of our Association, one of the interesting and inspiring signs of the times is seen in the increasing number of international conferences for the promotion of art, commerce, education, science, and, above all, peace and good will to men. At the joint meetings held last year by the British and French Associations for the Advancement of Science, steps were taken to form an international organization, which has since been perfected under the name of the International Association for the Advancement of Science, Art and Education. The first meeting of this body will be held during the present summer at the Paris Exposition. May we not entertain the confident hope that, under the influence of such an association, science, which has done so much to enlighten the minds and ameliorate the conditions of men during the nineteenth century, will play a still more beneficent rôle during the twentieth century?

And now, with a cordial invitation to our hosts, the Trustees, the President, and other representatives of this institution of learning, and with a like cordial invitation to the general public as well, to attend the sessions of the various sections of the Association, I declare this meeting formally open for the transaction of its regular business.

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*ON THE TEACHING OF ASTRONOMY IN THE UNITED STATES.**

HAVING to teach Astronomy at the University of Michigan, it has been necessary for me to make inquiries regarding the instruction in this subject given at other universities. I have tried to learn also the character of the work done at the different observatories, from the point of view of the development of students and the encouragement of the spirit of scientific research. Thus I propose to discuss briefly the position taken by our colleges, and observatories also, in the teaching of Astronomy.

Not so very long ago in this country of ours, which is rather new after all, many of the young men educated at the colleges were intended for the ministry. They were trained in Latin, Greek, Hebrew, and a little Natural Philosophy, as it was called, this latter subject including all the known sciences, and being taught by one man. There was almost no laboratory work. At present, whether for good or ill, the rule of the clergymen over our colleges is pretty well broken. The old style college president, usually a clergyman of scholarly tastes and sympathies, who teaches the seniors Moral Philosophy, is becoming rare. His place is being taken by the sharp business man, who in his scholarship corresponds very much to a librarian, having a wide knowledge, but not necessarily an accurate one on any subject.

Of late years the elective system has been introduced, and has been extended very far, so that a degree may represent almost anything, in many cases a good deal of technical and professional work being included. If a large number of students are to go to colleges it is necessary, probably, that the technical studies should be allowed to remain, as many would not have the means to give themselves a liberal education.

Of course, it is hard to discuss in a fair and intelligent way the intrinsic merit of Astronomy or any other study. I believe myself that students who can manage it ought to obtain something of a classical training. But in the case of any given student who elects Latin, for instance, is the subject really chosen for the culture which it gives? I must say that in most cases that I know about I can't tell. Sometimes I think that in college all studies

* Address of the Vice-President and Chairman of Section A—Mathematics and Astronomy—at the New New York Meeting of the American Association for the Advancement of Science.

ought to be elective with the exception of a moderate requirement in English, and that as regards mental discipline and culture one thing is about as good as another, if it is properly taught.

To begin with the elementary Astronomy, it seems to me that it should be taught in the high schools and preparatory schools as well as in the colleges. Preparatory work in it ought to be accepted for admission to college. By elementary Astronomy I mean those common, every-day facts of the science which can be learned by any intelligent student without mathematical training; for example, why the stars rise and set, the motions of the planets and the moon among the stars, the reason for the seasons, the names of the principal constellations and why they seem to change with the seasons. These are things that are before our eyes all the time, and every one who is fairly well educated ought to know something about them. I would not say that this Astronomy ought to be required for entrance to college, or required in college, but it certainly ought to stand on the same plane with Botany, for instance, and Zoology.

As a culture study in college I would bring to your notice also the history of Astronomy. The study of this science no doubt goes back to a time before we have any historical records, and probably was connected with religious worship and festivals. The motions of the sun, moon and planets were watched and studied. It was seen very soon that the seasons and crops and life on the earth depended on the sun's position in the sky. Thus the sun was worshipped as a god, giver of life and harvests. It may be that our Christmas is the remnant of an old pagan festival when rejoicing was had because now the sun would turn and go north and winter would leave the northern hemisphere, and vegetation and life would come back.

Therefore, in the earliest times Astronomy was studied a good deal by the priests. They kept the calendar and the dates of the religious festivals. They followed the motions of the sun, moon and planets, and knew that the planets sometimes advanced and sometimes retrograded in the sky. They had a considerable observational knowledge of the heavens. It is said the Chaldeans had a very exact calendar, better than ours, and giving only an error of one day in ten thousand years. They must therefore have known the length of the tropical year with great exactness.

It would be natural, too, for the sailors of the Mediterranean sea to have considerable practical knowledge of Astronomy. Much commerce was carried on this sea. The Phœnicians voyaged to Britain and Spain and Carthage. The Greeks had many distant settlements. The Romans had large navies, and sailed over all the Mediterranean and to Britain.

But I think one of the most interesting portions of the history of Astronomy would be the philosophical study of the diffferent theories of the universe. Pythagoras is said to have taught the true system of the world, that the earth moves around the sun and at the same time turns on its own axis. But probably this was only one of the doctrines of the speculative Greek philosophers and it was soon abandoned.

It is a curious fact that the system of Ptolemy prevailed for fourteen centuries, and that the new ideas of Copernicus, Galileo and Kepler were so long in being adopted. This may have been because the natural vanity of the human race was appealed to by making the earth the center of the universe. The Ptolemaic theory had come to be supported also by the church, by the old Greek philosophy, and by all the weight of authority. The new theories of Galileo were opposed, no doubt, to the

hopes, fears and prejudices held at that time by mankind; his treatment by the church represented these and cannot be charged to any particular church. But it is a strange commentary on the fallibility of human authority and prejudice. Even now most people have little knowledge of the scientific method of experimentation.

As affairs are really conducted it is difficult to secure any readjustment of studies, since so much of practical college politics is involved. First it is necessary to secure a vote of the faculty, then the president appoints a committee, and a majority of the committee divides among itself anything there is in the way of profit. Thus, in the case of some studies a sort of endless chain arrangement has been established, the college requiring the subject for entrance and after entrance, and in that way being enabled to send out a large number of students to teach it. A number of High School teachers of Astronomy have told me that they were not able to obtain money for apparatus because the subject could not be offered for admission to College.

It would seem to me that all who had a long enough training ought to be encouraged to come to College, even though they may not have begun with that idea, but may have intended to stop with the High School. Therefore the number of subjects to be received for admission ought to be a pretty large one, so that the student may use any study that he has taken. The tendency is, I think, in this direction, as well as towards a greater freedom of choice of studies.

Regarding the Astronomy which is somewhat more advanced than the beginning work, as spherical Astronomy and the elements of celestial mechanics, these subjects might be more generally taught than they are at present, both as a part of a liberal education, and looking at them from a commercial point of view. I will explain what I mean by this latter phrase by taking the case of Latin again. For many students Latin is just as much a technical training as that of a bridge engineer. They do not care for it especially, but expect to teach it as soon as they graduate, and earn money, and they are obliged to look at the subject in that light.

Taking, then, what might be called a practical standpoint, some Astronomy is necessary in all surveying and geodetic operations, and a number of engineering schools and colleges offer courses in field work.

Most of the teachers of mathematics and physics in the small colleges are required to give instruction also in astronomy. It would be worth while for them to fit themselves to do this well, both in the use of instruments and in some of the mathematical theory. Also, in this present epoch of the function theory and higher algebra there is a real need of men who are qualified to teach applied mathematics. So many mathematical processes have been invented by the masters for the solution of astronomical questions, especially in differential equations and theoretical mechanics, that every teacher of applied mathematics ought to have some knowledge of astronomy.

Extended instruction in celestial mechanics is offered in few colleges. Not many men can be found who are qualified to teach it, and perhaps it is hardly advisable for the student to go very far unless he has special gifts in that direction. But it certainly requires a much higher order of ability to make advances in celestial mechanics than to execute what are ordinarily called scientific researches, and colleges that have the means ought to provide for the men of this superior ability. I dwell on this somewhat, as the difference is not very clearly understood between ordinary, routine, respectable work, and that which involves some distinct progress. Ability to do the latter is a gift with which a very few men are

born, just as there are very few good artists and good poets. Some of the best known and ablest scholars of the world have been those who have made substantial advances in celestial mechanics. I do not see why such men should not be supported and encouraged by the colleges as well as those who study Hebrew, for instance. The working out and discussion of the laws which govern our universe gives strength to a natural theology much more than does the study of Hebrew.

For extended instruction in practical astronomy and observatory work opportunities are now offered at a number of places in this country. Not many years ago it was difficult to obtain it. It was given regularly only at one or two places, and occasionally as a sort of personal favor by a working astronomer. Some twenty years back most of such teaching was done by Professor Stone, now of the University of Virginia. I think it is hardly understood how much he did in this direction, and how many men were once students with him who are now active in the science or have influential positions in the educational world.

The best equipped observatory for teaching purposes that I know of is at Princeton, built, I believe, under the direction of Professor Young. A number of other colleges have observatories, keep them up well, and offer good courses of instruction, both elementary and graduate. In the large astronomical establishments there is a tendency sometimes towards the factory system, which is to be regretted. But where the question is of obtaining the greatest amount of work from a given income, something of the kind may be unavoidable, though when carried too far it tends toward the extinction rather than the extension of research. I have been told that after he became an old man Sir George Airy regretted that he had introduced such a system at Greenwich.

However, at almost all the college observatories that I know of some attention is given to students. It is recognized that it is just as important to train men as to carry on investigations, the German view, and probably the result of so many of our young men going to Germany to study.

With regard to the part that government institutions ought to take in training students and the encouragement of original research, it is difficult to make a criticism. They are often engaged on pieces of heavy work, extending over long intervals of time which private establishments cannot undertake. It may be somewhat necessary to have this done in a routine way, without such regard to whether the computer or assistant is benefited or is making any progress in scholarship. The Naval Observatory is required, for instance, to keep up observations of the sun, moon and planets. However, some arrangement might be made to change assistants about and give them experience in every kind of investigation that is being carried on at any institution. It might be wise to appoint men on very small salaries at first, and allow them half their time for study.

It is interesting to look over the names of the men connected with the American Ephemeris in the early years of its history. I find Davis, Benjamin Peirce, Gould, Newcomb, Hill, Van Vleck, Runkle, Ferrel, and others who became well known in science. I have not had an opportunity to find out how the office was managed.

I have made some examination of the theses in practical astronomy produced in this country, and have attempted to compare them with those presented in Germany and France. On the whole I think we make a creditable showing. Perhaps our instruction is not so thorough and painstaking as that given abroad. There may be with us a tendency to be satisfied with making observations merely, without dis-

cussing them properly or attempting to derive the best results. For educational purposes I think too great emphasis cannot be given to the distinction between the two kinds of work I have referred to. That which is planned and carried out in a scientific way alone has value. No matter what skill one may have in observing or making photographs, if he cannot discuss his observations or photographs he stands very much in the relation of a skillful stonecutter to the architect of a building. Very many good photographers can be found in the galleries of our cities, men of great experience and skill, but most of them have no scientific standing and deserve none, though with a little additional experience they could make good astronomical photographs. It is true, also, that many theoretical problems can be solved without having much idea of the theory involved. Orbits are computed by men who do not know very well the meaning of the formulas which they are using. Questions in perturbations are worked out in the same way. Often good and useful results are thus obtained. But this technical skill in using instruments or handling formulas, though necessary, is not a faculty of the highest order. At the same time, however, it ought to be remembered that it is something very useful, and cannot be obtained to a high degree without years of experience.

In practical astronomy I should say that our model ought to be Bessel, that he combined in just the right proportion theoretical knowledge with skill in handling instruments and ability to obtain from an instrument the best results. Especially in relation to college instruction do I think it worth while to call attention to Bessel's papers.

It is true that men of ability will get on without teachers, and that teachers cannot furnish brains. But it is also true that a good teacher can be of very great help even to men of genius. We all have known such, uneducated or self-educated, who would have been helped very much, and been kept from bad blunders if they could have had some training. Encke, Argelander, Gould, Winnecke, Schönfeld, Brünnow, Watson, all studied with experienced astronomers, who are known by their students as well as by their scientific labors. Most of the men just mentioned were teachers, also, and probably left their impress upon the science to as great an extent through their teaching as through their scientific investigations.

It is worth while to take a book like Watson's 'Theoretical Astronomy,' and look over some of the articles, such as the theory of the computation of an elliptic orbit, and the theory of special perturbations, and then examine the treatment given by the different teachers, and see how these theories, after leaving the hands of Gauss, the great master, were modified somewhat by Encke, who was a student with Gauss, and finally by Brünnow and Watson, Brünnow having studied with Encke, and Watson with Brünnow. There is no doubt that Tisserand did a great service to Astronomy by publishing his 'Mécanique Céleste,' putting in a clear and elegant form the principal facts of Mathematical Astronomy, though it is hardly to be ranked with the making of important advances in the science itself.

I think that the standard of scholarship in this country is steadily becoming higher, and that we are having better opportunities for instruction in Astronomy as well as in the other sciences. For however much it may hurt our national vanity, the criticisms of such men as Henry James on our civilization are sound. We are a new country. Our first business has been to clear it up and make roads. We are a nation of business men, trades people. Commercial ideas control, to some extent, our college education, and we lack much that in older coun-

tries makes for the advancement of science and art. But time has changed this somewhat, and I think it will change it more.

With regard to all the sciences a large number of misstatements are made regarding their commercial value. Probably Astronomy has been of as much benefit to mankind as any. Every ocean passenger owes to it his safe and rapid passage. Through its help the carriage of every ton of freight is made cheaper. It would be difficult to calculate the money value it has been to the world.

The conception which most people have of the nature of the questions to be solved in Astronomy is a false one. They look on them as text-book problems in mathematics which are arranged to come out nicely. They suppose such questions can be solved definitely and exactly, once for all. They do not know that instruments are imperfect and that observers have personal errors, nor that it is possible to be sure only to a certain limit, personal opinion founded on experience carrying us a little farther, and the rest being uncertain, though methods and instruments and mathematical conceptions may, after a while, be improved. So that in any actual question in practical or theoretical Astronomy it is necessary to deal with facts as they are in nature, and obtain the best possible solution, though perhaps not the one which is exactly true.

Many people, too, and well educated ones, have very curious ideas as to the amount of labor involved in the solution of questions in Astronomy, and as to the progress of the science. An intelligent doctor, who knows that the science of medicine, as far as it is a science, is something of slow growth, who experiments for a year or two on some fairly simple question, cannot understand the same thing in Astronomy, and thinks that it was really founded and developed by some one whom he happens to know about.

In the case of the small observatories, where teaching is expected of the astronomer, the question of economy of time is a difficult one. At Harvard and Johns Hopkins, for instance, six hours of lectures per week would be expected to occupy half of a teacher's time, while in a small establishment one cannot give that proportion and make and reduce observations. At the smaller observatories, too, there is difficulty in requiring proper preparation and in enforcing a high standard of scholarship. Men who believe that the training in law, medicine or engineering should be thorough and severe, because they think the students will be better off commercially, cannot understand that students in Astronomy ought to have the same thorough discipline.

THE EIGHTH GROUP OF THE PERIODIC SYSTEM AND SOME OF ITS PROBLEMS.

II.

We have seen that nearly half a century ago, it was clear to Claus that iron, ruthenium, and osmium belonged in a group together. It was later easily recognized that cobalt, rhodium, and iridium furnished a second triad, while nickel, palladium, and platinum must also be grouped together. The analogies between the three metals of each of these groups is too patent to require discussion, though incidentally we shall have occasion to recur to it. When the elements were arranged in the first periodic tables, these metals did not fall into orderly arrangement; as late as 1878 the atomic weight of osmium was considered greater than that of iridium, platinum, or even gold, while gold was given a weight less than that of iridium or platinum. Cobalt and nickel on one hand and iridium and platinum on the other were considered to have an identical atomic weight. The seeming impossibility of reconciling these nine metals with the periodic law is undoubtedly the reason why they were thrown