SCIENCE

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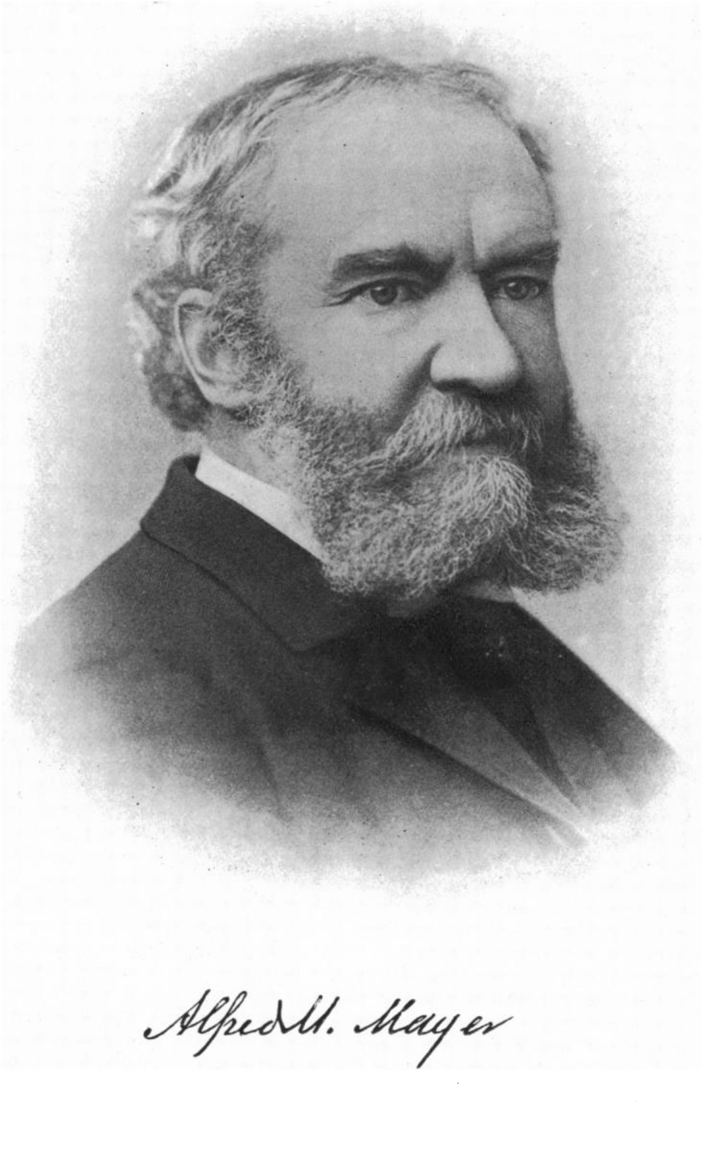
ALFRED MARSHALL MAYER.

A MAN of science, whose work was unique in the domain which he had selected, and who will long be held in warm remembrance by a large circle of friends, has lately passed away.

In 1784 there emigrated to America a young German, Christian Mayer, a member of an ancient family in the city of Ulm, in Würtemberg. He made his home in Baltimore, where, by strong intelligence and well directed industry, he amassed a fortune. To his two sons, Charles F. and Brantz, he gave the best educational advantages of the day. The former became a prominent lawyer, well known in the best social circles of Baltimore on account of his refinement and broad literary culture, while the latter traveled and wrote extensively, his historical work, especially in connection with Mexico, being of high authority and acknowledged value.

On the thirteenth day of November, 1836, a son was born to Charles F. Mayer. At an early age the boy exhibited great mechanical ingenuity and a lively interest in the external world of nature. At St. Mary's College, in Baltimore, he was afforded all the usual facilities for an elementary liberal education, and especially for classical training; but this did not suit his native bent. At the age of sixteen years he gave up the school room, and the following two years were spent chiefly in the workshop and the draughting room of a mechanical engineer. Here was abundant opportunity for acquiring familiarity with the use of tools and developing manipulative skill. At the same time there was a continual stimulus to private study in connection with the daily application of the laws of physics and mechanics. This course of study in applied science was a natural precursor to the resumption of more systematic work, not in the class room, but in the laboratory. A course of


Alfred M. Mayer

chemistry was undertaken, and two years were spent largely in mastering the principles and processes of quantitative analysis.

It was during these years of private study and practical work that young Mayer attracted the attention of a man whose personal influence was chiefly instrumental in determining the future direction of the student's energies. Joseph Henry was at this time Secretary of the Smithsonian Institution, and for thirty years he had been identified with the advancement of pure science in America. Industrial science needs no advocates. Its importance is recognized by all. Its immediate connection with material progress and its quick response to commercial demands are sufficient to bring within the ranks of its devotees the great majority of those who undertake laboratory work with a definite purpose. Henry had never underrated the value or the need of industrial science, but he had emphasized the importance of investigation from the more unselfish standpoint of one who regarded intellectual acquisition as a priceless good in itself apart from all commercial recompense. He apprehended the brightness, the alertness, the originality of the Baltimore student, and accorded him that sympathetic recognition which constitutes the greatest stimulus that a young man can receive. The friendship of an acknowledged master makes a willing and easily directed pupil. Ideals of excellence are thus formed for life. Subsequent experience may sometimes modify these, but they are rarely ever discarded.

At the early age of twenty years Mayer was appointed to the chair of physics and chemistry in the University of Maryland. He had already during the previous year published his first contribution to science, the description of a 'new apparatus for the determination of carbonic acid.' This was soon republished in Germany. His new duties absorbed now most of his time, but a second paper appeared in the *American Journal of Science*, in 1857, on the estimation of the weights of very small portions of matter. In this he showed that by the deflection of a fine glass fibre it is possible to estimate a variation in weight so small as the thousandth part of a milligram. In 1859 he accepted a chair in Westminster College, Missouri, where two years were spent; but the equipment of this institution was insignificant and no original work was accomplished. The breaking out of the Civil War determined his return to Baltimore, and in 1863 he went to Paris, where two years were occupied in special study, chiefly under the direction of Regnault. The influence of the great French physicist, and the general atmosphere of the University of Paris, strengthened the bias in favor of pure science which had been received in youth from Henry.

Soon after his return to America, in 1865, Professor Mayer was called to the chair of physics and chemistry at Pennsylvania College, in Gettysburg, which he gave up, in 1867, to accept that of physics and astronomy in Lehigh University. This in turn was renounced in 1871 for the purpose of joining in the upbuilding of the new Stevens Institute of Technology, at Hoboken, with which his connection continued up to the time of his death, July 13, 1897. It is with this institution, therefore, that his name will always be chiefly identified, though his researches were for the most part in channels somewhat removed from those that are usually characteristic of an engineering school. Its instrumental equipment was unusually good, and proximity to a great metropolis afforded the intellectual stimulus and the prompt recognition of merit which are wanting in isolated institutions of learning.

While connected with Lehigh University,

Professor Mayer designed an astronomical observatory and superintended its construction. He erected the instruments and, without assistance, finished the tedious work of adjusting them. A series of observations on Jupiter followed, and its publication was reproduced in England. During the summer vacation of 1869 he was deputed by the United States government to take charge of a party of astronomers at Burlington, Iowa, where the solar eclipse of August 7th was observed. During the eclipse more than forty successful photographs were taken, each exposure lasting 0.002 second. Four of these were during the eighty-three seconds of totality. This was in the early days of instantaneous photography and was accounted an unusual feat. An abstract of the results of measurements on these photographs was published in the Journal of the Franklin Institute. In the same journal, about this time, he published a number of articles on physical and astrophysical subjects. At the Salem meeting of the Scientific Association, 1869, a paper was read 'On the thermodynamics of waterfalls.' At Trenton Falls and at Niagara Falls careful observations had been made on the temperature of the water at the top of the cataract and just beyond the point of impact at the bottom. The arrest of motion develops heat, and this was found to be manifested in a measurable rise of temperature, when the air was charged with moisture and not much warmer or colder than the water, the change being in accordance with calculation based on Joule's equivalent. But under other conditions this effect was masked to such an extent by the cooling effect of evaporation and conduction that there was sometimes a lower temperature at the bottom than at the top.

Soon after entering upon his duties at Hoboken, Professor Mayer began the series of investigations in acoustics for which he is perhaps best known, and which made him decidedly the leading authority on this subject in America. In the first of his papers he showed how the co-vibration of two nearly unisonant tuning forks may be utilized to demonstrate Doppler's well-known principle that wave-length may be modified by translation of the vibrating body. This was soon followed by another paper in which he gave a method of detecting the phases of vibration in the air surrounding a sounding body. Two resonators responding to the pitch of the source were employed, each connected with a manometric capsule. One of these resonators being fixed and the other movable, the recurring changes in the compound flame image gave the means of measuring wave-lengths directly in the vibrating air and exploring the form of the wave surface. A simple and precise method was developed from this for measuring wave-lengths and velocities of sound in gases at various temperatures; and an acoustic pyrometer was devised by which furnace temperatures were capable of measurement with a degree of accuracy approaching that of the air thermometer. The same optical method of interference was then further applied to the determination of the relative intensities of sounds. The range of application of this method is somewhat limited, but within this range it is more precise than any other method devised for the same purpose. One application was to the measurement of the powers of various substances to transmit and to reflect sonorous vibrations. An investigation of the relative absorbing powers of different media for sound led to an approximate determination of the mechanical equivalent of an aërial sonorous vibration. The energy per second given forth in aërial vibrations by an Ut_3 fork (256 vd.), set in motion by intermittent electro-magnetic action and placed before an appropriate resonator, was found to be about one millionth of Joule's unit, or enough to raise one gram through a height of ten centimeters. This result was accomplished by measuring the relative intensities of the sound given forth by the same fork, first when vibrating freely, then when the motion of its prongs was damped by the expenditure of part of its energy on india rubber. The rise of temperature of the rubber was measured by use of thermopile and galvanometer, and its specific heat determined by ordinary methods. The difficulties attendant upon such an experiment are very great, and no one but an experimentalist of exceptional skill and patience would be apt to undertake it.

These strictly physical investigations led Professor Mayer into the domain of physiology in its bearing upon the phenomena of audition. The most important principle in acoustics is that of harmonic motion, simple and compound, as embodied in Fourier's theorem. Helmholtz was the first to apply this to the analysis of musical quality, and in doing so the subjective method of resonators was utilized with great skill. Professor Mayer sought objective methods and devised several of these, the most striking of which was that of employing tense threads as media for the conveyance of energy from a vibrating membrane to mounted tuning forks adjusted in pitch to respond to the components of the compound sound under examination. Recognizing the capacity of the ear, when sufficiently trained, to accomplish this analysis to a considerable extent without instrumental aid, he sought to learn the mechanism of the auditory apparatus of some of the lower types of animal life. Some new and interesting facts were thus discovered in relation to the function of the antennæ of the mosquito in audition, and he showed how an insect may determine the direction of sounds by means of its antennæ. In this connection good reason was found for the belief that the terminal auditory nerve fibrils in the human ear vibrate just half as often in a given time as the membrane of the tympanum and the ossicles. This hypothesis partially accounts for the marked difference in quality when the same sound is successively heard, first directly through the open ear and then through the medium of the bony portions of the head.

Professor Mayer's most important acoustic research was his determination of the law connecting the pitch of a sound with the duration of the residual sensation in the ear. An explanation of the method adopted cannot be here given without entering unduly into details. This law gave a quantitative character to results which Helmholtz had attained only qualitatively. It is of fundamental importance in its application to musical harmony. It explains why certain combinations of tones which are harmonious in the upper portions of the musical scale become rough and discordant in the lower portions. This mere fact the musical composer was long compelled to recognize, though hitherto it had been inexplicable. The labor involved in this work was great, and before its completion the investigator's power of audition in one ear was thereby permanently impaired. The first experiments were published in 1874; a redetermination was made in 1875, and again with improved apparatus in 1893. He received the assistance of the most accomplished musical experts, including Madame Seiler, who had been associated with Helmholtz for a somewhat similar purpose, and Dr. Rudolph Koenig, of Paris, whose training in the detection of musical beats is unrivaled. Dr. Koenig, in 1893, rendered important service in ascertaining the limitations of what may now be properly called 'Mayer's Law.' This law is expressed by an equation in which the duration of the residual sensation is given as a function of vibration frequency, and this equation is readily translated into a curve. Between the limits of 100 and 4,000 vibrations per second there is closer accordance between the results of calculation and observation than in the case of Fechner's law, or indeed any other physiological law for which the attempt has been made to express sensation mathematically. Between 200 and 2,000 vibrations, including the range most constantly resorted to in music, the accordance is satisfactory, even when measured by physical rather than physiological standards. Due recognition of these important contributions to acoustic theory have been made by Mr. Ellis in his translation of Helmholtz's 'Tonempfindungen,' and by Professor Zahm in his recent book (1892) on 'Sound and Music.' Mr. Ellis gave a special lecture in London for the purpose of explaining these discoveries and their application to the principles of musical harmony.

It was natural for Professor Mayer to apply acoustic methods in work primarily undertaken for other purposes. In 1876 he devised improvements in what is now generally known as the electrographic method for the measurement of the velocity of projectiles and the determination of pitch. He utilized the spark from an induction coil for the purpose of marking seconds upon the sinuous trace of a tuning fork on smoked paper, and attained results of great accuracy. He studied with care the laws of vibration of tuning forks, and was the first to give accurately the correction to be applied in all such determinations on account of variation in temperature of the fork. Between 1889 and 1894 he conducted an elaborate research on the variation of the modulus of elasticity of various materials with change of temperature, as indicated by the transverse vibration of bars. From the observed pitch the velocity of propagation of sound in the bar is found, and this gives the modulus of elasticity. For the accurate determination of pitch it was necessary to visit Paris, where access was had to Dr. Koenig's grand tonometer, and where this accomplished acoustician freely gave his time and skill in furtherance of the work. The remarkable regularity in the results shows that this acoustic method, as conducted, is worthy of the greatest reliance. Among the materials thus studied was aluminum. Its modulus was found to be subject to large variation, and in every respect it is far inferior to steel for acoustic purposes.

Among the acoustic discoveries of Professor Mayer may be mentioned his observation that the sensation of a sound may be obliterated by the simultaneous action on the ear of another sound of greater volume and lower pitch, but that the converse is not true. The higher pitch, even when intense, cannot obliterate the sensation of another sound of lower pitch. This does not imply that the higher pitch is thus always completely obliterated. Its presence modifies the compound perception after the possibility of singling it out has vanished. The apprehension of this truth caused him to suggest certain changes in the method of conducting orchestral music, but they were not adopted on account of counter-balancing inconveniences in practice.

In 1876 Professor Mayer discovered that the air pressure on the inner surface of the bottom of a resonator in action exceeds that on the corresponding outer surface. This led to the construction of the 'sound mill,' composed of pairs of resonators so balanced and pivoted on their supports as to be set into rotation by reaction on sounding near them a tuning fork to which they are adapted. This phenomenon of acoustic repulsion was shortly afterward discovered independently by Dvorâk in Austria. Another application of resonators by Professor Mayer was in the invention of the topophone, an instrument with which the direction of sound at sea, such as that of a fog horn, could be determined with a close approximation to accuracy. His last publication in acoustics was on the production of audible beat tones from two vibrating bodies whose frequencies are so high that the separate tones are inaudible. This paper was read at the Oxford meeting of the British Association in 1894. The existence of such beat tones has been doubted by some. In the present case I was associated with Professor Mayer during some of his experiments, and had previously had considerable experience in the use of the sources of sound which he employed. As to the reality of the results he claimed there cannot be the least doubt on the part of any person possessing ordinarily acute powers of hearing, who will take the trouble to repeat the experiments.

The study of the physiology of sensation tempts to the investigation of the problems of vision in connection with those of audition. During the winter and spring of 1893 Professor Mayer became much interested in the phenomena of simultaneous color contrast, of which it may yet be said that no satisfactory explanation is provided by any existing theory of color vision. It has been common to assume that the modification of color perception induced by contrast is due to unconscious motion of the observer's eyes, to error or fluctuation of judgment, or to incipient retinal fatigue. Professor Mayer devised a variety of methods of presenting these phenomena with unexampled vividness, and on so large a scale as to enable him to arrive at quantitative statements of such subjective color by comparison with standard hues with which they were matched on the revolving color disk. Vivid contrast hues were readily perceptible when the illumination was secured by means of a momentary electric flash, and with entire accordance between different observers who had been purposely misled to expect something different from what they actually perceived. The hypothesis of retinal fatigue, or fluctuation of judgment, or ocular motion, is excluded under such conditions. This psychological element of color contrast led to the development of a disk photometer for measurement of the brightness of colored surfaces. In the use of it a degree of accuracy was attained in excess of that usually found possible with the Bunsen photometer.

While still at the Lehigh University Professor Mayer began investigations on electricity, on magnetism and on heat, which were resumed from time to time during subsequent years in the intervals between his acoustic researches. His lecture notes on physics were published serially in the Journal of the Franklin Institute, and, subsequently, put into book form. He devised a zero-method of comparing the strengths of electro-magnets and electrical conductivities, made many observations on magnetic declination, and improved on previously known methods of fixing and photographing magnetic spectra. He undertook an elaborate research on the effect of magnetization in changing the dimensions of iron and steel bars, an effect discovered by Page in 1837, investigated by Joule in 1842, and then neglected for thirty years. It was about this time that an unusually large electro-magnet was constructed for the Stevens Institute of Technology, and was employed with much effect in public lectures. One of these, entitled 'The Earth a Great Magnet,' was given by invitation of the Yale Scientific Club and, subsequently, published. In connection with it a special form of lantern galvanometer was devised for vertical projection, which attracted much notice. Another lecture demonstration which a few years afterward attracted general attention was that of the configurations formed by magnets floating vertically and subjected to the attraction of a superposed magnet.

The multiple or oscillatory character of the electric discharge from a Leyden jar was discovered by Henry in 1842. It was carefully studied afterward by Feddersen, who used a revolving mirror, and yet more fully by Rood, who employed several methods, but more particularly that of the revolving disk with radial slits. Professor Mayer, in 1874, took advantage of centrifugal action to give steadiness to a disk of blackened paper rotated rapidly between the electrodes employed for transmission of the spark. The perforations were then subjected at leisure to micrometric measurement. Since the rotation of the disk is known, the means is thus afforded for measuring the duration of the discharge and the intervals between the successive sparks which compose it. The conditions were then studied for securing the most nearly simple discharge possible. This served as the necessary antecedent to the successful employment of the induction coil in conjunction with a method previously devised for measuring minute intervals of time with the tuning fork, or rating a tuning fork by comparison with a standard clock. The combination formed an admirable chronoscope for a variety of purposes, but more especially for measuring the velocity of projectiles.

On the general subject of heat Professor Mayer published several articles. The first of these, in relation to waterfalls, has been already mentioned. In 1872 he devised a method of tracing the progress and determining the boundary of a wave of conducted heat by taking advantage of the variation in color with change of temperature which is characteristic of certain double iodides. The same method was applied three years afterward to the securing of thermographs of the isothermal lines of the solar disk. In 1890 he gave publication to a paper on the determination of the coefficient of cubic expansion of a solid from the observation of the temperature at which water in a vessel made of this solid has the same apparent volume as it has at 0° C., and on the coefficient of cubic expansion of a substance determined by means of a hydrometer made of it. The method was applied to several different substances, including brass and vulcanite. This led to a general investigation of the properties of vulcanite, which was published soon afterward. One of these properties is its remarkably large coefficient of expansion, exceeding that of mercury.

Soon after the publication of Röntgen's discovery of a new species of radiation Professor Mayer's interest in this was aroused, and in June, 1896, he published the outcome of his investigation of herapathite, which had been employed by him to test the possibility of polarizing the Röntgen rays. Formulæ were deduced for the transmissive powers of several substances for these rays, including tourmaline, herapathite, glass, aluminum and platinum.

Professor Mayer's last scientific work was an experimental investigation of the equilibrium of the forces acting in the flotation of discs and rings of metal, and an application of such rings to the determination of the measure of surface tension of liquids. The method was wholly new, and the agreement among results was remarkable. At best, it has been difficult in the past to secure reliable results in work of this kind, and the present work is fully equal, if not superior, to the best hitherto accomplished by Plateau and Quincke. It was done during the intervals between periods of acute physical suffering, and its appearance in the *American Journal of Science* for April of the present year preceded by only a few days the paralytic stroke which demonstrated that the investigator's life work was already ended.

In this brief sketch of Professor Mayer's labors but little has been said of his numerous happy devices for lecture demonstration. His restless ingenuity was ever ready for any demand, and his mechanical aptitude was so directed by a delicate æsthetic sense that he could never be satisfied with any objective proof which was not neat and simple, as well as adequate. A few of these he published from time to time. Among them may be mentioned methods of measuring the angle of inclination of the mirrors employed in Fresnel's interference experiments; of obtaining a permanent trace of the oscillation plane of the Foucault pendulum; of registering and exhibiting the vibration of rods; of deducing the fundamental laws of electric repulsion by means of the pendulum; of measuring potentials and specific inductive capacities with the spring balance electrometer; of proving Ohm's law, and of expressing electric potential as work. Many of his demonstrations in acoustics were gathered into a small volume on 'Sound,' and have thence been copied into the elementary text-books of to-day. The same may be said of a little volume on 'Light,' prepared with the co-operation of Mr. Charles Barnard. In the student laboratory he was as efficient as in the lecture room, fertile in devices and ever insistent upon a high standard of accuracy. No one knew better than he that demonstration and practice work are of insignificant value in comparison with investigation; but he kept always in mind the fact that, in America at least, the physical investigator is nearly always compelled to be in some way a teacher, and that in teaching physical science demonstration and theoretic instruction must go hand in hand. He was conscious of his skill and, naturally, took keen pleasure in exercising it successfully. That in so doing he gave pleasure and help to others is manifested by the extent to which his methods have served as models.

The manipulative skill and tactile delicacy which are so necessary as adjuncts to independence and ingenuity in the laboratory were applied with no less success by Professor Mayer in out-door recreation. Early in life he became an accomplished marksman; and during manhood, as long as good health lasted, he was an ardent and exceptionally successful sportsman. His field and laboratory interests were combined in his application of the tuning fork to the problems of gunnery. In the *Century Magazine* he published a number of articles on sporting subjects. These were incorporated, along with contributions from other sources, in a volume entitled 'Sport with Rod and Gun in American Woods and Waters.' This volume was edited by Professor Mayer, and for it he specially prepared two valuable articles, one on 'The Shot Gun,' and another on 'The Blow Gun.'

In addition to these literary labors, Professor Mayer contributed many articles to the Cyclopedias of Appleton and Johnson, besides occasional popular articles on scientific subjects for other media of publication. In acknowledgment of his earlier contributions to science the degree of Doctor of Philosophy was accorded him in 1866 by Pennsylvania College. He was admitted to membership in the National Academy of Sciences in 1872, and was a member of each of the leading scientific societies of America, besides being a corresponding member of the British Association. He served during one year, 1873, as an associate editor of the *American Journal of Science*, and during the first eight months of that year five articles from his pen appeared in its pages. The partial failure of his eyesight then necessitated cessation from all work, and a considerable part of the next scholastic year was spent in England, where his reputation had preceded him and where hospitable entertainment was accorded by the most prominent representatives of science.

In the closer circle of personal friendship it is hard to speak with impartiality while the sense of bereavement is still fresh. A man's personality penetrates into all that he does, into his writings quite as unmistakably, if less positively, than into his conversation and the atmosphere of his home. In a eulogy on Joseph Henry, to which I listened at Cambridge just seventeen years ago, Professor Mayer said: "His best eulogy is an account of his discoveries; for a man of science, as such, lives in what he has done, and not in what he has said, nor will he be remembered for what he has proposed to do." In comparing Henry with Faraday he remarked: "Each loved science more than money, and his Creator more than either." Mayer proved himself a worthy pupil of Henry, and their friendship grew in strength until broken by the last great Destroyer. His words may now be properly applied to himself. The characteristics of the gentleman, the high-toned man of honor, were born in him. They needed no cultivation beyond the natural development and confirmation which accompany the attainment of maturity. Those who were favored with his friendship need no reminder of his generosity, his ready sympathy, his quick insight and hearty appreciation, his enthusiasm verging sometimes almost upon that of boyhood.

The value of Mayer's work will be tested by time. For some parts of it he will unquestionably be long referred to as an authority by stranger as well as friend. He dwelt in an atmosphere essentially unfavorable to the spirit which directed his work, for nowhere in the world can there be found so high a degree of general civilization conjoined with so small a degree of general appreciation of pure science as in America. This may be said with full recognition of the abundant rewards here accorded to science successfully applied in industrial fields, and of the rich endowments given by wealthy individuals to some of our educational institutions. But the man who advances theoretical science in America receives not a tithe of the recognition given to the inventor who puts on the market a merchantable device which pleases the multitude. Professor Mayer would have done his scientific work to better advantage in France or Germany. But be this as it may, we who knew him in his work must now know him only in memory. To have had him as a co-worker and friend is now a sad pleasure, and one that nothing can take away.

W. LECONTE STEVENS.

ADDRESS OF THE PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.*

ONCE more has the Dominion of Canada invited the British Association for the Advancement of Science to hold one of the annual meetings of its members within the Canadian territory, and for a second time has the Association had the honor and pleasure of accepting the proffered hospitality.

In doing so the Association has felt that, if by any possibility the scientific welfare of a locality is promoted by its being the scene of such a meeting, the claims should be fully recognized of those who, though not dwelling in the British Isles, are still inhabitants of that Greater Britain whose prosperity is so intimately connected with the fortunes of the Mother Country.

Here, especially, as loyal subjects of one beloved sovereign, the sixtieth year of whose beneficent reign has just been celebrated with equal rejoicing in all parts of her Empire; as speaking the same tongue, and as, in most instances, connected by the ties of one common parentage, we are bound together in all that can promote our common interests.

* Delivered by Sir John Evans at Toronto, August 18, 1897.