

act it is yet quite as nearly correct as our observed information requires.*

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(To be concluded.)

THE POSITION THAT UNIVERSITIES SHOULD TAKE IN REGARD TO INVESTIGATION.†

WHAT position shall universities take with regard to investigation? When the honor was done me of asking me to take part in this discussion, my first thought, after the sensation of complacency at the compliment, was that there could hardly be a *discussion* where all held probably very nearly the same views, and that the great difficulty would be to say anything that would not be better said by another. Then as I began to think more carefully, I saw that the question was not, as I had at first imagined it to be, "what shall universities do to encourage those on their staffs to investigate?" It is far wider than that. It comprises a whole group of questions concerning which there may be every shade of opinion. So the more I thought, the more I admired the wisdom the committee had shown in their choice of a subject. Later still, it dawned upon me that surely it is a most satisfactory sign of progress that this Society should meet to discuss such a sub-

ject, with the conviction that, though without the shadow of a legal right to make claims, we are, nevertheless, sure of a sympathetic hearing from both universities and the public.

First of all let us consider the place of investigation in education, as a means of mental training, quite apart from any definite results. Surely this alone opens a wide field for one afternoon's ramble, in which there are diverging and recrossing paths enough to furnish us the surprises of unexpected partings and un hoped-for reunions.

I would here remark that perhaps some confusion is possible from different interpretations of the word 'investigation.' According to some it means simply practical work, object teaching, or, better still, object study. According to others it is the search for something new. With regard to the value of the former we are all pretty well agreed. We do not need to be told what an advance it is over the old way of learning the statements of others concerning matters well within the sphere of observation. It may sometimes be carried too far, but in view of its great usefulness we will not quarrel with a little abuse. With what is meant by the second interpretation the case is different. Excepting some singularly gifted natures, it does not, in my opinion, concern the student. The universal or even the very general application of this method is the result of an extreme reaction. It rests on a fallacy. Because investigation is a good thing, and worthy of encouragement, which all must admit, it is assumed to be good for all, and an accepted method of education, which conclusion I cannot adopt. It is for the beginner to learn what is worth learning in his particular field first of all. It is not easy in these days to learn all that is worth learning even in a very restricted department. To start on investigation with this only half-learned is a direct

$$\begin{aligned}\Delta^2 V + 4\pi k\rho &= 0, \\ dp &= \rho dV, \\ \frac{\partial p}{\partial \rho} &= c\rho;\end{aligned}$$

where p , ρ , V are the pressure, density, and potential at any point of the mass, k is the gravitation constant, and c is a constant securing the equality of the members of the last equation.

* With regard to what constitutes an adequate theory in any case, see an instructive paper by Dr. G. Johnstone Stoney on 'The kinetic theory of gas, regarded as illustrating nature.' *Proceedings, Royal Dublin Society*, Vol. VIII. (N. S.), Part IV., No. 45.

† Discussion before the American Society of Naturalists at the New Haven Meeting, December 25, 1899

injury to the student, whom it turns to premature specialization. It is both foolish and cruel to exact investigation as a part of the regular training of every student, and very unjust to imply that those whose taste does not lie that way are mentally inferior to those who dabble in research, no matter how ineffectively. It may be replied that, granting this, still it is a good and necessary training for those who in after life are to become investigators. I incline to dissent still, for the born investigator (and no other is worth much trouble) no more needs encouragement to investigate than the fish does to swim. I would, if anything, restrain him till his education has become broad and his mind mature. He will very quickly more than make up the lost time. Then let him have every encouragement.

As regards education I speak as a professor in a medical school, whose career has been so placed that he has seen this school develop into a department of a university. I feel that, in common with others, it has reached a point when it is in danger from the side of its scientific friends who mistake or will not learn the true purpose of a medical school. I so rarely find myself in complete accord with Huxley, that I cannot forbear, though it is not for the first time, quoting his deliberate opinion, that whoever adds one tittle that is unnecessary to medical education is guilty of a very grave offense. If this be true, as I firmly believe it is, we must look to it that the candidate for the degree of M.D. be not robbed of his time, none too long for learning medicine as an art, by specially conducted excursions into abstract science. It may be said, and said truly, that without such auxiliaries the education of the student wants something of the breadth which he should have who aspires to stand on the pinnacle; but this only emphasizes the fact, now becoming daily clearer, that there has grown up the need of what may be called advanced med-

icine. Some would have this strictly post-graduate, but it is probably wiser to have a difference in the course. On the one hand there is the young man who aspires to be a conscientious every-day practitioner of medicine, looking forward to a life of hard work among suffering humanity. Such a one is not to be refused the degree of an honored university, and told superciliously to go to the little school round the corner. Neither is he who, looking at the matter more as a scholar, desires through his studies to train himself to teach others and to widen the horizon of knowledge, to be told that we have no help to offer to one of his ideals. We must provide for both; but with what power I have I shall always protest against sacrificing the first to the second, though the latter is the one with whom my tastes incline me to sympathize.

To sum up thus far, I conclude that it is not the duty of universities to urge, still less to force, original investigation upon students. It should be at hand for those whose zeal is so great that it will take no denial.

The next question is what universities should do for research in the community at large. Are more prizes and scholarships to be offered? As to prizes I should hesitate to say yes. It is not well that they should be too common; but of scholarships for deserving men we can hardly have too many. It is most desirable that the universities should award them. They cannot, indeed, give the funds, but, these being provided, committees from the universities should give their time, care and experience to their proper administration. This is a most beneficent and dignified attitude for a university, midway between the generous donor and the deserving student, to see that the generosity of the former is neither neglected nor abused.

The next and last aspect of the question that I shall consider is "what shall a uni-

versity do for the support and encouragement of investigators within its walls?" The primary function, in my opinion, of a professor is to teach; but, with certain exceptions of rare merit, it is necessary for his reputation and influence that he should do original work. The first duty of the university to him is that he should not be overburdened with teaching. The next problem is, how the expenses of his work are to be met. These must vary with the department. For some lines of research distant expeditions are requisite, necessarily so costly that they can hardly be provided for otherwise than by national or private munificence. But putting these aside, and speaking more particularly of biological and morphological work, the problem reduces itself to this: what help shall the university give to the investigator, (1) in the matter of providing the material, namely, the subject matter for the study, (2) the machinery and reagents for the work, (3) the means of illustrating it, and finally of publishing the paper. The last need is not urgent on account of the great number of journals of all kinds, but it exists in isolated cases. Till comparatively recently the position of universities has been much like that of the Pickwick Club, which when sending its honored founder and his companions on their travels saw no objection to every member paying his own bills. But professors for the most part suffer from 'that perpetual lack of pence which vexes public men,' and those who are not yet professors are, of course, vexed the more. Is it fair that a serious tax, ever increasing in direct ratio to his merit, should be laid on the investigator, especially as the university profits in no small degree by his success? I am sure we shall all agree it is not. But then difficulties present themselves as to how this help is to be given and distributed, assuming that the university admits the claim. Who are to be the

chief beneficiaries? The most distinguished or the most needy? The oldest because of his years? Or the youngest because of his youth? And again is it just that the university should furnish large sums for bringing out papers of unknown merit? It seems to me that the most feasible way, if the money can be procured, is to place a sum in the hands of the professor at the head of each scientific department, to be spent for the good of that department, including publication, according to his discretion, or his lack of it. Should the latter be painfully apparent, the resulting unpopularity will surely be irresistible, and thus there will be a check on a system which may at first seem too arbitrary.

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THE primary function of a university is the diffusion of knowledge, and it is, I believe, equally true that these higher institutions of learning are in great part responsible for the extent to which knowledge is spread throughout the land. Before there can be diffusion of knowledge, however, there must be acquisition of knowledge, and we may at once ask the question, how far shall the university lend its aid in the encouragement of scientific research with a view to the enlargement of the boundaries of human knowledge? It is obvious that the force and energy of a great university must of necessity be given to the training of its students in the various departments of study laid down in the curriculum, and a university worthy of the name certainly cannot afford to devote the major part of its energies to the pursuit of scientific research, neither in my judgment would it be justified in so doing. By such a procedure, it would forfeit the right to the name of university, and its power for usefulness would be curtailed in no small measure

It is clear that loss in one direction might be counterbalanced by gain in another, but the true university must ever remain a place where the student can obtain knowledge of past discoveries, and of the sciences based thereon, together with that broad training which helps to make the educated man. In other words, the university cannot escape from its responsibility as an educational center for the diffusion of knowledge, and any attempt to transform the university into an institution for research alone would be detrimental to the best interests of higher education.

Shall the university, on the other hand, limit itself to routine instruction? To this there can be but one answer, and that is most emphatically, no. The true teacher of science, for example, must ever be a student, not only familiar with the past, but ever on the alert to interpret such signs as nature may make, quick to seize the opportunity to add to man's knowledge, to broaden and extend the limits of his chosen science, to keep in touch with the advances of the present and to harmonize these advances with the knowledge of the past, bearing clearly in mind that whatever is gained by scientific inquiry or research is never lost. As Sir Michael Foster has well said in a recent address, "what is gained by scientific inquiry is gained forever; it may be added to, it may seem to be covered up, but it can never be taken away."

The teacher of science who is content to devote himself entirely to the exposition of that which is known will never make an ideal teacher. He can never hope to arouse that enthusiasm among his students which comes from the man who adds to his power of teaching that love for his science and its advancement which prompts to steady, courageous application in the unravelling of nature's secrets. This influence for good upon the man himself is not to be overlooked, for I take it that the university has

a selfish interest, if no other, in the intellectual development and advancement of the teacher who presides over this or that department of science. The pursuit of scientific inquiry, under proper conditions, tends to the development of moral courage and steadfast endurance; it is a school of discipline which leads to the acquisition of strength and power, which helps to make a man master of himself and at the same time obedient to nature's ways. As Professor Foster has said, men of science, though in themselves no stronger or better than other men, "possess a strength which is not their own, but is that of the science whose servants they are. Even in his apprenticeship the scientific inquirer, while learning what has been done before his time, if he learns it aright, so learns it that what is known may serve him not only as a vantage ground whence to push off into the unknown, but also as a compass to guide him in his course. And when fitted for his work he enters on inquiry itself, what a zealous, anxious guide, what a strict, and, because strict, helpful schoolmistress does nature make herself to him! Under her care every inquiry, whether it bring the inquirer to a happy issue or seem to end in nought, trains him for the next effort. She so orders her ways that each act of obedience to her makes the next act easier for him, and step by step she leads him on toward that perfect obedience which is complete mastery. Indeed, when we reflect on the potency of the discipline of scientific inquiry, we cease to wonder at the progress of scientific knowledge."

May we not, therefore, claim, from this standpoint alone, that the university should look with favorable eye upon scientific investigation within its boundaries, since its encouragement must lead to the development of strength and power in its teachers? Indeed, may we not urge that this recognition of the indirect advantages of scientific

research to the university should give way to direct and positive encouragement, an encouragement which should manifest itself in such an allotment of routine duties as would afford a reasonable amount of time for research to all suitable teachers in the university? I say *suitable* teachers, and, speaking as a physiologist, I should like to raise the question, whether the teacher of an experimental science, like physiology, if he is truly a suitable teacher, must not be an investigator also. Do not the two of necessity go together? And must not the university, if at all zealous for the character of the instruction offered within its walls, see to it that its teachers of science are not merely adepts at expounding that which is known, but are equally ambitious to open up new paths of knowledge in their respective departments of science?

Another, and more direct, reason why the university should encourage and aid scientific investigation is that by so doing it enlarges its own scope of usefulness as an educational center. The modern university, if it is to fulfill its purpose as an educational institution, must be well equipped with laboratories and those other facilities which go to make the teaching of an experimental science a success. What would the teaching of physiology and physiological chemistry, even in elementary form, amount to without the aid of laboratory facilities? The university, whether it looks with a favoring eye upon investigation or not, must have ample appliances for the teaching of the experimental sciences, and the more complete the equipment the better adapted is the university for carrying on its legitimate work. Moreover, the university of to-day is called upon to provide instruction for more advanced students; men and women who are themselves looking forward to the possibility of becoming teachers, who are anxious to

learn the methods of scientific work, and who are desirous of demonstrating for themselves experimentally the facts upon which the important theories and hypotheses of their chosen science depend. For the realization of proper instruction in these respects, the university must provide suitable equipment if it is to live up to its high privileges, as well as have a suitable corps of instructors capable of leading on such advanced workers. The university must, therefore, have at hand all those appliances which are essential for research or investigation, and which the individual worker can rarely afford. Why should not these be utilized by competent investigators for scientific research? Fine laboratories and fine apparatus are of value only so far as they contribute to the spread of knowledge, and if they can be utilized for the acquisition of new facts, so much greater will be their usefulness, and so much more credit to the university that renders them available. But, having the appliances, should not the university make strenuous efforts even to encourage research; not passive encouragement, but direct, positive encouragement, that will not rest until the laboratory is filled with earnest workers taking advantage of the various facilities provided? I think, yes, and it takes very little imagination to picture the direct and indirect advantages accruing both to the university and to science by the fulfillment of such a suggestion.

Contrast, as you easily can, the difference in the atmosphere between a physiological laboratory, for example, occupied solely by a class at stated intervals on certain days of the week, and the laboratory in which zealous workers are to be found, ever experimenting on new problems, spurred on continuously by the stimulating influence of new facts and new observations, making a rallying place for the earnest thinkers and workers who constitute an ever-present

example for the elementary workers in the science. Who can measure the influence for good which emanates from such a laboratory? Does not the university derive, both directly and indirectly, an inestimable advantage from such surroundings, and may we not justly claim that the university by such encouragement of research adds directly to its own power and strength, while at the same time aiding in the advancement of the science? Its scope of usefulness is thereby greatly enlarged; advanced workers in the science are attracted to the university, and even the routine instruction given to the various classes, both graduate and undergraduate, is influenced by the atmosphere of earnest endeavor which permeates the laboratory. The tone of the institution is raised, while both student and instructor feel the stimulating effects of that environment which permits the carrying out of successful scientific work.

Granting all this, the question may be asked, how *far* is it allowable for the university to extend aid in the encouragement of research? It seems to me that the answer to this question must depend upon the resources of the individual institutions. The university must be true to the primary object of its existence. It cannot overlook the fact that it was created for a specific purpose, and the fulfillment of that purpose must be its first care. All higher institutions of learning, however, are bound to recognize the necessity of providing means for the carrying on of original investigations in the various branches of science. I believe, as a rule, it is better for our scientific workers to be connected with the university, than to carry on their work in connection with a special research laboratory, with complete freedom from academic duties. I think higher education would suffer if research work was limited to special research laboratories, and the advancement of science would not be as rapid

as under existing conditions, where the research worker must spend a portion of his time in careful retrospect. Just as work in investigation helps to make a better teacher, so, in my judgment, the necessity of giving instruction to a body of young workers helps to make a better investigator. It should be the duty of the university, however, so far as possible, to allow time and provide means for investigation, and by the aid of scholarships and fellowships, judiciously awarded, offer inducements for the younger workers to spend a portion of their time in scientific research.

Do not the results which have been obtained by scientific workers in connection with our own and foreign universities afford ample proof of the value of this method of encouraging investigation and advancing scientific knowledge? Consider, if you will, the results which have been attained during the last twenty years in physiology; the advancement made along so many lines and in so many different directions, and then glance at the names of the men who have carried out these investigations and note their positions in life. They are practically all university men; men who have carried on research work in connection with their academic duties, in some cases unaided, but frequently with the co-operation of younger workers, assistants, fellows, etc., to whom they have taught in this way the methods of scientific investigation. I have just received the *Jahresbericht für Thierchemie* for 1898, containing the record of investigation for that year in physiological chemistry. The book contains 850 pages filled with brief abstracts of the researches in this somewhat narrow field of investigation. Does not this record indicate that investigation is being encouraged? That the universities and other institutions of learning are consciously or unconsciously taking a position of helpfulness toward scientific research? I believe

this to be the case, and while we must admit that in this country there is not quite the same liberality as exists abroad, yet I believe that all of our more prominent institutions of learning are willing and anxious, so far as their means will allow, to foster the spirit of investigation, both for the personal advantage to be derived therefrom, and for the sake of advancing the knowledge of science in its various departments. Certainly, the university cannot afford to take any position other than that of helpfulness towards scientific research, or manifest any disposition other than one of coöperation in the attempts that are made to advance the boundaries of human knowledge.

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EDUCATION as a preparation for conduct involves a fitting in respect to the two all-important factors by which conduct is determined. The educated man differentiates himself from the uneducated by the greater range and variety and by the intrinsic character of the influences to which he is responsive, and again by his mode of response to these influences and to the ordinary and extraordinary events and situations which our common environment presents. The receptive side of education is the more tangible and therefore apt to absorb attention beyond its due. It is so obviously important—especially in days like these, when there is such an endless series of things which it is necessary and useful to know—to furnish the individual with the maximum opportunities of acquiring information, that the problem that is apt to be relatively neglected is that of fitting him to use what he acquires, of making his stock of knowledge not a burden to be carried, but part of the strength that carries.

In the realm of education action and reaction are not necessarily equal; the individual may be exposed to wholesome

and inspiring influences and yet derive from them neither health nor strength. A thorough education includes a training in both action and reaction; it educates one to be widely and deeply and yet critically receptive, to be judiciously and ably and yet creatively expressive. From the first to the last it considers both these aspects; feeling and knowing, observing and assimilating must step by step be complemented by doing and experimenting, by coördinating and originating. However true that the response presupposes the stimulus, yet the latter alone in the complicated conditions here pertinent will not produce it; it requires a strengthening of the reaction impulse, a guidance of the executive capacities.

To indicate the application of this principle to the elementary and intermediate phases of education is no part of the present discussion; and yet it may be in place to record my conviction that the furtherance of the responsive and origina-tive functions in these stages of education is itself an important aid to the proper recognition of the place of investigation in the university. If from kindergarten to common school, and from these to high school and college, coördinative thinking could be successfully taught, if each step of knowledge could be made to yield an increase in the capacity to handle and arrange one's thoughts, then the necessity of keeping aglow the flames thus kindled, of laying stress upon originality and achievement in the university would more easily gain due recognition.

It is apparent that I claim as an important function of investigative work in the university its directive influence upon collegiate and university studies; and the recognition of this function on the part of the university authorities must always be a prominent motive for the proper provision of opportunities for investigation. From whatever other points of view it may be or

become the duty of the leading institutions of learning to contribute to the advancement of the boundaries of knowledge, the pedagogical motive will never lose its pertinence. But whether for the strengthening of its internal educational structure, or as a proper expansion of the university sphere of influence, there will always remain a close community of method and interest in all provision for research. That community is the furtherance of the investigative spirit. Fruitful investigation flourishes only in a proper soil and blossoms profusely only in a congenial atmosphere. One cannot have investigation without investigators; in some directions money may provide the materials, for the lack of which investigation must go halting, but in all directions investigators must be both born and trained. The inspiring intellectual life of our foremost universities certainly offers a most congenial atmosphere for the growth of that investigative spirit; the furtherance of that spirit is an indispensable factor in a worthy national and cultural progress.

It thus becomes not a supplementary duty but the very purpose of the university to provide an environment so thoroughly suited to the growth of investigation that it cannot but become its natural habitat. Research is indispensable to a university. says President Eliot, "because a university which is not a place of research will not long continue to be a good place of teaching; and, secondly, because this incessant, quiet, single-minded search after new truth is the condition of both material and intellectual progress for the nation and for the race."

It will be well to examine somewhat more closely the two aspects of investigation which I have selected for special emphasis—investigation for training and investigation for discovery. The working ideal of American universities is to provide their students with the maximum opportunities

and privileges of which their degree of maturity and responsibility enables them to profit; and at the same time we continue the guidance of their progress in ever more indirect but no less efficient manner, until they strike out confidently, and as a rule creditably, in their chosen walks of life. We have not been tempted to imitate the German system which makes the passage from gymnasium to university an abrupt change from set tasks and stringent discipline to complete liberty with little guidance and no control. While it is proper that conventional ceremonies and new privileges should add zest to the assumption of the toga virilis, it is not proper that mistakes should be encouraged, nor that, for lack of a gradual transition, time and energy and strength should go astray. Men and women should have the liberty of making mistakes; there is a very real danger in over-guidance as well as in license. But the golden mean between these, though a narrow path, is broad enough to be readily found.

In the ideal which American universities attempt to realize, there are to be guideposts enough to give the young explorer a confident feeling that others have trod the path before him, and to prevent useless wanderings into by-paths and *culs-de-sac*, and yet not enough to take away the incentive of independence and adventure, nor to lose the slightest opportunity to foster self-reliance and courage. It is necessary to understand this ideal and the consequent attitude of both guide and guided to appreciate the function in the university of investigation for training. For it seems to me that no other aspect of university studies can so readily be adapted to this ideal as the investigative aspect. I mean by this not merely the one topic that forms the basis of a thesis (which in the nature of things must often be quite detailed and not comprehensively significant);

but also the research attitude of the seminary, the participation in the problems of fellow-workers in the laboratory and study, the preparation for lectures and demonstrations, the presentation of technical material before clubs and societies, the critical digest of current contributions to learning and the tentative but stimulating first steps in productive authorship. In all these activities the attitude of the student is participative and expressive; not only absorbent but responsive; he must do and dare, he must count and weigh, he must thrust and parry; he is no longer wholly a spectator nor an auditor, he has a part, though a minor one, on the stage; and even the acquaintance with *the scene-painting* and *stage-carpentering* is a useful one for the training of the actor. It is in the special adaptation of investigation to accomplish these ends, to round out the motor side of education, that I see its pedagogical value. Research under judicious guidance is a training in coördination, a training in self-reliance, a training in readiness and resource, a training in reserve and critical ability, a training in construction and expression. It gives zest and dignity to what might otherwise seem to be insipid drudgery; by presenting conditions which must be met as best one can, investigation becomes a stern discourager of hesitancy; by its constant reference to and dependence upon the errors and outgrown opinions of the past, it is a wise encourager of caution and foresight. It teaches both how to look and how to leap. It maketh the full, and the ready, and the exact man. It would be unwise to forget that other aspects of university studies and university life contribute an essential quantum to the furtherance of the same qualities; but considering it with reference to its fitness in a systematic course of higher education, to elicit the full whole-souled response of ambitious youth, and in requiring just that proper

measure of guidance and independence suitable to the capacities and purposes of university students, the position of investigation for mental training and discipline cannot hold a subordinate place.

Regarding investigation for discovery, I desire only to touch upon one or two aspects of it which are not so commonly associated with the term as they should be. While there is something to be said—in many departments much to be said—for investigation as a prudent and practical investment, there is no danger in a commercial democracy that this will remain unsaid. It is only in its relations to its constituency that it becomes important for the university to emphasize this aspect of investigations. Still less legitimate is it for a worthy university to exploit the contributions to knowledge which it has been fortunate to have developed within itself as an advertisement of its merits, not in this respect mainly but in general. There is no feature in the management of American universities that in my mind so easily arouses disgust and despair as this much varied but always objectionable heralding of their opportunities and successes. This field may properly be left to the manufacturers of proprietary and dietary specialties.

Investigation for discovery is a university function because of its incentive to the highest activity of those who in their several departments approach the confines of acquired knowledge and attempt to extend or to modify them; because of its contribution to the totality of the university spirit which permeates and stimulates every output of its energies; and, independently of these, because the advancement of learning by the creative capacities of the men of greatest endowment is in itself as proper a function of a university as teaching or the maintenance of libraries and museums.

Regarding its relation to the individual development of the professor, it would be

foolish to ignore the fact that teaching and research do not always make an harmonious pair. There will always be in letters and in science a group of men, often marked by genius as her own, who are keenly sensitive to the restraints and routine of instruction. Lowell said that being a professor was not good for him; it damped the gunpowder of his mind, so that "when it took fire at all (which wasn't often), [it] drawled off in an unwilling fuse instead of leaping to meet the first spark." The joy of feeling that the marks of the ball and chain had worn off induced him to write, "If I were a profane man, I should say, 'Darn the College!'" Some mutterings of similar import may occasionally be overheard in the vicinity of laboratories and lecture rooms. The best teacher is not always an investigator, nor the best investigator a teacher. The university should be broad enough to provide for men of both types and set each to work at that which he does best. And yet, because of its influence upon the totality of the university spirit, I believe that in the long run the fruits of instruction will be choicest when they have been ripened in the sunshine of investigation.

To what extent universities will be willing to encourage investigation as a complementary obligation to their other functions is largely a practical question; it depends upon means of support, it depends upon a public spirit liberal enough to appreciate and provide for its development in a spirit of the husbandman who plants the tree the fruits of which he shall not live to enjoy. 'Serit arbores quae seculo prosint alteri.' There are welcome signs that such a spirit is not foreign to our civilization, and that this is one of the respects in which the twentieth century may be expected to exceed the achievements of the nineteenth.

So far as I have attempted to crystallize

my contribution to this symposium it may be said to center about these points: Investigation constitutes a motor or expressive factor in education at a stage in which that factor becomes particularly significant. It occupies an important place in the university by reason of its disciplinary value in the direction of self-reliant activity. The place of investigation in building up the spirit that makes for the safest and sanest progress is no less conspicuous. Investigation for discovery is a function co-ordinate in worth with other purposes of a university, and is more likely than almost anything else to keep the mind of the professor from 'drawling off in an unwilling fuse,' and to make it ready to leap to meet the first spark.

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It may be conceded in the beginning of this discussion that a modern university is an institution which devotes attention to all subjects information upon which can be systematized or reduced to a science, and that it is constantly striving to extend the boundaries of knowledge in every branch of human inquiry.

In its strictly educational function it develops a proper conception of these subjects in the minds of its students by the logical and inspired presentation of certain basal facts and underlying principles, with which the learner may build up the mental edifice representing the structural aspect of each subject in its completeness or incompleteness.

With a fairly general agreement upon these points it might be said that the subject for discussion is one which vitally concerns the integrity of the university, and any question of the abstract relation of the university to investigation would imply a most serious state of affairs. I take it for granted, however, that the real theme for

consideration is not the ethical relation of the university to research, since its obligations in the matter are invariable and undeniable, but rather one of the practicability and pedagogical expediency of carrying out this obligation.

Can the facilities of a university be used to advantage in the furtherance of research, and what influence does effort of this character exert upon its pedagogical functions?

The most prominent feature in the majority of our universities under their present organization is undoubtedly their academic department, in which the older, often mis-called the elementary, parts of the subjects are presented in a manner which absorbs the greater proportion of the facilities of the institution. The intent of such instruction is most commendable in its thoroughness and honesty of purpose, but here the good and honest intention, as with many others blindly followed, leads to a most iniquitous ending. No university of standing fills its chairs with men who are not prominent by the results of their investigations and active in their present prosecution. Having proceeded so far wisely and well, the administration then falters in its high purpose, and permits, rather insists that practically all of the energy of its members should be expended in the more or less mechanical duties attendant upon elementary instruction, especially in natural sciences, and fails entirely to provide either opportunity or facilities for the development of research work and its use in the presentation of the subjects. Such failure may be due to financial disability, though administrative lapses of judgment are not unknown or infrequent. In either case it is unfair and unfortunate to such a degree as to stretch the conception of honesty to its utmost limits, and to make the name of the university a travesty. Such non-appreciation of the actual importance of investigation is most conducive to stagnation, or indeed it may be taken as a

symptom of it, and its deadening, thwarting effect is doing more to retard the development of the American university than any other one cause.

The presentation of any subject by an instructor who is not participating in its development will lack freshness of treatment, sharp distinctions between established and speculative deductions, will be more or less dogmatic, and will fall far short of its possible value, both for culture work and professional training. To this sweeping statement I am bound to add that there are a few teachers, not investigators, whose apparent success in instruction is due to an enduring and contagious enthusiasm which implants a permanent interest in a subject, in the mind of a student, which may lead him to follow it later and elsewhere to a more orderly and natural attack, from which he will gain a proper perspective for the first time. The arousing of enthusiasm and the imparting of information do not constitute the highest form of instruction however, and the teacher who does no more, fails not only in his special office, but also in his duty to bear a share in carrying out the obligations of the institution to society.

So far as investigation as a method of teaching is concerned, it is to be said that the acquisition and systematization of information gained in this manner, have a value both for culture and professional training lacking in any other method. It is a procedure by which the student is led to grasp the chief concepts included in a subject, the principles to be deduced from their orderly arrangement, to trace the manner in which every increment of new fact or advanced thought has been accumulated, and to follow the technique of this development in making his own acquaintance with the subject in its known aspects. So far he has been an investigator merely as a matter of discipline. Later he may project his activities beyond the boundaries of the

subject, and by contributions of his own winning, alter its limits and make a readjustment of its generalizations possible and necessary. The value of this investigating, or find out for himself, method of learning is too well established to need more than mention at this time; a value clearly conceded by its almost universal usage. Whether or not a student should be led into the specialization necessary to make discoveries, in his undergraduate days, is a question which may be answered only in the light of information as to his training, his purposes, and his mental capacity. The same may be said of the graduate student, except that the value of investigation for discovery is more immediate in his case if his graduate work logically follows his earlier training.

With the realization of the value of research in the university, it may be said that no worker who is thoroughly in earnest will fail to find means of attack upon some of the problems pressing in upon him, and to use this method in the presentation of his subject, no matter under what straitened circumstances he may find himself. The investigator who does not show this adaptability will certainly encounter ample opportunities for unhappiness.

With a devotion to research in its faculties it needs but the expressed appreciation of the administration to promote the pedagogical practice of investigation to a creditable degree, even if the material facilities are lacking. The extension of investigation to a point where it may actually contribute to the development of a branch of knowledge will depend very largely upon the actual financial resources of the institution, although the born investigator is not easily turned from his path. In any case the needs of a university for research facilities are quite as elemental and quite as pressing as for libraries, chapels, memorial halls, gymnasiums, or any other part of the in-

stitution's mechanism, and should receive corresponding attention from those in charge of its organization and administration.

The following statements may be made in conclusion :

1. One of the primal duties of the university is the furtherance of research.

2. The presentation of subjects by instructors not engaged in research will lack originality of treatment and will not be properly inductive.

3. Investigation is itself a method of advanced teaching by which a student comes to a full realization of the structural aspect and relations of a subject, participates in its development, strengthens his mental grasp and broadens his powers of generalization; a method by which the highest form of culture and training is secured.

4. Investigation is, therefore, not only an obligation of the university to society and to its students, but also one of its most effective weapons.

5. Any tendency to the restriction or curtailment of the opportunities for research is to be regarded as a most alarming retrograde movement, which may in time vastly impair the usefulness of the institution compelled to take this step, and is certainly indicative of disabled function or evasion of one of the plainest duties of the university.

D. T. MACDOUGAL.

N. Y. BOTANICAL GARDENS.

It is hardly necessary to emphasize here the importance of investigation as a part of the training of the university student.

Training in research methods is chiefly valuable in that it stimulates the perception and the imagination and increases the power of self-guidance and immediate productivity. As a means of instruction it is slow and cumbersome and often fails to accomplish its object.

With the rapid growth, in recent years,

of the spirit of research, instruction in the methods of research is regarded as an essential part of the teachers' university training. The same kind of instruction is being rapidly transplanted into the college curriculum, where it may form part of the work of advanced students during their junior and senior years.

We shall not try to point out here the value of research to the university, or to discuss what may be done to give it new scope and direction. Let us rather inquire whether there is not a tendency to confound the university attitude toward investigation as a method of training, with that of the learned society or academy toward research as an end, and whether, as a result of this confusion, our higher educational institutions are not substituting too extensively a training in investigation for more direct methods of instruction.

The criticism may be fairly made that in research work an enormous amount of time is devoted to mechanical details that do not yield adequate returns, either in instruction or in training; that much of this work is begun before the student is properly prepared to undertake it, and done at the expense of the best opportunity he is likely to have of acquiring a broad, sympathetic culture, and a secure foundation knowledge of the subject in which he proposes to specialize; and finally, that the research work to which the student devotes so much of his time rarely, if ever, serves as a preparation for the kind of work by which he expects to earn a living,—namely, teaching in the college or secondary schools.

It seems to me that such criticisms are largely justified, and that they are specially applicable to the biological student, whom I shall have in mind in the discussion that follows.

This is mainly due to the nature of biological work, and to the character of the biologist. The latter is generally an en-

thusiast who follows his subject for its own sake, without hope of the large financial rewards of the inventive chemist or physicist. In rare cases he may be a man of wealth and leisure, but more generally he has very moderate means and is without the best preliminary training. In the great majority of cases, he must earn his living by teaching, and use his leisure time only for research.

In biology the frontier separating the known from the unknown is everywhere close at hand, and new methods of research make it easy for comparatively untrained workers, with a little guidance, to bring important facts to light.

It is not necessary to devote the long years of training required in music and art, to make the eye and hand of the biologist effective instruments for the performance of his work, and the apprehension of the mere materials with which he deals, taken alone, does not make great demands on his mental resources.

The daily occupation of the biologist may be so absorbing, that once he begins to section and stain, and put things safely away in bottles, he is likely to keep on doing so till he dies.

There is, therefore, a great temptation for the biological student to begin his creative work at an early period, and he is eager to do so because it gratifies his pride to be investigating something, and because, on the whole, investigation is a very entertaining occupation. The instructor is not likely to oppose his inclinations in this direction, since he finds it an easy way of keeping the student busy, and incidentally of clearing up little problems he has no time to work out for himself.

But there is probably no other subject in which there is greater danger of too early specialization than biology, because there is no other science which sends its roots more deeply or intricately into other sci-

ences, or in which the personal equation, the character and training of the man, exerts a greater influence over the interpretation of results.

As the biologist's greatest skill is shown in the marshaling and weighing of a multitude of what must always remain incomplete and fragmentary data, his best preparation for such work will be the formation of that sound judgment which comes from a wide knowledge of his special subjects, and something more than the mere vocabulary of related ones.

The college courses do not usually give the required training, not for lack of time, but because so much time is wasted in getting ready to teach, and in observing the mouthings of science, that there is none left to hear what she has to say.

In some instances the instructor apparently tries to find out how long he can instruct without telling anything, and how long he can keep the student guessing what he is expected to see. After the student has made careful drawings of various organs and covered them with unintelligible names, he is often left to draw his own conclusions as to their meaning and function. This method may satisfy the student's curiosity to get a good interior view of the organization of an earthworm, but it does not enable him to discover what the science of biology has to say on the subject. It is as though one should begin a course in the science of football by requiring the student to make careful drawings of the stitching on the ball, and to section its germ layers, and then leave him to form his own notions as to how the game is played. Such a method is said to be of value in cultivating the powers of observation. But if the teacher of biology would teach biology only, and let the powers of observation alone, better results would be obtained. In my own judgment, you can hardly tell a student too much, or tell it too

quickly, provided you tell it so that he can understand.

In the university the student often suffers from a similar lack of direct instruction. He generally finds that two kinds of courses are open to him: in one the treatment of the subject is so elementary that he can afford to ignore it; in the other some subdivision of it is discussed in great detail, and perhaps necessitates the expenditure of so much time and energy in the use of investigation methods that he does not want it, or cannot afford the time to take it.

In these courses, the instructor prides himself on giving the very latest report of the hour, with much controversial matter, better suited for the archives of some learned society than to be detailed in the class or lecture room. A prolonged diet of this kind is depressing, and is apt to leave in the mind of the student a succession of vague impressions of small educational value, and a feeling that it is more important that a certain investigator should receive full credit for having made a discovery than it is to give that discovery its due weight and position.

It has been said that biological instruction in America is not what it pretends to be, because the botanical side of the subject is neglected and most of the time given to zoology. But even the zoological instruction, that is supposed to be biological, is itself one-sided, since it may be treated from the purely morphological standpoint, ignoring altogether the experimental, physiological and ecological sides of the subject.

With all this special work goes a great deal of technique, something that readily degenerates into an interminable pattering over different methods, with very little attention given to the real questions to be solved by them.

On reaching the university the student's

first thought is to obtain some problem for his doctor's thesis, and, if he is fortunate, in the selection or assignment of a workable subject, and can obtain material to work with, his best energies are henceforth centered round that particular work, for he is led to believe that his future career depends largely on his discovering at once something of importance.

He feels that his time has been thrown away if at the end of a certain period he has no results on hand worth publishing. In the absence of such results and in his haste to get his degree, there is danger that after prolonged meditation he may unconsciously supply the deficiency by giving to his discoveries an importance they do not possess. By padding his paper with personal and irrelevant details, or by picking an unnecessary quarrel with his predecessors, and with the aid of an elaborate historical summary, he can generally get together an article of sufficient dimensions to produce a favorable impression on the biological community, excepting, of course, the half dozen or so individuals that read it.

In his research work the student is sustained by the thought that he is carrying on some profound investigation. But his work is largely mechanical. It may require a great deal of patience, a little manual skill, and perhaps some intelligence, but it very rarely shows any genuine originality. The student is really seeing and doing what he is told for he has not sufficient knowledge of his subject to steer his own course, or to clearly grasp the significance of the question at issue. Much of the research work of the faithful student type is of this nature. In fact, the instructor does the research, and the student the manual labor.

Another evil likely to arise from the over-emphasis of research work is the danger of a great waste of time and energy on sterile problems. If it is downright cruelty,

as Huxley says, to add one unnecessary hour to the work of the medical student, it is no less an offense to assign a line of special inquiry to a candidate for the doctor's degree with a possibility that at the end of one or two years his chances of getting the degree are as far off as ever, because through no fault of his own the work gave negative results, or because his results have been anticipated elsewhere. Another student, more fortunate in the assignment of his problem, may get his degree with the expenditure of half the time and labor.

Of course it may be urged that in most cases no one can know whether a given problem will be fruitful or not till it has been tried, and the candidate must take his chances. He must, no doubt, take his chances in after life, and he accepts the conditions more or less cheerfully, provided he is not asked to wager more time and strength on the hazard than are honestly his.

Meantime the candidate for a doctor's degree has been so absorbed in his research work, that he has not had time to think about his own development or his examinations. It is usually assumed that, when the time comes, 'a few weeks hard plugging will fix that all right,' and experience generally justifies the assumption. In a case that came directly under my own observation, a Japanese student of zoology was to demonstrate his knowledge of botany by describing how they cultivated tea in Japan.

After two or three years of investigation, the graduate student is liberated with an exaggerated idea of his own importance as a contributor to the world's store of knowledge, and quite untrained in the only work he is likely to do well, or even have a chance to try, namely, teaching in the secondary schools.

The layman, looking for a teacher with an up to date equipment for his work, may be impressed by the doctor's volumi-

nous treatise, but he will probably discover, when it is too late, that his candidate has but one imposing garment to conceal his unfitness for the work required, or, worse still, may find that he does not want to teach at all, but to investigate.

It may take several years for such a misfit teacher to adjust himself to his proper environment, and to discover that it is worth more to be a good neighbor and a useful man in the community than it is to be known in Germany.

In conclusion, therefore, it seems to me that by the over-emphasis of research the university is in danger of sacrificing the sound, symmetrical education of the individual for the sake of a too rapid growth of science. The university student should be trained in the methods of investigation, because it may give him fertility and power, not because it is his business or duty to contribute something new to the world's store of knowledge.

As the value of his contribution may or may not afford a measure of his originality or of his ability to teach, the university should not insist too rigidly on an original contribution as a requirement for the doctor's degree, and should eliminate every possible element of chance that may deprive the candidate of his well-earned license to teach, or that may unnecessarily prolong his term of apprenticeship.

The examination for the doctor's degree should precede rather than follow the approval of a thesis, in order to check too early specialization and an undue haste in the publication of fragmentary research work.

The biological material already available for teaching should be condensed and put into logical order for purposes of more direct instruction, and the educational requirements of the medical man, the teacher, and the professional investigator should, so far as necessary, be met separately.

The physiological and experimental sides of biology should receive greater attention, and that kind of out-door work on living animals in their natural surroundings, for which the marine and lake laboratories offer such excellent opportunities, should be specially developed, because among other reasons, of its bearing on the nature work in the public schools. The work done in these laboratories should be formally recognized as part of the requirements for the higher degrees, and the laboratories themselves grafted on to the university and college so as to form as much a part of their equipment as do the library and museum. Results of the greatest importance for biology, in all its relations to education, will surely follow coöperation in this direction.

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AMERICAN MATHEMATICAL SOCIETY.

THE sixth annual meeting of the American Mathematical Society was held at Columbia University on Thursday, December 28, 1899. On the same and the following day the Chicago Section met at the University of Chicago. Occurring in the holidays, these two meetings are more easily attended than those of other seasons, and afford better opportunities for personal conference and discussion. The annual meeting offers the additional interest of the election of officers, the presentation of annual reports which regularly bear testimony to the remarkable prosperity of the Society, and the general marking of the close of one year of progress and the opening of another. An especially attractive feature of this year's annual meeting was the scholarly Presidential Address of President R. S. Woodward on 'The Century's Progress in Applied Mathematics.' This address, which appears in the present number of *SCIENCE*, as well as in the next number of the *Bulletin* of the Society, was delivered before