SCIENCE

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*SCIENTIFIC RESEARCH.**

IN connection with the so-called form of initiation as prescribed by the constitution of this Society we find this precept, 'The president or his deputy shall explain the aims and objects of the society.'

I understand it to be a common interpretation of this provision that a more or less formal address is to be presented, either by the president of the chapter, or what in the present case at least would be better, by some distinguished member of the society acting as deputy, to retain the phraseology of the written law.

In connection with the exercises of this evening the duty appears to fall upon my shoulders, but it is not my purpose to make this communication either lengthy or formidable.

As to the aims and objects of this society we find them fully set forth in section 2 of the Constitution viz.:

> The object of this Society shall be to encourage original investigation in science, pure and applied: by meeting for the discussion of scientific subjects; by the publication of such scientific matter as may be deemed desirable; by establishing fraternal relations among investigators in the scientific centers and by granting the privilege of membership to such students as have, during their college course, given special promise of future achievement.

* Address delivered at the initiation of new members of the University of Pennsylvania Chapter of the Society of Sigma Xi, April 18, 1902.

It is then with science, pure and applied, that we have to deal as distinguished from those departments of study, called by their votaries the humanities. These are defined as 'the branches of polite or elegant learning, as languages, rhetoric, poetry and the ancient classics.'

Now we shall have no quarrel with these pursuits or with those devoted to them, unless it be with the assumption that they are essentially the polite and elegant branches of learning as distinguished from the pursuits of science, and that the latter must be relegated to a lower plane. We accept no second place for science either from the standpoint of its importance to the welfare of the human race, or as a means of culture in a system of education.

No doubt it would greatly benefit many or all of us if we could spare more time from our pressing duties for the enjoyment of poetry, of literature and the fine arts, but we are also persuaded that very many of those who find their vocation in these fields would find great advantages in a more intimate acquaintance with physics, chemistry and biology.

The object of our Society, as above stated, is to encourage original investigation in science, pure and applied. What then is science and what constitutes original investigation? The term science is much abused by many who appropriate it. Ever since the days of St. Paul, and doubtless for a much longer period the human race has had with it innumerable forms of science falsely so-called. It is as important to-day and for ourselves as it was for Timothy nearly 2,000 years ago, that we should avoid what Paul called the vain babblings of this description of science.

When, however, we examine critically the meaning of this term we find it to be one which may be employed to designate all departments of human knowledge. 'Scire,' to know, is the root from which it springs. We understand it to apply, however, only to such departments of knowledge as have been formulated and classified with reference to general laws, and it is the attempt to discover such laws, underlying and connecting the phenomena which we see about us that constitutes scientific investigation. Whenever all of the observed facts of any science, as astronomy or chemistry or biology, can be so fully understood as to admit of expression in a strictly mathematical form, this science may be considered complete. It is perhaps unnecessary to add that we possess no such completed science, nor is there any promise that we ever shall.

The term science then embraces a great number of departments of knowledge and deals with truth in almost every form, so soon as we have the means of assuring ourselves that foundation principles are indeed truth and not fiction. Thus we have psychology, theology, economics, sociology, mathematics, the entire range of physical and biological sciences, and many other departments of mental activity which may be regarded as possessing claims, more or less admissible, to be included within this honored body.

When we refer to the object of this Society as expressed by its founders—to encourage original investigation in science—we might perhaps infer that we were taking all knowledge as our province. This, however, is not our purpose. The science with which we are now concerned is understood to be limited to the mathematical and physical branches.

This limitation is emphasized by reference to the history of the Society. I quote from the report of a committee appointed in 1893 to consider some matters related to the policy to be pursued.

> The Society was established in 1886 by a few earnest workers in the engineering sciences, as a means of rallying and encouraging those qualities which were deemed of the first importance in their own lines of investigation. It soon became

broadened and enlarged to represent the general ideals of highest scholarship in the minds and before the ambitions of every earnest student in any branch of science. It proposed to recognize and elect to its membership those men in our institutions of learning who should exhibit in a marked degree the qualifications of natural endowment and training required for successfully conducting original research in various branches of science.

Then among the conditions which must be met in order to qualify an institution for the establishment of a Chapter we find this:

That the number of distinct branches of science represented by full professors in the institution shall be at least five; and these branches should include mathematics, physics, chemistry, biology (some department of it) and engineering (some department of it).

This Society then has for its object the encouragement of original investigation in science. But what constitutes original investigation, and how is it to be carried on? Probably all of us have known earnest students of science in some of its forms, men or women it may be who by reading and study have acquired a great fund of information, but who have no more idea of any way in which they can add anything to the existing store than has a new-born babe.

Some have regretted their misfortune in being born too late. If they could have appeared on the scene before Shakespeare had exhausted the field of dramatic literature, or Newton and Laplace that of universal gravitation, or Columbus that of geographical discovery, they could have done these things, and thereby have achieved immortal fame.

On the other hand as an illustration of the true scientific investigator let us consider the example of Mr. S. W. Burnham, of Chicago. Mr. Burnham is the leading authority of the world in the astronomy of double and multiple stars. His profession is that of a stenographer, astronomy or physics occupying no prominent place in his early training. Forty years ago, as many other men have done before and since, Mr. Burnham purchased for his entertainment and instruction a cheap telescope of five inches aperture. This was soon afterwards replaced by a slightly larger one, which in turn gave way in 1869 or thereabouts to a six-inch glass by the celebrated Alvan Clarke. This modest instrument Mr. Burnham pronounces simply perfect in performance.

The thousands of double stars which are scattered in every part of the heavens had an especial fascination for this amateur astronomer. To quote his own words:

My attention for some reason or other which I am unable to explain, had been almost exclusively directed to double stars previous to this while using the smaller telescope referred to. This preference was not in any sense a matter of judgment as to the most desirable or profitable department of astronomical work, or the result of any special deliberation upon the subject. It came about naturally without any effort or direction on my part.

A little building in the rear of Mr. Burnham's residence sheltered his telescope from the elements, and here he found his pleasure after the work of the day was over in scanning the heavens, identifying and measuring the systems which had been found by the Herschels and the Struves, and in gathering up hundreds of pairs which had been overlooked by his predecessors. During all the early years of his activity in this field, he was actuated only by the satisfaction which he was deriving and probably never suspected that it involved anything remarkable. It is hardly an exaggeration to say that he awoke one morning to find himself famous.

Contrast this brief account with the history of another aspirant for glory in this same field, Sir James South, of England.

In 1842 the late Professor O. M. Mitchel visited Europe for the purpose of inspecting foreign observatories, and purchasing a telescope for the

proposed Cincinnati Observatory. In the interest of this object he visited most of the leading European astronomers, and among others, Sir James South. This was during or about the time of a long litigation, which grew out of a contract between this astronomer and a firm of instrument makers who undertook to mount equatorially a large object-glass belonging to South. Mitchel describes his interview as follows:

One apartment was examined after another, until finally we reached a large room surmounted by a dome of great size and expensive construction, while fragments of the framework for mounting a great equatorial were scattered about. "Here," exclaimed Sir James, "you behold the wreck of all my hopes. Here I have expended thousands and flattered myself that I was soon to possess the finest instrument in Europe, but it is all over, and there's an end."

I remarked that the object-glass was still in his possession and might yet be mounted, so as to realize his hopes and expectations.

"No," said Sir James, "Struve has reaped the golden harvest among the double stars and there is little now for me to hope or expect."

It would be difficult to appreciate the feelings which at that moment were sweeping through the mind of the astronomer. Long cherished visions of fame and high distinction, or perhaps of grand discoveries in the heavens which for years had played round his hopes of the future, had fled forever. Another had reaped the golden harvest, and like Clairault who wept that there was not for him, as for Newton, the problem of the universe to solve, Sir James South could almost weep to think that another's eye had been permitted to sweep over the far distant realms of space, which he had long hoped might remain his own peculiar province.

Yet this very field which Struve was supposed to have exhausted is precisely where Burnham was winning his laurels a quarter of a century later. As to its exhaustion we have the best of authority in Burnham's own words. He says:

The late L. W. Webb, author of 'Celestial Objects for Common Telescopes,' one of the most eminent English amateur astronomers, in a letter written to me in 1873, after the publication of my first three catalogues said: "It will hardly be possible for you to go on for any great length of time as you have begun because the number of such objects is not interminable, and every fresh discovery is one less to be made." Since that time more than 1,000 new double stars have been added to my own catalogue, and the prospect of future discoveries is as promising and encouraging as when the first star was found with the six-inch telescope.

It seems strange when we think of the thousands of years during which the human race has inhabited this planet, that so long a period elapsed before anything which could properly be called scientific inquiry manifested itself.

One of the first problems to present itself was the greatest of all and may be said to include all others, viz., the problem of the universe itself; the origin, structure and end of the world on which we live and of the attendant bodies as the sun, moon and stars were supposed to be. Naturally the first attempts at solution were what may be called theological. One such with which we are all familiar forms the opening paragraph of the book of Genesis, 'In the beginning God created the heavens and the earth.' As humble inquirers after knowledge I have no doubt we may accept this account without the slightest hesitation, but this helps us very little in our quest for scientific truth. Neither the heavens nor the earth nor anything therein is the result of a supreme act of creative power exerted once and for all, but rather of an unfolding or evolution from a former condition in accordance with the unchanging laws of nature.

Suppose by the way of fixing our ideas that we were able to trace backward the history of our earth from its present status to that of a highly heated self-luminous globe, before life in any form had made its appearance, or carrying our history farther into the past to a time when this earth with the sun and all of the planets were united in a single mass of nebulous matter filling and extending far beyond the orbit of Neptune. Have we now reached

the beginning spoken of, or shall we push our investigation farther into the remote past, to account for the existence and characteristics of this nebulous matter which constitutes raw material out of which suns and worlds are formed?

After a long and active struggle which even now perhaps is hardly ended, it has come to be understood that scientific research and theological views cover entirely different ground and that any conflict between the two is purely of man's invention. It is now more than 250 years since Galileo was compelled to renounce the heretical doctrine which placed the sun and not the earth at the center of the planetary system. But little more than one tenth of that time has passed since a distinguished geologist, himself an active Methodist, is said to have been compelled to sever his connection with a so-called university for holding the view that this planet had been occupied by the human race for a longer period than 6,000 years.

It was the Greek philosophers who first attempted by reason and research to solve the physical problems with which we as a society are concerned. Many of these were men of remarkably keen intelligence and the measure of their success marked the highest level reached in these directions for 1,500 years or more. Until the somewhat indefinite period known as the renaissance, almost the only science known, at least in Europe, was that of the Greeks. No one can deny that humanity is deeply indebted to them for this heritage. Regarded however as a solution of the problem in view, the efforts of the Greek philosophers were one and all a sad failure. Their effort was nothing less than to find an answer to that ancient and insoluble riddle, the problem of the universe; their method, the utterly fruitless one for this purpose, that of deduction. They hoped to find a great, general, all-embracing principle, and by pure reason to evolve from it everything which exists. Thus Thalis regarded water as the origin of all things, another ascribes this place of honor to air, and another to fire. It is true that Aristotle and others insist upon the importance of observing and classifying the facts of nature, and studying in this way the fundamental laws connecting and governing them, but how effectually or ineffectually this was done may be shown by one simple example, viz., the law of falling bodies as enunciated by Aristotle himself. This he states to be that bodies descend more quickly in proportion as they are heavier. It seems almost incredible that a statement, the falsity of which is so easily proved, should have been made by Aristotle in the first place, and in the second place should have been accepted apparently without question for 2,000 years. I know of no example drawn from the history of science which impresses me more forcibly with the propensity of the average human being persistently to close his eyes to those things going on around him, and to refer to the authority of another for an account of that which it would seem he could hardly avoid seeing for himself. In the present case it was only necessary to drop two stones of unequal weight from a house top to prove the statement erroneous, but if any one took upon himself the small amount of trouble this implied, before Galileo utilized for the purpose the leaning tower of Pisa, history is silent on the subject.

Perhaps the most ambitious attempt ever made towards evolving a universal science was that of Descartes. This philosopher boldly asserted that he should consider it of small importance to show how the universe is constructed, unless he could show that it could not have been constructed in any other way. His method was that which had been so often tried and found wanting as an instrument for the study of nature—

that of deduction. Time is wanting for an examination of the details of this ambitious scheme, nor is it necessary to say that in its main purpose it proved a lamentable failure. Nevertheless the Cartesian philosophy enjoyed great popularity on the continent of Europe for many years, where it blocked the way to the acceptance of the true doctrine of gravity as developed by Newton. It is a disputed point whether this system was more of a help or a hindrance in furthering the cause of truth.

It seems a little strange perhaps that a mind so acute as that of Descartes, whose possessor made such important contributions to pure mathematics, should not have perceived, as did his contemporary, Bacon, that the truths of nature can only be learned by the study of nature, by a patient and careful attention to details, discarding at once the notion that our feeble powers can by any possibility attain to a comprehension of the entire scheme of the universe.

As an illustration of the process by which the sciences having to do with the material things of nature are developed let me invite your attention to that one with which I am more familiar than with any other, astronomy.

There is no people or tribe so rude or so low in the scale of intelligence as not to be familiar with some of the fundamental truths of astronomy. In fact we may almost say that the lower animals possess some astronomical knowledge. But a familiarity with the diurnal and annual motions of the sun, the changes of the moon, and even the ability to recognize at sight every star visible to the eye, to assign its proper place in the constellation to which it belongs and to tell at what season of the year it is visible, all this comes far short of constituting a science of astronomy. These phenomena and many others had occupied the attention of the Chaldeans and Egyptians for hundreds of years, but these people never had anything which could properly be called a science of astronomy. Nevertheless the records of eclipses and other phenomena preserved by these students of the heavens were of very great service to the true founder of the science, Hipparchus, about 150 B.C. The first step toward the founding of any science is the same in character. A working hypothesis must be devised which will connect together in the best manner possible the detached facts of observation. It is here that a judicious use of the scientific imagination is called for.

If the choice of a hypothesis is a happy one it may prove to be the first approximation to the true law of which we are in search. It is to be adhered to so long as we can represent by it in a satisfactory manner all of the facts of observation, and the moment when it is found to conflict with observation it must be modified or abandoned. The investigator who sets himself to work looking for facts to sustain a favorite theory is pretty likely to succeed to his own satisfaction, but he is not the man who contributes greatly towards increasing the world's store of scientific knowledge.

But to return to Hipparchus. His system is well known. The earth was the center of the universe; the mechanism of the celestial motions was a combination of circles; by properly proportioning the parts of the machine the celestial motions could be represented with as high a degree of accuracy as they could be observed with the primitive instruments of those days. Eclipses and other celestial phenomena could be predicted, and the thoroughness with which the work was done is attested by the fact that this system answered all requirements for a period of more than 1,500 years. Yet we know that what we may call the two fundamental hypotheses

of Hipparchus were erroneous—placing the earth at the center, and assuming the motions to be uniform and circular. As to the first of these we must admit that with the evidence then attainable it was the most plausible. In fact as regards the stars we are now, or were until quite recent times, in very much the condition which confronted Hipparchus in considering the earth and sun. We know that many of the stars have proper motions, as they are called. In reference to any individual star the appearance would be the same whether we ascribed this motion to the star itself or to our system. The true condition of things is one of the problems which is engaging the attention of the astronomers of to-day.

As to the attempt to represent the planetary motions by combinations of circles, this is precisely what we are constantly doing when we expand the expressions entering into our planetary theories in terms of sines and cosines.

A time came when the primitive system of Hipparchus could no longer be made to harmonize with the results of observation. It was therefore destined to give way to another which may be considered as a second approximation—that of Copernicus, as perfected by the labors of Kepler. Here the sun is the center of planetary motion; the orbits are ellipses with the sun in one of the foci, but the fundamental cause of these motions, the law of gravity, and the modifications produced by the mutual perturbations are as yet unrecognized. No place is found for those apparently erratic bodies called comets.

The next great advance is due to the labors of Newton; by referring all to the law of universal gravitation he was able to explain not only the elliptic motions, but the departures from these curves produced by the mutual perturbations of the planets. At the same time it was shown that the comets which heretofore had been regarded with suspicion as erratic visitors, were in fact orderly, law-abiding members of the system like the planets themselves.

Is this then a final solution? Is the law of gravity as enunciated by Newton to be regarded as rigorously true, or does it merely form another approximation to the truth? Apparently we may consider it as absolutely true, though from time to time doubts have arisen on this point. The perturbations of Jupiter and Saturn, the secular acceleration of the moon's motion, the behavior of Encke's comet and the motion of Mercury's perihelion have at one time or another given rise to difficulties some of which have never been completely overcome.

But whether or not the law is rigorously true, no progress whatever has been made toward its physical explanation. In spite of all the ingenuity which has been exercised in this direction it remains as much a mystery as in the days of Newton. The true physical explanation is one of the great problems whose solution is still in the future.

In this development we have noticed a few names which stand out in bold relief. Hipparchus, Copernicus, Kepler, Newton. Are these the only ones to whom credit is due for the creation and development of this department of science? By no means; the astronomer who accumulated observations, the mathematician who helped to perfect the methods of research, and the student of mechanics all contributed to this end and are all entitled to a share in the glory of victory. As has been said: If the Greeks had not studied conic sections Kepler could not have superseded Hipparchus; if the Greeks had studied mechanics Kepler might have anticipated Newton.

Doubtless many branches of science which will occupy the attention of future investigators are still unborn. The status of many of the younger members of this

family resembles that of the astronomy of Hipparchus. Detached facts have been collected, hypotheses have in many cases been formed as to their relations and the laws governing them. In reference to any one of them the near or remote future may produce a Newton to demonstrate the fundamental law by a rigorous mathematical analysis. Meanwhile any laborer in the particular field who has the patience or skill to make an observation or an analysis or perhaps a contribution to pure mathematics may be entitled to his share in the triumph. Though the amount contributed be small there is a great satisfaction in feeling that your labors have been the means of adding something to the world's store of knowledge.

Mankind is no longer striving to evolve a universal science, or an all-embracing system of philosophy. We now recognize the fact that the same frontier which bounds our knowledge bounds also our ignorance, and as the area of the known increases, in the same ratio do the points of contact with the unknown. Every problem solved calls into being new ones for future struggles, and whether or not the universe is infinite, it is at all events for our purposes inexhaustible, so there is no lack of employment for all who may have the ambition to enter the field.

This society is especially designed to further the cause of science in the colleges and universities. As I understand the matter its most important function is that of offering encouragement and recognition to those who are about entering the arena of active life. We make no distinction between pure and applied science. Our purpose is to strive for the advancement of knowledge and the conquest of nature. The earnest student of truth will find his highest reward in the satisfaction which attends the discovery and recognition of the fundamental laws of nature and the essential unity of all, with the consciousness that he has contributed something, however small the amount, towards a proper understanding of her mysteries.

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*THE IMPORTANCE OF A LABORATORY COURSE OF PHYSICS IN THE STUDY OF MEDICINE.**

Many medical colleges include in their teaching a course of physics, consisting of lectures illustrated by experimental demonstrations of important principles. Few give a laboratory course in which qualitative and quantitative experiments are made by the students themselves. In order to ascertain approximately how many medical colleges in the United State give laboratory courses of physics, letters were recently sent by the writer to about thirty-five medical institutions asking for information on the subject. Colleges were selected which by reason of standing, endowment, equipment, number of students, etc., were likely to employ the best and most modern methods of teaching. Answers from thirty were received. Only three colleges give the course in question. Some express regret that the course is not given, others hope to see it established.

The medical colleges which give the course are:

Barnes Medical College, St. Louis, Mo.

Dartmouth Medical College, Hanover, New Hampshire.

Medical Department, University of Virginia, Charlottesville, Va.

To this number should be added:

The College of Physicians and Surgeons, Columbia University, New York City.

There are at present approximately 160 medical colleges in the United States, of which only 122 are so-called regular schools, the others being homœopathic,

* Read before the Society of the Alumni of Bellevue Hospital, February 5, 1902.