THE FIRST CENTURY OF THE REPUBLIC.

[Fifteenth Paper.]

SCIENTIFIC PROGRESS.

I.—THE EXACT SCIENCES.—[*Concluded.*]

LIGHT, HEAT, ETC.

FROM the time of Newton to that of Young the science of optics made no material progress. The correction by Dollond, in 1758, of one of the few mistaken inferences of Newton, that the dispersive powers of transparent bodies are not proportional to their mean refractive powers, however practically important, was not a large contribution to theory; and Bradley's discovery of the aberration of light belongs rather to dynamics than to optics. It is, in fact, somewhat surprising that this latter phenomenon had not been recognized in anticipation of observation as a physical necessity, since the progressive motion of light had been demonstrated by Roemer half a century before. The first note of returning activity in the field of optical investigation was given by Dr. Young in the memoirs which, in 1800 and the two or three years following, he read before the Royal Society, reviving the hypothesis of Huyghens that light is propagated by undulations and not by the emission of material particles, and supporting this view by evidences and reasonings so cogent as to advance it to the dignity of a theory. It is a remarkable fact, illustrating the tenacity with which even enlightened minds cling to opinions long received without question, that these able and unanswerable papers failed to convince, or even, as is remarked by Principal Forbes, to secure a single adherent among the members of the learned body to which they were addressed. The discovery by Malus in 1808 of the polarization of light by reflection awakened a new interest in optical questions, and a large part of the history of this science during the first half of the nineteenth century is occupied with the development of the consequences of this discovery by Fresnel, Arago, Brewster, Seebeck, and others. Important contributions to the mathematical theory, left in some respects incomplete by Fresnel, were made by Cauchy, Macculagh, and Sir William Rowan Hamilton. No part of this belongs to American science.

Spectrum.—In 1802 Dr. Wollaston, of London, in observing through a prism the image of an elongated and very narrow aperture, perceived it to be intersected by well-defined straight lines perpendicular to its length—lines which Young seems to have regarded at first as boundaries between the several elementary colors of the spectrum. Dr. Brewster subsequently observed that certain bodies, solid, liquid, and gaseous, have the power of producing not lines only, but broad bands in the spectral image of the light transmitted through them. But the most remarkable discovery in this branch of investigation was made by Fraunhofer in 1814, who, employing a telescope to aid the observation, detected and was able to count nearly six hundred lines like those seen by Wollaston, fixed in position—a number which Brewster subsequently increased to two thousand, and which later observations have shown to be practically unlimited. The earliest investigations of this curious, but, as it has since appeared, highly important class of phenomena, undertaken in the United States, were made by Dr. John William Draper, of New York, a man whose name occupies a very conspicuous place in the world as well of letters as of science. Dr. Draper's labors in this department were spread over so large a field that it would be quite impracticable to do them justice in the limited space at our command. They embraced at once the physical, chemical, and thermal properties of light, and the relations of this principle to the organic world and the physiology of vision. He was the first to apply the method of photography to the study of the Fraunhofer lines. A memoir published by him in 1843 describes many new lines in the ultra-red and ultra-violet. The great bands in the ultra-red were first detected by him. Some of these were subsequently rediscovered by the aid of the thermo-multiplier. In 1844 he photographed the diffraction spectrum formed by a *Gitter-platte*, or ruled grating, and published a memoir showing the singular advantages which that spectrum possesses over the prismatic in investigations on radiation. Since the science of spectroscopy (a science of which the foundations were laid in Dr. Draper's early researches) has attained so high an importance in connection with investigations both of celestial and terrestrial chemistry, the spectrum has been photographed upon a much larger scale than was attempted by Dr. Draper.

The most admirable photograph of this kind, so far as the visible spectrum is concerned, was obtained by Mr. Lewis M. Rutherfurd, of New York, in 1866. It was enlarged from an original taken with prisms constructed of plate-glass, hollow, and filled with bisulphide of carbon—a plan first adopted by Professor O. N. Rood, in 1862. To a very powerful train of such prisms, six in number, made effectively twelve by means of a repeating prism, Mr. Rutherfurd subsequently applied a system of mechanical or automatic adjustment for varying the angular position without deranging the regularity of the train, which was the first contrivance of the kind ever invented. Of the map, eighty-two inches in length, and embracing more than 2500 sharply defined lines, Mr. Lockyer, the celebrated spectroscopist of London, remarked recently in a public lecture, it was a thing so admirable that he could not look at it without a feeling of the intensest envy. Still more recently (1873), Dr. Henry Draper, son of Dr. J. W. Draper, has produced a photograph of the ultra-violet rays of the diffraction spectrum which far exceeds in distinctness any thing previously attempted in this difficult spectral region. The gitter from which it was taken was ruled by Mr. Rutherfurd, who had long been engaged in the attempt to perfect plates suitable for this purpose. The earliest gitters were prepared by Fraunhofer, and were ruled through leaf metal or thin coatings of grease on glass. He subsequently ruled with a diamond point on the glass itself; but none of his rulings were closer than about 8000 lines to the inch, and none of over 3500 were regular enough to be serviceable. For the last twenty or thirty years the plates most in use by investigators have been furnished by Mr. F. A. Nobert, of Barth, in Pomeranian Prussia, who has carried his rulings to a degree of fineness far beyond that at which spectra cease altogether to be produced, the object being to provide tests for the resolving power of microscopes. Admirable as these productions certainly are, they are deficient in uniformity, which is the quality of most essential importance in the gratings required for the study of diffraction spectra. Mr. Rutherfurd's finer gratings have nearly 18,000 lines to the inch, and their uniformity, as tested by the sharpness of their definition of the spectral lines, is all but perfect. The delicacy of this ruling operation may be judged by the fact that when the machine which draws the lines is operated by hand, although not touched but only moved by a cord attached, the ruling is liable to be made uneven by the effect of expansion from the radiant heat of the person. In consequence of this, Mr. Rutherfurd resorted to the expedient of driving the machine by a miniature turbine wheel, with very satisfactory results.

The memoir of Dr. Henry Draper accompanying the photograph above mentioned was read before the French Academy of Sciences, and published in their *Comptes Rendus*. It has also been printed in full in the principal journals devoted to physical science in France, England, Italy, and Germany, and the discussion of the photograph has settled the wave lengths of all the ultra-violet rays, and has finally corrected the errors of previous observers.

The first suggestion of the relation between the spectra of incandescent or incandescing bodies and their physical condition or chemical composition was made by Dr. J. W. Draper, in an important memoir "On the Production of Light and Heat," published in 1847. This, among other things, pointed out the means of determining the solid or gaseous condition of the sun, the stars, and the nebulæ. In it the author demonstrated experimentally that all solid substances, and probably all liquids, become incandescent at the same temperature; that the temperature of red heat is about 977° F.; that the spectrum of an incandescent solid is continuous, containing neither bright nor dark fixed lines; that from common temperatures up to 977° F. the rays emitted by a solid produce no effect on vision, but that at that temperature they impress the eye with the sensation of red; that the heat of the incandescing body being made continuously to rise, other rays are added, increasing in refrangibility with increase of temperature; and that while the addition of rays so much the more refrangible as the temperature is higher is going on, there is an augmentation of the intensity of those already existing. In the following year, in a memoir on the production of light by chemical action, Dr. Draper gave the spectrum analysis of many different flames, and devised the arrangements of charts of their fixed lines in the manner now universally employed. The former of these memoirs had a circulation in American and foreign journals proportionate to its importance. An analysis of it in Italian was read in July, 1847, by Melloni, before the Royal Academy of Naples, and this was afterward translated into French and English. Yet, notwithstanding the publicity thus given to these discoveries, the same facts were thirteen years later published by Professor Kirchhoff, under the guise of mathematical deductions, with so slight a reference to the original discoverer that he secured substantially the entire credit of them himself; and in a historical sketch of spectrum analysis subsequently published, he omitted the name of Dr. Draper altogether. This is the more remarkable, as the historical sketch here referred to was professedly prepared because the writer had become aware of the existence "of some publications on the subject which he had not before known, and had found that other publications which had appeared to him to possess no special interest" were not similarly regarded by all. The object, therefore, of this sequel was "to complete the historical survey." It is entirely occupied, nevertheless, with an argument to disprove that any observer had contributed any thing to "the solution of the proposed question whether the bright lines of a glowing gas are solely dependent on its chemical constituents" until 1861, when it was solved by Bunsen and himself—excepting only Swan, who in 1857 identified the sodium line, although "he did not answer the question positively, or in its most general form." The writer considers and passes judgment on the claims of Herschel, Talbot, W. A. Miller, Wheatstone, Masson, Angström, Van der Willigen, and Plücker, all of whom had examined the well-known bright lines in the spectra of flames or of the electric spark, and had made suggestions indicating that this question had been present to their minds; but remarkably omits from the enumeration the name of the only observer whose publications were most directly suggestive of such a course of investigation as that which he himself subsequently pursued. In 1858, three years before the announcement of the results obtained by Bunsen and Kirchhoff, a memoir appeared by Dr. Draper on the nature of flame and the condition of the sun's surface, which was the precursor of the numerous investigations out of which has grown the imposing science of celestial chemistry.

The spectra of the stars were earliest studied by Mr. Rutherfurd, who published in 1863 a comparative map or diagram giving the spectra of seventeen different stars compared with those of the sun, the moon, and the planets Mars and Jupiter. The star spectra were arranged by him in three classes, to some extent corresponding to those since made by Secchi. In 1861 Professor Kirchhoff made public his well-known map of the solar spectrum, in which the very numerous lines given are determined in place by a millimetric scale. To remove the uncertainties attendant on the use of such a system, Dr. Wolcott Gibbs, of Harvard University, proposed, and to a certain extent constructed, in 1866, a normal map of the spectrum founded on wave lengths. His map embraced 187 lines lying between C and G of Fraunhofer. In 1871 a preliminary map or catalogue of the spectral lines of the solar chromosphere was published in the *Philosophical Magazine*, of London, by Professor C. A. Young, of Dartmouth College, which was afterward republished by Schellen in his large work on the spectroscope. This embraced 103 lines, identifying such as had been observed before, and giving the names of former observers. In the following year this number was increased by Professor Young to 273. The most important contribution to stellar spectroscopy yet made is a photograph of the spectrum of Alpha Lyræ taken by Dr. Henry Draper with his great speculum of twenty-eight inches aperture, showing in the invisible region four great groups of lines never before seen. This interesting result has been attained only after seventeen years of persevering effort, and is the fruit of probably the most difficult and costly experiment in celestial chemistry ever made.

The conclusion as to the chemical constitution of the heavenly bodies to which the study of their spectra has led, is that the same elements are found in them as in the earth, and only the same, with the single exception of a supposed element in the sun, called for the present, helium. But it appears that the temperatures of the different bodies must be materially different; and this difference is without doubt the occasion of the varieties of their spectral aspects, and of their very observable differences of color to the eye.

In regard to the distribution of heat in the spectrum, an important discovery was made by Dr. Draper so recently as 1872. He has shown that the observed decrease of the intensity of heat from the more to the less refrangible region, is due not to any inherent quality of the rays, but solely to the action of the prism itself, which compresses the less refrangible region and dilates the more refrangible.

Photography.—The sensibility of many chemical compounds to the action of light was very early observed. Attempts were made by Sir Humphry Davy and others early in this century to take advantage of this fact for the purpose of producing copies of prints, leaves, etc., by pressing them under glass against sheets of paper which had been impregnated with silver salts, and exposing them in the sunlight. Imperfect copies were obtained, but they were evanescent, no successful process having been discovered for removing the unchanged salt from the paper. They were counterparts of the originals, but presented, of course, the lights and shades reversed. For a number of years, beginning in about 1830, Mr. Nicephore Niepce and Mr. Daguerre in France, and Mr. Fox Talbot in England, occupied themselves in persevering endeavors to discover some mode by which the fleeting images might be fixed, and to increase the sensitiveness of the chemically prepared surface employed to receive the impression. These efforts were at length crowned with success. In 1839 Mr. Daguerre made public the beautiful process which bears his name, and this was immediately followed by the announcement of the very different one which Mr. Talbot had been engaged in perfecting, and which he was thus constrained somewhat prematurely to disclose. The production of these light-pictures was attributed to the action of a class of rays present in the sunlight, but non-luminous, called, for want of a better name, the chemical rays. For this term Dr. Draper proposed to substitute the name tithonic, from a fancied analogy with the fable of Tithonus, the favorite of Aurora; and somewhat later Sir John Herschel suggested the term actinic—a term which, in spite of its etymological vagueness, has since prevailed. In regard to this class of rays, the researches of Dr. Draper, protracted through a period of ten or fifteen years, commencing about 1835, were more fertile of results than those of any contemporary investigator. Though embracing the class of phenomena on which the art of photography has been founded, their scope was in the largest degree comprehensive. They included, among other things, experiments on the absorption of the chemical rays by solid and liquid media, the decomposition of carbonic acid by light, the interference of chemical rays, the crystallization of substances in the rays of light, the supposed magnetizing properties of the solar rays, which he found not to exist, and the effects of light upon vegetation. The memoirs published by him on these subjects in foreign and American journals amounted to nearly forty. Many of these were collected in 1844 in a large quarto volume, entitled, *A Treatise on the Forces which produce the Organization of Plants.* Particularly noticeable among these are a memoir explanatory of the mechanical cause of the flow of sap in plants, which is ascribed to the carbonization of water on the leaves by the light of the sun; and another, demonstrating that it is the yellow ray which produces the reduction of carbonic acid in plants, and not the violet, as had been previously supposed. The first photographic portraits of the human countenance were taken by Dr. Draper soon after the announcement of Daguerre's discovery, and at a time when such a thing had been pronounced impracticable by so high an authority as Sir David Brewster. He taught the art to Professor Morse, by whom it was long successfully practiced, and who possessed exclusively the secret until it was at length made public by the originator in the *London and Edinburgh Philosophical Magazine.* This consisted essentially in quickening the sensitiveness of the Daguerrean plates by brief exposure to the vapor of bromine. By this treatment they became so extremely sensitive as to receive an impression instantaneously in the open air, and in the light of an ordinary apartment in a very few seconds. About the same time, and while the method of Dr. Draper was still undisclosed, a similar result was attained by the writer of this article by the use of chlorine. Photographs of the moon were taken by Dr. Draper as early as 1840, at a time when the moon's rays were supposed to possess no actinic power, and when, in fact, bright objects strongly illuminated by the intensest light of the full moon failed, after hours of exposure, to produce any trace of an impression on the plates of Daguerre. These photographs showed very well the light and shade characteristic of the different regions of the satellite, though by no means comparable to the magnificent photographs since taken by Dr. Henry Draper and by Mr. Rutherfurd.

The useful applications of the photographic art are very numerous. In portraiture it has created a special industry, large and lucrative, and of world-wide popularity. In mechanical engineering and in every branch of constructive art it furnishes the means of obtaining designs of the most complicated machinery or structures without the expenditure of time and labor necessary for the execution of drawings. It provides a perfect means of cultivating the popular taste or of instructing the popular intelligence by bringing faithful representations of the choicest works of art, or of the most interesting scenes of nature and of human life, within the reach of every one. Aided by the ingenious invention of Professor Wheatstone, the stereoscope, it actually seems to reproduce before us the objects which it represents, with all the aspect of reality. In its later degrees of perfection it has made it possible to prepare plates from which prints in ink can be directly taken; and as an aid to the lithographic art it has substituted a direct impression on the stone for the patient labor of the engraver or the draughtsman. In the magnetic observatories established by the British and other European governments, it traces the record of the daily and hourly fluctuations of the magnetic elements; and it has in some instances been employed to record in like manner the indications of the barometer and the thermometer. Its highest applications are undoubtedly to astronomy, to uranographical measurements according to the method of Mr. Rutherfurd, to the study of the solar and stellar spectra as practiced by Mr. Rutherfurd and Dr. H. Draper, to that of the sun spots so perseveringly pursued by De la Rue, Loewy, and Carrington, and to fixing the phases of solar eclipses, and of still more rare phenomena, like the transit of Venus.

Production of Cold.—One of the most important applications of the principles of physics to a practical purpose is to be found in the various forms of apparatus at present in use for the artificial production of cold. All of these owe their efficacy to the absorption of heat which takes place in the vaporization of highly volatile liquids; and the discovery that this principle can be practically and economically utilized is due to our countryman, Professor A. C. Twining, of New Haven, by whom the first apparatus for the purpose on a working scale ever constructed was put into operation in 1850, and was made the subject of a patent in this country and in England. Professor Twining made use of common sulphuric ether as the liquid to be vaporized. Subsequently

Mr. Tellier, an English inventor, substituted for this, methylic ether, which has the advantage of being greatly more volatile; and Mr. Carré, of Paris, employed liquefied ammoniacal gas, which possesses the same advantage in a still higher degree. An important industry has grown out of this discovery, which is every year enlarging the magnitude of its operations.

The Microscope.—The discovery made in 1829 by Mr. J. J. Lister, of London, that every achromatic combination of lenses has two aplanatic foci, and that by the combination of two achromatics the spherical aberration of oblique pencils can be effectually suppressed, formed an epoch in the history of this instrument from which dates an almost miraculously rapid advance toward perfection. Results toward which Chevallier and others had been blindly feeling their way without ever satisfactorily reaching them were now made dependent upon well-ascertained principles; and the question who should produce the best microscope became a question of relative ingenuity in the application of theory no less than of practical skill in producing the curves which theory dictated. In 1846 Mr. Charles S. Spencer, a young, self-taught, and previously unknown optician living in the interior of the State of New York, submitted to the microscopists of the country microscopic objectives exhibiting a sharpness of definition and power of resolution which excited the greatest surprise, and entitled them to be esteemed, for the time at least, as superior to any other known in the world. The great multiplication of microscopic observers produced by the wonderful improvement of the instrument, and the great increase in the demand for objectives consequent upon the multiplication of observers, soon, however, produced the natural effect of rivalry among opticians, and foreign objectives appeared which justly challenged comparison with those of Mr. Spencer. In the subsequent progress of improvement the artisans of England, France, Germany, and the United States have maintained a pretty equal strife. Mr. Spencer still sustains the high reputation which he so early established; and upon the same plane with him may be placed Mr. R. B. Tolles, of Boston, and Mr. William Wales, of Fort Edward, New Jersey. Of the naturalists among us who have devoted themselves to the use of the microscope, none have done more honor to the science of our country than the late Professor Bailey, of West Point, whose contributions to the knowledge of the diatomaceæ are distributed through the journals and Transactions, and Professor H. L. Smith, of Hobart College, one of the highest living authorities upon this order of the algæ, who has now in the hands of the Smithsonian Institution, awaiting publication, a systematic and comprehensive monograph on the subject, founded on the studies and observations of twenty years, and illustrated with numerous original drawings from nature.

ELECTRICITY, MAGNETISM, ETC.

Down to the end of the eighteenth century the science of electricity existed only in a very elementary condition. Its phenomena, so far as they were known, belonged to static electricity only, and were referred to the agency of a subtle fluid or fluids present every where, but becoming manifest only when in a state of disturbed equilibrium. The hypothesis of a single electrical fluid is usually ascribed to Franklin, and passes by his name, though Leslie claims that it had been earlier suggested by Watson, of London. The opposing hypothesis of Dufay presumed the existence of two fluids neutralizing each other in the ordinary condition of bodies by their union, and exhibiting attractions and repulsions when separated. The Franklinian hypothesis is liable to the objection that it necessitates the supposition that material bodies deprived of electricity are mutually repellent. But neither is any longer entertained. Franklin demonstrated the identity of lightning with the ordinary electric spark as early as 1752. It is commonly believed that the first suspicion of this identity originated with him; but it had already been suggested by Nollet in 1746, who compared a thunder-cloud to the prime conductor of an electrical machine (it resembles more nearly one coating of a Leyden-jar), and had been urged in a plausible course of reasoning by Winkler. Franklin's merit was that he suggested the means of setting the question forever at rest by actually drawing electricity out of the clouds. It is a curious fact that he was not the first to try his own experiment. The plan he had publicly proposed was to erect on some eminence a lofty insulated iron rod tapering to a point; and this plan was followed by Dalibard, who drew sparks from such a rod erected near Paris, and even charged from it a Leyden-jar, as early as the 10th of May, 1752. The famous kite experiment of Franklin was performed more than a month later, on the 15th of June; but in those days, in which ocean cables and steamships were equally unknown, he was, of course, ignorant of Dalibard's previous success. It is upon this experiment that the immense reputation of Franklin as a man of science mainly rests. Considering the simplicity of the conception and the still greater simplicity of the apparatus by which it was realized, we can not at this distance of time but be astonished at the profound impression it produced upon the world. Such was his popularity in France that, when he appeared as the representative of the American colonies at the court of Louis XVI., the sale of his portrait made the fortune of the engraver; and beneath this portrait was inscribed, by the minister of a monarch himself a few years later dethroned and executed as a tyrant, the famous legend,

"Eripuit cœlo fulmen, sceptrumque tyrannis."

Not long after this, moreover, the celebrated Erasmus Darwin, writing to compliment Franklin on having united philosophy to modern science, directed his letter merely to "Dr. Franklin, *America*," adding that he was almost disposed to write "Dr. Franklin, *The World*," there being but one Franklin, and that Franklin being known of all men. After making all allowance for the weight of Franklin's political position and the sound practical sense displayed in his writings on subjects of popular interest, there remains no doubt that his singular celebrity was due mainly, after all, to the association of his name with the lightning. The great discovery of Volta, just at the close of the century, originated a new and prolific branch of electrical science, not at first recognized as such. In the infancy of the investigation which this discovery opened, it was a first necessity of progress to improve the means by which the electric current is generated. For the inconvenient pile of the discoverer, trough batteries with immovable plates were soon introduced in England, and it was by means of such that Sir Humphry Davy made many of his very numerous and celebrated electro-chemical discoveries. Dr. Wollaston greatly improved these batteries by giving them a construction which caused both sides of the zincs to be effective, and permitted the plates to be removed from the troughs. But all these forms of apparatus were attended with the serious disadvantage that their power when in action rapidly declined, in consequence of the formation upon the negatives of a coating of minute bubbles of hydrogen gas. This difficulty was first effectually overcome by Dr. Robert Hare, of Philadelphia, who in 1820 introduced the form of voltaic battery which, from the intensity of its effects, he called the deflagrator. The deflagrator was made very compact by forming the metals into coils, their opposed surfaces being very near to each other, but separated by insulating wedges; but its important characteristic consisted of a mechanism by which the entire series of elements could be instantaneously immersed in the liquid or lifted out. For experiments of brief duration, therefore, the battery was always ready to act with its full power. A similar device occurred later to Faraday, but though it was original with him, he very honorably admitted that on examination he found this new battery to be "in all essential respects the same as that invented and described by Dr. Hare." Besides the deflagrator, Dr. Hare constructed another form of voltaic apparatus, designed with low intensity of electricity to generate an enormous volume of heat. This, which he called the calorimotor, was formed by combining many very large plates of zinc and copper into two series, and immersing them at once into a tank of dilute acid. By means of it large rods of iron or platinum are ignited and fused in a few seconds, and its magnetic effects are equally surprising; yet it is hardly capable of producing the faintest spark between carbon electrodes. Dr. Hare was an extremely voluminous writer on subjects connected with voltaic electricity and chemistry. Nearly one hundred and fifty articles from his pen may be found in the *Journal of Science* alone. In invention he was wonderfully fertile, and in the variety of ingenious contrivances devised and constructed by him in aid of investigation or for purposes of illustration, he deserves to be ranked with men like Hooke, Wollaston, and Wheatstone.

The constant battery, the next improvement in voltaic electro-motive apparatus, was produced by Daniell in 1836. It is a battery of four elements, two metallic and two liquid, the liquids being separated by a porous partition. In this arrangement the nascent hydrogen set free on the zinc side, combining with the oxygen of the metallic base of the solution on the copper side, no longer appears in the gaseous form, and the obstruction it had occasioned to circulation is thus suppressed. Daniell, nevertheless, was not the first to suggest a battery of four elements. The credit of this suggestion is due to Dr. John W. Draper, of New York, who, as early as 1834, described such a battery in the Journal of the Franklin Institute.

The relation of electricity to magnetism was a discovery accidentally made by Oersted, of Copenhagen, in 1819. He noticed that if a wire conveying a voltaic current be brought near a suspended magnetic needle, the needle will be deflected from its normal position. This remarkable discovery was followed by one no less remarkable, made simultaneously by Arago and Davy, that the conducting wire itself, whatever may be the material it is composed of, is capable, while conveying the voltaic current, of attracting soft iron. Ampère next discovered that two wires conveying electric currents attract each other if the currents are in the same direction, and repel if the directions are opposite. Upon this he founded his celebrated theory which made magnetism only one of the forms of manifestation of electrical force. This theory suggested to Arago the idea that a steel needle might possibly be magnetized by subjecting it to the action of an electric current passing spirally round it. He tested the truth of this conjecture, and his experiment was a success. A repetition of this experiment in modified form by Sturgeon, of Woolwich, England, in 1825, drew after it important consequences. Bending a piece of stout iron wire into the form of a horseshoe, and coating it with varnish to secure insulation, he wound round this a copper wire, which he introduced into the battery circuit. The iron wire thus treated became temporarily a feeble horseshoe magnet, capable of sustaining a weight of two or three pounds. At this stage of the investigation the subject attracted the attention of Professor Joseph Henry, of Albany, New York, and the next step in the progress of this history—a very large one—was taken by him. Considering that the intensity of the effect must be proportioned to the closeness of the coil, and that with a naked conductor the spirals could not permissibly be brought into contact, it occurred to him to insulate the conducting wire itself, which he did by winding it with silk. This expedient enabled him not only to envelop the iron closely in the first instance, but also to wind several successive coils over each other. The result was to produce an electro-magnet in the proper sense of the word—an instrument not limited in its use to the purposes of lecture-room illustration, but capable of important and largely varied practical applications. Some of the magnets constructed by Professor Henry sustained weights of between one and two tons.

In pursuing his investigations on this subject, Professor Henry ascertained a number of important facts concerning the laws of development of magnetism in soft iron. Having surrounded a given bar with a number of short helices abutting end to end, he tried the effect of first uniting the similar ends of these so as to make one short compound conductor, and of afterward uniting their dissimilar ends so as to make a single continuous conductor of them all. With a battery of a few elements, the first arrangement proved to be most effective, but with one of many, the second was superior. Hence the distinction introduced by him between quantity and intensity magnets.

The possible practical applications of the electro-magnet were not overlooked by Professor Henry, though he contented himself with pointing them out without pursuing them. The practicability of an electric telegraph was illustrated by him in an apparatus fitted up in 1831 in the Albany Academy, by which an electric current transmitted through a circuit of more than a mile was made to ring a bell. The invention of the first recording magnetic telegraph—that is, of the instrument by which signals are actually written down by magnetism, and not merely addressed to the sense of hearing or sight—was made by Professor S. F. B. Morse, of New York. He had conceived it as early as 1832. The instrument did not take form till some years later. It was impossible that either mode of signaling (the mode actually used by Professor Henry in 1831 or that conceived by Professor Morse in 1832) should come into public use or be economically a possibility so long as there existed no form of constant or sustaining battery, and the batteries of Daniell and Grove were only known in 1836 and 1837.

In the construction of long lines of telegraph it became early necessary to devise some practicable means of crossing the larger streams or the narrower estuaries by means of submerged conductors. When this had been successfully accomplished, the same system was naturally extended to the smaller seas or arms of the ocean, such as the British Channel and the Mediterranean. But when, a little more than twenty years ago, it was first proposed to lay an electric cable from continent to continent in the bed of the ocean itself, the audacity of the project was such that, at its first announcement, it struck the world as too visionary to be seriously considered. Even to contrive a form of conductor which should combine the strength and completeness of insulation indispensable to such a purpose, was a problem in applied science of no slight difficulty, and to lay it in its place demanded the exercise of mechanical skill of the highest order. Supposing it to have been laid, science, again, had not yet devised the means of making it available. The exhaustless energy and indomitable perseverance of Mr. Cyrus W. Field nevertheless triumphed at last over all the practical difficulties; and the patient study of the scientific side of the question by the electricians, especially by Sir William Thomson, with his marvelous fertility of invention, was equally successful in overcoming the rest. The electrical telegraph, therefore, one of the most magnificent gifts of science to the world, may be justly claimed as especially a gift of American science, and the energy which was mainly instrumental in giving it its latest and largest availability was no less American.

Professor Henry was the first to point out the practicability of applying electro-magnetism as a motive power, and in illustration of this he constructed an oscillating apparatus, described in the *American Journal of Science* in 1829. The attempts which have been made to turn this power practically to account have been very numerous. Almost or quite the earliest was made by Messrs. Davenport and Cook, of Vermont, in 1836. A machine in model exhibited by them in New York attracted much attention; but a working engine which they subsequently attempted did not meet their expectations. In all these forms of mechanism there is one unavoidable disadvantage, which in the infancy of the science was not known, consisting in the fact that the moving magnets generate in each other currents directly opposed to those from which their own magnetic energy is derived; and hence the dynamic power of the engine is not proportional to the static energy of its component magnets. Electro-magnetic engines of some power have in a few instances been tried, and subsequently abandoned, not on account of any mechanical failure, but for reasons of economy. One of this description, constructed under the direction of De Jacobi at the expense of the Emperor of Russia, was employed to propel a boat on the Neva. Another was the electro-magnetic locomotive of our countryman Dr. Charles G. Page. This was remarkable for its original and ingenious method of applying the power, which was by means of solid cylindrical steel magnets rising and descending in the interior of a pile of short helices, the helices being successively thrown into and out of the circuit. With two such engines, Dr. Page drove a car weighing eleven tons and carrying fourteen passengers on a level track at the rate of nineteen miles an hour. Electro-magnetic engines can never compete with steam-engines in point of economy until it shall be possible to construct batteries in which the materials consumed shall be, weight for weight, a great deal cheaper than coal. Experimentally it has been proved that a grain of coal consumed under the boiler of a Cornish engine lifts 143 pounds one foot high, while a grain of zinc consumed in a battery to move an electro-magnetic engine lifts only eighty pounds to the same height. But it requires the consumption of a number of grains of coal to produce one grain of zinc.

The applications of the electro-magnet to purposes of use are too various to permit here an enumeration in detail. The astronomical electro-magnetic chronograph has been already mentioned. The instruments for measuring still more minute intervals of time, called chronoscopes, are dependent, in several of their large variety of forms, on similar means of operation. This same remark may be made of numerous very ingenious and very valuable contrivances introduced in recent years for demonstrating the laws of falling bodies, for registering vibrations in acoustics, for recording the indications of meteorological instruments, and for many other purposes auxiliary to scientific investigation.

As more practical applications, there may be mentioned fire-alarms, by means of which information of the exact locality of a fire in any large city may be instantaneously communicated to the central office, and definite orders issued at once to fire-companies how to proceed; burglar-alarms, which instantly indicate the door or window in a dwelling at which entrance has been attempted, and at the same time turn on a light and arouse the sleepers by ringing bells or sounding rattles; time-balls dropped in centres of business or in sea-ports by electrical communication from distant astronomical observatories; and clocks operated by electro-magnetism as a motive power, or systems of dials by which a single clock may show simultaneously the same time in every part of a large business establishment. In the year 1859 a clock of peculiar and original design, operated by electro-magnetism, was constructed, under the direction of the writer of this article, by Mr. E. S. Ritchie, of Boston, for the observatory of the University of Mississippi. The pendulum was entirely free, the force required to maintain its motion being applied by depositing a very light weight (of one or two grains) upon an arm of the pendulum at the beginning of the swing, and removing it in the middle, by an arrangement of electro-magnets. The small weight served itself to make and break the battery connections necessary to actuate the auxiliary mechanism. The intention was, by relieving the pendulum from the work of operating the escapement, and by reducing its swing as low as possible (to a fraction of a degree), to remove every external cause which might interfere with the perfect uniformity of its beat. But a very low power was required to run it. A single cell of Farmer's so-called water battery (pure water next the zinc, and copper sulphate next the copper) was sufficient to maintain its action, but two were commonly used. Mechanically it was a perfect success, but after some months of action it was found that the electric contacts became vitiated by the spark produced, even with that low power, at every rupture of the circuit, and the current ceased to flow. Though the most refractory metals were employed, they were still vaporized and oxidized. The difficulty was at length overcome by introducing Fizeau's condenser into the circuit, by which the spark was effectually suppressed; but owing to the troubles of the times, which prevented the completion of the observatory, it was never brought into use.

Within recent years some interesting contributions to the progress of electro-magnetic science have been made in this country by Professor A. F. Mayer, of Hoboken, New Jersey, Professor John Trowbridge, of Harvard University, and others. Professor Mayer's experiments have led to some very important deductions as to the most effective forms of soft iron core to be given to electro-magnets, and have shown that in general, when such cores are solid cylinders, the central portion is practically ineffective, and may be removed without diminishing the power of the magnet. They have shown also that the inducing action of the enveloping wire on itself, or that of the adjoining spirals on each other, has no effect on their power to magnetize the core, or on the intensity of the current passing through them. We owe also to Professor Mayer one of the most delicate and at the same time simple modes yet devised of investigating the resistance of conductors to electric currents passing through them.

That the molecular changes produced in a bar of iron by magnetization are attended with simultaneous changes of dimensions, was rendered probable by the observation (made many years ago by Dr. Page) that they are attended by audible sounds, and was experimentally proved by Joule and Wertheim. By a very elaborate and carefully conducted investigation, aided by the exceedingly delicate micrometric comparator constructed for the Coast Survey by Mr. Joseph Saxton, Professor Mayer has determined quantitatively the precise character and magnitude of these changes. Professor Trowbridge has also made some interesting discoveries relating to this subject, among which is the fact that if the core of an electro-magnet be made a part of a voltaic circuit, and the magnetizing current be then sent through the enveloping helix by another battery, a magnetic power may be obtained materially greater than that which the latter current is capable of producing alone, but that this effect will not be repeated if the magnetizing circuit be broken and again renewed.

Voltaic Induction.—The power of a voltaic current to induce currents in neighboring conductors was discovered by Faraday in 1831. If both conductors are motionless, the induced current is but momentary, occurring only when the primary current begins or ceases to flow. If they approach toward or recede from each other, the induced current is continuous so long as this movement continues, being opposite in direction to the primary while approaching, and similar in direction while receding. By using helices instead of single conductors, Mr. Faraday succeeded in producing induced currents of great energy. In the same year Professor Henry made the remarkable discovery that a voltaic current induces an extra current in the conductor in which it is itself conveyed, which, however, manifests itself only on making or breaking connection with the battery, the intensity being proportional to the length of the conductor, and being greatly increased by giving the conductor the form of a close spiral. Professor Henry demonstrated later that, if a series of closed circuits be placed side by side, the first receiving a primary current from the battery, then on making or breaking battery connection a series of induced currents will be generated in these several circuits, which will be alternately in opposite directions. The system of conductors best adapted to this demonstration is a series of flat spirals known as Henry's coils, formed of wire, or better of copper ribbon, insulated. Induced currents of the ninth order have thus been demonstrated, and the possible number is theoretically unlimited.

Magneto-Electricity.—The year 1831 was very fruitful of electrical discovery. It was in this year that Faraday detected the power of a permanent steel magnet to induce electric currents in neighboring conductors, and in this year also he succeeded in producing from the induction of such a magnet a visible electric spark. From this memorable discovery the science of magneto-electricity takes its date. Almost immediately after it a powerful magneto-electric machine was constructed by Mr. Joseph Saxton, of Philadelphia, which was almost the first of its kind. Another, still more powerful, was subsequently invented by Dr. Page, who added the simple but ingenious contrivance called the pole-changer, by which the currents, incessantly reversed in the helices of the machine, are transmitted through the circuit in one constant direction. With this improvement the machine may be made a substitute for a galvanic battery in the operations of electrolysis. Magneto-electric machines have consequently in recent years to a large extent superseded batteries for many important practical purposes. The galvano-plastic art, so largely employed in copying in fac-simile objects of ornament and use, in plating and gilding, in duplicating the plates of the engraver, in stereotyping pages for the letter-press, and in a variety of other ways, is now conducted almost entirely by the use of these machines. Constructed on a large scale, they have been employed by the governments of France and England to furnish electric lights for some of their most important light-houses.

Induction Coils.—After the power of a permanent magnet to induce electric currents had been demonstrated, it could not be doubted that electro-magnets would do the same. This was Faraday's inference, and experiment confirmed the anticipation. A secondary coil, surrounding but independent of the coil of an electro-magnet, gave currents whenever the battery connection of the magnet was made or broken. In this discovery is found the first suggestion of a form of electrical apparatus which has in recent years become a powerful instrument of physical investigation, the induction coil. In its earliest form this apparatus was the invention of our countryman, Dr. Page, and was called by him the "separable helix."

There was an inner helix, fixed upright upon a support, into the hollow interior of which might be introduced bars or wires of soft iron. An outer helix, which was removable, was designed to convey the induced current. Dr. Page, in the study of this instrument, made several important discoveries. These were, first, that the intensity of the induced current may be greatly increased by making the wire of the secondary coil many times longer, and also very much smaller, than the primary; secondly, that the effect of a number of soft iron wires introduced into the inner coil is vastly greater than that obtainable from the same weight of iron in a single bar; and thirdly, that unless the primary current is broken very abruptly, the induced current of that circuit will leap over the break, neutralizing to some extent, by secondary induction, the induced current in the outer coil. To counteract this he invented an ingenious and successful contrivance called the spark-arresting circuit-breaker. These discoveries date back to 1838 and earlier. In 1853 Mr. Fizeau, of Paris, suggested the use of a condenser constructed on the principle of the Leyden-jar, as a means of absorbing the extra current in the primary; and this has since superseded Page's circuit-breaker. About the same time Mr. Ruhmkorff, of Paris, commenced the construction of the induction coils known by his name, which were in no respect different, except in magnitude, from the separable helices of Page above described, but which attracted much attention in consequence of the length of spark they produced. This, in Page's instrument, had hardly exceeded one-eighth of an inch; but in Ruhmkorff's it was increased to nearly an entire inch, and in his later instruments to two or three inches. A practical limit to increase of power in this direction was, however, found in the liability of currents of high intensity to strike through the insulation from layer to layer of the secondary coil. This liability is the greater in proportion as the points of the wire of the helix which are brought near each other in winding, are more distant as measured upon the length of the wire itself. As a means of preventing it, it occurred to Mr. Ritchie to wind the wire in many flat spirals, placing these side by side and connecting them at their inner and outer extremities, so as to form a continuous helical conductor of which no two points should be more distant from each other, measured along the wire, than the length of two such contiguous spirals, developed. The result was a surprising increase in the length of spark, which has been carried up by him to twelve, fifteen, and even twenty inches. One of Mr. Ritchie's coils was exhibited in Paris in 1860, by Professor McCulloh, of Columbia College, New York. By an examination of this, Mr. Ruhmkorff became acquainted with the mode of its construction, which Mr. Ritchie had not previously disclosed, and adopting it, produced others of enormous power—one of which projected sparks two feet in length. For this great success, mainly due to the ingenuity of our countryman, Mr. Ruhmkorff received in 1864 the prize of 50,000 francs offered in 1852 by Napoleon III. for the most important discovery connected with the progress of electricity.

Static Electricity.—Some very interesting discoveries in static electricity were made by Professor Henry as early as 1830. He demonstrated that the discharge of a Leyden-jar consists of a series of oscillations backward and forward, something like the vibration of a spring. The mode of proof employed in this demonstration is at once simple and ingenious. It rests on the two experimentally ascertained facts—first, that a steel needle may be magnetized by surrounding it with a spiral conductor, and sending through the conductor the discharge of a Leyden-jar; and secondly, that there is a point of saturation beyond which the needle will not receive magnetism. By passing successive discharges of gradually increasing intensity through the coil, the needle will undergo changes of polarity, showing that it derives its magnetism alternately from the direct and the reversed movement of the electric force. It follows that the electric spark, though to the eye apparently single, is, in fact, made up of many sparks. This multiplicity has recently been optically demonstrated by Professor Rood, of Columbia College, who, by means of a rapidly rotating mirror, has made the successive component sparks visible. A very striking palpable demonstration of the same fact was also exhibited to the National Academy of Sciences in November, 1874, by Professor A. M. Mayer, of Hoboken, New Jersey. Professor Mayer caused disks of blackened tissue-paper to revolve with great rapidity between the points through which the discharge of the Leyden-jar is made. Subsequent examination of the disk shows it to be perforated with a very great number of minute holes along the circular arc which was passing between the points during the brief continuance of the discharge.

The fact which he had demonstrated of the jar, Professor Henry afterward proved to be true of thunder-clouds. These stand to the earth beneath them in the relation of the coatings of the jar, the stratum of air between being the insulating medium. When the insulation is broken through, the lightning flash which follows is multiple and oscillating, presenting on a grand scale an analogy to the discharge of the jar.

The duration of flashes of lightning, as well as of the spark from the jar, has been the subject of interesting investigations by Professor Rood, in which he has succeeded in measuring more minute intervals of time than have ever before been made the subject of exact determination. By his methods, which appear to be quite unexceptionable, it is proved that a jar of small surface discharges itself in a space of time not greater than forty one-billionths of a second; and that its light, though of inconceivably brief duration, makes surrounding objects perfectly visible. As there is reason to believe that this time is at least tenfold greater than is necessary to impress the retina, it follows that the perfect sensation of vision may be excited in an interval as brief as four one-billionths of a second. The duration of lightning flashes is much greater. Besides investigating the form and nature of the spark by optical methods, as already mentioned, Professor Rood has employed photography in the same research, and has demonstrated marked differences between the positive and negative sparks, as well as between the sparks obtained through the jar from the induction coil and from the common frictional machine.

In thermo-electricity not much has been done by American investigators. In 1840 Dr. J. W. Draper published a memoir on the electro-motive power of heat, with descriptions of improved thermo-electrical couples. A pretty effective thermo-electric battery has been constructed by Mr. Farmer, of Boston, thirty-six elements of which are about equivalent to one of Grove's nitric acid elements. Professor Rood has made an interesting application of a thermo-electrical couple to the determination of the heat produced by percussion when the mechanical force exerted is very small. He has been able thus to demonstrate that in the fall of a weight of a single pound through trivial heights, varying from one to five inches, the amount of heat generated is measurable, and is directly as the amount of living force acquired by the body in falling.

CHEMISTRY.

Chemistry as a science may be said to have been the creation of the century we are reviewing. Many important facts which have now a recognized place in this science had, it is true, been previously gathered; but they were either facts of accidental discovery, or they had been discovered in the course of investigations guided by no intelligent theory. The doctrine of phlogiston, introduced early in the eighteenth century by Stahl, though now usually spoken of as a reproach to the science of that age, was really a step of progress, for it was part of a system which proposed to ascertain by experimental research the elementary composition of natural bodies. But it is also true that the overthrow of that doctrine by Lavoisier, near the end of the same century, forms the epoch from which modern chemistry in a proper sense takes its rise. The contemporaries of this great philosopher, Black, Cavendish, and Priestley in England, Scheele in Sweden, and Wenzel in Saxony, contributed largely by their discoveries, and by their researches on heat and on the laws of chemical affinity, to build up the new science on a rational basis. The doctrine of definite proportions, which had been already substantially established by the labors of Higgins, Proust, and Richter, was formally announced by Dalton in his atomic theory, taught as early as 1804 and published in 1808. The question whether there does not exist, also, a law of definite proportion between the combining or equivalent weights of the different bodies called elementary, was naturally suggested as a consequence of this discovery. When the numbers are compared with the assumption of any particular equivalent weight as unity, while the results are in many cases integral, there remain always some which continue to be fractional. A comparatively recent and laborious investigation of this subject, however, by Dumas, has led to the result that when a unit is adopted which is equal to one-fourth of the equivalent weight of hydrogen, all the numbers are integral. It is, therefore, a view not without plausibility, entertained by some chemists at present, that all the bodies commonly called elementary may be compounds; and even that, on a complete decomposition of them all, there might remain but a single elementary substance. The power of heat, when sufficiently exalted in temperature, to break up all known chemical compounds, has been fully established of late years by Henri St. Clair Deville; and spectroscopic observation has shown that many substances exist as vapors in the sun and the stars which no degree of heat which we can artificially produce upon the earth is competent to vaporize. It is therefore not unreasonable to presume that, if there is such a primitive elementary matter as is above supposed, it may be set free in the intense heat of the self-luminous celestial bodies. And it is an interesting fact that, in the spectroscopic examination of the envelopes of the sun, there are detected lines which belong to no element known upon our planet, and which seem also to indicate the presence of a substance lighter than hydrogen.

Organic chemistry, or the chemistry of animal and vegetable compounds, became early a distinct department of the science. The study of organized bodies led to the discovery of *series*, in which a number of bodies differ from each other only in the number of times a simpler definite combination is repeated in their formulæ. This discovery was first distinctly announced by Dr. James Shiel, of St. Louis, Missouri. In this same study also was found the conception of types, in which one element may be replaced by another—a conception which lies at the foundation of the chemical science of the present day. This conception, originated by Dumas, and followed up and developed by Laurent and Gerhardt, was first reduced to its most simple and satisfactory form of expression by Professor T. Sterry Hunt, now of Boston, who so early as 1848 demonstrated that all the various saline forms are reducible to two, the types of which are seen in water, and in hydrogen with the equivalent doubled. In a series of papers published subsequently at intervals, Professor Hunt further applied these views and extended them to embrace the multiple or condensed types afterward adopted by Williamson and Gerhardt, to whom the entire credit of these important generalizations has been often ascribed in foreign publications.

So wide is the field covered by the science of chemistry, and so rapid has been the growth of the science during the last half century, that any attempt in the brief space at our disposal to do justice to the numerous laborers to whose activity this great progress is due, would be vain. In this department of science our country has produced a larger number of active investigators than in any other, and of these also a larger proportion have become honorably eminent. We must content ourselves in this place with mentioning a few only of the names which have become worthily identified with the history of American chemistry. Among the early teachers of this science in our country who, without engaging largely in original research, did good service in their enlightened defense of the doctrines of the new school of Lavoisier, may be fitly mentioned Dr. John Maclean, of Princeton College (elected 1795), Dr. Benjamin Rush, of the University of Pennsylvania (1769), Dr. James Woodhouse, of the same institution (1795), and Dr. Samuel L. Mitchill, of Columbia College, New York (1792). Both Dr. Woodhouse and Dr. Mitchill published somewhat largely upon chemical topics. Dr. Mitchill was a man of exceptionally varied attainments, but his favorite studies were in natural history, especially in zoology, in which he was long regarded as the highest authority in the United States.

In 1801 there was read before the Chemical Society of Philadelphia a memoir "On the Supply and Application of the Blow-Pipe," by a young man of twenty years of age, destined subsequently to attain a high celebrity—Robert Hare. In this was described the apparatus long known as "Hare's compound blow-pipe," and more recently as the oxyhydrogen blow-pipe, the most powerful means yet known for generating artificial heat. The apparatus referred to was not so much an invention, in the ordinary sense of the word, as a logical deduction from a consideration of the conditions necessary to secure the maximum effect from a given amount of heat generated. Lavoisier and others had obtained remarkable effects by directing a stream of oxygen upon ignited carbon. In this case, however, though the body to be operated on was raised to a very high temperature on the side which rested on the carbon support, this temperature did not reach the upper surface, and the fusion or volatilization attempted was only partially accomplished. Mr. Hare reflected that this difficulty might be got over if some means could be discovered of "clothing the upper surface with some burning matter the heat of which might be equal to that of the incandescent carbon." It soon occurred to him that a flame produced by the combustion of the oxygen and hydrogen gases ought, "according to the theory of the French chemists" (for this was in advance of any demonstration), to be attended with a higher heat than even that generated by the combustion of carbon. But it was known that a mixture of oxygen and hydrogen in proper proportion to produce a complete combustion is dangerously explosive, and in order to attain the end in view some means of creating the flame had to be devised which should be free from this danger. The expedient actually adopted—that of storing the gases in separate vessels and bringing them together by tubes which meet at the point of ignition—seems simple enough now; but that it was not so obvious as it seems is made evident by the fact that, some fifteen years later, Dr. E. D. Clarke, Professor of Mineralogy in Cambridge, England, introduced and employed an oxyhydrogen blow-pipe in which the gases were mingled in explosive proportions in the same vessel. If Dr. Clarke, in 1816, knew nothing of what Hare had done in 1802, and had described in the same year in *Tilloch's Philosophical Magazine*, the construction he gave his apparatus proves that the artifice by which the original inventor provided against the possibility of explosion was one which would not readily occur to any but an ingenious mind. If he did possess a previous knowledge of the invention of Hare, his silence in his own paper in regard to it admits of no honorable explanation. The blow-pipe was but one of Dr. Hare's very numerous contributions to the instrumental means of chemical investigation, but we have room for the mention of no other.

Professor Benjamin Silliman, the elder, Professor of Chemistry in Yale College (elected 1802), continued for a long series of years to occupy a very conspicuous position in the world of American science. Though he published a large number of papers on chemical topics, as well as a voluminous systematic treatise on the general subject, his early acquired reputation rested in great measure on his eloquent and forceful presentation of the truths of science to his numerous classes and to popular audiences. The monument which will speak most enduringly of his labors, however, is undoubtedly the *Journal of Science*, one of the most powerful stimulants of the scientific spirit which has existed among us, established by him when this spirit was at a low ebb, and maintained by him almost single-handed for years under discouragements against which few would have had the energy to persevere.

Dr. Samuel Guthrie, of Sackett's Harbor, New York, deserves mention here as the discoverer of the very remarkable anæsthetic compound known as chloroform. It is a little curious that the same discovery was made about the same time by Soubeiran, a French chemist, and that both discoverers were similarly mistaken as to its nature, and both called it chloric ether. Soubeiran published his discovery in February, 1831, and Guthrie his in January, 1832. It was not till 1834 that the true constitution of the substance was understood, when it was analyzed by Dumas, who gave it the name it has since borne.

The numerous and important contributions of Dr. John W. Draper to physical science have been already mentioned. His chemical researches are scarcely less original, though many of them occupy the border region between physics and chemistry. The most noticeable are his ingenious experiments and deductions on osmosis, and on interstitial movements taking place among the molecules of a solid, as in cases of alloys in which the adulterating metals make their way to the surface. Also his beautiful and sensitive photometric apparatus, called by him originally the tithometer, in which chlorine and hydrogen are mingled in combining proportions. In absolute darkness the gases remain free, but on exposure to light they combine with a rapidity dependent on the intensity. One of his later publications is his treatise on *Human Physiology*, which discusses with much originality questions concerning the chemistry of animal life, as well as the chemical and physical functions of the various organs of the body.

Dr. William B. Rogers, of Boston, has published many chemical papers, some of them of special interest. One of these embraces the discovery that the thermal springs of Virginia contain free nitrogen in large proportion, exceeding in quantity the carbonic acid and the hydrogen sulphide. Another describes a method of determining carbon in graphite, which is still one of the best methods of effecting the same determination in the analysis of cast iron.

Dr. Charles T. Jackson, of Boston, has been one of the most active investigators the country has produced. His chemical and geological papers number nearly seventy. What has given him probably a wider reputation than any other of his discoveries has been the efficacy of ether to produce anæsthesia. For this he has been made the recipient of honorable decorations from many European governments, yet his title to the credit attributed to him has been contested by two of his countrymen, both now deceased—Dr. W. T. G. Morton, of Boston, and Dr. Horace Wells, of Hartford.

Dr. James Blake, of San Francisco, is noticeable for his interesting researches in physiological chemistry made by experiments on the living subject. Two of his conclusions are striking: first, that the character of the changes produced in living matter by inorganic compounds depends more on the physical properties of the reagent than on the chemical; and second, that the action of such compounds on living matter appears not to be related to the changes which they produce in the same substances when not living.

Dr. Wolcott Gibbs, now Rumford Professor of the Applications of Science in Harvard University, commenced his career as an investigator while an under-graduate in Columbia College, in 1840, in a description of a new form of magneto-electric machine, and an account of a carbon voltaic battery. This, it will be perceived, was earlier than the date of Bunsen's carbon battery. The contributions of Dr. Gibbs both to chemistry and to physics have been very numerous. The more important relating to chemistry are, "New General Methods of Chemical Analysis," "Theory of Polybasic Acids," "Researches on the Platinum Metals," and, in association with Professor Genth, "Researches on the Ammonio-Cobalt Bases"—a memoir which occupied the authors several years, and is more full of new results than any chemical research before undertaken in this country. This was published in 1857 among the *Smithsonian Contributions to Knowledge.*

Dr. Gibbs has recently announced the empirical discovery of a new optical constant, which may possibly prove to be an important contribution to the resources of the analytic chemist. The number of interference bands produced in the spectrum between two given wave lengths by the partial interception of the light falling on the prism by any transparent substance is different for different substances, and for the same substance diminishes as the density diminishes with increase of temperature. For any given substance, therefore, and for a constant thickness, the actual number of bands produced, divided by the density, gives a sensibly constant quotient; and this quotient is called by Dr. Gibbs the interferential constant. Its value in mixtures is a function of the values belonging to the components, and in compounds a function, apparently, of those of the molecular constituents; hence its probable usefulness in the operations of analysis.

Professor Frederick A. Genth, of the University of Pennsylvania, a native of Germany, was a chemist of distinction before coming to this country. The first ammonio-cobalt bases were discovered by him in 1846. As an analytic chemist he is without a superior. His chemical labors of recent years have been chiefly contributions to the chemical constitution of minerals.

Dr. J. Lawrence Smith, of Louisville, is the author of many valuable researches in chemistry and mineralogy. In 1850 he addressed an important memoir to the Academy of Sciences of Paris on the geology, mineralogy, and chemical history of emery, prepared after a thorough examination of the emery deposits of Asia Minor. This subject had been previously but little understood, and the memoir was received with marks of high approbation. Dr. Smith has made larger investigations upon the physical and chemical constitution of meteorites than any other American chemist. Of his very numerous scientific papers he has recently collected and published forty-seven in a volume.

Professor T. Sterry Hunt, whose name has been already mentioned, has been the most active contributor to theoretic chemistry in the United States. The credit due to him in the construction of the theory of types has been already mentioned. His various memoirs on chemical geology published from 1859 to 1870 have made him, perhaps, the highest living authority upon that subject. In fertility he is unrivaled, having within the last thirty years produced between one hundred and fifty and two hundred scientific papers, many of them elaborate.

Dr. J. P. Cooke, of Harvard University, is another of our prominent chemists whose labors have done much to advance theoretical chemistry. He is the author of *Chemical Physics* and *First Principles of Chemical Philosophy*, both of them profound and admirable expositions of theory, and of other publications of less extent, exhibiting great originality. One of these, a memoir on the numerical relations between atomic weights, and the classification of the chemical elements, elicited expressions of high commendation from Sir John Herschel before the British Association for the Advancement of Science.

The applications of chemistry to the arts are too various, too large, and too multiplied to admit of enumeration here. There is scarcely a department of industry into which they do not enter; while, on the other hand, there are many industries which, without this science, could not exist at all. In the words of Dr. J. Lawrence Smith at the Priestley centennial, "Industrial chemistry links itself with every modern art in such an intimate manner that were we to take away the influence and results of chemistry, it would be almost like taking away the laws of gravity from the universe; industrial chaos would result in one case, as material chaos would in the other." In some instances chemistry has rendered to industry a reduplicated aid—first, by creating or by greatly improving the industry itself; and secondly, by providing in wonderfully increased abundance or at wonderfully diminished expense the material on which or through which the industry is exercised. For instance, the manufactures of glass, of soap, and of textile fabrics, while indebted in a variety of ways unnecessary to specify to chemical science, are largely dependent upon a particular chemical product, the carbonate of soda, commonly called in commerce soda-ash. By the substitution, early in this century, of the manufactured carbonate, derived by a chemical process from common salt, instead of the natural substance previously obtained from sea-weed, the price was reduced to the tenth or twelfth part of what it had been before. By a new and more recently invented process this cost is likely to be reduced still lower. Again, in the manufacture of paper, to which chemistry has in various ways contributed, great embarrassments have in later years been experienced in consequence of the growth of a demand outrunning the supply of the substances out of which paper is made. Chemistry has done much to meet this demand by rendering available vast masses of rags which from discoloration had been previously unavailable, and by converting the fibre of various kinds of wood and grasses into suitable material for the same manufacture. Early in this century the process of bleaching linens occupied many months, and was attended with much labor, and some hazard of loss from mildew. Chemistry has made this a process occupying at present but a few hours. To every department of metallurgy chemistry has largely contributed, as is illustrated by the Bessemer process for steel, and in nearly every economical process in use for the precious metals. To the dyer's art a whole series of the most brilliant colors has been supplied, rivaling and often surpassing the rarest and most costly of those which have been hitherto only obtainable from natural sources. To the miner and the engineer have been furnished, in gun-cotton, nitro-glycerine, dynamite, and other explosive compounds, sources of resistless energy to aid in the prosecution of their often gigantic undertakings. The sources of artificial illumination at present in general use—viz., kerosene, stearine, paraffine, and coal gas—are the gifts exclusively of chemistry to the common uses of life. Fifty years ago the substance known as India rubber had no use but that which its name implies, to efface the marks of the draughtsman's pencil. At present, under the transformations given to it by chemistry, it enters into a larger variety of manufactures than almost any other material, except wood and a few of the metals.

The benefits rendered to the science of medicine by chemical discovery and chemical art are beyond calculation. An entirely new pharmacopœia has been created by it, in which the active principles of the drugs known to the old have been separated from the masses of inert matter with which they are naturally combined; and to these, new compounds have been added of an efficacy in assuaging pain or subduing disease surpassing all former experience. Of the wonderful variety of exquisite perfumes now offered to the choice of the fashionable world, only a very limited number are any longer sought from natural sources. Most are artificial products, in which chemical art has outdone nature. The numerous delicious preparations by which the confectioner succeeds in delighting the palates of the lovers of sweet things are due to a similar origin. Of the different descriptions of strong liquors, of which, to the misfortune of mankind, so incredible quantities are annually consumed as beverages, under the names of rum, gin, choice brandies, superior old Bourbon, Monongahela, etc., probably half or more than half the quantities sold are merely dilute solutions of alcohol, to which chemically prepared essential oils and chemically prepared sugars have communicated so perfectly the odors, flavors, and colors of the liquor imitated, as to defy detection by the most practiced dealer or drinker. In this case it is some compensation to be able to say that the chemical substances employed are entirely innocent, and that the liquors so manufactured, contrary to the popular impression, have nothing in them more noxious than the alcohol they contain; which, however, is just as noxious in the genuine liquors of the same name. Some of the gifts of chemistry to the ordinary uses of life have been so long and so constantly familiar that we habitually forget the source to which we owe them. The adhesive stamp, the gun-cap, the lucifer-match, are used daily and hourly by multitudes to whom it never for a moment occurs that science has had any thing to do with their production. And thus it happens, not only in small things but in great, that precisely in the points in which science has been most serviceable to mankind, her services, for the very reason that they are most constantly in sight, cease to be regarded as services, but are habitually confounded in the common mind with the things which come into existence in the ordinary course of nature's operations.

In closing this cursory sketch of a century's progress in science, a word may not be out of place as to the effect of this progress on the mental characteristics of the race. It is certain that not only has increase of knowledge largely modified prevalent popular opinions in regard to natural phenomena, but also that the modes by which knowledge has been increased have still more largely modified the spirit in which every new question is received which addresses the popular judgment. Even the less educated in enlightened lands no longer tremble at the advent of a comet, or imagine human destinies to be controlled by the stars, or see a mischievous sprite in the Will-o'-the-wisp, or conceive it possible for man by magical arts to subvert the ordinary course of nature. One by one those mysteries in natural things which to the common mind have heretofore from the foundation of the world been associated with the supernatural, have resolved themselves, under the scrutiny of scientific investigation, into their simple natural causes. The rainbow, the lightning, the tempest, the earthquake, the volcano, the aurora borealis, the star-shower, and even the rarer and more startling phenomenon, the shower of seeming blood, by which whole provinces have been occasionally appalled, are no longer regarded as evidences of the arbitrary interposition of invisible agencies, and no longer afford cause for either alarm or encouragement. It is a dogma of modern science that all the phenomena of the natural world, without exception, are subject to unalterable law; and accordingly that mysteries, wherever they still exist, are only evidences of our still existing ignorance. Standing upon this law, the investigator accepts no solution of a difficulty which does not clearly associate the observed effect with its efficient cause. For him authority has no weight whatever. He demands incontrovertible proof for every proposition advanced. The scientific spirit is, therefore, not a spirit of respect for traditions as traditions. It respects them only for the truth they contain. Its motto is, Prove all things —hold fast that which is good.

This spirit, which has been always that of the true investigators of nature, has in past centuries been confined almost exclusively to those who were immediately engaged in such investigation. The popular spirit has been directly opposed to it, even up to the point of hostility and bitterness; so that any man who, like Albertus Magnus, or Roger Bacon, or Baptista Porta, allowed himself to seek for natural causes in natural things, drew upon himself the dangerous suspicion of dealing with spirits of darkness. Those were ages in which authority was all in all; in our own, this matter is entirely reversed, and authority has ceased to be any thing.

The effect of this change is especially noticeable in the discussion of questions which concern education. The ancient learning is no longer respected because it is ancient. Rather, on the contrary, its claim to precedence as the basis of the highest education is prejudiced by the consideration that it was the only learning of the age which gave it such prominence. Larger space is naturally demanded for that new knowledge which is the growth of our own time, and is based on positive demonstration—knowledge which reveals to us the natural laws under the rigorous rule of which we are compelled to live, and which it concerns the immediate welfare of every individual to know. Hence the growing favor for what in recent years has received the name of "the new education." It is a demand that of the three elements, the good, the true, and the beautiful, the second shall have as full a recognition as the other two.

The same effect may be observed in the discussion of religious questions. The basis of belief is investigated with a freedom unknown to other centuries. This is not merely the prompting of a skeptical spirit. If the unbeliever would discredit revelation, the believer no less desires to give a reason for the faith that is in him. There is no ground for the imputation which we hear occasionally expressed, that science is hostile to religion, or that infidelity is more rife in the present age than in the last. Modern science hardly existed when the French Republic, "one and indivisible," abolished religion by public decree. The thing which is true is that the infidelity of our time is open in its utterance, while that of other periods has been restrained by fear of penalties both judicial and social. It is in the nature of things impossible that science and religion should be in conflict, since truth, which is the aim of the one, is also the substance of the other, and truth can never be inconsistent with itself.

A failure to recognize this simple principle has operated more powerfully than any other cause to retard the progress of the world's enlightenment; and it must be counted as the largest service of modern science that it has burst at length the shackles by which human thought has been held for centuries in bondage.

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II.—NATURAL SCIENCE.

AT the commencement of the century which is distinguished by the existence of the United States of America as an independent nation, students of nature had regard almost alone to "natural history," or the observation and description of what in nature immediately appealed to their senses.

At the present time the "natural sciences" are acknowledged constituents of general science, that great superstructure which enables us by a long-established series of observations and assured deductions to predicate the nature of the unseen from what has been observed, and to throw into a few terse general propositions and principles the results of all our studies.

How the several branches of natural history have grown and developed into the natural sciences, and what quota America has contributed to this progress, will be the subject of inquiry in this chapter.

The distinction just indicated between the stages of our knowledge of natural objects in times past and present is exemplified in the relations of the several branches to schemes of classification of general knowledge. In the celebrated synopsis of Bacon, in which the triple division is based on the faculties which are called into activity in the consideration of the various branches, "natural history" is placed with "civil history" as a branch wherein "memory" is chiefly demanded, while the "mathematical sciences" belong to the domain over which "reason" presides—"philosophy." Such was in his time and long afterward, and, in fact, until this century had well advanced, to some extent a true exhibit of the facts and the mode of study of nature. Natural history was, indeed, a mere record of empirical observations and of the crude impressions produced on the senses. The chief aim of the naturalist was then to know the name of a given species, and only long afterward did the name become of secondary importance, and simply a means toward an end, that end being the knowledge of the relations of the forms in question to others, and, *a posteriori*, to the economy and plan of nature.

FIRST STEPS.

It was in 1766 that Linnæus published his last edition of the *Systema Naturæ*; in the earlier editions of that celebrated work he had, in intention at least, incorporated all the species of animals, plants, and minerals which had been made known in a recognizable manner by his predecessors and contemporaries, and, in this final edition published during his lifetime, he had systematically applied the binomial method of nomenclature, which has been so powerful an auxiliary as a method of notation to the naturalist; he also revised, and in a number of cases very materially modified, the arrangement adopted in the previous editions of his work, and he added the species in each department of nature which had in the mean while been described. This, therefore, will furnish a fitting starting-point for our inquiries in each case; and this work, be it observed, was almost the last in which a single naturalist attempted to cover the whole domain of nature, and to recapitulate all known species. The impulse which had been given to the cultivation of natural history, and the zeal with which travelers collected, as well as the researches of the European colonists in the lands of their adoption, soon increased the numbers of species to such an extent that their survey by one man became impossible.

The species of animals and plants—especially the former—known to Linnæus from America, or at least from the limits of the present United States, were comparatively few. It is true that in numerous works devoted to the description of the country or its several parts the characteristic species were enumerated, and even alleged lists of species were published; but in few cases were they scientifically or at all intelligibly described: in default of specimens, therefore, they could not be incorporated in the *Systema Naturæ*. Linnæus was consequently confined in his work to the descriptions or identifications of the species which were in the museums or herbaria of Europe accessible to him, or which had been sent to him by American correspondents, among the most conspicuous of whom were Cadwallader Colden, of New York, and Alexander Garden, of South Carolina. A student of his own, the afterward well-known Kalm, in 1747 and 1748 visited this country and collected especially the plants. The comparative facilities then enjoyed for the manipulation of plants, the tastes of his correspondents, and, indeed, Linnæus's own greater familiarity with the vegetable kingdom, all tended to his acquaintance with our plants rather than animals, and consequently while the number of species of the former attributed by him to North America was considerable, that of the latter was small.

SOCIETIES AND LOCAL DEVELOPMENT.

Although after Linnæus equal individual attention to the several branches became rare, societies devoted to the cultivation of all in common originated, and several of them exercised a notable influence on the development of science in its various branches, either being called into existence in response to an active want for the means of expression for individuals, or being themselves the agents for eliciting communications which might otherwise have never been made known; these, therefore, always demand special notice in a history of science.

The earliest of such societies, founded when the States were yet colonies of Britain—the American Philosophical Society for promoting useful knowledge, held at Philadelphia—was originated by Franklin and some companions as early as 1743; its first volume of Transactions was published in 1771. The American Academy of Arts and Sciences was next established, in 1780, at Boston, and published the first volume of its Memoirs in 1785. Both these societies contributed much in their youth (as they still do) to the cultivation of the natural sciences, and various articles on animals, plants, and minerals were published in their serial volumes. Before the close of the eighteenth century (1799) another society—the Connecticut Academy of Arts and Sciences—was founded at New Haven, but after the publication of one volume languished, or was entirely inactive, till after the establishment of the Sheffield Scientific School, when it awoke to active life, and has since (1866–75) published many excellent memoirs. In 1814 there was founded in New York a society whose existence was ephemeral, but which played a notable part in American science; this association was the Literary and Philosophical Society of New York. In 1815 it published a large quarto volume of Transactions, which contained memoirs by Dr. Samuel L. Mitchill, Governor De Witt Clinton, Dr. David Hosack, and others less known, but the principal article was by Dr. Mitchill, and was a monograph of the fishes of the State, illustrated by six plates, containing sixty figures. For years afterward the society was inactive, and after publishing the first part of a second volume in 1825, dissolved. The year 1814 saw also the birth of a society destined to have an extraordinary connection with the growth of science in the United States generally—the Academy of Natural Sciences of Philadelphia. This body commenced the publication of a Journal in May, 1817, and in this first volume, as well as in all the succeeding ones, were published some of the most important papers on the animals, plants, and minerals of the country. A very considerable portion of our most familiar species of animals was, in fact, first made known in that journal, and in the earlier volumes Say and Lesueur published their classical memoirs. In 1818 the Lyceum of Natural History in the city of New York was organized, and a new impetus was given to the cultivation in that city of the natural sciences, and Mitchill, Leconte, Cooper, De Kay, and others contributed numerous articles to the pages of its Annals. Next, in 1834, the Boston Society of Natural History was established, and soon popularized in the city of its home the several subjects of its preference, which till then had received comparatively little attention. Finally were successively established in Albany, San Francisco, St. Louis, Chicago, Buffalo, Washington, and other cities, active societies devoted to science in several or all of its branches, which have in each case exercised a healthy influence in their several spheres.

All the societies specially noticed have not only continued to live, but are more active now than ever. Their inception coincided with the awakened activity in the several cities where they are located, and thus mark distinct epochs of progress.

Besides these local societies, two national ones, the American Association for the Advancement of Science and the National Academy of Sciences, have accomplished important results. The Smithsonian Institution, established at Washington in 1846, by its policy of facilitating intercommunication between the learned societies and individuals of this and other countries, of seconding the efforts of investigators by collection of materials and publishing the results of such investigations, and in other ways, greatly increased the means for the pursuit of the natural as well as mathematical sciences. To a large extent, too, it has been intrusted by the government of the nation with a superintendence of scientific exploration, and has done much thus to direct expenditure for such purposes in a proper channel.

In this connection may be fitly noticed a journal which is not the organ of any society, but which has, perhaps, exerted more influence on the progress of science in this country than any other. This is the *American Journal of Science and Arts,* commenced by the elder Silliman in 1818 in New Haven, and uninterruptedly continued there to the present time by him or members of his family. Its pages are replete with original and copied articles on the natural as well as the other sciences, and furnish in themselves an epitome of the progress of science in America.

GENERAL EXPLORATIONS.

The general government early adopted the policy of sending, from time to time, expeditions to the comparatively unknown portions of the country for their exploration, and with these in many cases naturalists were connected. Only those most notable from a scientific point of view can be referred to. In 1804–6 Lewis and Clarke traversed the continent, and more or less intelligibly indicated previously undescribed species of animals from the far West, which were subsequently incorporated by Ord, Rafinesque, and others into the zoological system. In 1819–20 S. H. Long (then major) conducted an expedition to the Rocky Mountains, of which Edwin James was the historian (1823), and also detailed the geology and botany, while Say described the new animals, and Torrey enumerated the plants. In 1848, and again in 1852–53, Fremont led expeditions across the continent, and brought back new riches in botany and geology. In 1849 and 1850 Stansbury explored the Great Salt Lake basin; in 1852 Sitgreaves the Zuni and Colorado rivers; and, also in 1852, Marcy the Red River of Louisiana. All of these expeditions were accompanied by energetic collectors, who brought back from the regions in question, whose natural history had been previously almost unknown, many new species, which were described and illustrated by naturalists mostly within the walls of the Smithsonian Institution. In 1854–56 General Emory (then major of cavalry) and Señor Salazar, as commissioners of their respective governments, surveyed and determined on the boundary line between the United States and Mexico. The United States commission was accompanied by a corps of scientists; and the report, published in 1857–59, contained most valuable contributions, richly illustrated, on the zoology, botany, paleontology, and geology of the country surveyed.

But all these must yield in importance to the several expeditions which were sent out by the War Department, under the auspices of the Bureau of Topographical Engineers, for "explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean." These expeditions were mostly prosecuted from 1853 to 1856, and were conducted nearly on the parallels of latitude: (1) the 47th; (2) the 38th and 39th; (3) the 35th; (4) the California line; (5) the 32d, (6) under Parke, and (7) under Pope; and (8) the California and Oregon line. All these parties had naturalists attached, and as the natural history of the Pacific slope was almost unknown, a very large proportion of the species brought home for examination were new. These were reported upon by the naturalists of the surveys, but more fully elaborated by Professor S. F. Baird and Dr. Charles Girard. The results were published under a common title in a uniform series of twelve volumes in quarto. Professor Baird undertook the great task of revising, in connection with the new forms studied by himself, all the existing material from every part of North America. The fruits of his researches were issued in two very large volumes, respectively describing the mammals and birds of North America, in which the species were subjected to a critical examination; and for the first time those classes were completely and systematically exhibited according to their affinities, detailed descriptions given of all the species and successively including groups, and clear synoptical tables added. The fishes collected by the expeditions were elucidated chiefly by Girard and Suckley. Plates were published of the reptiles, under the direction of Baird; the coleoptera were partially reported upon by Leconte, and the mollusca by Cooper; the plants were catalogued and described by Torrey, Gray, Engelmann, Newberry, and others; the paleontology was investigated by Hall, Conrad, Agassiz, etc.; and the geology by the several geologists of the survey.

Two other surveys undertaken by the Bureau of Engineers should be noticed in this connection. One was the United States geological survey of the 40th parallel, prosecuted under the charge of Mr. Clarence King in 1867, 1868, and 1869; the other a geographical and topographical survey of certain of the Western and Southern Territories, under Lieutenant George M. Wheeler, still in progress. Both have done much for the furtherance of our knowledge of the zoology and botany, as well as the topography and geology, of the sections explored.

Under the Department of the Interior a geological and geographical survey also originated in 1869, and gradually developed into importance, under the charge of Dr. F. V. Hayden; and recently a second division of the same, with Professor J. W. Powell at its head, has been added to it. These vie with the other surveys in adding information respecting the physical geography and life, past and present, of the Territories under the government.

The geological survey of the State of California, under the superintendence of Professor W. D. Whitney (1861–74), also merits special notice on account of the completeness of its organization and the ability of execution of the work undertaken.

While the knowledge of the natural history of our country was being thus made known, that of foreign lands likewise received attention from American naturalists. During the years 1838–48 an exploring expedition was engaged, under the command of Admiral (then Captain) Wilkes, in a voyage of circumnavigation, and in the course of its long cruise visited several countries whose natural productions and features were almost or wholly unknown. The expedition was accompanied by several energetic and accomplished naturalists, chief of whom in labors was the versatile Dana. The results of these explorations were most satisfactory, numerous new species were collected, and the publications on the collections were, as a whole, in the highest degree creditable to American science. The mammals and birds were reported on by Peale and Cassin; the reptiles, by Girard; the mollusks, by Gould; the crustaceans and zoophytes, by Dana; the botany, by Torrey, Gray, Eaton, etc.; and the geology of the countries visited, by Dana. The most noteworthy of these were the volumes on crustaceans and polyps, wherein the classification of those animals was entirely revised, and a great mass of new material added.

In the years 1849–52 a "United States Naval Astronomical Expedition to the Southern Hemisphere" was for the most part stationed in Chili, and the commander thereof (Captain J. M. Gilliss) and his assistants paid zealous attention to the natural history of the regions traversed. Collections were made in the various departments, and on the return of the expedition were studied by Baird, Cassin, Girard, Gould, Gray, Wyman, Conrad, J. Lawrence Smith, etc. The collection richest in new forms was of the class of fishes, of which some remarkable new types were described by Girard.

An expedition which was excelled by none, if it did not, indeed, surpass all, in the collections amassed sailed from New York in 1853 for the Northern Pacific, and for about four years cruised in all the great seas, at first under the command of Captain Ringgold, and afterward under Captain Rodgers. In this expedition Mr. Wright was attached as botanist, and Mr. Stimpson as zoologist. The collections made, especially in the department of zoology, were very large. Mr. Stimpson for the first time dredged in many of the harbors visited, and the results, as might be expected, were very rich. Numerous remarkable types of marine as well as other animals were thus discovered. These were partially described in preliminary reports by Stimpson, Cassin, Hallowell, Cope, and Gill, but the final reports were never published, and several of them, with the original illustrations, were consumed in the great fire which destroyed Chicago, and the loss thus incurred is irretrievable.

Such are the principal explorations which have been instrumental in the extension of our knowledge of nature. Numerous others have concurred, but limited space forbids any mention of them. We may now best inquire how each department has been forwarded by American naturalists, commencing with the most simple, and advancing to the most complex.

MINERALOGY.

Linnæus applied the same system of nomenclature to the mineral kingdom, or *lapideum regnum*, as he did to the animal and vegetable, dividing it into three "classes"—*petræ*, or stones; *mineræ*, or minerals; *fossilia*, or fossils; and this exposition alone will give a good idea of the imperfect conception then entertained of the relations of those objects, and especially of the last. Chemistry and crystallography were almost ignored, or made use of in a very crude manner. More than any of his predecessors, however, Linnæus availed himself of the crystallographic characters of minerals in their diagnoses; but their action when subject to friction, fire, and acids was the chief means of determination used. Linnæus was, however, much surpassed as a mineralogist by contemporary investigators, and the status of mineralogy became rapidly improved by the discoveries of chemists, physicists, and crystallographers, and it had assumed the dignity of a science before any native Americans applied themselves with intelligent zeal to the study.

It is true that the occurrences at various places of certain minerals and peculiar conditions of some were noted from time to time, but nothing which deserves special notice was published for a long time. A journal professedly devoted to mineralogy, the *American Mineralogical Journal*, was, indeed, commenced by A. Bruce, but was discontinued with the first volume. In 1816, however, Professor Parker Cleveland published *An Elementary Treatise on Mineralogy and Geology*, whose science was respectable for its day, and gained a demand for a second edition in 1822. In 1832 appeared the first, and in 1835 the second, parts of Shepard's *Treatise on Mineralogy*. This was soon succeeded by a work which was destined to become the *opus magnum* of the science, *A System of Mineralogy*, by James D. Dana. It has passed through five entirely revised editions, and several are, to all intents and purposes, distinct works, and fairly exemplify the several stages of science. In the first (1837) the system of nomenclature introduced by Linnæus was retained, and a modification of the so-called natural classification by Mohs, proposed several years previously (in 1833), was adopted. This system was based chiefly on the consideration of the superficial characters of the minerals, but which were claimed to be true coordinates of the chemical, upon the superior value of which many mineralogists had already insisted. In the second edition (1844) the same system of classification, with some modifications, was retained, but another, "placing the minerals under the principal element in their composition," was added. In the third edition (1850) the old system of nomenclature and classification was discarded, and the author adopted a provisional system in which the chemical constitution of the mineral was taken more cognizance of, the chief aim, however, being to "serve the convenience of the student for easy reference and for the study of mineralogy in its economical bearings, while at the same time it should exhibit many natural relations, and inculcate no false applications or distinctions of species." A more rigid chemical classification, in which the Berzelian method was coupled with crystallography, was appended. In the fourth edition (1854) the arrangement appended in the previous, amplified and corrected, was adopted as the regular system. In the fifth and last (1868) the same method was essentially retained, and in obedience to the necessities imposed by the more detailed study of the subject, and to show the proper subordination of the several characteristics, varieties were recognized.

In the course of time the demands on the other branches of science in behalf of mineralogy had become greater and greater. As we have seen, originally mineralogy was simply the art of identifying mineral forms by reference to their superficial physical characteristics. Gradually the chemist was called upon to tell the constitutions thereof; the crystallographer and mathematician to define and classify their forms; the physicist to answer various questions as to characteristics; the spectroscopist to aid the chemist. Finally the chemist was accorded the rank of prime arbiter, and in most cases his judgment is now accepted as final. In each of these departments America has had and still has most distinguished investigators. Dana's work stands *facile princeps* among mineralogical text-books, and is a true "manual" in the Old World as well as in the New. He ranks pre-eminent in the special department of crystallography. In chemical mineralogy there have been many successful students, chief of whom are T. Sterry Hunt, George J. Brush, F. A. Genth, C. M. Shepard, and B. Silliman. A son of Professor Dana (Mr. E. S. Dana) has, with scarcely unequal skill, begun to continue the work so well commenced by the father, and has been paying especial attention to the physical characters of minerals.

BOTANY.

Devotion to plants has been a favorite source of enjoyment to man. The attractiveness of the objects, the positiveness and superficial concentration of characters, and the ease of preserving have all tended to this bias. As a natural result, to a certain extent the value and characteristics of plants were earlier appreciated than any other group of natural objects. Those of this country were tolerably well known at a comparatively early period. Jean Robin, a Frenchman, as early as 1620 published on the plants of old Virginia; J. Cornuti, a French physician, in 1635, on those of Canada; J. R. Forster in 1771 issued a *Flora Americæ Septentrionalis;* Cadwallader Colden, of Newburgh, New York, communicated to Linnæus a descriptive account of the plants indigenous to Orange County; Mr. Cutler in 1785 published in the Memoirs of the American Academy of Arts and Sciences a catalogue of the New England species; and numerous other works and articles of various degrees of merit were published (some meanwhile, but especially in succeeding years), the most notable of which were the elder Michaux's *Flora Borealis Americana* (1803); Pursh's *Flora Americæ Septentrionalis* (1814); and Eaton's *Manual of Botany for the Northern and Middle States*. In all of these and the minor contemporary productions the artificial sexual system of Linnæus was adopted, and this had a wonderful hold on the affections of the older botanists. A man of remarkable versatility but disordered mind (C. S. Rafinesque), who had come to this country in 1814, had published much on botanical subjects, and had in several of his works suggested and partially carried into execution a quasi-natural scheme of classification; but his influence had no weight, and not until the end of the last half century did any one of recognized standing discard the Linnæan method. In 1823 Dr. John Torrey had published the first part of a *Flora of the Northern and Middle States*, in which he still retained the sexual system; but having become satisfied of its incongruity with the existing state of science, he discontinued the work, and immediately after applied the natural system to the classification of the plants collected on Long's expedition to the far West, and subsequently rendered it more popular by the publication of a catalogue of the North American genera, arranged in accordance with Lindley's classification (1831). Lewis Beck, in a *Botany of the United States North of Virginia*, also adopted this system. The natural system was thus fairly adopted by scientific botanists and those who appreciated the aims of science, but was long in obtaining favor with the masses. The publication of such works as the *Flora of North America*, by Torrey and Gray, in 1838–43, the *Manual of the Flora of New York*, by Torrey, in 1843, *Manual of the Botany of the Northern United States*, by Gray, in 1848, and kindred ones, however, procured its ultimate adoption even in manuals for schools and colleges.

The States of the Atlantic sea-board and the Mississippi Valley were sedulously explored by native botanists, and catalogues, and even extensive descriptive works, of the plants of many of the separate States, as well as sections, counties, and townships, were published. The expeditions that have been already alluded to in connection with natural history generally extended our knowledge of the flora of the extreme West, and the progress of botany advanced hand in hand with that of geography. Private collectors, too, devoted themselves to the search for the plants of various unexplored sections, and among these may be especially enumerated Fendler, who herborized in New Mexico; Lindheimer, who collected in Texas; Wright, Parry, and Vasey, who penetrated to divers places in the Southwestern sections and Rocky Mountains; and Rothrock, who has visited the extreme North (Alaska), and the furthest Southwest (Arizona).

The monographers of groups have also been active. Above all must be mentioned Gray, Torrey, and Engelmann, and during later years Watson, who have studied various groups of phænogams; Eaton has especially attached himself to the ferns; Sullivant and Lesquereux to the mosses; Curtis, of South Carolina, to the fungi; Tuckermann to the lichens; and lately Dr. H. Wood has monographed our fresh-water algæ, and Dr. Farlow has catalogued the marine species.

The consideration of the geographical distribution of plants has also engaged the attention of many students, and the researches of Gray demand especial notice. Pursh had as early as 1814 called attention to the similarity between the flora of North America and Northern Asia. Gray in 1846 pointed out many analogies, and in 1856 insisted on the similarity between the floras of corresponding sides of the Old and New Worlds. He also at the same time recognized that, although the number of tropical types was much greater than in the northern portion of the Old World, "the peculiar and extra-European families do not predominate nor overcome the general European aspect of our vegetation." He has more recently recognized a casual relation in this similarity, and contended that they indicated derivation from a common source.

ZOOLOGY.

Although more or less pretentious lists of the animals of North America were given in many works descriptive of the country, scarcely any are worthy of notice, and so little was known of our species that an extremely small percentage appeared in the *Systema Naturæ* of Linnæus. The field in zoology is so vast that none have in this country attempted to do what has been so well done for botany, that is, to prepare compendiums of descriptions of all the known species. From the complete dissimilarity and want of homologies between the great groups of the animal kingdom a peculiar terminology for each is entailed, and consequently the students are more specialists than in botany. Each group of animals, however, has had its devotees. The progress in each, too, has, like that of botany, been to a considerable degree coincident with the growth of our geographical knowledge; and this statement must serve in lieu of particularization in each case. The more difficult groups have been backward in attracting students, and the more pleasing types have received most attention. Thus the birds early excited the admiration of lovers of nature, and numerous works have been dedicated to the portraiture of their beauties, while the worms and other lower invertebrates have only lately attracted the notice science demanded.

Before indicating the progress of our knowledge in the several branches of zoology a notice of one who did much to shape the course which investigation took for some years may be fitly given.

In 1846 Louis John Rudolph Agassiz visited the country, and soon was induced to make it his home, and in 1848 accepted the chair of zoology and geology at Harvard College. Gifted with quick powers of perception and a remarkable memory for specimens, he had early applied himself to the study of fossil fishes, which till then had been nearly neglected. The publication of a very extensive and finely illustrated work gained for him a great reputation in Europe. A peculiarly genial and impulsive disposition procured him the favor of those with whom he came into personal contact. This impression communicated itself quickly to others. He gathered around him a number of young men who were destined to pursue with distinguished success different branches of science. His prestige caused the ready acceptance of his teaching and principles by others, and insured their application to the various branches of zoology. Many of these principles were most sound; others (among them unfortunately were those most frequently applied) were less justified by scientific reason. Such were the views respecting the rigid limitations of species in time and area. He was also prone to differentiate genera because of minor differences, and to trust to intuition rather than to the inexorable logic of facts in the classification of data. His views were generally accepted, as well by amateurs as scientists, in this country, and not for a long time was there any strong counter-current. This subsequently set in, and the present tendency is toward a recognition of species with more variable limits, and with greater extension in time and space. But in spite of the drawbacks indicated the influence of Professor Agassiz was most salutary; he raised the standard of scholarship looked for in the naturalist, incited general respect and even enthusiasm for natural science, and his popularity enabled him to found a Museum of Comparative Zoology which is an honor to Massachusetts and to the country at large, and the best monument to his own zeal and learning.

The United States presented long the anomalous position of being the only great nation which had no public museum. The collections that were brought back from time to time were, after the establishment of the Smithsonian Institution, intrusted to its custody, but only within a few years has it been recognized as a duty to appropriate at all adequate amounts for their preservation and use. But some provision has been made for several years for a national museum; this still remains as an appanage of the Smithsonian Institution, under the charge of its assistant secretary, Professor Baird, and now bids fair to soon rival the most important in Europe in the extent and actual value of its collections.

The most notable accessions to our special knowledge have been as follows:

Some of the more conspicuous quadrupeds of North America had been early described and figured in a recognizable manner by compilers and iconographers, and especially in the works of Catesby, Edwards, and Brisson, and these were incorporated in the *Systema Naturæ* by Linnæus; but, all told, he only attributed twenty-five species to North America, and even of these he does not seem to have had autoptical knowledge of more than two or three. Others were subsequently made known, chiefly by English and French naturalists, and later by Americans (especially Say and Ord), and in 1825 Richard Harlan published a special volume on the class, in which were recognized 147 species, a number of which were, however, synonyms. Soon after (1826–28) John D. Godman issued a corresponding work, in three volumes, containing nothing new. Subsequently Townsend and Audubon obtained from the West many new species, which were described by Bachman, and in 1846–54 Audubon and Bachman published a work on *The Viviparous Quadrupeds of North America*, in three volumes. Finally, in 1859, the great work by Professor Baird, already referred to, appeared, and in this were described a number of previously unknown species, incorporated with others he had previously made known. On the basis thus laid various zoologists have built. Among these have been the natural historians of various regions and the monographers of distinct groups, such as Harrison Allen, J. A. Allen, Cope, Coues, Gill, etc.

The birds have excited the most lively interest, and the works published on the class have been many. The more common and conspicuous species were early introduced into the system, and from the time of John Bartram (1791) and Benjamin S. Barton (1799) to the present there have always been active students of the class in America. The most distinguished of these are Alexander Wilson, a native of Scotland, naturalized in the United States, who published in 1808–14; Charles L. Bonaparte (a nephew of Napoleon, and afterward Prince of Musignano and Canino), who published, besides many other articles, a complementary volume to Wilson's work (1825–33); T. Nuttall, who issued a *Manual of the Ornithology of the United States and Canada* (1832–34); J. J. Audubon, who contributed the most superbly illustrated work to ornithology that had up to that time been seen; and S. F. Baird, who first (1858), in conjunction with J. Cassin and G. N. Lawrence, revised the entire system of North American birds, and very recently (1874), in union with T. Brewer and R. Ridgway, has published the first three volumes of a work which surpasses all others in accuracy of description, philosophical breadth of views, and comparative valuation of characters. Lastly may be mentioned *Birds of the Northwest: a Hand-Book of the Ornithology of the Region drained by the Missouri River and its Tributaries*, by Elliott Coues (1874).

While these general works were in course of publication, many minor works and articles were printed on the general subject, on the species of limited regions, and on the modifications of structure and color induced by geographical and climatic causes, etc. The most successful students of the causes of geographical variation have been Baird, Allen, and Ridgway.

The reptiles and amphibians, although extremely unlike in structure, superficially resemble each other so closely as to have been always confounded together and studied in common under the general head of herpetology. This has been a less cultivated branch than others, but several eminent naturalists have elucidated our species, and more than either of the preceding classes has the present owed its advancement to natives. J. E. Holbrook, of South Carolina, published, in 1843, a *North American Herpetology*, in five volumes, which was then unsurpassed by any similar production in Europe. S. F. Baird, Charles Girard, Edward Hallowell, and Louis Agassiz have done eminent service on different groups, and more recently E. D. Cope has revised the entire herpetological fauna in connection with the general system of reptiles and amphibians.

The students of fishes have been more numerous. In the last century but little was known of these inhabitants of our waters, and even that little was inexact. In 1814 S. L. Mitchill, a man of great eminence in his day, published a valuable though crude memoir on the fishes of New York; in 1839 D. H. Storer reported on the fishes of Massachusetts; in 1842 J. E. De Kay published an important work on the fishes of New York; and in 1855, and again in 1860, J. E. Holbrook commenced an illustrated work on the *Icthyology of South Carolina*, but suspended it with the first volume.

The fishes of the extreme West and of the Pacific coast, almost absolutely unknown till 1854, were in that and in immediately succeeding years described by Agassiz, Girard, Ayres, etc. Among other cultivators of the science may be mentioned Kirtland, Baird, Brevoort, Gill, Putnam, Abbott, Cope, Bliss, Goode, Garman, Milner, Yarrow, and Jordan.

The invertebrates for purposes of study fall into two groups—the air-breathing insects and the marine forms.

The insects soon attracted attention, and the various groups engaged active students. Say (1818 *et seq.*), Fitch, Packard, Walsh, and Riley have described species of almost every group. The coleoptera have been studied by Melsheimer, J. Leconte, Haldemann, and above all by J. L. Leconte and Horn; the lepidoptera have had numerous students—Morris, Clemens, Edwards, Packard, Scudder, Grote, and many others; the hymenoptera, or groups thereof, have been examined by Norton, Saussure, etc.; the orthoptera have been investigated by Scudder, Thomas, and Sydney Smith; the neuroptera by Hagen; the hemiptera by Uhler; and the diptera have engaged the attention of Loew and Osten-Sacken. The myriopods have been described by H. Wood, as have also the pedipalp arachnoids.

The marine invertebrates were almost wholly neglected till Say, in 1818, commenced his investigations, and for some years worked upon several of the groups, describing our most common crustaceans, shells, and other forms. A. A. Gould, in a work on the invertebrata of Massachusetts, made evident the paucity of our knowledge of all except the shells; and a few years afterward (1851) W. Stimpson, then a very young man, commenced his researches, which added very largely to our information. In recent years the work thus commenced has been worthily continued by the two Agassizes, H. J. Clarke, A. E. Verrill, S. Smith, O. Harger, and others.

The mollusks, on account of the beauty of their shells and the ease of preserving them, have, like the birds, been favorite subjects for amateur students, and this has directly and indirectly accelerated our acquaintance with the species. The laborers have been very many. It must suffice to name, besides the general students of invertebrates previously referred to, Isaac Lea, A. A. Gould, Amos and William G. Binney, Thomas Bland, Edward S. Morse, William H. Dall, and George W. Tryon. These have studied, some all the groups, others the land or fresh-water shells, others the anatomy, and still others have especially considered the problems connected with their geographical distribution.

PALEONTOLOGY.

In no department of natural history has progress been so distinctly marked, or the revelations so interesting and unexpected, as in that which takes cognizance of the former life of our globe. The science of paleontology, as this branch has been named, had absolutely no existence or name when the United States became a nation. Fossils were classified by Linnæus not with animals or plants, but with minerals. Their nature was then in doubt. By some they were supposed to be sports of nature, or abortive *simulacra* of what the Deity destined afterward to create. By the best informed and orthodox they were believed to be witnesses of the Noachian deluge. In a number of cases their nature was, indeed, recognized, but by none was it definitely realized that most fossils were the remains of forms that are no longer living. Although this truth became apparent to several at nearly the same time, Cuvier was the first to render it clear and popular by the restoration of numerous fossil remains of the skeletons of mammals found in the tertiary deposits of the neighborhood of Paris. These were so demonstrably different from any animals that were known in a living state, and the improbability of their having remained undiscovered if still living was so extreme, that conviction of the truth necessarily struck every one who considered the evidence. The clew thus gained, although at first imperfectly held, was soon firmly grasped and followed by many interested students, and the present assured superstructure has been the reward of their zeal. In this country the science engaged the attention of many, and Say, Lesueur, De Kay, and Greene were among the earliest. Morton, Conrad, Lea, Hall, Meek, Gabb, White, and Whitfield, besides many others, have described and identified the fossil invertebrates. Hall has especially published a noble work on the fossils of the paleozoic formations of New York. Meek has done more than any one else to illustrate the fossils of the carboniferous and mesozoic beds of the West; and Conrad has excelled in knowledge of and labors on the species of the tertiary rocks. Lea and Gabb have efficiently supplemented the works of the last two.

The vertebrates have received attention from another class of scientists. For their comprehension an exact knowledge of the details of comparative osteology was requisite, and the students have, therefore, been comparatively few. De Kay, Harlan, Godman, Hays, Cooper, Redfield, Warren, and Wyman simultaneously or successively touched the subject, but the great labors have been accomplished by Leidy, Cope, and Marsh. It had by some become supposed that America would furnish no deposits of fossil bones such as had been discovered in Europe, but in 1846 and 1847 Dr. Hiram A. Prout, of St. Louis, and in 1847 Dr. Leidy, published communications on remains found in the Mauvaise Terres of the then Territory of Nebraska, and those deposits have since been a fruitful source of new discoveries. Other regions containing analogous deposits were subsequently made known, and the mammalian faunas of past times, pliocene, miocene, and eocene, have become tolerably well known. Among the most interesting of the types discovered are many forming "connecting links" between the existing ruminants (cattle, deer, etc.) and hog-like animals first made known by Leidy; others lessening the interval between the proboscidians and ordinary pachyderm ungulates, discovered by Cope and Marsh; others demonstrating the line of descent of the horses of the present day, elucidated by Marsh; and still others establishing the former existence in North America of animals most nearly related among living forms to the lemurs of Madagascar, as Marsh was the first to clearly demonstrate. Numerous other almost equally important discoveries have been made, illustrating the structure and range in time and biological generalizations for almost every group of vertebrates; but this is not the place to recount them.

GEOLOGY.

Geology is almost entirely the child of the present century. Its foundations were chiefly laid by Werner, of Freyberg (after 1775), and his school in the clear recognition of the nature and the relations of rocks to each other, and their distribution; by Hutton, of Edinburgh (1788), in the comprehension of the origin and natural causes of the strata and rocks, and in the limitation of cataclysmal agencies; and by William Smith, an English surveyor (1790), and Cuvier (1808), in a general perception of the restriction of fossils to definite horizons, and the value of those fossils in determining the relative age of the strata in which they were imbedded. In each case, indeed, these had been to some extent anticipated in their discoveries, but their ideas were clear and positive, while their predecessors failed to recognize the full significance of the facts in question. The age had also become ripe to apply the truths thus perceived.

Nothing worthy of mention was done for the geology of North America till William Maclure (a pupil of Werner), in 1806, came to this country and undertook a geological survey, traveling in the prosecution of this self-imposed task from our Northern border to the Gulf of Mexico. He was engaged on it for about three years, and in 1809 published the first geological map, and a commentary thereon in a special memoir. As was to be expected, he adopted the Wernerian system of nomenclature, and having been unable to apply paleontological evidence, his work exhibited little more than certain points in structural geology. Lardner Vanuxem (1828) first availed successfully of paleontology for the determination of the age of several of our formations and their approximate synchronism with European beds. The natural history survey of the State of New York, commenced in 1836, brought together a great mass of facts, and by the concert of the several geologists and paleontologists, but especially guided by the judgment of Vanuxem and James Hall, a classification of the rocks on sound paleontological principles was instituted, which, as since perfected by Hall, has been adopted as the standard of reference for the paleozoic rocks of the United States and British North America. Henry D. Rogers, in his final report on the geology of Pennsylvania (1858), made evident the skill with which he had disentangled the complications of the geological structure of the Alleghany system. F. B. Meek during a long series of years has acted as the universally accepted arbiter for the determination of the age of the groups of rocks in the far West. Meanwhile the details of the geology of the various geographical sections and States engaged the attention of many laborers, and one after the other almost every State instituted a geological survey, and many of them undertook at intervals two or more. In the order of first publication of results they are as follows: 1824, North Carolina; 1826, South Carolina; 1832, Massachusetts; 1834, Maryland; 1835, Tennessee; 1836, New Jersey, New York, Ohio, Pennsylvania, Virginia; 1837, Connecticut, Maine; 1838, Indiana, Michigan; 1839, Delaware, Kentucky; 1840, Rhode Island; 1841, New Hampshire; 1845, Vermont; 1850, Alabama; 1853, California, Illinois; 1854, Mississippi, Wisconsin; 1855, Missouri; 1858, Arkansas, Iowa; 1859, Texas; 1865, Kansas; 1866, Minnesota; 1869, Louisiana; 1875, Georgia.

The general government also from time to time instituted special geological surveys, independent of the exploring parties mentioned in the first part of this article. In 1834 and 1835 G. W. Featherstonhaugh investigated the elevated country between the Missouri and Red rivers and the Wisconsin Territory. At various times D. D. Owen conducted surveys in several States and Territories of the Northwest, publishing the chief results in 1844, 1848, and 1852. In 1869 the persistent solicitations of F. V. Hayden, already well known as a field geologist and collector, secured a geological survey of Nebraska, under the auspices of the Land-office, a bureau of the Interior Department. For two years this was prosecuted, and the wedge having been thus driven, the survey was continued, and, organized under a more ample scope and with enlarged designs, is continued to the present time. A number of eminent men have availed themselves of the means of investigation and publication presented to them by the survey, and consequently a number of valuable publications have appeared under its auspices. Also productive of similar work have been, or are, the surveys of the 40th parallel, and the Territories west of the 100th meridian, already referred to under the head of general natural history.

In every department of geology America has exhibited efficient works. Stratigraphical, chronological, dynamical, and mineralogical geologies have each had its votaries, and so numerous have they been that the simple mention of their names is precluded.

Such are the principal incidents of progress in the knowledge of the natural history of our land. Many important discoveries have not been even alluded to, and the limitations of space preclude notice of the advance of anthropological science and the general propositions and principles of biology to which American naturalists have contributed.

THEO. GILL.

SMITHSONIAN INSTITUTION, WASHINGTON, D. C.

OUTSIDE.

By CARL SPENCER.

WITHIN, the hearth is warm and light,
Yet none of all the group about
Knows what a glory strikes the night
Where one poor wanderer stands without.

To them their right of earth has come;
One only—oh, how sad her eyes!—
Outside of love and hope and home,
Looks in, beholding paradise.

For all that cold and famine say,
Scarce can the happy hearts believe
How sweet the bread of every day,
How glad the fires of every eve.

The poor know well what wealth can do;
The rich their happiest chances miss;
We sit too near to grasp the view,
Or stand too far to feel the bliss.

Ah, life! what songs are sung outside
For alms of voiceless souls within!
What halo crowns the bliss denied!
What glory flies from hands that win!

For eyes see more than taste and touch—
Poor senses—to the soul can prove;
The longing heart divines too much;
Joy mocks her still at one remove.

How passes this wild night of time
With songs around the Father's hearth,
When these slow hours of darkness chime
With but the exile strains of earth!

Eye hath not seen, ear hath not heard,
The heart goes wandering up and down;
From fleeting glimpse and broken word
Grows fast and fair her love's renown.

Dear heaven! no more this heart could bear,
So sweet thou art, so sore she longs;
Thy very darkened doors are fair;
Thy silence broods to warm her songs.

And not thine endless years can win
Her first high rapture from the Bride,
Who still remembereth, safe within,
The years she wept and prayed outside.