share its spirit and method. They must love learning as well as professional success, in order to have their perfect usefulness.'' The perfect usefulness of the professional school consists, not merely in teaching our embryo physician how to destroy bacteria, to remove tumors, or to calm the fire of fevers. These things he must understand, and these he must do daily for the suffering individual. But beyond these are larger tasks. The physician's should be a life of service and of leadership combined. He serves well when he relieves suffering; still better when he teaches men how to live; but he serves best of all when he pushes out into the unknown and makes medical science the richer for what he contributes to it. The knowledge of wise men, the deeds of diligent men and the valor of heroes are the gift of those who have preceded him. Let us see to it that he pass on this heritage, augmented, to those who follow.

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HISTORIES AND BIBLIOGRAPHIES OF PHYSICS.

THE study of the science of physics, like that of any other of the expressions of activity of the human mind, may be approached from two different points of view. First, the attention may be confined to the study of phenomena and of the inductions based upon them. These inductions are seen to lead to what are called laws of physics. From the method of their establishment it is evident that these laws are but résumés of physical experience—they are classifications of phenomena according to some principle of analogy. The study of physics is usually approached in this way —a way which is open to the very serious objection that the student is very apt to think that the principles or laws with which he becomes familiar are laws in the judicial sense and not mere résumés of experience in the formation of which the mind which makes the résumé also plays a part. This must be evident to any one who considers the nature of classification and induction. There is always behind the induction, in the mind of the man who makes it, some idea or principle upon which the classification is based.

In the second place the science of physics may be studied as if it were a vital organism. We say without hesitation that this science grows and develops—expressions in which it is tacitly agreed that we are dealing with a living organism, for what grows and develops must surely have life in some form. We may then fairly put the question, 'In what does the life of science consist?' The answer to this question seems to me to be 'In the ideas and conceptions upon which the inductions and classifications of the science are based.' Examples may help to make this clear. Ptolemy explained the solar system upon one set of ideas, Copernicus on another. Sir Isaac Newton deduced the laws of optics with the help of certain conceptions of rapidly moving particles of matter. Young and Fresnel classified those same observed phenomena upon the basis of ideas of waves in an elastic medium. Faraday and Maxwell resumed the same experimental facts by conceiving them to be manifestations of electric and magnetic forces. The development in these sciences is thus seen to consist in the changes in the conceptions and ideas which lie at the basis of the classifications and inductions which lead to scientific laws. Hence if we would study science as if it were a living organism we must investigate the ideas which are back of it and which form its real life.

When studied in this latter way it will be found that the science of physics is not an isolated subject in the thought of man-

kind. For example, the discovery of America, the propounding of the Copernican system of astronomy, the invention of printing, the reformation, and the first glimmerings of observational methods of induction in the inductive sciences in the works of Paracelsus, Bruno and others of their contemporaries all appeared in the world about the same time, and may be considered to be but different manifestations of some one impulse which was acting at that time upon the composite mind of humanity. The point may be made clearer by considering the state of the European mind before these events. One of the most characteristic factors in the development of the mind of mankind during the middle ages was the gradual growth of the spirit of rationalism. As this spirit gained in influence the power of the church declined. This was due to the fact that many of the dogmas of the church, like that of exclusive salvation and infant damnation, became repulsive to reasoning men. In order to retain its hold upon mankind and prevent that worst of sins, heresy, the church had recourse to pious frauds. Miracles were invented, sanctified relics became numerous, and the church tried diligently to support its creed by imposture and falsehood. Thus a spirit of lying became prevalent and was even made systematic and raised to the dignity of a regular doctrine. This habit of continual falsehood became so powerful that the sense of truth and the love of it—both essentials of the scientific spirit—became almost extinct in the human mind. It is not, therefore, strange that science could not thrive in such an atmosphere, and that when this love of truth was revived, the reformation and the other events mentioned above followed as a necessity. This example is mentioned to illustrate what seems to be a general fact, namely, that the fundamental concepts of science at a given epoch are of the same nature as the general concepts which are characteristic of that age.

Now how is physics to be studied in this way? Evidently by a study of its history, provided, of course, that the history be of the right sort. In the light of what has been said above, it appears that a history of physics is of the right sort if it brings out clearly the life of physics, *i. e.*, if it shows what the fundamental concepts of the science at any epoch are, if it shows how those concepts change from time to time and how they grow, and if it brings out clearly the relations which exist at any epoch between the particular ideas of physics and the general ideas which are at the basis of the civilization of that epoch, and points out how those particular ideas have developed in a certain way because the more general ones have done so.

Having established this ideal of a history of physics, we may well ask whether any of the existing histories of the subject fulfill the requirements. Have any such works been written by an artist rather than by an artisan? For it has been written:* "The artist in history may be distinguished from the artisan in history; for here, as in all provinces, there are artists and artisans; men who labor mechanically in a department without eye for the whole, nor feeling that there is a whole; and men who inform and ennoble the humblest department with an idea of the whole, and who know that only in the whole is the partial to be truly discerned. The proceedings and duties of these two, in regard to history, must be altogether different. Not, indeed, that each has not a real worth, in his several degree. The simple husbandman can till his field, and, by knowledge he has gained of its soil, sow it with fit grain, though the deep rocks and central

* Carlyle, 'Essay on History,' 1830.

fires are unknown to him; his little crop hangs under and over the firmament of stars, and sails through whole untracked celestial spaces, between Aries and Libra; nevertheless it ripens for him in due season, and he gathers it safe into his barn. As a husbandman he is blameless in disregarding those higher wonders; but as a thinker, and faithful inquirer into Nature, he is wrong. So likewise is it with the historian, who examines some special aspect of history; and from this or that combination of circumstances, political, moral, economical, and the issues it has led to, infers that such and such properties belong to human society, and that the like circumstances will produce the like issue; which inference, if other trials confirm it, must be held true and practically valuable. He is wrong only, and an artisan, when he fancies that these properties, discovered or discoverable, exhaust the matter; and sees not, at every step, that it is inexhaustable.''

Having thus established the ideal by which we shall judge the histories of physics, let us see how closely the published works on the subject satisfy that ideal. We are compelled to admit at the start that there is one characteristic in the ideal history which no one has as yet attempted to embody in his work. This is the recognition of the relations between the concepts of physics and those of other subjects, *i. e.*, the writers of physical history have shown themselves to be artisans rather than artists; they have failed to perceive that there is a whole and that only in the whole is the partial to be truly discerned. It is thus evident that this discernment of the whole is beyond the present attainments of the scientific historian. Its realization is reserved for some future historian and offers to him a most enticing and remunerative field.

If then we pass over this requisite of an ideal history as being at the present time a Utopian ideal, what do we find? We shall find that there already exist several very satisfactory books upon the history of our subject. Thus some of the chapters in Whewell's 'History of the Inductive Sciences,' and especially some in his 'History of Scientific Ideas,' as the later editions of his 'Philosophy of the Inductive Sciences' are called, will be found to be very satisfactory. The best part of the work is, in my opinion, that which deals with the ancients and the middle ages. In fact, in this portion of the book he seems sometimes to move toward the realization of the first point in our ideal history—the point which we have dismissed as at present Utopian. In the later parts of the work he falls back into the much easier task of describing discoveries in their chronological order and explaining them in popular ways.

Another excellent work is that of Mach, 'Die Mechanik und ihre Entwickelung,' 1895, of which there is an English translation. This author carefully analyzes the conceptions upon which the mechanics are based, and shows how those conceptions have varied from time to time. Especially satisfactory is his chapter on the analytical mechanics in which he shows how far Newton developed the subject, using as his fundamental conception the attraction between two points. His method was purely geometrical and synthetic. He then points out how Euler and Maclaurin introduced the idea of resolving each such force into forces along three coordinate axes; and further, how finally Lagrange, by his introduction of the ideas of the calculus of variations, completed the structure. The succession of ideas here outlined is admirably treated by our author.

The historical works of Todhunter are of great value. His method is simple, direct,

and appeals strongly to a scientific mind. Thus in his 'History of the Mathematical Theories of Attraction and the Figure of the Earth,' 1873, he takes up every memoir which had been published upon that subject, analyzes it carefully, and gives his opinion as to its merit and the importance of its bearing upon the subject in hand. The same is true of his 'History of Elasticity.' It seems to me that a student could not possibly get a better grasp of these two subjects than by a careful study of these two works. Todhunter's style is rigidly scientific, being clear, exact and extremely terse.

Of the older histories of our subject those of Priestley deserve mention. This many-sided man composed, besides his theological works and his scientific works, two histories of physics: one, 'History of Electricity,' 1769; the other, a 'History of Vision, Light, and Colours,' 1792. In the preface to the latter he says it is his intention to write the histories of the other branches of the subject if the reception of the one on vision, light and colors shows that his efforts are appreciated. As the other works never appeared, it would seem that the time was not yet ripe for a history of optics. This volume contains as an appendix a list of the works which were consulted in its preparation—a rather interesting little bibliography of the subject.

There are also the treatises of Fischer, 'Geschichte der Physik,' eight volumes, 1801, and of Libes, 'Histoire philosophique des progrès de la physique,' four volumes, 1810. Both of these are rather biographical dictionaries than histories. Saverien's 'Histoire des progrès de l'esprit humain dans les sciences exactes,' 1766, should also come under this head. On the other hand, Powell's 'History of Natural Philosophy,' 1834, is a very creditable little work. In fact it deserves a far greater recognition than it has received. It has characteristics somewhat similar to the works of Whewell. There are also chapters in Montucla's 'Histoire des mathématiques,' four volumes, 1801–3, which deal with physical subjects such as mechanics and optics. However, inasmuch as its contents are largely mathematical, its discussion does not properly belong here. It is, as the German bookseller of whom I bought a copy remarked, 'ein sehr quellenreiches Werk.'

Of the more recent histories of physics, Marie's, 'Histoire des sciences mathématiques et physiques,' 1883–8, is an ambitious work in twelve volumes. It consists of a series of short biographies with a list of the writings of each man and a criticism of both. It is interesting reading, for it is often well told and there are frequent anecdotes thrown in without extra charge. Caverni, 'Storia del methodo sperimentale in Italia,' five volumes, 1891, describes mainly discoveries and instruments. There are further the German works of Rosenberger, 1882; Heller, 1882; Dannemann, 1896; Hoppe, 1883; Poggendorff, 1879; Gerland, 1892, and Duhring, 1887. All of these, though marked with the careful, thorough, and plodding scholarship of the nation which produced them, are not, in my opinion, true histories in the light of the ideal which has been adopted above. The same is true of the most recent work on the subject, namely, Cajori's 'History of Physics,' 1899. In this book the entire treatment of the wonderful mental growth and the marked changes in intellectual life which marked the end of the middle ages—changes to whose operation the science of physics owes it origin—is contained in one short paragraph. The book is well written and its contents are presented in an interesting way, but it cannot be re-

garded as more than a reminder that the history of our sciences deserves attention.

There are numerous other works which contain chapters upon portions of our subject. Thus Libri, 'Histoire des sciences mathématiques en Italie,' four volumes, 1865, is very valuable. Also Pouchet's 'Histoire des sciences naturelles au moyen age,' 1855, and Cuvier's 'Histoire des sciences naturelles,' three volumes, 1831–8, contain some treatment of physics along with that of the other sciences.

From the above discussion it should be clear that an ideal history of physics, or one which approaches somewhere near to that ideal, is a much-desired and needed thing. That such a work would receive a warm welcome is evident when we note that the works of Whewell passed through three editions in ten years and have been reprinted several times since and are still carried by the Appletons among their regular books. It has also been translated into German. The work of Mach is now in its fourth German edition and has been translated into English. These are the best, in my opinion too, of the histories of science.

A satisfactory history should then be written, all the more since Whewell's work ended in 1847. The first step in the preparation of such a history seems to me to be the compiling of a bibliography. Now while astronomy has its Lalande, its Houzeau and Lancaster, its Weidler, and others, physics can boast of nothing better than Poggendorff's 'Biographisch-litterarisches Handwörterbuch zur Geschichte der exacten Wissenschaften.' This is an extremely valuable work as a reference, but it is not at all complete as a bibliography. The author expressly states that he has included in the work no one concerning whom he could find no biographical record. This being so, he has, as he himself acknowledges, omitted many books which should be in a bibliography. There are partial bibliographies, like the 'Bibliographie Neèrlandaise' of Bierens de Haan, 1883. This is a fairly complete list of the works in mathematics and physics published in Dutch during the sixteenth, seventeenth and eighteenth centuries. There are quite a number of smaller bibliographies of the works written by Italians in various towns. In fact, the Italian towns seem, now that their glory is in the past, to show a desire to exhibit their departed prowess by each town printing a list of the great works which have originated there or whose writers were born there. There are several attempts to cover certain portions of the subject which have been made by the Smithsonian Institution such as Tuckermann's 'Bibliography of the Spectroscope,' 1888. From the result it would appear either that the library in which Mr. Tuckermann worked was inadequate or that he did not spend time enough upon the subject. Kayser's 'Handbuch der Spektroscopie,' 1900, is more complete than this.

Thus a satisfactory bibliography of physics is also a much-to-be-desired thing. It does not, however, seem strange that one has not yet been compiled, for most of those who know enough physics to do the work well find that their energy is all needed to keep up with the rapid progress and expansion of their subject. But it seems now as if the time were come when such work must be done. Men are beginning to question more than ever the basis of scientific work, to look behind the principles and laws which lie on the surface, and to inquire into the real nature of the ideas upon which their science has been founded. A satisfactory answer can only be obtained through a careful study of the history of those ideas—through a knowl-

edge of the development which has taken place in bringing the concepts of science into their present form.

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UNIVERSITY REGISTRATION STATISTICS.

THE table on page 1022 furnishes an eloquent criterion of the continuous rapid development of higher education in the United States. The opening of each new academic year shows a marked advance over the last, and the number of young men and women eager to obtain a university training is keeping steady pace with the rapid growth of our country's population. It is certainly an encouraging sign to witness this growing endeavor to lead the intellectual or the scientific life, which will inevitably tend to raise the standard of American civilization and general culture.

The statistics given herewith are, with few exceptions, approximately as of November 1, 1902, and relate to the registration at eighteen of the leading universities throughout the country. It will be noticed that Syracuse University has been added this year for the first time, and the reason for this is self-explanatory. The figures have been obtained from the proper officials of the various institutions concerned, and are as accurate as statistics of this nature can be made. A number of changes may occur during the year, but they will not be of such a serious nature as to affect the general result. The question of proper enrolment figures is assuming greater importance each year, and it goes without saying that there is a tendency to attain as much uniformity as possible in the methods employed at the various universities. At the annual meeting of the Association of American Universities, to be held under the auspices of Columbia University in New York city on December 29, 30 and 31, 1902, a representative of Columbia will present a paper on the subject of 'Uniformity of University Statistics' which should bring out some interesting facts relating to this matter. The question of double registration, for example, presents more than one perplexing problem, and a number of universities are endeavoring to eliminate enrolment in two faculties from their figures altogether by simply taking into consideration the primary registration. One great obstacle in the path of this desire is the number of summer session students who return for work in the fall, of which there were this year 291 at Cornell, 139 at Harvard, 210 at Columbia, and so forth. These students were not registered in two faculties, and yet they caused duplication. In the case of several universities this was lost sight of altogether in last year's compilation, and the apparent falling off in the total enrolment of Harvard, Michigan, and Cornell is due to this circumstance. On the whole, there has been a noticeable increase shown in the summer session enrolment throughout the country, and this particular feature of university work seems to be meeting with popular favor.

Last year the relative rank of the seventeen leading universities on the basis of total enrolment was as follows: Harvard, Columbia, Michigan, Chicago, California, Minnesota, Cornell, Wisconsin, Yale, Pennsylvania, Northwestern, Indiana, Nebraska, Missouri, Princeton, Leland Stanford, Johns Hopkins.

If we count in the students attending courses for teachers, who are held to the full requirements of regular courses in Teachers College, it will be seen that Columbia has passed the 5,000 mark and has almost reached Harvard. Chicago has had a considerable increase over last year, has