the strong, if indirect, effect which such studies have had upon them in the direction of clearer moral judgments and more unselfish devotion to duty.

I come now to the last of the important functions of a university laboratory which I wish to discuss before you to-day. It is scarcely necessary to say that this is research—not simply the attempt to add to man's material comfort by new appliances, not the seeking of useful knowledge in any narrow sense, but the diligent and devoted search after new truth for its own sake, careless of consequences so long as the truth is served. This is a great and lofty ideal and it is followed with all the enthusiasm and loyalty which a high ideal inspires, and which nothing else in the world can inspire. Now I should not for a moment wish to persuade you that the scientific investigator is actuated only by unselfish motives; he is not quite such a monster of virtue as that. Dr. Jowett once said that we were all liable to error—even the youngest of us; and it may be admitted freely also that we are all human—even the most scientific of us. But I am convinced from considerable observation of men of science that by far the strongest selfish motive which actuates them, especially those in the higher ranks of ability, is the great pleasure which they take in the work itself. That this pleasure is so keen and satisfying is a consequence of the ideal character of the work; it is the sort of pleasure which the artist finds in his real pictures—and does not find in his pot-boilers. It is true also that scientific men are very glad when they can obtain the commendation and respect of their professional brethren; but what soldier, what statesman, what minister of the gospel does not share in the desire for such intelligent approbation. It is a confirmation of his hopes that his strenuous labors are not in vain; and it adds a human element to his reward, the desire for which, if it is a weakness, is certainly an amiable one. The true man of science, the true scholar in

any department of knowledge, does not desire unintelligent popular applause; and it is almost always safe to conclude that the "newspaper scientist," the man whose name and deeds are constantly before the public, is not having a very great or beneficial effect upon the progress of his science.

True research, real scientific pioneering, does not strongly appeal to the general public; its applications may be remote, it shows no immediate profit, its achievements are not spectacular and are often too technical to be fully understood by any but experts. And thus it comes about that it must be fostered, encouraged and supported by the more enlightened fraction of mankind; and the chief agency through which this support may be given is the university or college. I will go further than this and express the decided opinion that no other institution has been devised or seems likely to be invented which can perform the task so well. Of late years there have been established a number of institutions of various types, especially for research; they have done excellent work and it has seemed to many that such foundations might probably absorb gradually the research functions of the universities. The ground for this expectation is that, as they have nothing else to do except to advance knowledge, whereas the universities must also teach young men, the institutions for research alone must inevitably surpass the universities in achievement and eventually take over the whole business of research. We must remember, however, in the first place, that research is not altogether a business, but an art as well; and that while organization and division of labor may be the life of business, it is not the soul of art. To produce the highest results in scientific research there must be individuality and freedom, and there is room for far more individuality in a university laboratory than in any special research laboratory which has hitherto been established or seems likely to be established.

There is a certain sort of new knowledge which can be gained more readily by the well-organized, machine-like attack of government departments and special institutions than by the guerilla warfare of the universities. There are great bodies of facts, relations, properties of matter, and habits of living beings which have only to be looked for to be found; as soon as we have time, money, a corps of trained men, and especially proper organization, we may count upon a steady annual crop of new knowledge of this kind. Institutions of the type we have been discussing are doing admirable service to science by pushing forward such work. It seems, *a priori*, almost inevitable that their work should be mainly in this direction; it is the work for which their organization is best fitted—and it is a sure thing. When an institution exists solely for research, when a man gets his salary for research alone, then the results must appear pretty regularly and promptly, or there is likely to be trouble. The institution, or the man, knows that he must reckon with human nature—especially with the human nature of administrative officers; and in consequence we find (as we should expect) that, in nine cases out of ten, the productions under such conditions are very steady, very voluminous, very meritorious and very dull. Now the collection of facts of this kind is most necessary, but it is *only* "the beginning of wisdom" in science; such collections are not science but only the raw material out of which science may possibly be made if the right men arise for the task. It is here that the university laboratory, that the college professor, has

his opportunity—an opportunity which has been made use of brilliantly in the past and which I hope and believe will not be neglected in the future. For the university professor is not compelled to stick to the sure thing in research; it is not necessary that he should make an annual or semi-annual contribution to science, for he has another excuse for living and drawing his salary. And so it comes about that he is much freer to attack bigger problems, the outcome of which is very uncertain and which may after several years of work lead to no conclusive result. Such work, if intelligently undertaken and carried out, is by no means a waste of time; great results are always accompanied by great risks; and no great discovery has ever been made by a man who was unwilling or unable to risk a great failure.

Even if we return to lower ground, to the "business" analogy which was used a moment ago, I believe that university laboratories are not at a hopeless disadvantage as compared with special institutions for research. For the most successful manufactory is not always the one which adheres most closely to one specialty but the one which most successfully utilizes its bye-products. Now I am a very strong believer in Lord Kelvin's opinion that in a university, so far as is humanly possible, every investigator should be a teacher and every teacher an investigator. The reaction of the two forms of activity on each other is immensely stimulating and helpful. To the man whose chief concern is the investigation of special problems on the remote borders of knowledge, it is very wholesome that he should occasionally survey his subject broadly and in simple terms, as he must do if he teaches young men. On the other hand, he conveys to them some part of his own enthusiasm and, in some cases, makes recruits for scientific investigation; and when he does this he multiplies his own effectiveness many times in the present and future activities of his pupils.

In the same way the man who, from natural bent, or from force of circumstances, finds his chief usefulness as a teacher, is greatly helped in the proper fulfillment of that most important service, if he can spend some part of his time in research. The teacher who does nothing else, who goes over the same subject year after year with successive classes, is of all men, I think, the most in danger of intellectual stagnation. While he is young he may ward off this paralysis by study, by the acquisition of knowledge which other men have discovered. But (with somewhat rare exceptions) the real passion for such acquisition and the pleasure one takes in it are nearly gone by the time middle age is reached. In fact a great deal of the capacity for such study has also vanished by that time. We all know how much easier it is to acquire a new language when one is young, and how much less patient we are of the drill and drudgery of grammar as the years go on. I do not believe I shall ever learn Russian or Swedish; certainly I should expect no pleasure in the early stages of the study. And I am quite sure that, if I had not learned the multiplication table when I was a boy, I should never learn it now and should be obliged to carry it about on a card in my pocket.

Now so far as I have been able to observe, the passion for research and the pleasure which it gives do not pall as the years go on. As we read the biographies of men of science we find that the fascination of the game is as strong or stronger to the veteran of seventy-five as to the youth of twenty-five. Unless ill-health or some other circumstance prevents, they usually keep steadily and enthusiastically at their

task until the end of life; and in many cases even serious decrepitude can not stop them.

So I believe that engaging in research is the best way and the only certain way for a teacher to keep himself alive intellectually and to retain his spirit and enthusiasm to the end. And even if the college he serves regards teaching and not research as its chief business, even then, I contend, he must be given a reasonable amount of time and reasonable opportunities for research in order that he may keep his intellectual health, just as he is given time for physical exercise in order that he may maintain his bodily health.

Fortunately too, the process is not an esoteric mystery open only to the elect, but a thing which can be taught and learned by ordinary men. It is true that great discoveries are not made by ordinary men —at least not often. But there is a great deal of useful work quite within the powers of almost any intelligent man which will add to the knowledge of the world and add to the happiness and usefulness of the man himself and to his success as a teacher. He must usually be taught the elements of the process and started on his career as an investigator in order to be able to accomplish much; and he must have some time and energy left over from his teaching to devote to this purpose. Both these conditions are being fulfilled more and more as time goes on; and the result will be, I believe, that the profession of the teacher will attract more able men, that they will keep their vigor and enthusiasm longer, and that the quality of their teaching will be much improved.

By the establishment and equipment of this building, Acadia is lending a helping hand toward the fulfillment of that promise, whose complete fulfillment we shall never see on this earth but toward which we are constantly making progress: "Ye shall know the truth and the truth shall make you free."

H. A. Bumstead

Yale University

THE CARNEGIE FOUNDATION AND ITS SERVICE PENSIONS

The announcement of the Carnegie Foundation that it is the intention to limit retiring allowances on the basis of a twenty-five years' service to cases of disability, has brought dismay and surprise both to those directly interested and to the larger public to whom academic interests are of concern. The report of the foundation stating this action and its reasons is now available; and the propriety as well as the wisdom of the change in rules may be discussed.[1]

There are three issues involved: whether the reasons given for the abandonment of one of the two fundamental provisions of the foundation are adequate, legitimate and convincing; whether independently of its desirability the abandonment of the original plan is made necessary by financial reasons; whether the sudden withdrawal from the obligations which the foundation has assumed is just.

The practical importance of the last issue entitles it to first place in the immediate situation; and on this matter it is possible

[1] Since the situation requires a certain freedom of expression, I may be permitted to explain that I have publicly and privately expressed the most cordial approval of the foundation, its purposes and its provisions, particularly and above all of the provision which is now to be withdrawn. Articles in the *Dial* will sufficiently indicate this fact. An article in the *North American Review* will further indicate the high opinion I formed of the influence of the foundation and of the necessity of including the state universities in order that this influence shall be of national scope. This commendation must stand as evidence of my interest and favorable attitude towards the foundation and its mission.