SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

FRIDAY, JULY 15, 1904.

CONTENTS:

The Age of Science: PRESIDENT IRA REMSEN. 65

Higher Education in Germany and the United States: RUDOLF TOMBO, JR. 73

Scientific Books:—
The Ward-Coonley Collection of Meteorites: DR. OLIVER C. FARRINGTON. *Woodworth's Le Mouvement:* DR. SHEPHERD IVORY FRANZ 77

Societies and Academies:—
Society for Experimental Biology and Medicine: DR. WM. J. GIES. *The Torrey Botanical Club:* WILLIAM T. HORNE. *The Psychological Club of Cornell University*..... 79

Discussion and Correspondence:—
Kindergarten Science: DR. C. R. EASTMAN. *'Vegetable Balls':* J. ADAMS. *A Notable Paleobotanical Discovery:* EDWARD W. BERRY 85

Special Articles:—
Evolution and Physics: O. F. COOK...... 87

Agricultural Exhibits at St. Louis.......... 91

Honorary Degrees Conferred by the University of Wisconsin...................... 92

Scientific Notes and News................ 94

University and Educational News.......... 95

MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

*THE AGE OF SCIENCE.**

As much of the time of those who go forth from this institution to-day has been spent in the study of the sciences, it has seemed to me fitting to ask your attention to some considerations suggested by the phrase, 'This is the age of science.' I do not remember ever to have heard this statement questioned, much less denied, nor do I remember ever to have heard it satisfactorily explained. It sounds simple enough, and does not appear to call for explanation or comment, and yet I think it worth while to examine it a little more carefully than is customary, to see in what sense it is true. For in a sense it is true, and in a sense it is not true. The statement raises two questions which should be answered at the outset. These are: (1) What is science? and (2) In what sense is this the age of science?

First, then, what is science? Surely there can be no difficulty in answering this, and yet I fear that, if I should pass through this or any other audience with the question, I should get many different answers.

A certain lady, whom I know better than any other, has told me that, should she ever be permitted to marry a second time, she would not marry a scientific man, because scientific men are so terribly accurate. I often hear the same general idea expressed, and it is clear that accuracy is one attribute of science according to prevailing opinions. But accuracy alone is not science. When we hear a game of baseball or of whist spoken of as thoroughly scientific, I sup-

* Commencement address delivered at Worcester Polytechnic Institute, June 9, 1904.

pose the idea here, too, is that the games are played accurately; that is, to use the technical expression, without errors.

Again, there are those who seem to think that science is something that has been devised by the Evil One for the purpose of undermining religion. This idea is not so common as it was a few years ago, when the professors of scientific subjects in our colleges were generally objects of suspicion. The change which has come over the world in this respect within my own memory is simply astounding. In general terms an agreement has been reached between those who represent religion and those who represent science. This agreement is certainly not final, but it gives us a *modus vivendi,* and the clash of arms is now rarely heard. Religion now takes into consideration the claims of science, and science recognizes the great fundamental truths of religion. Each should strengthen the other, and in time, no doubt, each will strengthen the other.

Probably the idea most commonly held in regard to science is that it is something that gives us a great many useful inventions. The steam-engine, the telegraph, the telephone, the trolley car, dye stuffs, medicines, explosives—these are the fruits of science, and without these science is of no avail. I propose farther on to discuss this subject more fully than I can at this stage of my remarks, so that I may pass over it lightly here. I need only say now that useful inventions are not a necessary consequence of scientific work, and that scientific work does not depend upon useful applications for its value. These propositions, which are familiar enough to scientific men, are apt to surprise those who are outside of scientific circles. I hope before I get through to show you that the propositions are true.

Science, then, is not simply accuracy, although it would be worthless if it were not accurate; it is not devised for the purpose of undermining religion; and its object is not the making of useful inventions. Then what is it? One dictionary gives this definition: "Knowledge; knowledge of principles and causes; ascertained truth or facts. * * * Accumulated and established knowledge which has been systematized and formulated with reference to the discovery of general truths or the operation of general laws, * * * especially such knowledge when it relates to the physical world, and its phenomena, the nature, constitution and forces of matter, the qualities and function of living tissues, etc."

One writer says: "The distinction between *science* and *art* is that *science* is a body of principles and deductions to explain the nature of some matter. An *art* is a body of precepts with practical skill for the completion of some work. A *science* teaches us to know; an *art,* to do. In *art,* truth is a means to an end; in *science* it is the only end. Hence the practical arts are not to be classed among the sciences." Another writer says: "*Science* and *art* may be said to be investigations of truth; but one, *science,* inquires for the sake of knowledge; the other, *art,* for the sake of production; and hence *science* is more concerned with the higher truths, *art* with the lower; and *science* never is engaged, as *art* is, in productive application."

Science, then has for its object the accumulation and systematization of knowledge, the discovery of truth. The astronomer is trying to learn more and more about the celestial bodies, their motions, their composition, their changes. Through his labors, carried on for many centuries, we have the science of astronomy.

The geologist has, on the other hand, confined his attention to the earth, and he is trying to learn as much as possible of its composition and structure, and of the processes that have been operating through untold ages to give us the earth as it now is. He has given us the science of geology, which consists of a vast mass of knowledge carefully systematized and of innumerable deductions of interest and value. If the time should ever come when, through the labors of the geologist, all that can possibly be learned in regard to the structure and development of the earth shall have been learned, the occupation of the geologist would be gone. But that time will never come.

And so I might go on pointing out the general character of the work done by different classes of scientific men, but this would be tedious. We should only have brought home to us in each case the fact that, no matter what the science may be with which we are dealing, its disciples are simply trying to learn all they can in the field in which they are working. As I began with a reference to astronomy, let me close with a reference to chemistry. Astronomy has to deal with the largest bodies, and the greatest distances of the universe; chemistry, on the other hand, has to deal with the smallest particles and the shortest distances of the universe. Astronomy is the science of the infinitely great; chemistry is the science of the infinitely little. The chemist wants to know what things are made of, and, in order to find this out, he has to push his work to the smallest particles of matter. Then he comes face to face with facts that lead him to the belief that the smallest particles he can weigh by the aid of the most delicate balance, and the smallest particles he can see by the aid of the most powerful microscope, are immense as compared with those of which he has good reason to believe the various kinds of matter to be made up. It is for this reason that I say that chemistry is the science of the infinitely little.

Thus have I tried to show what science is and what it is not. Now let me turn to the second question.

In what sense is this the age of science? In the first place, it is not true that science is something of recent birth. Scientific work of one kind and another has been in progress for ages—not in all branches, to be sure—but nature has always engaged the attention of man, and we may be sure that he has always been trying to learn more about it. The science of astronomy was the first to be developed. Astrology was its forerunner. Then came chemistry in the guise of alchemy. It would be interesting to follow the development of each, and to see how from the crude observations and imaginings of the earlier generations came the clearer and broader conceptions that constitute the sciences, but time will not permit us to enter upon this subject. I can not, however, do justice to my theme without calling your attention to one of the most serious obstacles that stood in the way of the advance of knowledge.

To make clear the nature of this obstacle, it will be best to make a comparison. A child learns a great deal in regard to his surroundings in his earliest years before he goes to school, and without the aid of his parents. He is constantly engaged in making observations and drawing conclusions, and his actions are largely guided by the knowledge thus gained. After a time school life begins, and the child then begins to study books and to acquire knowledge at second-hand. This is an entirely different process from that by which he gained his first knowledge. The latter is natural, the former is artificial. Then, too, he soon discovers that many things he sees call for explanation, and he is led to wonder what the explanation is. If he has a strong imagination, as most children have, he will probably think out some explanation. He finds that he can use his mind, and that this helps him in dealing with the facts in nature. Now comes the danger. It being much easier to think than to work, the chances are that in trying to find the explanation of things, he will give up the natural method and be satisfied with the products of his imagination. He will gradually give up dealing directly with things, and take to thinking alone. When this stage is reached his knowledge will increase very slowly, if at all.

Whether this picture of the development of a child is in accordance with the facts of life or not, it gives an idea of the mental development of mankind. First came the period of infancy, during which observations were made and much learned. Efforts were early made to explain the facts of nature. We have remnants of these explanations in old theories that have long ceased to be useful. They no doubt served a useful purpose in their day, but gradually one of the most pernicious ideas ever held by man took shape, and I am willing to characterize it as one of the most serious obstacles to the advance of knowledge. I refer to the idea that it is a sign of inferiority to work with the hands. This idea came early and stayed late. In fact, there are still on the earth a few who hold it. How did this prove an obstacle to the advance of knowledge? By preventing those who were best equipped from advancing knowledge. The learned men of the earth for a long period were thinkers, philosophers. They were not workers in nature's workshop. They tried to solve the great problems of nature by thinking about them. They did not experiment. That is to say, they did not go directly to nature and put questions to her. They speculated. They elaborated theories. During this period knowledge was not advanced rapidly. It could not be. For the only way along which advances could be made was closed.

Slowly the lesson was learned that the only way by which we can gain knowledge of nature's secrets is by taking her into our confidence. Instead of contemplation in a study, we must have contact with the things of nature either out-of-doors or in the laboratory. Manual labor is necessary. Without it we may as well give up hope of acquiring knowledge of the truth. When this important fact was forced upon the attention of men, scientific progress began and continued with increasing rapidity. At present the old pernicious idea that a man who does any kind of work with his hands is by virtue of that fact an inferior being—that idea is no longer generally held. But we have not got entirely rid of it. In a recent address I find this reference to the subject: "However the case may have been with what forty years ago was called the education of a gentleman, it seems to me to be one of the services of the scientific laboratory that it has taught to that part of mankind which has leisure and opportunities that manual skill is a thing to be held in honor both as a means for reaching mechanical results, and still more, as a way to train the mind. * * * Fifty years ago many men who called themselves educated were mere untrained, undeveloped children in manual skill, and some of them were proud of their incompetency, for nothing would have more surprised them than an assertion that their inability to help themselves with their hands was a badge of ignorance. * * * While the high character and sterling worth of the medical man has always won respect, their skill in the use of their hands was long held by those who were superior to such weakness to place them beneath the lawyers and the clergymen in the social scale." Recently I came upon this old idea within college walls. In the college connected with the Johns Hopkins University there are several groups of studies which lead to the degree of bachelor of arts.

Group I. is largely made up of the classics, and it is therefore generally called the classical group. I happened once to be dining with a gentleman whose son was a student in Group I. in our college. Our professor of Latin was also present. Turning to my colleague, the professor of Latin, our host, the father of the classical student, exclaimed: 'How those fellows in Group I. look down upon all the others!' I afterwards learned that this feeling undoubtedly existed among the students, those who studied the classics, especially, forming, in their own opinion at least, a well-characterized aristocracy. I have referred to these cases simply for the purpose of showing that the pernicious idea that hand-work is a sign of inferiority is not yet dead. But it has nevertheless been disappearing rapidly for some years past, and with its disappearance the development of science has kept pace. Which is the cause and which the effect it would perhaps be hard to say. At all events, the growth of every department of science has been more rapid within the last fifty years than during the preceding fifty years, though we should be doing gross injustice to our predecessors were we to belittle their work. The fact is, I am inclined to think that there never was a more fruitful period, in chemistry at least, than the last quarter of the eighteenth century. Farther on, I shall have occasion to speak of a few of the great chemical discoveries that were made during that period. No greater discoveries have been made since. In astronomy, Newton's great work was done more than two centuries ago. An age that can boast of the discovery of the law of gravitation may fairly lay claim to the title, 'the age of science.' Many and many a great discovery in science preceded the present age, but from what I have already said, you will see that the reason for calling this age in which we live the scientific age is found in the fact that scientific work is much more extensively carried on at present than at any time in the past, and, further, the world is beginning to reap the rewards of this work. So striking are some of these rewards that they appeal to all. The world is dazzled by them, and is to a large extent unable to distinguish between the scientific work which has made these rewards possible and the rewards themselves. The idea is prevalent that scientific work is carried on in order that rewards in the shape of practical results may be reached. I have no desire to bring my fellow-workers in science into disrepute. It would therefore perhaps be best for me to stop here; but, if you will bear with me, I will try to make it clear to you that one may be engaged in scientific work all his life, never thinking of what the world calls practical results, that he may in fact not achieve a single result that can be called practical, and yet not waste his time; and that one may hold such a worker up to admiration without running much risk of being taken for a fool. This will be my object in what I still have to say.

While I have thus far referred to science in the broadest sense, meaning the science of nature, let me now turn more especially to the science to which it has been my lot to devote my life, and let me endeavor to show by a few examples the relations that exist between work that appears to be of little practical value when first performed and results that, from the industrial point of view, are of the highest value.

I have often been embarrassed by these questions put to me in my laboratory: 'What are you doing?' and 'Of what use is the work?' Generally I am obliged to answer to the first, "I regret that I can not possibly explain what I am doing. I have tried to do so in some cases, but I have been begged to stop"; and to the second, the only possible answer has been, 'I do not know.' I am well aware that such answers seem to show that the work is in fact of no value, and that this is the impression that my visitors carry away with them. Now I do not propose to try to justify my own work, nor to try to explain it. For the most part it has had to deal with matters that do not touch our daily lives, and therefore it can not be made interesting, not to say intelligible. I shall, to be sure, show you how one piece of work carried out twenty years ago has become of world-wide interest, though when it was carried out it appeared as little likely to be of practical value as anything ever done. But this is anticipating.

During the latter half of the last century there lived in Sweden a poor apothecary who, in his short life, probably did more to enlarge our knowledge of chemistry than any other man. Throughout his life he had to contend with sickness and poverty. He was obliged to carry on the business of an apothecary in order to keep the wolf from entering his house—he never succeeded in keeping it from the door. His great delight was to investigate things chemically, and to find out all he could about them. It is simply astounding to the chemist to find how many discoveries of the highest importance he made. But I have not mentioned his name. I refer to the immortal Scheele. He died in the year 1786 at the age of 43, yet he will always be remembered, and those who know most of the work he did will respect him most.

Though Scheele was an apothecary, his chemical work was not practical in the ordinary sense, and it was no doubt often difficult for him to explain what he was doing. His most important discovery was that of oxygen—a discovery that was made at the same time (1774) by the English clergyman, Priestley. Chemists know that this is one of the most important discoveries ever made in the field of chemistry, and, filled with this conviction, in 1874, one hundred years after the discovery was made, the chemists of the United States made a pilgrimage to Northumberland on the Susquehanna to do honor to the memory of Priestley, who there spent the last years of his life.

But why was this discovery so important? Oxygen, to be sure, is the most widely distributed and the most abundant substance in and on the earth; it plays a controlling part in the breathing of animals, and in most of the changes that are taking place upon the earth; a knowledge of it and of the ways in which it acts has done more than anything else to give chemists an insight into chemical action in general; and therefore has contributed more than anything else to the development of chemistry. All this is no doubt true, but are these results practical? Could we go out into the world and form a company and sell stock on the basis of such a discovery? Or could the discoverer in any way realize in cash? The average man of the world would say: "No! there is nothing in it. It may be well for a few men who have not the power to compete with their fellow-men in the busy marts to devote themselves to such useless pursuits. Possibly something may come of it in time, but better something practical, something that can be converted into hard cash. That is the test, and the only fair test by which we can judge whether any particular piece of scientific work is or is not of value."

But I have already said that the discovery of oxygen was the most important discovery ever made in chemistry, and I might have added, the most valuable. In what, then, did its value consist? In the fact that it led to a more intelligent working with all things chemical. Operations that had before this discovery appeared mysterious suddenly became clear, and every one engaged in chemical work was helped in many ways. If it is not enough for us simply to gain a clearer insight into the processes around us, if we must insist upon more tangible reward, no doubt it could be shown that the discovery of oxygen has contributed largely to the material welfare of mankind—not directly perhaps, but by enlarging our knowledge of chemistry, so that it may be said that most discoveries made since 1774 have been in a way consequences of the discovery of oxygen. Indirect results are often of more value than direct ones.

But there is another discovery of Scheele's that illustrates in another way that a discovery that when made appears of little or no practical value, may eventually prove of immense practical value and become the basis of a great industry. This is the discovery of chlorine. Among the many substances examined by Scheele was one that is commonly known as black oxide of manganese. This occurs in nature in large quantity and has long been of interest to chemists. Scheele treated this with about everything he could lay his hands on, as was his way. When muriatic acid, or, as it was called by the older chemists, the spirit of salt, was poured on the black oxide of manganese, he noticed that something unusual took place. He soon became aware that a colored gas was given off, and that this gas had other properties besides that of color. It affected his eyes, nose, throat and lungs in most disagreeable ways. Many of those before me have had the experience of inhaling a little of this gas. I hope no one has inhaled much of it. It is one of the most disagreeable things chemists and students of chemistry have to deal with. And it is not only disagreeable, it is extremely poisonous. But Scheele did not stop his work because it involved discomfort and even danger. He persisted and carried it to a successful issue, and when he stopped he was able to give as satisfactory an account of the now familiar chlorine as we can give to-day. The investigation is a model. It could not have been accomplished without the enthusiasm, the patience, the knowledge and the skill possessed by Scheele. No ordinary chemist would have been equal to it. We shall not overstate the case if we say that Scheele's discovery of chlorine ranks with the most important and the most valuable of chemical discoveries. That of oxygen outranks it certainly, but chlorine falls in line not far behind.

Now, why was this an important and a valuable discovery? Primarily because it, like the discovery of oxygen, though to a less degree, aided chemists in their efforts to understand chemistry and thus to put them in a position to deal more intelligently with chemical problems of all kinds. That statement may, once for all, be made of every important chemical discovery. But while Scheele had no thought of any practical uses to which chlorine could be put, and his discovery was not at first regarded as one with a practical bearing, it proved eventually to be of the highest practical value, and to-day it plays an exceedingly important part in practical affairs. As is well known, chlorine is the great bleacher, and as such is used in enormous quantity, especially for bleaching straw, paper and different kinds of cloth. As it would be expensive and inconvenient to transport a gas, and especially such a gas as chlorine, it is locked up, as it were, by causing it to act upon lime, and the 'chloride of lime' or 'bleaching powder' thus formed, which readily gives up its chlorine, is a most important article of commerce, many thousands of tons being manufactured annually. Then again chlorine is one of the most efficient disinfectants, and as such it is finding more and more extensive use every year, and is plainly contributing to the welfare of man by interfering with the spread of disease. Further, it is essential to the manufacture of chloroform, and that this calls for a large quantity of chlorine will appear when it is stated that nearly nine tenths of the weight of chloroform is chlorine. Chloroform, which has been of such inestimable value as an alleviator of pain, can not be manufactured without chlorine, and it could never have been discovered without the previous discovery of chlorine.

Finally, without attempting to give a full account of all the uses to which chlorine has been and is put for our benefit, let me mention one more application, though in doing so I may run the risk of leading some of you to the conclusion that chlorine has its dark side as well as its light. It is with some misgivings that I venture to tell you that chlorine has found extensive application in the extraction of gold from its ores, and as gold is held by some to be the root of all evil, chlorine must, by the same token, be regarded as *particeps criminis*. A few years ago I visited the gold mines in the Black Hills of South Dakota, and there I spent some time in examining the chlorination process. I could not help thinking of Scheele and his simple experiments that first brought chlorine to light. I wondered whether, if he could see the extensive applications of that greenish-yellow gas that first set him to weeping and coughing—I wondered whether his satisfaction in his work would be any greater than it must have been when the discovery was made. Compare the little room in the apothecary shop, the simple apparatus, and the apparent uselessness of the noxious gas with the great factories, the complicated machinery and the valuable applications already mentioned, and it is evident that a discovery that appears least promising from the practical point of view may be the beginning of the most valuable industries.

Before leaving this part of my subject let me take a much less important example than those already spoken of, but one that comes nearer home. Nearly twenty-five years ago in the laboratory under my charge, an investigation was being carried on that seemed as little likely to lead to practical results as any that could well be imagined. It would be quite out of the question to explain what we were trying to do. Any practical man would unhesitatingly have condemned the work as being utterly useless, and I may add that some did condemn it. There was no hope, no thought entertained by us that anything practical would come of it. But lo! one day it appeared that one of the substances discovered in the course of the investigation is the sweetest thing on earth; and then it was shown that it can be taken into the system without injury; and finally, that it can be manufactured at such a price as to furnish sweetness at a cheaper rate than it is furnished by the sugar cane or the beet. And soon a great demand for it was created, and to-day it is manufactured in surprising quantities and used extensively in all corners of the globe. Thousands have found employment in the factories in which it is now made, and it appears that in some European countries the new substance has become the sweetening agent of the poor, it being sold in solution by the drop.

It is unnecessary here to discuss the question naturally suggested by the facts just spoken of, whether the discovery of the sweet substance has benefited the human race. It would be extremely difficult, if not impossible, to answer this question. But whatever the answer, it is clear from what has been said that the discovery was of importance from the practical point of view, and there was nothing originally in the work to suggest the possibility of a practical result in the sense in which the word practical is commonly employed.

This is the lesson that we learn over and over again as we study the great industries.

Rarely have they been the results of work undertaken with the object of attaining the practical. Look at the beginnings of electricity. A piece of amber when rubbed attracts bits of pith. A frog's leg twitches after death when touched in certain ways with metals. That was all. Are such things worth investigating? No doubt the practical man said: 'No; stop trifling: do something worth doing.' And if he had been permitted to have his way, all the wonderful results that depend upon the applications of electricity would have been impossible. In every line, much study, much work, and much investigation are absolutely necessary before enough knowledge can be got together to make profitable, practical applications possible. During this early preparatory stage the work is of no direct interest to the purely practical man; and yet without this work the applications which he values would be impossible. Scientific work in its highest form does not pay directly. Those who devote themselves to the pursuit of pure science do not, as a rule, reap pecuniary reward. They probably enjoy their lives as much as if they did, though it is often difficult to make them believe this. But because it does not yield immediate reward to the worker, should the work stop? Surely not. Our only hope of progress in intellectual as well as practical matters lies in a continuation of this work. And even though not a single tangible, practical result should be reached, the work would be valuable. Why? Because we are all helped by knowledge. The more we know of the universe the better fitted we are to fill our places in the world. All will concede the truth of that proposition. But if this is true we have the strongest argument for scientific work, for it is only through such work that we are enlarging our knowledge. There is no other way of learning. Somebody must be adding to our stock of knowledge, or what we call progress in intellectual and material things would stop. It also seems probable that moral progress is aided by intellectual progress, though it might be difficult to make this perfectly clear. I believe it is so; though of course it does not follow that every individual furnishes evidence of the relation between intellectual and moral progress.

But, my friends, whether we will or not, scientific investigation will go on as it has been going on from the earliest times, and it will go on more and more rapidly with time. The universe is inexhaustible, and its mysteries are inexplicable. We may and must strive to learn all we can, but we can not hope to learn all. We are finite; the mysteries we are dealing with are infinite.

IRA REMSEN.

HIGHER EDUCATION IN GERMANY AND THE UNITED STATES.

AN article on 'Thirty Years' Growth of German Universities,' which recently appeared in one of the educational magazines, suggests an investigation along similar lines with reference to our own country and a comparison of existing conditions. There can be no doubt of the fact that there is manifested in this country an increasing purpose to lead the intellectual or the scientific life, which will inevitably tend to raise the standard of American civilization and culture. The growth of our leading universities within the past decade bears eloquent testimony to this fact, and we have no reason to be dissatisfied with the progress that has been made in the field of higher education. A mere glance at the figures in the above-mentioned article describing the growth of the higher institutions of learning in Germany will convey a good idea of the marvelous intellectual advancement of the nation since the Franco-German war. The author shows that, while there had been an increase of 38.9 per cent.