also voted to hold a summer meeting, probably during the week beginning June 28, 1908, at Dartmouth College, Hanover, N. H.

Dr. T. C. Chamberlin, of the University of Chicago, was elected president of the association.

Dr. J. Paul Goode, of the same institution, was elected general secretary.

Dr. Dayton C. Miller, of Case School of Applied Science, was chosen secretary of the council.

The sectional officers stand as follows:

A—Mathematics and Astronomy.
Vice-president—C. J. Keyser, Columbia University.
Secretary—Professor G. A. Miller, University of Illinois.

B—Physics.
Vice-president—Carl E. Guthe, State University of Iowa.
Secretary—A. D. Cole, Vassar College.

C—Chemistry.
Vice-president—Louis Kahlenberg, University of Wisconsin.
Secretary—C. H. Herty, University of North Carolina.

D—Mechanical Science and Engineering.
Vice-president—Geo. F. Swain, Massachusetts Institute of Technology.
Secretary—G. W. Bissell, Michigan Agricultural College.

E—Geology and Geography.
Vice-president—Bailey Willis, U. S. Geological Survey.
Secretary—F. P. Gulliver, Norwich, Conn.

F—Zoology.
Vice-president—C. Judson Herrick, University of Chicago.
Secretary—Morris A. Bigelow, Columbia University.

G—Botany.
Vice-president—H. M. Richards, Columbia University.
Secretary—H. C. Cowles, University of Chicago.

H—Anthropology and Psychology.
Vice-president—R. S. Woodworth, Columbia University.
Secretary—Geo. H. Pepper, American Museum of Natural History.

I—Social and Economic Science.
Vice-president not chosen.
Secretary—J. Pease Norton, Yale University.

K—Physiology and Experimental Medicine.
Vice-president—Wm. H. Howell, Johns Hopkins University.
Secretary—William J. Gies, Columbia University.

L—Education.
Vice-president—G. Stanley Hall, Clark University.
Secretary—C. R. Mann, University of Chicago.

F. W. McNAIR,
General Secretary

THE INTERDEPENDENCE OF MEDICINE AND OTHER SCIENCES OF NATURE[1]

SIXTY years ago, when the American Association for the Advancement of Science was founded, all of the main divisions of the sciences of nature existed as they do to-day, but no greater change has come over the face of science during these years than the many subdivisions which have arisen. Then the naturalist or the natural philosopher—how unfamiliar even the names are beginning to sound!—or the chemist could follow with critical judgment at least the work of all who were cultivating his own broad field of science, and a single scientific association, such as ours, could unite all of the workers in the natural and physical sciences into a relatively homogeneous and compact group, supply their needs for intercourse with each other and furnish a comprehending audience for presentation of the results of scientific investigation. To-day no man of science can pretend to follow all of the work even in his own department, and the investigator more often than not must seek an audience capable of critical understanding and discussion of his studies in a society of biological chemists, or of experimental zoologists, or of plant pathologists, or of dairy bacteriologists, or whatever may be the body

[1] Address of the retiring president of the American Association for the Advancement of Science, delivered at the meeting in Chicago, December 30, 1907.

which represents his own particular corner of science.

We may regret the loss of many charming features which have been erased from the landscape of science by all of this minute specialization, of which no one can foresee the end, but such a sentiment is much the same and as unavailing as that for the return of the days of the stage-coach. The great instruments of progress in modern life—steam and electricity in the industries, subdivision of labor and increasing specialization in science—are not altogether lovely, but they are the conditions of advancement in material prosperity and natural knowledge.

A necessary expression of the changed conditions of modern science has been the rapid formation of more and more highly specialized societies, which, it must be admitted, meet the personal needs of many individual workers more fully than a general association, representative of all the natural sciences, can possibly do. But the horizon of a man of science must indeed be narrowly circumscribed, if he can not look beyond what he conceives to be his personal needs and the little plot of ground which he cultivates to those necessities of science as a whole which an organization such as ours is designed to serve. The common interests of science grow with its expansion, and the more minute and specialized its subdivision, the greater the need of an association representative of these common interests—a central, national organization which shall keep to the front the essential unity of all the sciences of nature and of man, and the vital importance to the welfare of the community of the extension and application of scientific knowledge in all directions.

In order to serve most efficiently these common interests of science the central organization requires from time to time readjustment in details of plan and working to changed conditions resulting from the development of science and national growth, but its underlying purpose remains always the same. This purpose is so fundamentally important that its attainment in the fullest measure possible by this association should secure the personal service, the active interest and the zealous loyalty of all scientific workers and lovers of science in this country. The association becomes a living organism through the devotion of its members to its interests and, when fired by this breath of life, the machinery of organization, otherwise inert, is made a powerful instrument for the advancement of science. Gratifying as has been the growth of the association in recent years in membership and usefulness, no one will claim that it has taken full possession of its rightful heritage. The membership of the association should be doubled, yes trebled, to secure needful additions to its resources and influence. The time is near, if it has not already arrived, when the association urgently needs a central office and the services of an executive officer and secretary sufficiently recompensed to enable him to devote his main time, thought and energies to the perfection of the organization, to the extension of membership, to the voluminous correspondence, to the arrangements for the meetings and to other manifold interests of the association. Familiarity with the benefits which such an arrangement has secured for the medical profession through the remarkably effective reorganization within recent years of the American Medical Association leads me to place the first emphasis upon this direction of improvement for the organization of science.

In speaking, as I have done, of modern science as subdivided and specialized, in order to indicate some of the problems relating to the organization of this association, there is danger of giving a false impression to those not fully informed of the actual conditions of science. In truth, the boundaries between the divisions and subdivisions of the sciences are being rapidly effaced by a deeper insight into the nature and phenomena of the material universe. Natural science has been compared to a continent separated into kingdoms, but a more appropriate comparison, it seems to me, is to the spectrum composed of different rays which merge imperceptibly into each other and combine into one white light with radiant energy to be discovered beyond the limits of the visible.

Who will undertake in these days of physical chemistry to separate the domain of the physicist from that of the chemist? The problems of the geologist have long been recognized as essentially physical and chemical in their nature. An ever larger part of the biological sciences, including the medical, is opening to exploration and conquest by physical and chemical methods. To mathematics belongs the primacy, for the exactness of a science is in direct ratio to the degree with which its subject-matter can be investigated by measurement and calculation, that is by mathematical methods. The ideal thus implied has been fully attained only by celestial mechanics, but it is approached by some other departments of physics. It is in accord with this ideal that Priestley admirably said that the object of science is "to comprehend things clearly and to comprise as much knowledge as possible in the smallest compass." The ultimate problems of reality and of knowledge belong to metaphysics which we may, following Descartes, bury deep in the soil as the root of the tree of science.

While this mutual dependence of all the sciences of nature, so significant of the operation everywhere of common principles and forms of energy and of an underlying uniformity in the order of nature, both animate and inanimate, is closest between the physical sciences in the restricted sense, it is strikingly illustrated in the history of the biological sciences, and it has seemed to me that the consideration of certain aspects of the interdependence of that department of biological science with which I am most familiar and the other sciences of nature would be an appropriate theme for an address by a representative of the science of medicine upon this occasion. It is to be understood that under the sciences of nature I include those of inanimate nature, the physical sciences, as well as those of organized beings, and indeed I shall dwell more particularly upon relationships between the medical sciences and physics and chemistry, for the points of contact between the various branches of biological science and medicine are self-evident and more familiar.

It need hardly be said that any systematic and full consideration of this broad theme far transcends the limits of an address and that in selecting particular aspects of the subject and certain illustrations I am quite aware that other points of view and other examples will come to the minds of my hearers as equally, if not more, worthy of presentation. Medicine has derived such inestimable benefits from the physical and natural sciences that I desire to lay some emphasis upon the services which it has rendered to them. For my present purpose it is not necessary to assign any limits to the operation of physical and chemical laws in living beings, for the most extreme vitalist must leave so large a part of the phenomena of living beings under the subjection of these laws that their application in medical and biological studies must always be of the highest importance.

An historical sketch, necessarily brief and inadequate, of some of the principal phases in the reciprocal relations between medicine and the physical sciences, up to the time when the latter became fully independent at the close of the seventeenth century, will show with what propriety medicine has been called the "mother of the sciences."

Physical science has derived from the Greeks no such extensive records of sound observation and experience as those which medicine has inherited from the writings of Hippocrates and his followers. Physical theories embodied in the speculations of the nature-philosophers concerning the constitution and properties of matter furnished the starting point for the Hippocratic doctrine of the four humors and other generalizations, but these theories sat so lightly upon Hippocrates that his name is attached to that method of medical study which rejects dogma, authority and speculation and confines itself to the observation and record of clinical facts. As Gomperz in his admirable work on the "Greek Thinkers" has clearly pointed out the age of enlightenment in scientific thought was inaugurated by Hippocrates and his medical contemporaries.

The influence of physical theories upon medical thought in antiquity can be traced not only in the humoral doctrines of Hippocrates and of Galen, but also in rival schools, and especially in the so-called methodic school founded upon the atomistic philosophy of Democritus, which is so interesting in the history of scientific theories. As this school produced such admirable physicians as Asclepiades, Soranus and Aretæus it is to be regretted that their solidistic pathology was so completely displaced by the authority of Galen.

The large body of medical knowledge and doctrine which had grown up during the six centuries since Hippocrates was further developed and fixed by Galen at the end of the second century after Christ into a system not less complete in its field, nor less satisfying to the minds of men for nearly fifteen centuries, nor scarcely less remarkable as a product of the human mind than the physical and philosophical systems of Aristotle. Within their respective spheres the system of doctrine of each of these great men has exerted a similar dominating influence upon human thought and has met a similar fate through influences almost identical.

Although the contributions of the Greeks to mathematics were of the highest order, and the names of Aristarchus, Eratosthenes, Hipparchus and Ptolemy attest the great debt of astronomy to the school of Alexandria, and Archimedes had founded one branch of mechanics, and the works of Aristotle on "the history" and on "the parts of animals" entitle him to be called the "father of zoological science," I think that it is safe to say that the largest body of ordered natural knowledge in any single domain bequeathed by the ancients to posterity was represented by medicine. The botanists trace the beginnings of their science to the physicians, Theophrastus and Dioscorides, but botany was then, as it long remained, an integral part of pharmacy.

As medicine, practically in the shape in which it left the hands of Galen, continued for many centuries to be the shelter for most of the natural sciences, it is worth considering how worthy a home it furnished. For this purpose it is not necessary to enter into details of doctrine or even the state of existing knowledge. A few words concerning the general scope and spirit of medicine, as conceived and transmitted by the Greek physicians, must suffice.

Gomperz formulates the ideal of these physicians as regards their conception of the relation of medicine to the philosophy of nature in these words:

> The human being is a part of the whole of nature, and can not be understood without it. What is wanted is a satisfactory general view of

the process of the universe. Possessing this, we shall find the key in our hand which will open the most secret recesses of the art of medicine.

Certainly such an enlightened conception of the relations of medicine, however unattainable it may be, is broad enough to provide welcome lodging under the roof of the healing art to any additions to the knowledge of nature. Although priestly and magic medicine and charlatanry existed then by the side of rational medicine, as they have always done, the Galenic system, which was a development of the Hippocratic, was in essence observational and inductive, mainly physical, as distinguished from vitalistic, and nearly devoid of superstition and the supernatural. Galen conceived medicine as a science and constituted anatomy and physiology its basis. He himself made valuable use in his physiological studies of the method of experiment, the singular and almost unaccountable lack of which is largely responsible for the fantastic, though often singularly prophetic, ideas and the sterility of the Greek natural philosophers as contributors to natural knowledge. Although later cultivators of the domain of medicine followed far behind these ideals of Greek medicine, there survived enough of their spirit to enable us to understand why the sciences of nature were for so long a time fostered within this domain, which furnished them a fitting and no unworthy abode until they were strong enough to build their own homes.

Although the Byzantine, Arabic and medieval periods afford a number of interesting illustrations of my theme, I shall not take time to consider them, for these periods were relatively unproductive for most of the sciences as well as for medicine. It may be noted, however, that the majority of the names which appear in the histories of the various natural sciences for these times figure also in the history of medicine.

The great awakening of western Europe, marked by the revival of learning and the reformation, stirred the long dormant spirit of inquiry and led to revolt against authority, a fresh outlook upon a wider world, the study of original sources, the questioning of nature at first hand and the search for new knowledge in all her kingdoms. The seat of learning was transplanted from the cloisters to the universities, which multiplied and flourished in the sixteenth and seventeenth centuries as never before.

For medicine and the sciences of nature the fire was kindled and for two centuries burnt brightest in the universities of northern Italy. Here the science of human anatomy was reformed and marvelously developed by Vesalius and an illustrious line of successors in the sixteenth century, and from this period onward anatomy never ceased to be taught by practical dissection, that is to say, by the method of the laboratory. It deserves to be emphasized that for over two hundred and fifty years human anatomy was the only subject taught in the universities by the laboratory method and that it thereby acquired a commanding position in the study of medicine. Bearing in mind the exceptional educational value thus imparted to the study of anatomy and that for a long time medicine was the only technical subject taught in the universities, we can not doubt that under conditions existing previous to the nineteenth century the study of medicine furnished the best available training for the pursuit of any branch of natural science. From his practical anatomical work the student could acquire the habit of close observation, manual dexterity and the sense for form in nature, and learn that real knowledge comes only from personal contact with the object of study. The term "comparative anatomy," even if it serves no other useful purpose, at least points to the historical fact that human anatomy was the starting point and basis of comparison for the morphological study of the lower animals.

In the sixteenth century practically all of the valuable contributions to botany and to zoology were made by physicians, so that natural history scarcely existed apart from medicine. Of the medical contributors to botany it must suffice to mention the names of Brunfels, Fuchs, Dodoens, Gesner and above all Cesalpinus, who has been called "the founder of modern scientific botany," the most important name before John Ray in the history of systematic botany, and a distinguished figure likewise in medical history. Of names associated with the history of zoology in this century the most important are those of the physicians, Conrad Gesner, a marvel of encyclopædic learning, and Aldrovandi, who ranks with the founders of modern zoology and comparative anatomy; of lesser lights Edward Wotton may be singled out for mention as the pioneer English zoologist. He was doctor of medicine of Padua and of Oxford, president of the Royal College of Physicians, and physician to Henry VIII.

A name of the first rank in the history of science is that of the physician, Georg Agricola, who founded before the middle of the sixteenth century the science of mineralogy and developed it to a state where it remained for nearly two hundred years without important additions. I may here remark in passing that the first American chair of mineralogy was established in 1807 in the College of Physicians and Surgeons of New York and was occupied by Dr. Archibald Bruce, a name familiar to mineralogists, the founder of the first purely scientific journal in this country, the *American Journal of Mineralogy,* which was the immediate predecessor of Silliman's *American Journal of Science.*

The difficult step from Hippocrates and Galen to Euclid and Archimedes was surmounted by several physicians of the sixteenth century, as it has also been repeatedly in later times. The reader of Don Quixote will recall that as late as the seventeenth century the physician was also called "*algebrista*" in Spain, a survival of a Moorish designation—and the sixteenth-century physicians Geronimo Cardano, as extraordinary a figure in the history of medicine as in that of mathematics, and Robert Recorde, the author of the first treatise on algebra in the English language, exemplified the union of the healing art with the pursuit of mathematics as strikingly as did the Sedbergh surgeon, John Dawson, in the latter part of the eighteenth century, who had eight senior wranglers among his pupils and was one of the few British analysts of the period who could follow the work of the great contemporary, continental mathematicians. It may here be mentioned that of the celebrated Bernoulli family of mathematicians, two of the most distinguished, John and Daniel, were doctors of medicine, the latter being for a time professor of anatomy and botany at Basel.

The student of medical history, who takes up a history of physics, such as that of Rosenberger, will probably be surprised to find how many of the contributors to the latter subject in the sixteenth century were physicians and that among these are such old friends as Fernel and Fracastorius, whom he has identified so intimately with the annals of his profession. It is to be presumed that he already knew that the most famous of all, Copernicus, was a doctor of medicine of Padua and practised the medical art gratuitously among the poor in Frauenburg.

Far more important for the subsequent history of science than any relations between medicine and physics at this period was the union between medicine and chemistry effected by Paracelsus and strengthened by van Helmont and Sylvius in the following century, a union so intimate that for nearly a century and a quarter chemistry existed only as a part of medicine until freed by Robert Boyle from bonds which had become galling to both partners. The story of this iatro-chemical period, as it is called, has been told by Ernst von Meyer in his fascinating "History of Chemistry" in a way not less interesting to the student of medicine than to that of chemistry, and should be there read by both.

In reply to the question what benefit accrued to both medicine and chemistry from their mutual interaction during this period von Meyer says:

> The answer is, a mutual enrichment, which did almost more for chemistry than for medicine; for the former was raised to a higher level through being transferred from the hands of laboratory workers, who were mostly uneducated, to those of men belonging to a learned profession and possessing a high degree of scientific culture. The iatrochemical age thus formed an important period of preparation for chemistry, a period during which the latter so extended her province that she was enabled in the middle of the seventeenth century to stand forth as a young science by the side of her elder sister, physics.

Paracelsus in carrying out his program that "the object of chemistry is not to make gold but to prepare medicines" made the pharmacist's shop a chemical laboratory and until the establishment of laboratories by Thomas Thomson and by Liebig in the first quarter of the nineteenth century this continued to be the only kind of laboratory available for practical training in chemistry. Through this portal entered into the domain of chemistry Lemery, Kunkel, Marggraf, Klaproth, Scheele, Proust, Henry, Dumas and many others. Liebig, who also began as an apothecary's pupil, has graphically described these conditions.

That strange, iconoclastic genius, Paracelsus, typifies, as no other name in science, the storm and stress, the strife, the intellectual restlessness and recklessness of the sixteenth century which prepared the way for the glorious light of science which illuminated the following century. With boundless enthusiasm minds, now fully liberated from the bondage of authority, entered upon new paths of philosophical thought and scientific discovery and achieved triumphs unequaled even in the nineteenth century. The great achievement was the full recognition and the fruitful application of the true method of science in all its completeness.

Although isolated and limited use had been made of the method of experiment in former times—I have already cited Galen and I might have added physicians of the Alexandrine school—the real birth of experimental science was toward the end of the sixteenth and the beginning of the seventeenth centuries. Medicine can hardly be said to have presided at this birth, but its influence was not absent. Galileo was a student of medicine, one of his teachers being the celebrated physician and botanist, Cesalpinus, when in 1583 he watched the great bronze lamp swinging before the high altar of the Cathedral of Pisa, and I question whether it would have occurred to anyone without some interest in medicine to determine the isochronism of the pendulum by counting the beats of the pulse. It seems improbable that without his medical training Galileo would have made the measurement of the pulse the first application of the new principle and have called the instrument the pulsilogon. Nevertheless we must bear in mind that natural philosophers of this period and throughout the seventeenth century were greatly interested in anatomy and physiology. Dr. Weir Mitchell in an address, as charming as it is erudite, has called attention to interesting observations of Kepler on the pulse, which the great astronomer believed to have some relation to the heavenly motions, in this and certain other views exemplifying, as some modern physicists have done, the compatibility of a firm hold of positive scientific truth with an irresistible tendency to mysticism and occult science. Kepler was not, as has been stated, the first actually to count the pulse, for we read that as long ago as the Alexandrine period Herophilus timed the pulse with a water-clock.

But if Galileo was only half a doctor of physic, as Dr. Mitchell calls him, his elder contemporary, William Gilbert, second in importance only to Galileo among the creators of experimental science, the founder of the science of magnetism and a significant name in the history of electricity, was fully identified with the profession, being the most distinguished English physician as well as man of science of his day, physician to both Queen Elizabeth and James I., and president of the Royal College of Physicians.

Galileo's younger contemporary, William Harvey, the discoverer of the circulation of the blood, occupies in the history of experimental science an independent position, quite unlike that of the other experimental physiologists of the century. These other physicians, as Sanctorius, Borelli, Lower, Mayow, consciously took possession of the method of experiment as a powerful and newly discovered instrument of research and were swayed in all their physiological work by the discoveries of the physicists. Not so Harvey, who was influenced but little by contemporary physical science and is linked on, not to Galileo or to Gilbert, as exemplars of experimentation, but in a very direct way to the experimental physiologist, Galen, and to Aristotle, as well as to the Italian anatomists of the preceding century. Harvey's genuinely scientific mind was in greater sympathy with Aristotle than with the essentially unscientific Lord Bacon, who was his patient and of whom he said, "He writes philosophy like a Lord Chancellor."

There is no more striking characteristic of seventeenth-century science than the wide range of inquiry covered by individual investigators. The natural sciences were no longer apprenticed to medicine, after Boyle had liberated chemistry, but the problems of anatomy, of physiology and even of practical medicine were not separated from those of the natural philosopher and of the naturalist. With unparalleled versatility every one seemed to roam at will over the whole domain of knowledge and thought. How they leaped and tumbled in the virgin fields and hied "to-morrow to fresh woods and pastures new"!

Descartes was an anatomist and physiologist as well as philosopher, mathematician and physicist, and John Locke, the other great liberator of thought in this century, was educated in medicine, practised it and, like Boyle, accompanied Sydenham on his rounds. Kepler studied the pulse, contributed to physiological optics and calculated the orbits of the planets. Borelli was an important mathematician, physicist and astronomer, as well as one of the greatest physiologists and physicians of the century. Bartholinus was also professor of mathematics as well as of medicine, and discovered the double refraction of Iceland spar. His even more remarkable pupil, Steno, left a name memorable in geology and paleontology as well as in anatomy and physiology, and died a bishop of the Roman Catholic Church. Mariotte, a pure physicist, discovered the blind spot in the retina. Boyle anatomized, experimented on the circulation and respiration, started chemistry on new paths and perpetuated his name in attachment to an important physical law. Hooke, most versatile of all, claimed priority for a host of discoveries, and did in fact explore nearly every branch of science with brilliant, though often inconclusive results. Malpighi was an investigator equally great in vegetable and in animal anatomy and physiology, and what a glorious time it was for the microscopists, like Malpighi, Leeuwenhoek, Swammerdam and others, who could immortalize their names by turning the new instrument on a drop of muddy water, or blood, or other fluid, or a bit of animal and vegetable tissue! From the funeral sermon upon Nehemiah Grew, practitioner of physic and one of the founders of vegetable anatomy and physiology we are assured that he was "acquainted with the theories of the heavenly bodies, skilled in mechanicks and mathematicks, the proportions of lines and numbers, and the composition and mixture of bodies, particularly of the human body" and also "well acquainted with the whole body of Divinity and had studied Hebrew to more proficiency than most divines."

The early proceedings of the various scientific societies and academies, started in this century and destined to become powerful promoters of science, afford excellent illustrations of the wide scope of scientific inquiry. A quotation from the narrative of the famous mathematician, Dr. Wallis, gives further evidence of the position of the medical and other sciences in the aims and work of the little band of thoughtful students of nature who assembled in Oxford in 1645 and later in London, constituting the so-called invisible college, which grew into the Royal Society. He says:

> Our business was (precluding matters of theology and state affairs) to discourse and consider of philosophical enquiries and such as related thereto:—as Physick, Anatomy, Geometry, Astronomy, Navigation, Staticks, Magneticks, Chymicks, Mechanicks and Natural Experiments; with the state of these studies and their cultivation at home and abroad. We then discoursed of the circulation of the blood, the valves in the veins, the venæ lacteæ, the lymphatic vessels, the Copernican hypothesis, the satellites of Jupiter, the oval shape (as it then appeared) of Saturn, the spots on the sun and its turning on its own axis, the inequalities and selenography of the moon, the several phases of Venus and Mercury, the improvement of telescopes and grinding of lenses for that purpose, the weight of air, the possibility or impossibility of vacuities and nature's abhorrence thereof, the Torricellian experiment in quicksilver, the descent of heavy bodies and the degree of acceleration therein, with divers other things of like nature.

The work and publications of the small group of physicians and men of science composing the Accademia del Cimento, which was established in Florence in 1657 and flourished unfortunately for only ten years, exemplify in an equally striking manner the combination of medical with other scientific pursuits and the wide range of study.

Borelli, the most important member of this academy, founded the so-called iatrophysical school of medicine, which contested the field for supremacy with the iatro-chemical, to which I have already referred, during the greater part of the seventeenth century. The story of these two schools is epochal and occupies the larger part of the history of physic during this century. Medicine owes to adherents of each school a large debt for important contributions to knowledge and fresh directions of thought. Where physical methods and knowledge, as they then existed, were applicable, as in investigation of the circulation and of the action of muscles, the iatro-physicists carried off the palm, Borelli's "De motu animalium" being one of the medical classics. But notwithstanding the great inferiority of chemistry to physics at this time the paths of discovery opened, although not traveled far, by the iatro-chemists have led to more important results. The beginnings of our knowledge of digestion and of secretion and even of the chemistry of the blood and other fluids are to be traced in the main to the iatro-chemical school, and the study of fermentation, although this was not conceived in the same sense as to-day, of gases, salts, acids and alkalis was of importance to medicine as well as to chemistry.

There never has been a period in medical history, not even in recent years, when so determined an effort was made to convert medicine into applied physics and chemistry as that in the seventeenth century. Descartes's dualistic philosophy, which left no more room for the intervention of other than mechanical forces in the organized world than in the inorganic, had great influence upon the minds of physicians as well as of physicists. Galileo had founded, and a line of great experimental philosophers from him to Newton had vastly extended, the science of dynamics, which then seemed to many, as in potentiality it may be, as applicable to all the activities of living beings as to the inanimate universe. There came in the first quarter of the century the greatest physical discovery in the history of physiology, that of the circulation of the blood, which opened the large biological tract of hæmodynamics to rewarding study by the new physical methods. The balance, the pendulum-chronometer, the thermometer and other newly invented instruments of precision were turned to good account in anatomical, physiological and pathological investigations, and physicians began to count, to weigh, to measure, to calculate and to discover a world of form and structure hidden from their unaided vision. Such chemistry as existed was pursued almost exclusively by physicians and primarily in the interest of medicine.

What wonder, then, that physicians who came under the influences of this great awakening in physical science and took no small part in its advent and promotion, should have entertained hopes, soon doomed to disappointment, of the benefits to medicine from application of the new knowledge and have promulgated hypotheses and systems of doctrine which seem to us so false and extravagant! Great as was the advance in physical knowledge, it was utterly inadequate for many of the purposes to which the iatro-physicists and iatro-chemists applied it, and to this day many of their problems remain unsolved.

Grateful we should be for valuable discoveries and new points of view which medicine owes to these men, often so unjustly criticized, but the time had come for men of our profession to resume the Hippocratic method of collecting facts of observation within their own clinical field, and Sydenham, of all the physicians of his century the name, next to Harvey's, most honored by medical posterity, in calling out, "back to Hippocrates!" turned the face of medicine again toward nature.

There are interesting points of comparison between Sydenham's position in the history of medicine, and that of his fellow-countryman and contemporary, John Ray, in natural history. I am sorry that my profession, which has fostered so many ardent students of nature, including Linnæus and Agassiz, the respective bi-centenary and centenary anniversaries of whose birth have been celebrated with such enthusiasm in the year now closing, can not claim this greatest naturalist of his century. Both Sydenham and Ray stood apart from the great scientific movement of their day; both, little influenced by theory or tradition, concentrated their efforts strictly within their respective fields of observation, and both introduced new methods of studying their subjects. As Ray, the plants and animals, so Sydenham described diseases as objects of nature, his discriminations and descriptions being in several instances the first, and to this day in some cases unsurpassed and unimpaired by new knowledge. Like Ray, he was not a mere species-monger, but he had the synthetic power to assign the proper place to single observations and to combine them into well-ordered groups. By way of contrast, the attempt of Linnæus to classify diseases into species and genera, although of some historical interest, was utterly barren, the subject-matter permitting no such method of approach as that which enabled this great systematist to start a new epoch in botany and zoology.

With the close of the seventeenth century we reach a dividing line, which limitations of time compel me to make on this occasion a terminal one, in the historical survey of the interrelations of medicine and the natural sciences. I can not, however, refrain from at least the bare mention of the influence of physicians on the development of science in America—a theme which I hope on some other occasion to take up more fully. Leonard Hoar, doctor of medicine of Cambridge, England, brought something of the new experimental philosophy to America, and during his short incumbency of the presidency of Harvard College (1672–1674) planted the first seeds of technical training on American soil, but too early for them to germinate. Of much greater importance was Cadwallader Colden, an Edinburgh doctor, acquainted with the Newtonian mathematics and physics, and a botanist of note in his day, who did much to instil an interest in physical and natural science among physicians and others in Philadelphia and New York in the first half of the eighteenth century. Besides John Bartram, who studied and to some extent practised physic, the founder on the banks of the Schuylkill of the first botanical garden in this country, there is a long line of American medical botanists, as Clayton, Colden, Mitchell, Garden, Kuhn, Wistar, Hosack, Barton, Baldwin, Bigelow, Torrey, the teacher and collaborator of Asa Gray, himself a graduate in medicine, Engelmann, whose names are perpetuated in genera of plants, and many others up to this day. Until the coming of Agassiz, who trained many who did not enter medicine (although among his pupils were also not a few medical men, including the Le Contes and A. S. Packard), most of the zoologists were also physicians, and Agassiz found already at work in his field in Boston the physicians, Gould, Storer, Harris, and one worthy of a place by his side, Jeffries Wyman. Of the delightful naturalist type of physician there have been many, such as Samuel Latham Mitchell, John D. Godman, Jared Kirtland, and above all a man who belongs to the world's history of biological and paleontological science, Joseph Leidy, whose monument was recently dedicated in Philadelphia. Geologists will call to mind such names as Gibbs, Newberry, John Lawrence Smith, also a chemist and mineralogist, and the Le Contes; and ethnologists the names of Samuel G. Morton, Daniel G. Brinton and Edward H. Davis. How many of the Arctic explorers from this country, as Kane, Parry, Hayes, Schwatka, as well as from England, have been physicians! There have been many whose interest in science was first awakened by the study of medicine, but who were not graduated as doctors, as Joseph Henry, Sears Cook Walker, Thomas Sterry Hunt and Spencer F. Baird. Particularly interesting as investigators in physical science were members of the medical families of the Drapers, the Le Contes and the Rogers. This bare mention of a few of the American medical contributors to science, mostly of an earlier period, will perhaps afford some indication of the services of medicine to scientific development in this country.

After the seventeenth century in Europe the natural sciences, though often cultivated by those educated in medicine and practising it, were independent and followed their own paths, which, however, communicated by many by-ways with the road of medicine and with each other.

Botany and zoology acquired their independent position probably more through the work of Ray and Willughby than by that of any other naturalist. Botany, however, remained for over a century still mainly in the hands of physicians. An interesting chapter in its history is the story of the various apothecaries' and other botanical gardens established through the efforts of physicians and conducted by them primarily for the study of the vegetable materia medica. From such beginnings has grown the Jardin des Plantes in Paris, started by two physicians, Herouard and la Brosse, in 1633, into the great museum of natural history made by Buffon, Cuvier and others as famous for the study of zoology as by Brongiart and his successors for botany. Less humble was the foundation of the British Museum and its appanage, the great Museum of Natural History in South Kensington, the gift to the nation of his valuable collections in natural history and other departments by Sir Hans Sloane, a leading London physician in the first half of the eighteenth century.

Boyle's name is associated especially with the foundation of chemistry as a separate science. William Cullen deserves to be remembered in the history of this science, who, although not an important contributor to chemistry as he was to medicine, was in the second half of the eighteenth century the first to raise the teaching and study of chemistry to their true dignity in the universities of Great Britain, and imparted the first stimulus to his pupil and successor in the Edinburgh chair of chemistry, William Black.

Mechanics, never really dependent upon medicine, was lifted by Newton to analytical heights, rarely scaled by disciples of Æsculapius, although, as Thomas Young and Helmholtz have exemplified, not wholly beyond their reach. But not all of physics stands on the lofty plane of abstract dynamics constructed by Newton, Lagrange, Laplace and Gauss, the highest probably hitherto attained by the human intellect. There have been many educated in medicine who have made notable contributions to the physics of sound, heat, light, magnetism, electricity and the general properties of matter and energy. I have collected, without any pretence to exhaustiveness, the names of over a hundred physicians or men trained for the practise of medicine or pharmacy who have made contributions to physics sufficiently notable to secure them a place in the history and records of this science. A few of the more important are Gilbert, van Musschenbroek, Sir William Watson, Black, Galvani, Berthollet, J. W. Ritter, Olbers, Wollaston, Thomas Young, Oersted, Dulong, Mayer, Thomas Andrews, Sainte-Clair Deville, the Drapers, Foucault, Helmholtz. Sir Humphry Davy literally sprang out of the lap of medicine into the Royal Institution, just founded by Count Rumford, who himself had begun the study of medicine before he left his native country. If the surgeons of England at that time had only heeded what Davy told them concerning the anesthetic properties of nitrous oxide gas, America would have been deprived of the greatest service which she has rendered to medicine.

In the long line of important physiologists of the past century who represent especially the physical direction of investigation in their important branch of medicine and biology, there are not a few whose names find a place in the histories of modern physics, as E. H. Weber, Du Bois Reymond, von Brücke, Ludwig, Fick, Vierordt, Poiseuille and others, and the studies of the botanists, Pfeffer and de Vries, on the turgor of vegetable cells opened an important field of physical chemistry.

Aspects of my subject, full of interest, which I can now barely touch upon, are the influence of previous medical or biological training upon the work of a physicist or chemist, and closely connected with this the extent to which purely physical problems have been approached from the biological side. Call to mind how the central physical and chemical problem of the eighteenth century, the nature of combustion, was throughout this period intimately associated with the kindred physiological problem of respiration, and how John Mayow in the seventeenth century, approaching the subject from the biological side, reached a conclusion in accord with that fully demonstrated a century later by Lavoisier, who thereby opened a new era for physiology as well as for chemistry. For the first time clear light was shed upon the function of respiration, the nature of metabolism and the sources of animal heat, and such physical interest was attached to the study of these physiological phenomena that physicists of the rank of Laplace, in association with Lavoisier, Dulong, W. E. Weber, Magnus, A. C. Becquerel, Hirn, Regnault, and of course Helmholtz, have all made valuable contributions to the elucidation of these subjects.

The study of electricity, especially after the physiologist, Galvani's epochal discovery, more correctly interpreted by Volta, engaged the attention of physicians and physiologists scarcely less than that of physicists. The latter became greatly interested in animal electricity, a subject partly cleared up by the physicists, Ritter and Nobili, but mainly by the physiologist, Du Bois Reymond. Ostwald points out, as a matter of interest in the history of the human mind, that the physician Soemmering was led to conceive of the transmission of intelligence by electricity from analogy with the conveyance of impulses by the nerves, and thus to invent his practically useless form of the electric telegraph. However fanciful such a relationship may be, it is interesting, as Sir David Brewster discovered, that the first proposal for an electric telegraph worked by statical electricity was made and actually carried into effect as early as 1753 by the Greenock surgeon, Charles Morrison. It is now well understood that no one has the sole credit of inventing the electric telegraph, the idea of which was implicit in Stephen Gray's observation in 1727 of the transmission of electricity by a wire.

Of curious interest is the introduction of electricity for the treatment of disease by the physicists, Kratzenstein, Nollet and Jallabert, shortly before the middle of the eighteenth century, who reported cures by its use.

There is no more striking illustration of the correlation of two apparently distinct lines of approach to the same problem than the attack from the biological and from the purely physical sides upon the thermodynamic problem, which is as fundamental for biology as for physics. The conception of the principle of conservation of energy was supplied independently and almost simultaneously on the one hand by students of the conditions of mechanical work done by the animal machine and on the other hand by investigators of technical machines. Much of the essential preliminary study was on the biological side by Boyle, Mayow, Black and Lavoisier. Mainly from the same side the physician and physicist, Thomas Young, first formulated the modern scientific conception of energy as the power of a material system to do work. Davy and Rumford contributed, and from the physiological side Mohr, Mayer and Helmholtz, and from the purely physical side, after preliminary work by Poncelet and Sadi-Carnot, Joule, Thomson and Clausius reached the same grand conception. The first to enunciate clearly and fully the doctrine of the conservation of energy and to measure the unit of mechanical work derived from heat was the physician, J. R. Mayer. Joule's work completed the demonstration, but Mayer's name is deservedly attached to this principle by Poincaré and others, as Lavoisier's is to that of the conservation of mass, and Sadi-Carnot's to the principle of degradation of energy. As regards this last principle it is almost as interesting to biologists as to physicists that in the so-called Brunonian movement, discovered by the physician and more eminent botanist, Robert Brown, and the subject of interesting physical investigations in recent years, we behold an apparent exception to the principle of degradation of energy, such as Clerk Maxwell pictured as possible to the operations of his sorting demon.

I must forego further citation of examples of this kind of correlation between the work of physicists and of physiologists, and leave untouched the chemical side, which is much richer in similar illustrations. The significance to organic chemistry of the synthesis of urea by Wöhler, and to agricultural chemistry of the bacteriological studies of nitrification in the soil and fixation of nitrogen in plants, will perhaps indicate how large and fascinating a field I must pass by.

The great advances in physics and chemistry initiated in France toward the end of the eighteenth and beginning of the nineteenth century were quickly reflected upon the medical and biological sciences through influences which in large part are attributable to this new movement in physical science. New methods of physical examination of the patient were introduced, and pathology and experimental and chemical physiology were developed as biological sciences of the first rank. This reformation of the medical sciences in the first third of the nineteenth century was mainly the work of Frenchmen, the great names in this development being those of Lavoisier, Bichat, Laennec and Magendie, the last a friend and physician of Laplace, and contemporary of Cuvier, who represented a like movement in zoology. Liebig, the pupil of Gay-Lussac and founder of biological chemistry as a distinct science, carried in the third decade of the century the new spirit to Germany, where Johannes Müller and his pupils became the center of a movement which rescued medicine and biology from the shackles of the philosophy of nature and has given Germany the supremacy in these fields of science. The experimental physiological work of the brothers Weber, two being physicians and the third the great physicist who was so intimately associated with Gauss in Göttingen, was of great influence in introducing the physical direction of physiological research, but Magendie stands first in making the experimental method the corner-stone of normal and pathological physiology and pharmacology.

Most pertinent to my theme is it to note that the light which has transformed the face of modern practical medicine came in the first instance not from a physician but from a physicist and chemist, Pasteur. The field of bacteriological study was placed on a firm foundation and thrown open to ready exploration by Robert Koch, and thereby that class of diseases most important to the human race, the infectious, became subject in ever-increasing measure to control by man. Thus hygiene and preventive medicine, through their power to check the incalculable waste of human life and health and activities, have come into relations, which have only begun to be appreciated, with educational, political, economic and other social sciences and conditions, and with the administration of national, state and municipal governments. It is an especial gratification to record the stimulating recognition of these relationships by the social and economic section of this association in which was started a year and a half ago a movement for public health, particularly as related to the federal government, which has already assumed national significance.

To the marvelous growth of the medical and other sciences of living beings during the past century, and especially in the last fifty years, physics and chemistry and the application of physical and chemical methods of study have contributed directly and indirectly a very large and ever-increasing share. In many instances there is no telling when or where or how some discovery or new invention may prove applicable to medical science or art. Who could have dreamed in 1856 that Sir William Perkin's production of the first aniline dye should be an essential link in the development of modern bacteriology and therefore in the crusade against tuberculosis and other infectious diseases? As Robert Koch has said, it would have been quite impossible for him to have developed his methods and made his discoveries without the possession of elective dyes for staining bacteria, and no other class of coloring agents has been discovered which can serve as substitutes for the anilines in this regard. And how much assistance these dyes have rendered to the study of the structure and even the function of cells! If we trace to their source the discovery of Röntgen's rays, which have found their chief practical application in medicine and surgery, we shall find an illustration scarcely less striking.

No important generalization in physical science is without its influence, often most important, upon biological conceptions and knowledge. I have already referred to the great principles of conservation of mass and of energy which are at the very foundation of our understanding of vital phenomena. Although we can not now foresee their bearings, we may be sure that the new theories, regarding the constitution of what has hitherto been called matter, will, as they are further developed, prove of the highest significance to our conceptions of the organic as well as of the inorganic world. Clerk Maxwell in his article on the atom in the ninth edition of the Encyclopædia Britannica, on the basis of a computation of the number of molecules in the smallest organized particle visible under the microscope, reached a conclusion which he states in these words:

> Molecular science . . . forbids the physiologist from imagining that structural details of infinitely small dimensions can furnish an explanation of the infinite variety which exists in the properties and functions of the most minute organism.

Larmor, in the tenth edition of the same work in his article on the ether, points out that upon the assumption of either vortex atoms or electric atoms physical science is concerned only with the atmosphere of the atom, that is with the modification impressed on the surrounding ether, whereas the nucleus or core of the atom may perhaps be taken into account in the problems of biology, although it would appear that nothing can be known of this nucleus. With still later developments of the dynamical hypothesis, which resolves matter into nothing but activity or energy, there are those who think that the hard knot of ages is to be untied and the animate and inanimate worlds come together under a satisfying monistic view of the whole as in essence active energy.

The ultimate problems of biology reside in the cell. Whatever the future may hold in store, at the present day only a relatively small part of these problems are approachable by physical or chemical methods, and the day is far distant, if it ever comes, when cellular physiology shall be nothing but applied physics and chemistry. We can not foresee a time when purely observational and descriptive biological studies, which to-day hold the first place, shall not continue to have their value. They represent the direction which makes the strongest appeal to the great majority of naturalists. The broadest generalizations hitherto attained in biology, the doctrine of the cell as the vital unit and the theory of organic evolution, have come from this biological, as distinguished from physical, direction of investigating living organisms, and were reached by men with the type of mind of the pure naturalist, who loves the study of forms, colors, habits, adaptations, inheritances of living beings.

It is well that the sciences of nature hold out attractions to so many different types of mind, for the edifice of science is built of material which must be drawn from many sources. A quarry opened in the interest of one enriches all of these sciences. The deeper we can lay the foundations and penetrate into the nature of things, the closer are the workers drawn together, the clearer becomes their community of purpose, and the more significant to the welfare of mankind the upbuilding of natural knowledge.

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SCIENTIFIC BOOKS

Neure Anschauungen auf dem Gebiete der Anorganischen Chemie. By ADOLPH WERNER. Braunschweig, Vieweg und Sohn. 1905. Pp. xii + 189. Price 6 marks.

The book before us presents a system for classifying inorganic compounds in such a way that "complex salts," "molecular compounds," hydrates, etc., as well as simple substances, may be included. The fundamental idea which underlies Werner's scheme is a new conception of valence. It is a well-established fact that in many cases compounds in which all of the valences of the individual atoms seem to be fully saturated, still possess the power of combining with other similarly saturated compounds to form complex salts. From this fact Werner draws the conclusion that we must drop our idea of independent, definitely directed valences. In place of this conception he introduces that of "affinity"—an attractive force acting, in the manner of an electrical charge on a sphere, from the center of the atom and uniformly distributed on its surface. Valence is then simply an empirical relation regarding the effect of this force on other atoms. Through considerations based on manifold experimental data he decides that this valence—the manifestation of "affinity" —must be of two kinds which he calls, respectively, *principal* and *subordinate* valence. The former produces the combinations of atoms met with in ordinary salts, giving rise to ionizable radicles; this property can be expressed in modern terms by saying that principal valences can bind atoms or molecules to electrons. Subordinate valences are also active in joining atoms to atoms, but in no case can they produce ionizable substances. Thus in the case of compounds between platinum, ammonia and chlorine we have the following series of compounds in which Cl outside of the brackets represents ionizable chlorine—primary valence—and that enclosed by the brackets non-ionizable chlorine—subordinate valence:

$$[Pt(NH_3)_6]Cl_4;\ \left[Pt{(NH_3)_5 \atop Cl}\right]Cl_3;\ \left[Pt{(NH_3)_4 \atop Cl_2}\right]Cl_2;\ \left[Pt{(NH_3)_3 \atop Cl_3}\right]Cl;\ \left[Pt{(NH_3)_2 \atop Cl_4}\right].$$

It will be seen that the total number of molecules bound directly to platinum is a constant —six—called by Werner the "coordination" number. He has found that for all of the elements forming "complex salts" this "coordination number" is either four or six.

That there is ground for Werner's dissatisfaction with the present conception of valence, no one can doubt, especially after reading the introductory chapters of this book. It is equally clear that in his new classification