OBITUARY.

JOHN TYNDALL, D.C.L., LL.D., M.D., F.R.S., was born at Leighlin Bridge, near Carlow, in Ireland on the 21st of August, 1820. His father was a Protestant and one of the old Irish revenue police. He was a man of superior intellect for his station and of a singularly independent mind; apparently a good deal given to theological controversy—a trait of character which for many years was shared by his son. There is but little known of John Tyndall's mother, except that she was a woman of considerable culture and insisted that her son should be kept at school as long as possible. He remained there in fact to the unusual age of nineteen, when he had mastered—besides Thomson's and Gregory's arithmetic—euclid, plane trigonometry, and some algebra, as well as conic sections.

Soon after leaving school young Tyndall was appointed a Civil Assistant in a division of the Ordnance Survey, then under the direction of the late General Wynne, R.E., who not only recognised his talents and gave him facilities for their cultivation, but afterwards retained for him a lifelong friendship. He soon made himself master of all the operations of the Survey, in both office and field work. In 1843 he left the Survey with the intention of emigrating to America, but he was infected by the great railway mania of that time and prevented from carrying out his intention. He came to England and entered the employment of a Manchester firm of railway engineers, by whom he was set to work in levelling, surveying and making out plans and estimates in accordance with the rules of the Board of Trade. He was engaged on surveys in the valleys of the Churnet and Dove in Staffordshire, of the Ouse in Bedfordshire, and in the north of England. In this occupation he seems to have spent about five or six years, and the experience thus acquired doubtless contributed in no inconsiderable degree to develop his subsequent love of pursuits which necessitated accuracy of measurement and logical reasoning. His field work no doubt also contributed to the development of that great muscular strength for which, especially at this period of his life, he was renowned. He used to tell many stories of the conflicts he had with landed proprietors who declined to admit him into their grounds for the purpose of surveying. But, he remarked that what he called his "Irish blarney" was generally effective without resort to physical force, either actual or threatened. The strain upon him during those years was doubtless often very severe. He says, "The day's work in the field usually began and ended with the day's light; and, more especially as the awful 30th of November drew near, there was little difference between day and night, every hour of the twenty-four being absorbed in the work of preparation;" and he was often glad of the rest derived from five minutes' sleep on a hard table with "Babbage and Callet's Logarithms" for a pillow.

In the year 1847 Tyndall became acquainted with the late George Edmondson, who at that time was earnestly endeavouring to introduce into his large private school for boys practical instruction in chemistry and other experimental sciences. Early in that year Mr. Edmondson removed his school from Preston to the abortive socialistic establishment well known at that time as "Harmony Hall," where, under the leadership of Robert Owen, a number of carefully-selected men and women of the working classes had been brought together to practically solve the social problem. They were well housed in a commodious building situated in a most picturesque part of Hampshire. "Harmony Hall" was built almost regardless of expense and was replete with all desirable comforts and even luxuries. Excellent school-rooms were erected for the instruction of the children of the inmates and an estate of some 500 acres was placed at the disposal of the working members of the community. The day was divided into three equal parts—eight hours' work, eight hours' play and eight hours' sleep. The inmates were selected so as to include all necessary trades. There was a ball and a concert every week, and the sixteen hours devoted to play and sleep were a complete success. But as eight hours' honest work could not be got out of the inmates, the scheme utterly collapsed, and "Harmony Hall" was transformed, under the auspices of Mr. Edmondson, into Queenwood College. Here, for the first time in an English school, experimental science was practically taught in the laboratory and the field; and Tyndall, although at considerable pecuniary loss to himself, was easily persuaded to become a teacher of mathematics and surveying in this new establishment, being chiefly influenced by the opportunity afforded him of working in a chemical laboratory.

Besides formal instruction in mathematics, Tyndall gave lessons to the students in the use of the theodolite and in practical surveying in the country around Queenwood. He also lectured about three times a week on various subjects—the uses of surveying-instruments, land-surveying, mathematics, and occasionally on social and philosophical subjects, *e.g.*, "the importance of independent thought," etc.

At this time, although he was now twenty-seven years of age and a good mathematician, his knowledge of chemistry, or physical science in any form, was most rudimentary. At Queenwood, however, he soon became an intensely interested student of these sciences, and was especially anxious to obtain a thorough acquaintance with chemistry. His duties as a teacher were heavy, demanding seven, eight, and more often ten hours a day. It was his custom at this time to allow himself only six hours in his bedroom (ten to four). On leaving it he lit a fire in the laboratory, made coffee, and then worked at practical chemistry until eight o'clock. He was bright, sociable, original, and a most interesting companion, full of enthusiasm and humour. Tyndall remained only fifteen months at Queenwood College and then proceeded to Marburg in Hesse Cassel, there to study chemistry in the laboratory of the renowned Bunsen. Partly at Queenwood and partly in Marburg he went through a fairly complete course of qualitative and quantitative analysis, and would doubtless soon have commenced some original work in Bunsen's laboratory, had not an event occurred which diverted his attention to physics. This event was the arrival in Marburg, as Extraordinary Professor, of the enthusiastic young physicist Knoblauch, who soon exercised a great influence on Tyndall and was probably the main cause of the latter devoting himself for the future chiefly to physical science, in which he found more scope for the employment of his mathematical knowledge than was at that time afforded by chemistry.

Before the arrival of Professor Knoblauch, Tyndall had already graduated in the Philosophical Faculty, taking mathematics for his principal subject in the *vivâ voce* examination, and for the two subsidiary subjects, chemistry and physics. Before admission to examination at Marburg, it is essential to present to the Faculty a thesis on some original investigation made by the candidate. Tyndall's dissertation was entitled "On screw surface with oblique generating line, and the conditions of equilibrium for such screws." The subject of this thesis shows that, at this time, Tyndall's knowledge of mathematics was superior to his acquirements in chemistry and physics.

In conjunction with Knoblauch, Tyndall made his first physical investigation, the results of which were published in the year 1850 under the title "*On the deportment of crystalline bodies between the poles of a magnet.*" From Marburg he migrated to Berlin and worked for about a year in Magnus's laboratory, finally returning to England about the end of 1851. At this time there was no physical laboratory in England and no chair of experimental physics; consequently there was no career open to a young physicist, and for a year or more Tyndall was almost in despair of obtaining any appointment in which he could continue his investigations. He applied for such a chair, which was vacant at Toronto, but was unsuccessful in obtaining it. The credit of discovering and utilising Tyndall is due to the late Dr. Bence Jones, who, when visiting Berlin, heard much of his labours and personality, and in consequence caused him to be invited to lecture at the Royal Institution on February 11th, 1853. The subject of the lecture was "The influence of material aggregation on the manifestations of force." This lecture, although on such an abstruse subject, took his audience by storm, and he received at its close quite an ovation. His extraordinary powers of exposition and experimentation were at once recognised by Faraday and Bence Jones, and he was appointed Professor of Natural Philosophy in the Royal Institution on the 4th of July following. As a colloquial lecturer he was unsurpassed even by Faraday. The enthusiastic interest and pleasure he himself took in his subject and its illustration enchained his audience and compelled their attention.

Tyndall held this position at the Royal Institution for thirty-four years. During some years of this time he occupied also the Chair of Physics in the Royal School of Mines. He was also examiner in several Royal Military Colleges and in the University of London. He was elected a Fellow of the Royal Society in 1852. A Royal Medal was awarded to him in 1853 for his researches on magne-crystallic action, and he received the Rumford Medal from the Council of the Royal Society in 1864 for his researches on the absorption and radiation of heat by gases and vapours. He was an Honorary Member of a large number of learned societies at home and abroad. In 1866 he succeeded Faraday as scientific adviser to the Trinity House, which post he occupied for seventeen years. In 1872 he was invited to undertake a lecturing tour in the United States, and realised thereby between £6,000 and £7,000 from the large audiences attracted by his eloquence and experimental skill. The whole of this sum he generously devoted to the encouragement of scientific training in the United States, dividing it equally between Columbia College in New York, Harvard College near Boston, and the University of Pennsylvania at Philadelphia.

In 1876 he married Louisa, eldest daughter of the late Lord Claud Hamilton, and received, on the occasion of his marriage, a purse of 300 guineas from the members of the Royal Institution, and a medallion bust of himself in marble from his fellow-members of the "X" club.

It is impossible within the limits of an obituary notice to do adequate justice to Tyndall's original work. It ranged over nearly the whole domain of experimental science. Its chief subjects may be grouped under the heads of heat, light, acoustics, magnetism, biology, and the structure and motion of glaciers; whilst he invaded, in a subordinate way, the sciences of electricity, astronomy, chemistry and geology. During the thirty-three years of Tyndall's scientific life he published no less than 135 papers, or at the average rate of rather more than four per annum. One of his first investigations in the domain of heat was entitled, "On the Vibrations and Tones produced by the contact of bodies having different temperatures," and was communicated to the Royal Society in January, 1854. It related to observations made—in the first place in 1805—by an inspector of one of the smelting-works of Saxony, who, having a quantity of silver in a ladle which had just solidified after melting, placed it upon a cold anvil, for the purpose of hastening its cooling, when, to his astonishment, sounds, which he compared to those of an organ, proceeded from the mass. Afterwards, in 1829, Mr. Arthur Trevelyan was engaged in spreading pitch with a hot plastering-iron, when observing that the iron was too hot, he laid it obliquely against a block of lead which happened to be at hand. Shortly afterwards he heard a shrill note, which he at first attributed to the playing of the "smaller Northumberland pipes" by his father's gamekeeper. As, however, he failed to find the performer, his attention was at length attracted to the hot iron, which he found to be in a state of vibration and thus discovered the source of the music. The phenomenon was further investigated by J. D. Forbes and by Faraday, and a controversy had arisen between these last experimenters as to the cause of the sounds. Faraday referred it to expansion and contraction where the surfaces came in contact, whilst Professor Forbes considered it to be due to "a new species of mechanical agency in heat," and asserted that the vibrations never took place between substances of the same nature. In this memoir Tyndall describes a large number of experiments, proving that the vibrations can be obtained by iron upon iron, copper on copper, brass on brass, silver on silver, zinc on zinc, and tin on tin, and that they were also obtainable by placing heated brass upon rock-crystal, fluor-spar, rock-salt, and many other non-metallic bodies. Tyndall's experiments led irresistibly to the conclusion that the explanation offered by Faraday, Leslie and Trevelyan was the correct one.

One of the most interesting and important of Tyndall's discoveries in the domain of heat was the demonstration that the invisible heat-rays of the solar and electric-light spectra can have their rate of vibration augmented so as to render them visible. Professor Stokes had already shown that the invisible rays at the ultra-violet end of the spectrum could be rendered visible by a reduction of their rate of vibration, this phenomenon having received the name of fluorescence. Tyndall named the opposite effect calorescence. He showed that by the interposition of a saturated solution of iodine in bi-sulphide of carbon, the non-luminous heat-rays could be separated from the luminous rays almost without loss; and he found that the invisible radiation of electric light was, in thermal power, equal to eight times that of the visible. By thus sifting the electric beam, and concentrating it by means of a concave mirror, he obtained a focus of dark heat of great thermal power. He says: "Matches are at once ignited, and gunpowder instantly exploded. Dry paper bursts into flame. Chips of wood are also inflamed; and discs of charred paper glow with extreme vividness. Sheet lead and tin, if blackened, may be fused, and blackened zinc-foil placed at the focus bursts into flame. Magnesium wire, flattened at the end and blackened, also bursts into vivid combustion. The bodies experimented upon may be enclosed in glass receivers, the concentrated obscure rays will burn them after having crossed the glass. A small chip of wood in a jar of oxygen bursts suddenly into flame, and charcoal bark burns under the same conditions with showers of scintillations."[1] On these results Tyndall remarks: "The isolation of the luminiferous ether from the air is strikingly illustrated by these experiments. The air at the focus may be of a freezing temperature, while the ether possesses an amount of heat competent, if absorbed, to impart to that air the temperature of flame. An air thermometer is unaffected where platinum is raised to a white heat."

The great work of Tyndall's life, however, in connection with

[1] "Heat a mode of motion," p. 451.

heat, was his investigations "On the Action of Gases and Vapours on Radiant Heat."[1] These researches were continued for twelve years, and will, for all time, constitute an epoch in the history of physical science. Shortly summarised, the results of this classical investigation may be thus stated:—(1) Elementary gases scarcely absorb any perceptible amount of radiant heat; (2) All compound gases absorb proportions varying directly with the complexity of their molecules. Thus the vapour of ether was found to absorb, for equal volumes at maximum density, 100 times the quantity of radiant heat intercepted by the vapour of bi-sulphide of carbon. The molecule of bi-sulphide of carbon vapour contains only three atoms, whilst that of ether contains no less than fifteen. Nevertheless the quality of the atoms constituting the molecule has also a great influence upon the absorptive power. Thus carbonic acid contains in its molecule the same number of atoms as bi-sulphide of carbon; but, at a tension of 1·2 inch, its absorption is represented by the number 37, whilst the vapour of bi-sulphide of carbon at a tension of only 1 inch is represented by the number 62. Of all the molecules experimented upon, boric ethylate was the most complex, and exercised the most powerful absorptive effect upon radiant heat. This compound contains in its molecule no less than twenty-five atoms, and has an absorptive coefficient, at only $\frac{1}{10}$-inch tension, represented by the number 620. He found that the relative radiative powers of gases and vapours followed precisely the same order as their powers of absorption. Discussing the theoretical bearings of his experimental results, he draws attention to the enormous difference, in behaviour towards radiant heat, exhibited by mechanical mixtures of gases as compared with the same gases chemically combined. Thus a mixture of hydrogen and nitrogen in the proportions required to form ammonia produces scarcely a perceptible absorptive effect; whilst, chemically combined, they produce an enormous absorption.

He extended these experiments to the effect of odours in absorbing radiant heat. He found that the perfumes arising from patchouli, sandal-wood, oil of cloves, otto of roses, bergamot, lavender, thyme, rosemary and camomile flowers caused an absorption of from 30 to 372 times that of atmospheric air. The most surprising result was obtained with musk, which, as is well known, emits its odour for months or even years without any perceptible loss of weight; yet, when this odour was diffused through dry air, the inconceivably small amount thus introduced

[1] Proceedings of the Royal Institution, vol. iii. p. 295.

gave an absorption 74 times as great as that of the air in which it was diffused. Amongst other conclusions drawn from these experiments, Tyndall contended that planets, even at a great distance from the sun, might have atmospheres of such a character as to maintain upon their surfaces sufficient solar heat for the maintenance of life such as it is known on the surface of the earth.

In acoustics, one of Tyndall's most important investigations was communicated to the Royal Society in the year 1874 under the title of "The Transmission of Sound by the Atmosphere."[1] This paper contains some account of an investigation on fog-signals carried out at the instance of, and in conjunction with, the Elder Brethren of Trinity House. The knowledge of the transmission of sound through the atmosphere was at this time in rather a chaotic condition. It was generally considered that fogs and falling rain, but more especially snow, tended powerfully to obstruct the propagation of sound, and that the same effect was produced by a coating of fresh fallen snow on the ground, though, when glazed and hardened at the surface by freezing, it had no such influence. It was known that atmospheric currents interfere with sound waves, so that a gun or a bell which is heard several miles down the wind is inaudible more than a few furlongs up the wind. Still clear air was regarded as the best vehicle of sound, the alleged action of fogs, rain, and snow being considered as rendering the atmosphere a discontinuous medium. In 1871 Mr. Alexander Beazeley gave to the Institution[2] a very useful summary of this knowledge at that time. In the discussion which followed, Dr. Gladstone, who was a member of the Lighthouse Commission, said that a difficulty in the use of sound was, that fogs deadened sound very materially; but the evidence was very contradictory on that point. In a fog on land it was difficult to hear the passing of carriages or noises at a short distance; and so in a fog at sea these signals found a difficulty in penetrating the fog against which they were intended to be a protection. On the other hand Sir James Douglass, Engineer to the Trinity House, observed on the same occasion that he had found little difference in the travelling of sound in foggy or in clear weather. He had heard distinctly, in a fog at the Small's Rock, Bristol Channel, guns fired in Milford Haven, 25 miles off. Mr. Beazeley had also heard the Lundy Island gun at Hartland Point, a distance of

[1] Proceedings of the Royal Society, vol. xxii. p. 58.
[2] Minutes of Proceedings Inst. C.E., vol. xxxii. p. 95.

10 miles, during dense fog. Other opinions of eminent authorities are also given in Tyndall's Paper, proving that the evidence of the action of fog upon sound was at that time extremely conflicting.

Tyndall's experiments were begun on the 19th of May, 1873, and continued till the 4th of July; they were resumed on the 8th of October, and continued to the end of November. They also include observations made during the dense fog which enveloped London on December 9th and the following days. Gongs and bells were excluded from this investigation, in consequence of their proved inferiority to other instruments of signal. The experiments were made with trumpets blown by compressed air, with steam-whistles, guns, and a steam-siren associated with a trumpet 16 feet long. The trumpet, which had been reported as sending its sound to a distance of from 7 to 9 miles against the wind, and to a distance of from 12 to 14 miles with the wind, proved to be entirely unheard at sea at a distance of 4 miles; and, even at a distance of 3 miles, it was useless as a fog-signal on the 19th of May. On the same day at a distance of 2 miles from the Foreland the steam-whistles became useless. The 12 o'clock gun fired at Dover was well heard on the same day, when the horns and whistles were inaudible. On other days the permeability of the atmosphere to sound was somewhat greater, but the superiority of the 18-pounder gun over the horns and whistles was so decided as almost to warrant its recommendation to the exclusion of all the other signals. On the 3rd of June the atmosphere had changed surprisingly. It was loaded overhead with dark and threatening clouds, and the sounds were well heard beyond 9 miles. An acoustic shadow on the Dover side of the Foreland was observed, and the effect of passing into it was very striking. The superiority of the gun to the whistle and trumpet, which was so marked on the 20th of May, had on June the 10th entirely disappeared, the gun being equal to the other signals and nothing more. On the 3rd of July the acoustic imperviousness was very great, although the optical purity of the day was sensibly perfect. The cliffs of the Foreland could be seen on this day at ten times the distance at which they ceased to be visible two days previously, whilst the sounds were cut off completely at one-sixth of the distance. At 2 P.M. neither guns nor trumpets were able to pierce the transparent air to a depth of 3, and hardly to a depth of 2 miles. This extraordinary opacity to sound was conclusively proved to arise from the irregular admixture, with the air, of the aqueous vapour raised by a powerful sun. This vapour, though perfectly invisible, produced an acoustic cloud impervious to the sound, from which the sound waves were thrown back as the waves of light are from an ordinary cloud. The waves, thus refused transmission, produced by their reflection echoes of extraordinary strength and duration. This was the first time that audible echoes were proved to be reflected from an optically transparent atmosphere. By the lowering of the sun the production of aqueous vapour was checked and the transmissive power of the atmosphere restored to such an extent that at a distance of 2 miles from the Foreland at 7 P.M. the intensity of the sound was at least thirty-six times its intensity at 2 P.M.

In subsequent experiments on the 16th of October, which was a day of exceeding optical transparency but of great acoustic opacity, the siren proved itself to be very decidedly the best signal. It was heard at a distance of 3½ miles, whilst the gun was unheard at 2½ miles. This superiority of the siren was also proved by subsequent trials.

The real enemy to the transmission of sound through the atmosphere was clearly revealed by this inquiry. That enemy was proved to be not rain, nor hail, nor fog, nor snow,—not water, in fact, in either liquid or solid form, but water in the form of vapour mingled with the air so as to render it acoustically turbid and flocculent. This acoustic turbidity often occurs on days of great optical transparency. Any systems, or measures, therefore, founded on the assumption that the optic and acoustic transparency of the atmosphere go hand in hand, must prove delusive. In conclusion, Tyndall remarks, "There is but one solution of the difficulty; it is to make the source of sound so powerful as to be able to endure loss by partial reflection, and still retain a sufficient residue for transmission. Of all the instruments hitherto examined by us the siren comes nearest to the fulfilment of this condition; and its establishment upon our coasts will, in my opinion, prove an incalculable boon to the mariner. Thus, I think, has been removed the last of a congeries of errors which, for more than a century and a half, have been associated with the transmission of sound by the atmosphere."[1]

Amongst the numerous lines of investigation suggested to Tyndall during his mountain rambles, was the question of the cause of cleavage in slate rocks. He inquires, what is the agency which enables us to split Honister Crag or the cliffs of Snowdon into laminæ from crown to base?[2] In the year 1856, when he

[1] Proceedings of the Royal Institution, vol. vii. p. 178.
[2] *Ibid*, vol. ii. p. 298.

asked himself this question, the subject was one of the greatest difficulty to geologists, and occupied their attention perhaps more than any other. The planes of cleavage have no relation to the planes of stratification; in fact, in most cases the planes of cleavage stand at a high angle to those of bedding. Professor Sedgwick had endeavoured to explain the difficulties presented by this curious phenomenon as follows: "They appear to be only resolvable on the supposition that crystalline or polar forces acted upon the whole mass simultaneously in one direction and with adequate force. Crystalline forces have rearranged whole mountain masses, producing a beautiful crystalline cleavage passing alike through all the strata."[1] Tyndall shows this theory to be erroneous. By a series of well-devised experiments he produced perfect cleavage in such non-crystalline substances as white wax, fine mud, puff paste, and cream cheese, and he showed that cleavage in these cases is produced by the same agency as that which splits mountain masses into thin laminæ. He also instances the exfoliation of railway rails caused by the pressure of wheels and by the rolling of malleable iron. Pressure, and pressure alone, is quite competent to produce this phenomenon, the direction of cleavage being always at right angles to that of the pressure. In concluding his exposition of this matter, he says: "Expanding our field of view, we find the self-same law, whose footsteps we trace amid the crags of Wales and Cumberland, stretching its ubiquitous fingers into the domain of the pastry-cook and iron-founder; nay, a wheel cannot roll over the half-dried mud of our streets without revealing to us more or less of the features of this law."

Of his more important original work in other fields of investigation, mention may be made of his numerous memoirs on glaciers, their structure and motion; on the physical properties of ice and on the veined structure of glaciers; on sounding sensitive flames; on the blue colour of the sky; on a new series of chemical reactions produced by light; on the formation and phenomena of clouds; on dust and disease; on the optical deportment of the atmosphere in relation to putrefaction; and his classical researches in bacteriology. Many of these Papers may be found in the Proceedings of the Royal Institution.

In the year 1886 Dr. Tyndall's health became so impaired, mainly through overwork, that the Managers of the Royal Institution granted him a year's holiday; but, although this was of

[1] Trans. Geological Society, series II., vol. iii. p. 477.

some benefit to his health, he felt compelled to resign his appointment at the end of the year. In accepting his resignation, the managers, at their meeting in April, 1887, passed the following resolution: "The Managers desire to record the expression of their deep regret that the state of Dr. Tyndall's health should have rendered necessary the resignation of his position of Professor of Natural Philosophy at the Royal Institution, and that it should have compelled the Managers to accept that resignation. They also desire that there should be recorded the expression of their thorough appreciation of the unremitting and most valuable services which, during the long period of thirty-four years, Dr. Tyndall has rendered to the Royal Institution in carrying out the duties of his office—services which not only have upheld and have advanced the position of the Royal Institution, but have benefited science and the world at large."

After the retirement of Dr. Tyndall from the Royal Institution, the last years of his life were clouded by repeated attacks of illness. In the autumn of 1893 the usual sojourn in his cottage on the Bel Alp appeared to effect a substantial improvement in his health; but, almost immediately on his return, he had a serious relapse from which he was gradually recovering, when on the 4th of December he died from the effects of an overdose of chloral accidentally administered to him in mistake for sulphate of magnesia. His remains were interred in Haslemere churchyard on the 9th of December in the presence of a very large number of friends. The coffin bore the following inscription: "John Tyndall died December 4th, 1893. Aged 73 years."

Dr. Tyndall was elected an Honorary Member of the Institution on the 3rd of February, 1880, on the ground that by his distinguished attainments as a physicist, by his contributions to molecular physics, acoustics, radiant heat, and heat as a mode of motion, and by his position as Scientific Adviser to the Corporation of Trinity House, he had materially advanced Mechanical Science, the primary object of the Institution.

JOHN ALLISON was born at Pathhead, near Dalkeith, on the 26th of February, 1838. At eighteen he was articled for five years to an architect and surveyor, Mr. Thomas Jeffrey of Leith Walk, Edinburgh. On the expiration of his pupilage he was for twelve months an assistant in the engineer's office of the North British Railway Company. From 1861 to 1867 he was engaged