SCIENCE

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CONTENTS:

The Mission of Science in Education: PROFESSOR JOHN M. COULTER 281

The Zeeman Effect: DR. HERBERT M. REESE... 293

European Apple Tree Canker in America: W. PADDOCK 297

Zoology at the American Association: PROFESSOR C. H. EIGENMANN..... 299

Scientific Books:—

Bourne's Introduction to the Comparative Anatomy of Animals: PROFESSOR J. S. KINGSLEY. *Professor Mosso's Lectures at the Clark University Decennial:* PROFESSOR G. V. N. DEARBORN 311

Scientific Journals and Articles..... 313

Discussion and Correspondence:—

Three forgotten names for Birds: WILLIAM J. FOX 314

Notes on Inorganic Chemistry: J. L. H..... 314

The University of Birmingham: PROFESSOR R. H. THURSTON 315

The Prevention of Hail Storms..... 316

The British Congress on Tuberculosis..... 316

Scientific Notes and News..... 317

University and Educational News..... 320

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*THE MISSION OF SCIENCE IN EDUCATION.**

THE average graduate from an American university needs no counsel as to his conduct when he comes to face 'the untried world.' He has had his eyes open, and has tried the world more or less, often too much; and has already been surcharged with advice from those of larger experience. If he does not know the elements of success, it is not because he has failed to hear of them; and it only remains for him to receive the teaching which comes from experience. I address these graduates, therefore, with the consciousness that it is too late to add effective advice, and too early to appeal to their experience. I come, therefore, not to youths who are about to be sent away for the first time from the fostering care of a mother, but to university men and women, interested in whatever concerns higher education, and I wish to speak to them of the mission of science in education.

In its broadest sense science includes all knowledge, but the reference here made is to the ordinary application of the word in schemes of education. Perhaps even this needs limitation, if by chance any one has confused reading about science with scientific training; for reference is made to science taught by the laboratory method, which merely means direct and personal contact with the subject matter.

* An address delivered at the annual commencement of the University of Michigan, June 21, 1900.

The advent of science, as thus defined, into schemes of college and university education, was unpromising. It was like one born out of due season, for whom there is no place or preparation. The courses of study were already filled with subjects, all of which naturally seemed to be far more important than the interloper, who had to be content for a time with the crumbs which fell from the already crowded table. Scraps of time and information rather than training was not a happy combination to develop an educational result from any subject, and least of all from science. The general attitude at first towards the laboratory method is well illustrated by the experience of Rafinesque, the first teacher west of the Alleghanies who attempted to introduce it. From 1823 to 1826 he was professor of modern languages and the natural sciences in Transylvania University, in Lexington, Kentucky. In his botanical instruction he ventured to bring plants into the recitation room, which was objected to by the Faculty as 'tending to produce disorder among the students, and to convert a serious recitation into the mere examination of curiosities, thus wasting valuable time.'

After science had secured a definite place in the colleges and was making its first feeble attempts at laboratory work, it was confronted by an obstacle more serious than scraps of time, an obstacle which still exists in certain quarters, either in fact or in spirit. Instead of being admitted to equal rights in a republic of subjects, it was degraded by the organization of so-called scientific courses, which were confessedly inferior to the others; and as if to insure a weak result the scientific course was often made shorter than the others. In my own college, but a type of the great majority of colleges in those days, a student who was not strong enough to graduate in four years in the classical course could graduate in three years in the scientific course. No self-respecting student could afford to be a 'scientific' under such conditions, so that only the weaklings, with three-fourths of the legitimate time at their command, became the exponents of the advantages of scientific training! All those who are middle-aged can testify to a similar college experience, and the result was a deep-seated distrust of the value of science in education, an honest contempt for its results, which distrust and contempt have been handed down to the children now in college, so far as they are being influenced by parental advice. This result is natural, and I have no word of blame for those who possess the feeling, but the conditions which developed it were simply inexcusable.

In spite of the unfortunate conditions which accompanied the advent and much of the history of science in education, it has now become firmly established, has a reasonable rank and allotment of time, and is in a position to show what it has done and what it can do for education. Time enough has not yet elapsed, and absolute equality has not yet been sufficiently attained to permit the fullest expression of legitimate results, but in some degree and at some universities the results are beginning to be apparent. It is hard for one to appreciate 'the mighty power of what has been over the frail form of what might be,' so that sentiment as yet unconsciously influences the judgment even of the fair-minded. But certain results of the presence of science in education seem to be evident enough, and a few of these I propose to present in the form of definite propositions.

1. *Science has revolutionized educational methods.*—This proposition needs no special defence, as it seems to be well nigh universally admitted. In fact, it is the pride of almost every subject to-day that it is taught by the laboratory method. This simply means that the old recitation, which was the retailing of second-hand informa-

tion as to facts, and of second-hand opinions concerning them, has given place to the direct observation of facts and the expression of individual opinion concerning their significance. As a result, students are sought to be made thinking rather than memorizing machines, with the initiative power developed rather than the imitative.

Even in the study of literature, the very stronghold of the cult organized by the humanities, the books about literature have been banished, and the contact is with literature itself. The legitimate offspring of the laboratory is the seminar, and even in the most elementary work the laboratory idea of presentation prevails. In short, the introduction of the laboratory started the movement which has resulted in more rational methods of teaching in every department of college activity. It was my good fortune to be a member of the college association of a neighboring State during the whole period of this evolution of methods, and it well exemplified the three successive attitudes of mind which Agassiz said were always apparent when a new and somewhat startling conclusion of science was announced. At first people say it is not true; later it is contrary to religion; and last everyone knew it before. So in the later stages of my experience I have been interested in hearing that every real teacher uses the laboratory method, and that science has no special claim upon it. And this is true in the sense that its claim is now merely a historic one. Every result which comes merely from the method may be duplicated by non-scientific subjects, for teaching in general has become scientific. The present and future value of science in education, therefore, cannot come from its peculiar methods, but from something inherent in the subject itself. I am glad to make this statement emphatic, for it is often said that the mission of science in education is to teach the laboratory method. Incidentally it did fulfill this mission, but if that were all it could now be banished without weakening our schemes of education.

1. *It develops the scientific spirit.*—By the scientific spirit I mean a certain attitude of mind. What this attitude is may be indicated by noting some of its characteristics.

(1) *It is a spirit of inquiry.*—In our experience we encounter a vast body of established belief in reference to all important subjects, such as society, government, education, religion, etc. It is well if our encounter be only objective, for it is generally true, and a more dangerous fact, that we find ourselves cherishing a large body of belief, often called hereditary, but really the result of early association. Nothing seems more evident than that all this established belief which we encounter belongs to two categories: (1) the priceless result of generations of experience, and (2) heirloom rubbish. Unfortunately, the discovery of the latter has often resulted in weakening the hold of the former. The young inquirer, or the non-logical inquirer is in danger of condemning all the conclusions of the past when one is found wanting. Towards this whole body of established belief the scientific attitude of mind is one of unprejudiced inquiry It is not the spirit of iconoclasm, as some would believe; but an examination of the foundations of belief. The spirit which resents inquiry into any belief, however cherished, is the narrow spirit of dogmatism; and is as far removed from the true scientific attitude as the shallow-minded rejection of all established beliefs. The childhood of the race accumulated much which its manhood is compelled to lay aside, and the world needs a thorough going over of its stock in trade. Such work cannot be done all at once, or once for all, for it must be a gradual sloughing off as the spirit of inquiry becomes more generally diffused. It must become

evident that this spirit is diametrically opposed to intolerance, and that it can find no common ground with those who confidently and sometimes violently affirm that the present organization of society is as good as it can be; that the present republics of the world represent the highest possible expression of man in reference to government; that the past has discovered all that is best in education; that the mission of religion is to conserve the past rather than to grow into the future. This is not the spirit of unrest, of discomfort, but the evidence of a mind whose every avenue is open to the approach of truth from every direction. Like the tree, it is rooted and grounded in all the eternal truths that the past has revealed, but is stretching out its branches and ever renewed foliage to the air and the sunshine, and taking into its life the forces of to-day.

Dogmatism still finds numerous victims, for education has not yet touched the majority, but everyday the possible victims are becoming fewer in number, and those who seek to lead opinion must presently abandon the method of bare assertion. The factors in this general intellectual progress are perhaps too subtle and interwoven to analyze with certainty, but conspicuous among them is certainly the development of scientific training.

For fear of being misunderstood, I hasten to say that this beneficent result of scientific training does not come to all those who cultivate it, any more than is the Christ-like character developed in all those who profess Christianity. I regret to say that even some who bear great names in science have been as dogmatic as the most rampant theologian. But the dogmatic scientist and theologian are not to be taken as examples of 'the peaceable fruits of righteousness,' for the generel ameliorating influence of religion and of science are none the less apparent. It is not the speech of the conspicuous few that is thus leavening the lump of human thought, but the quiet work of thousands of teachers.

(2) *The scientific spirit demands that there shall be no hiatus between an effect and its claimed cause, and that the cause claimed shall be adequate.*—It is in the laboratory that one first really appreciates how many factors must be taken into the count in considering any result, and what an element of uncertainty an unknown factor introduces. In the very simplest cases, where we have approximated certainty in the manipulation of factors to produce results, there is still lurking an element of chance, which simply means an unknown and hence uncontrolled factor. Even when the factors are well in hand, and we can combine them with reasonable certainty that the result will appear, we may be entirely wrong in our conclusion as to what in the combination has produced the result.

For example, we have been changing the forms of certain plants at will, by supplying in their nutrition varying combinations of certain substances. By manipulating the proportions of these substances we produce the expected results. It was perhaps natural to conclude that the chemical structure of these particular substances produces the result, and our prescription was narrowed to certain substances. Now, however, it is discovered that the results are not due to the chemical nature of the substances, but to a peculiar physical condition which is developed by their combination, a condition which may be developed by the combination of other substances as well; so that our prescription is much enlarged. In this operation we are thus freed from slavery to particular substances, and must look only to the development of a particular physical condition. It seems to me that there is a broad application here. In education, we are in danger of slavery to subjects. Having observed

that certain ones may be used to produce certain results, we prescribe them as essential to the process, without taking into account the possibility that other subjects may produce similar results.

In religion, we are in danger of formulating some specific line of conduct as essential to the result, and of condemning those who do not adhere to it. This is the essence of formalism, and its logical outcome, unchecked by common sense, is illustrated by the final expression of Jewish temple worship.

That there may be many lines of approach to a given result, if that result be a general condition, is a hard lesson for mankind to learn.

If it is so difficult to get at the real factors of a simple result in the laboratory, and still more difficult to interpret the significance of factors when found, in what condition must we be in reference to the immensely more difficult and subtle problems which confront us in social organization, government, education, and religion, especially when it is added that the vast majority of those who have offered answers to these problems have had no conception of the difficulties involved in reaching absolute truth. It is evident that in the vast problems which concern human welfare in general we are but groping our way, and that our answers as yet are largely empirical. The proper effect of such knowledge is not despair, but a receptive mind. In my judgment, therefore, the diffusion of the scientific spirit will make it more and more difficult for any one with a *nostrum* to get a hearing.

The prevailing belief among the untrained is that any result may be explained by some single factor operating as a cause. They seem to have no conception of the fact that the cause of every result is made up of a combination of interacting factors, often in numbers and combinations that are absolutely bewildering to contemplate. An enthusiast discovers some one thing which he regards and perhaps all unprejudiced and right-thinking people regard as an evil in society or in government, and straightway this explains for him the whole of our present unhappy condition. This particular tare must be rooted up, and rooted up immediately, without any thought as to the possible destruction of the plants we must cultivate. The abnormal tissue must be destroyed without reference to the fact that the method of destruction may debilitate the normal tissue.

This habit of considering but one factor, when perhaps scores are involved, indicates a very primitive and untrained condition of mind. In the youth of science it often threw its votaries into hostile camps, each proclaiming rival factors; when the problem really demands all the factors they all had and many more besides.

It is fortunate when the leaders of public sentiment have got hold of one real factor. They may overdo it, and work damage by insisting upon some special form of action on account of it, but so far as it goes it is truth. It is more apt to be the case, however, that the factor claimed holds no relation whatsoever to the result. This is where political demagoguery gets in its most unrighteous work, and preys upon the gullibility of the untrained, and is the soil in which the noxious weeds of destructive socialism, charlatanism, and religious cant flourish.

It is needless for me to enlarge the horizon of illustration, by including numerous fields of human thought and activity, for your own thought outruns my statement, and recognizes the conditions in every direction. It is to such blindness that scientific training is slowly bringing a little glimmer of light, and when the world one day really opens its eyes, and it is well if it opens them gradually, the old things will have passed away.

(3) *The scientific spirit keeps one close to the facts.*—One of the hardest things in my teaching experience has been to check the tendency of many students to use one fact as a starting point for a flight of fancy which is simply prodigious. Such a tendency is corrected of course when facts accumulate somewhat, and flight in one direction is checked by a pull in some other direction. But most of us have the tendency, and the majority are so unhampered by facts that flight is free. This exercise is beautiful and invigorating if it is recognized to be just what it is, a flight of fancy; but if it results in a system of belief it is a deception. There seems to be abroad a notion that one may start with a single well-attested fact, and by some logical machinery construct an elaborate system and reach an authentic conclusion, much as the world has imagined for more than a century that Cuvier could do if a single bone were furnished him. The result is bad, even though the fact have an unclouded title. But it too often happens that great superstructures have been reared upon a fact which is claimed rather than demonstrated.

We are not called upon to construct a theory of the universe even upon every well-attested fact, and the sooner this is learned the more time will be saved and the more functional will the observing powers remain. Facts are like stepping stones; so long as one can get a reasonably close series of them he can make some progress in a given direction, but when he steps beyond them he flounders. As one travels away from a fact its significance in any conclusion becomes more and more attenuated, until presently the vanishing point is reached, like the rays of light from a candle. A fact is really only influential in its own immediate vicinity; but the whole structure of many a system lies in the region beyond the vanishing point.

We *must* wonder what lies beyond, we must try our wings in an excursion now and then, but very much stress must never be laid upon the value of the results thus obtained.

Such 'vain imaginings' are delightfully seductive to many people, whose life and conduct are even shaped by them. I have been amazed at the large development of this phase of emotional insanity, commonly masquerading under the name of subtle thinking. Perhaps the name is expressive enough, if it means thinking without any material for thought. And is not this one great danger of our educational system, when special stress is laid upon training? There is danger of setting to work a mental machine without giving it suitable material upon which it may operate, and it reacts upon itself, resulting in a sort of mental chaos. An active mind turned in upon itself, without any valuable objective material, can certainly never reach any very reliable results.

It may not be that the laboratory in education is the only agency, apart from common sense, which is correcting this tendency: but it certainly teaches most impressively, by object lessons which are concrete and hence easiest to grasp, that it is dangerous to stray away very far from the facts, and that the further one strays away the more dangerous it becomes, and almost inevitably leads to self-deception.

There is no occasion for a further analysis of the scientific spirit or attitude of mind. It could be followed out into various ramifications of greater or less importance, but enough has been said to indicate its tendency. Nor is any further claim made at this point than for the laboratory method, for the scientific spirit is now being developed by subjects which are not grouped among the sciences as defined in this paper. It simply follows from the laboratory method, but as this came in by way of the sciences, and is still of easiest

and most direct application in connection with them; so the characteristics of the scientific spirit indicated above are more easily and effectively developed in contact with the peculiar materials of science.

But I have still stronger claim to make for science as an essential constituent of all education, and that is

2. *It gives a training peculiar to itself, and one that is essential in every well-balanced education.*—The real educational significance of the training in laboratories devoted to science is very commonly overlooked, both by those who know nothing about it from personal experience, and even by those who are teachers of science. Many learn to go through the motions without appreciating the substratum of educational philosophy. Moreover, the knowledge of the educational significance of this special form of training has been slowly developed as the results have appeared.

Perhaps the earliest, and of course the most superficial form of statement explaining the purpose of scientific study was that it teaches the laboratory method. The inference was that the sciences are of no particular educational advantage in themselves, but are merely useful in teaching a valuable method. In so far as this emphasized the fact that reading or reciting about science cannot be regarded as training in science, and in so far as it recognized that science is to be credited with introducing a revolutionary and invaluable educational method, the statement is true enough; but to regard these purely incidental results as being in any sense the end of scientific training is far enough from the mark. The laboratory method holds no more relation to science than do algebraic symbols to algebra; they both merely represent useful machinery for getting at the real results. And further, as has been shown, if the teaching of a method is the only function of science in education, when this method has been learned and has become universally applied, the mission of science in education is at an end.

Another commonly stated advantage of training in science is that it cultivates the power and habit of observation. This is certainly true, but with equal certainty this result is not peculiar to scientific training, for it belongs to the laboratory method, and appears whenever the method is applied to any subject. It may be claimed that the most direct and tangible materials for observation fall within the province of science, but this is a difference of degree rather than of kind, and therefore the result may be obtained apart from science. It is true that in the elementary stretches of education the methods are still prevailingly conventional, and therefore, stunt the natural powers of observation. The fine tentacles of inquiry which are put out in every direction by the child thus become atrophied, so that when later in his educational experience he is introduced into the laboratory he is as helpless as though transferred to a totally different set of life conditions. It takes almost a surgical operation to open his eyes, and he is apt to have lost not only the power but with it also the desire of observation. This wholesale and criminal mutilation of natural powers, however, is not the fault of the subjects studied, but of the conventional methods employed, which demand faith rather than sight, memory rather than reason, the sacrifice of truth to conventional ideas. To keep these important powers functional may still be an important mission of science in elementary education, but when the conventional method has been replaced by the natural in all subjects of study, this mission also will have been fulfilled, and will be recognized merely as an incident in scientific training.

Those who are accustomed to look a little beneath the surface before formulating a statement are very apt to be content with

saying that the study of science trains in the power of analysis. This is certainly getting the subject upon higher ground, and suggests a result which is worthy of every effort. The power of analysis is one of immense practical importance, and the value of its cultivation will not be denied. To imagine, however, that analysis is the ultimate purpose of science, is not to go very much farther than to say that the ultimate purpose is the laboratory method. The latter is the method, the former is but the first step in its application. But even this step is by no means peculiar to science, for it is the initial one in the teaching of every subject. In our search, therefore, for the peculiar benefits of science in education, we are again compelled to look further.

Beyond analysis lies synthesis, and this certainly represents the ultimate purpose of science. The results of analysis are as barren as a bank of sand until synthesis lays hold of them. It is just here that a large amount of science teaching fails, for to many teachers the accumulation of unrelated facts seems to be the end of scientific study, and the results of the laboratory may be represented by a chaotic pile of brick rather than some definite structure dominated by an idea. Almost anyone may accumulate facts, but to relate them, to distinguish the significant and the insignificant, to recognize that they are merely external expressions of something general, belongs to the highest stretches of scientific training. May I be permitted to say, without being misunderstood, that the potent influence of the German laboratories upon American establishments has resulted in general in making our best investigators and our worst teachers. The influence is beneficent to the last degree in so far as it lays hold of a disposition to careless work and hasty generalization and holds it down to the patient collection of facts and their very cautious collection; but when it results in mere Gradgrind teaching all inspiration has evaporated, and the laboratory touches no more the finer mental powers than does a factory. The difference indicated finds its illustration in some of our best known texts, which are merely expressions of styles of teaching. In the one case the facts are presented in the helter-skelter fashion, solid and substantial enough, but a regular mob, with no logical arrangement, no evolution of a controlling idea. Details are endless, no emphasis brings out certain things into prominence and subordinates others, and the whole subject is as featureless as a plain, where the dead level of monotony kills off every one but the drudge. It is the spirit of analysis, a dead body of facts without a vitalizing spirit. In the other case fewer facts are presented, but they are the important ones, and marshalled in orderly array, battalion by battalion, they move as a great whole towards some definite object. The facts may fade away, even the battalions may grow dim, but the great movement remains definite and clear as a memory which is an inspiration. Instead of a level plain, there are mountain peaks and valleys, there is a perspective and there are vistas from every point of view. This is the spirit of synthesis, which vitalizes the great body of facts and makes them glow. To the teacher, in his work of training, an unrelated fact is worse than useless.

But even synthesis is not peculiar to science. To pass by the incidental and temporary and reach the real and permanent contribution of science to education is to discover that it lies not in teaching the laboratory method, in developing the power of observation, in cultivating the spirit of analysis, or even in carrying one to the heights of synthesis; but in the mental attitude demanded in reaching the synthesis. In this regard the demands of science are diametrically opposed to those of the hu-

manities, for instance, using this loose term to express the great region of literature and its allies. The humanities have been and must continue to be a noble course of intellectual development, without which an education is certainly incomplete. It is the most ancient and best known form of culture, and being ancient and bound up with the intellectual development of mankind it must necessarily continue to hold high rank. The general effect of the humanities in a scheme of education may be summed up in a single word *appreciation*. They seek so to relate the student to what has been said or done by mankind, that his critical sense may be developed, and that he may recognize what is best in human thought and action. To recognize what is best involves a standard of comparison. In most cases this standard is derived and conventional; in rare cases it is original and individual; in no case is it founded in the essential nature of things, in absolute truth, for it is apt to shift. In any case the student injects himself into the subject; and the amount he gets out of it is measured by the amount of himself he puts into it. It is the artistic, the æsthetic, which predominates, not the absolute. It is all comparative rather than actual. The ability to read between the lines is certainly the injection of self into the subject-matter, and the whole process may be regarded as one of *self-injection* in order to reach the power of *appreciation*. My claim is that any education which stops with this result is an incomplete one, and that there is another mental attitude which is a necessary complement before a full-rounded education can be claimed; and that this complementary mental attitude is developed by a proper study of the sciences. If the study of nature is conducted so as to cultivate merely a sentimental appreciation of natural objects, it does not fall within the category I am considering, and can in no way be considered as a study which acts as a complement to the humanities. It is merely more of the same thing. If the proper intellectual result of the humanities is *appreciation*, whose processes demand *self-injection*, the proper and distinctive intellectual result of the sciences is a *formula*, to obtain which there must be rigid *self-elimination*. Any injection of self into a scientific synthesis vitiates the result. The standard is not a variable, an artificial one, developed from the varying tastes of man, but absolute, founded upon eternal truth.

Two such distinct mental attitudes as self-injection and self-elimination must receive attention in education, which cannot be complete without both. They are not contradictory, but complementary, and it takes both to make the 'all-round' man. The exclusive cultivation of either one must result in a lop-sided development. Persistent self-injection tends to mysticism, a confusion of ideals or even vagaries with realities, a prolific cause of all irrational beliefs. Persistent self-elimination narrows the vision to a horizon touched by the senses and clips the wings that would carry us now and then beyond the treadmill of life into a freer air and a wider outlook.

The one needs the other as a check. In their combination self-injection is held back from dangerous flights by the demand to feel something solid beneath the feet; and self-elimination is compelled to raise its eyes now and then from the ground and sweep the heavens.

In our analysis, however, we strip off the flesh and lay bare the skeleton, and are apt to lose sight of the fact that the contour is a composite result. Although the skeletons of the humanities and of the sciences may differ from each other in the fundamental way described, I cannot conceive of the resulting contour of the one as distinct from combination with the other. The self-eliminating result of science must be asso-

ciated with the self-injecting result of the humanities, even though science alone be studied; and the power of appreciation developed by the humanities must always be tempered by the scientific spirit. And yet, the two processes and the two results are so distinct and so complementary that any scheme of education which does not provide for the definite cultivation of these two mental attitudes, and which leaves the complementary part merely to the chances of methods of teaching and mental structure, is in constant danger of resulting in mental distortion.

I have indicated in this very general way the broad principles involved in the mission of science in education. Numerous details might be presented which would justify the claims that have been made, and perhaps such details would have made my thesis more clear, and would have left me in less danger of being misunderstood; but neither the time nor the occasion will permit them.

There is a factor of such overwhelming importance in the effectiveness of the mission of science in education that I cannot forbear the mention of it, and that is the teacher. I have presented the possible, the ideal results, but they can be approximated only by the thoroughly competent teacher. The problem of the teaching of science in the universities is becoming a serious one. There is no need to include in this discussion the teaching of science in the schools, for those engaged in it are devoting their whole time and knowledge to its development. It is sadly true that as a rule they need more time and far more knowledge, but this need is being gradually met, and every year the teaching in the schools is becoming better. On the contrary, I am tempted to say that every year the teaching of science in the universities is becoming worse. Perhaps the statement is too strong, but it expresses a tendency, that must be checked. The university instructor is confronted by two serious duties; he is to instruct, and he is to produce. In the constitution of American universities the primary function of the instructor is to instruct; and, if time and strength permit, the secondary function is to produce. From the theoretical standpoint production is essential to a thoroughly good university instructor, for production makes all the difference between a pump and a perennial spring. There is no special inspiration in the continual retailing of second-hand information. Practically, however, the conscientious teacher must expend all his energy, or at least all his effective energy upon teaching and faculty duties. The logical outcome is that teachers who wish to investigate cease to be conscientious as teachers. Production becomes the principal thing, and instruction a mere incident. It might be expected that these unconscientious teachers would be gradually eliminated, but there are two facts which not only prevent the elimination but increase the evil. The first is that in large universities the tenure of office is practically unlimited, and if the instructor is making a name through production his tenure of office is not likely to be terminated, however bad his teaching. The second fact is that in the appointment of new instructors the universities to-day are looking more for productive power than for teaching power. This latter fact reacts seriously upon those who are preparing for university positions, and their whole training is upon problems connected with their subject, to the entire exclusion of those connected with its presentation. In short, my claim is that in the universities our instructors have been trained to investigate rather than to teach. I have never met such wretched teaching anywhere as is daily permitted in the greatest universities. Under such conditions the instructor for a few years makes a spasmodic effort to teach, presently loses his interest in it, and gradually lapses into indifference.

It is a common statement that large universities are no places for undergraduates, as they are turned over to the younger instructors and do not meet the heads of departments. Theoretically this is a serious charge, but practically it is a wise arrangement, for in general it is true that the undergraduate would do well to beware of the old instructor, unless it is his wish to be neglected. The instructor who is a novitiate will work hard for him, even to the point of drudgery, even if he does not always work effectively.

I must not be misunderstood. Those who are born to teach will always teach when placed before a class, and every university has its share of such teachers, and the older they get, the more effective do they become; but I think I am right in claiming that the majority of instructors who have been brought into the universities within the last decade or two are teaching as an incident to investigation. I am not blaming these instructors, for I enter into their feelings most sympathetically. I am merely stating a problem which must be solved. We must have production or teaching will become a treadmill and real universities will have no reason for existence; but we must also have effective teaching. The problem is, how can we have both? The answer is simple, but hard of application, for it involves the natural limitations of men, which they are slow to recognize. Some are born to teach and some are born to produce, and these two classes should be recognized and utilized by the University, but self-recognition is more difficult. As it is, every instructor feels upon himself a pressure to produce, for it is in the atmosphere to-day; but in the majority of cases yielding to this pressure involves a waste of valuable time and energy without any adequate result. Such instructors are unwilling to acknowledge, even to themselves, that they have not the initiative for profitable investigation, whatever may have been their preparation.

On the other hand, the born investigator is nearly as slow to recognize that he is probably not a successful teacher. With born teachers trying to investigate, and born investigators trying to teach, and still others born to do neither, the average university becomes a good illustration of misdirected energy. If in any way the lines could be drawn so that the two classes could be recognized by themselves, as they already are by their associates, the problem would be solved.

In my judgment it would be fatal absolutely to restrict either to his own field, for the teacher, in his own interest rather than that of his subject, must produce enough to retain and develop his inspiration, and to appreciate the methods and results of investigation; while the investigator, in his own interest rather than that of his students, must teach enough to retain his breadth of vision and to cultivate the power of clear and apt expression.

In connection with any claim for the great and peculiar contributions of science to education, it seems pertinent to refer to a complaint heard now and then that the encroachment of science upon university attention has changed the atmosphere from one that is literary to one that is commercial. A common phrase is: 'the commercializing tendency of modern education.' The idea seems to be that a certain fine flavor of thought and expression is becoming less evident, and that the somewhat indefinite but soaring balloon is being replaced by the locomotive. Without calling attention to the fact that if one wants to get anywhere at any definite time the locomotive is more effective than the balloon, and without inquiring into the personal training or idiosyncracies of those who make the complaint, I wish to call atten-

tion to a probable explanation of the imaginary change.

The old education, which is reputed to have had such beneficent results, was a magnificent training; but it must never be forgotten that it was an example of extreme specialization. A narrow round of subjects was continually studied and all that can be claimed for specialization appeared in the result. Like all specialization, however, its effective application depended upon the mental aptitude of the student. As these aptitudes are quite varied, the old specialized education selected from the mass the few to whom it was adapted, and these became really educated and dominated the university atmosphere, their more numerous fellows falling out unnoticed in the unequal race. And so the flavor which belongs to this special kind of education became the universal flavor of the educated.

When new subjects appeared, and courses began to be multiplied, other students began to be selected from the mass and joined the society of the educated, and the old flavor ceased to be one peculiar to education in general.

The change, therefore, is simply that more students than formerly are reaching what may be called an education, and the difference is one of proportion, not of actual number. Opportunity for the old education is still with us, and those who are adapted still take advantage of it, and their number is greater than ever before. But they are compelled to acknowledge as brothers in the fraternity of the educated a host who had been excluded before through lack of opportunity. There is no longer an aristocracy in education, and the democracy of to-day demands that all who are trained, by whatever method, shall strike hands as brothers and equals.

In conclusion, may I be permitted to say that the full significance of scientific training will appear only when it begins in some form in the primary schools and touches the student at every stage of progress. Appealing as it does to the most natural tendencies of childhood, its greeting at the threshold of school experience is that of the one familiar friend, whose presence relates the young to things which they can see and handle, and saves them from that desolation of spirit and mental warping which comes from exclusive contact with the conventional and the intangible. The university owes a great service to the schools in this particular, and the tentacles of its influence must constantly be reaching delicately and inquiringly into school instruction. What the schools can do or cannot do, what they should do or should not do, are questions which cannot be answered in *ex cathedra* fashion. The wilful ignorance of many university instructors in reference to the work of schools upon which they depend is amazing. The university as a whole recognizes and encourages the intimate relationship, but only an instructor here and there interests himself in discovering the real situation. The result of this appears usually in requirements for admission, which are often adapted to some theoretical university position rather than to the possibilities of the modern American high school. In the debates upon these admission requirements a large faculty is apt to be divided, and the line of division usually separates those who know the schools from those who do not. If the latter be in the majority, the university is at once effectively handicapped. There is much talk of forcing schools to university standards, but this forcing is necessarily artificial and temporary if it runs counter to the inevitable tendencies which one who knows recognizes in the American school system. This system is more impregnable than the universities, for it is more extensive and better adapted to the peculiar conditions of American civilization. It is only

a question of time when every university will recognize the fact that it must adapt itself to the possibilities of the schools, and that ancient or artificial standards can be maintained only so long as they approve themselves to the experience of the schoolmaster. The mountain will never come to Mahomet. To compel schools to differentiate early a small and select and expensive class for entrance to the universities is unfair both to school and to the university, and seriously checks the diffusion of higher education. To deny the privilege of breathing the university atmosphere to any product of a good secondary school involves such a narrow conception of education that one dislikes to associate it with the university. It has always seemed an anomaly that universities are inclined to rate themselves more upon the basis of their raw material than their finished product. A fine-meshed screen is set up at the beginning of the university career, when it would seem far more logical to set it up at the other end. This matter of entrance has much to do with the opportunity given to science to express itself in education. If its most promising and best trained material is turned back or handicapped when attempting to enter the university, a certain kind of educational theory may command the result, but it is a blockade against the general progress of education, in so far as it cuts off a great agency from operating upon the legitimate material.

A statement summarizing the claims set forth in this paper may be formulated as follows: The introduction of science among the subjects used in education has revolutionized the methods of teaching, and all subjects have felt the impulse of a new life; it has developed the scientific spirit, which prompts to investigation, which demands that belief shall rest upon a foundation of adequate demonstration, which recognizes that the sphere of influence surrounding facts may be speedily traversed and that everything beyond is as uncertain as if there were no facts; it has introduced a training peculiar to itself, in that it teaches the attitude of self-elimination, an attitude necessary in order to reach ultimate truth, and thus supplements and steadies the other half of life, which is to appreciate. To obtain these results, there must be teachers who can teach, whose background and source of supply is the investigator. Moreover, the results are immensely desirable, inasmuch as they do not interfere with anything that is fine and uplifting in the old education, but simply mean that the possibilities of high attainment and high usefulness are open to a far greater number.

JOHN M. COULTER.

THE ZEEMAN EFFECT.

EARLY in the year 1897 a paper was published in several journals by Dr. P. Zeeman, describing a series of experiments to determine the effect of magnetism upon the spectrum of a source of light placed in the magnetic field. The electromagnetic theory of light indicated in a general way that there would probably be some effect, and several investigators had already sought for it without success. The most noteworthy of these was Faraday, who made it the object of one of his last researches, and in this country Rowland made an examination with a Rutherford grating, before he had himself begun to rule the more perfect gratings of the present day. Zeeman himself had made an earlier unsuccessful attempt, and Fievez really observed what may have been the same phenomenon which Zeeman finally discovered, but he failed to understand its true character.

With the aid of a strong magnet and better spectroscopic apparatus than any of his predecessors had used, Zeeman attacked the problem the second time with success. He placed a Bunsen flame containing com-