OBITUARY NOTICES OF FELLOWS DECEASED.

RUDOLF JULIUS EMMANUEL CLAUSIUS was born on the 2nd January, 1822, in Cöslin, in Pomerania. He was the sixth son of the Rev. C. E. G. Clausius, D.D., Councillor of the Royal Government School Board, and later, Superintendent in Ueckermünde.

After the completion of his studies in the Gymnasium in Stettin, he attended the University of Berlin from 1840 to 1844. In the Easter of 1844 he passed his examination "pro facultate docendi," and then finished his year of probation at the Frederic-Werder Gymnasium. Here he taught the higher classes mathematics and physics. In the autumn of 1846 he entered Boeck's Royal Seminary for higher students. On the 15th July, 1848, he took his degree in Halle "eximia cum laude" (subject of dissertation—"De iis Atmosphæræ Particulis quibus Lumen reflectitur"). On the 25th September, 1850, he was invited to be Professor of Physics in the Royal Artillery and Engineering School at Berlin. On the 18th December he delivered his inaugural lecture as *docent* at the University of Berlin ("De Motu Corporum rotantium in Aëre resistente"). On the 29th August, 1855, he was called to be Ordinary Professor in the Polytechnicum in Zurich, and also at the same time in the University of Zurich. In 1867 he was appointed Professor in the University of Würzburg, and in 1869 he went to Bonn, where he fulfilled his duties till the day of his death, the 24th August, 1888.

While at Zurich he married, on the 13th November, 1859, Adelheid Rimpam, of Brunswick. They had six children, of whom two daughters and two sons are alive. His wife died in 1875, and he married again, in 1886, Sophie Sack, of Essen, by whom he had one son.

His brother, Herr Robert Clausius, thus writes of the character of this great man:—

"I had often the opportunity of admiring the rare energy and clearness with which, in a small study and with limited means, he untiringly pursued his great scientific aims. A chief characteristic was his sincerity and fidelity. Every kind of exaggeration was opposed to his nature. Even as a youth all intimate with him learnt to esteem his reliability and truthfulness. In the Gymnasium and in all circumstances of his later life the greatest confidence and trust were placed in him. His judgment, which was guided by the strongest feeling of rectitude, was highly valued. Another important trait was his unbending and firm faithfulness to duty, to which he was true in all affairs of life up to his death. Even on his last bed of sickness he held an examination. He was the best and most affectionate of fathers, fully entering into the joys of his children. He himself supervised the schoolwork of his children. He was simple and natural in his intercourse and possessed of a rare modesty. He was never tired of sacrificing himself in cases of necessity, and though immersed in abstract studies he always kept a warm heart for everything human. He was a great, noble-minded, good man, whom all who knew more intimately have loved and esteemed, not only on account of his scientific celebrity but especially on account of his noble, manly qualities.

"His burning patriotism did not permit him to stay idly at home during the war 1870–1. He undertook the leadership of an ambulance corps, which he formed of Bonn students. At the great battles of Vionville and Gravelotte he helped to carry the wounded from the battle and to lessen their sufferings. For his services in this campaign he received the Iron Cross. A contusion in his leg which he received on the field of battle caused him great pain for many years and often necessitated his driving to his lectures. On the doctor's advice, at the age of 56 he learnt to ride, and became an excellent horseman. Riding proved very beneficial to his health."

One of his sons thus writes of him :—

"The principal trait in my father's character was, without doubt, the splendid truthfulness of his nature. In his deeds and words he never could tolerate anything ambiguous, and particularly as regards himself he cherished no self-deception. For that reason he never suffered from the discovery of the motives of his actions; from thence sprang his thoroughly noble nature as well as his great modesty and the delight which he always felt, and was never too proud to express, at the recognition of his work; from thence his dislike to all smattering and superficiality in which he suspected some untruthfulness. Another remarkable characteristic was the uncommon one of seeing only the best side of his neighbours. He hardly noticed their faults, and when he did he had not the least inclination to cheap mockery. The general impression which he received of people was formed from the more or less strong development of their good qualities and was little dimmed by the presence of this or that defect. His hearty, pleasant, always thoroughly genuine address towards everyone was the result of this trait. Only when he discovered untruthfulness did he take a deep aversion."

Clausius received the following offers of posts :—

In 1858 to the Polytechnicon of Carlsruhe; in 1862 to the

Polytechnicum of Brunswick; in 1866 to Vienna; in 1868 to Munich; in 1871 to Strasburg; in 1883 to Göttingen.

He received the following orders and titles :—

When Professor in Würzburg he was appointed Court Councillor; in 1868, as Professor in Bonn, he was appointed Privy Councillor; in 1870 he received the Huygens Medal; in 1871 the Iron Cross; in 1873 the Order of the Crown, 3rd Class; in 1879 the Order of the Red Eagle, 3rd Class, and the Copley Medal: in 1881 he was named Officer of the Legion of Honour; in 1882 he was appointed Doctor of Medicine *honoris causâ* in Würzburg; in 1883 he received the Poncelet prize; in 1884 the Order of the Prussian Crown, 2nd Class; in 1885 the Bavarian Maximilian Order. During 1884–5 he was Rector of the University of Bonn, and for six months was Curator of this University. He took part in the academic education of Prince William, afterwards Emperor of Germany. In 1887 he was invited to be one of the Curators of the New Imperial Physical and Technical Institution. In 1888, at the Investiture of the Order for Art and Science, he was appointed Hereditary Knight.

He received the following honours from Learned Societies :—

In 1857 Hon. Mem. Harlem; in 1859 Hon. Mem. of the Engineers of Scotland and Corresp. Mem. Erlangen; in 1865 Corresp. Mem. of the Institute of France; in 1866 Hon. Mem. Frankfurt-am-Main, and Hon. Mem. Dublin and Corresp. Mem. Göttingen; in 1868 Royal Soc. Lond.; in 1869 Hon. Mem. Nat. Hist. Soc. Zurich; in 1871 Elected Mem. Munich; in 1872 Elected Mem. Pest; in 1873 Corresp. Mem. Bologna and Elected Hon. Mem. Boston; in 1875 Hon. Mem. Civil Engin. Lond., Elected Corresp. Mem. Vienna, and Mem. Brussels; in 1876 Corresp. Mem. Berne, Society of Arts Geneva, and Hon. Mem. Nat. Hist. Soc. Basel; in 1877 Elected Mem. Göttingen; in 1878 Elected Mem. Stockholm, Elected Mem. Naples and St. Petersburg; in 1879 Mem. Halle Natural Hist. Soc. and Elected Mem. Ling.; in 1882 Corresp. Mem. Milan, Corresp. Mem. Turin, and Hon. Mem. Mech. Eng. New York; in 1883 Elected Mem. Washington, Hon. Mem. Erlangen, and Foundation Mem. Internat. Soc. of Electricians; in 1884 Corresp. Mem. Cherbourg and Corresp. Mem. Lucca; Hon. Mem. Manchester, Mem. Amsterdam; in 1887 Hon. Mem. Brunswick, Hon. Mem. Hamburg, Ordinary Mem. Upsala; in 1888 Mem. Edin.

In his scientific work Clausius investigated the general mechanism of Nature rather than particular applications of the principles he discovered; he was constructively synthetical rather than analytical. It is remarkable how he was led by dim previsions, as when his theory of gases influenced his views on heat when his gas theory was yet quite imperfect; his greatest work is grouped round his insight into molecular structure. The other great branch of his work is connected with electromagnetic theory. As in the theory of heat, he worked from the theory of matter to the theory of the steam engine, so in electromagnetism, he worked from the theory of electromagnetic actions to the theory of its industrial application to dynamos.

Clausius' first publications were concerned with the action of atmospheric dust on sunlight. This seems to have directed his thoughts to molecular physics, which was indirectly the foundation of his greatest work. Thermodynamics was the region he explored, and his exploration was guided by his insight into molecular physics. When Clausius was beginning his independent activity the investigations of Rumford, Davy, Mayer, Joule, and Helmholtz had conclusively shown that heat could be produced from work, while the thermodynamic speculations of Carnot, founded upon the assumed indestructibility of caloric, were receiving every day additional confirmation. There was an obvious difficulty here of which Carnot himself was doubtless aware. Of this difficulty, in 1849, Sir William Thomson writes, that if we abandon Carnot's fundamental axiom "we meet with innumerable other difficulties insuperable without further investigation and an entire reconstruction of the theory of heat from its foundations. It is, in reality, to experiment that we must look, either for a verification of Carnot's axiom and an explanation of the difficulty we have been considering, or for an entirely new basis of the theory of heat."

It was at this juncture that Clausius, without waiting for additional experiments, read, in the Berlin Academy on the 18th February, 1850, his paper, "Ueber die bewegende Kraft der Wärme, und die Gesetze, welche sich daraus für die Wärmelehre selbst ableiten lassen."

Carnot had assumed that a heat engine gave out the same heat at the lower temperature as it took in at the higher, and founded his theory on this assumption and upon the impossibility of perpetual motion. Clausius, in the first place, emphasised that the heat given out must be less than the heat taken in by an amount equivalent to the work done, that this was required by the First Law of Thermodynamics, the equivalence of Heat and Work. Thus modified, Carnot's theorems could no longer rely for their proof on the impossibility of perpetual motion, and it was Clausius' great discovery to found Thermodynamics upon the New Second Law of Thermodynamics, "That heat tends to flow of itself from hot to cold bodies." On these foundations Clausius raised again the Theory of Thermodynamics, and thenceforward there was no serious doubt as to its security. Several different ways of stating the Second Law of Thermodynamics have been advocated, and objections have been raised to each of them. Of these things Clerk Maxwell writes that Clausius "first stated the principle of Carnot in a manner consistent with the true theory of heat." Of the varieties of statement he writes: "By comparing together these statements the student will be able to make himself master of the facts which they embody, an acquisition which will be of much greater importance to him than any form of words on which a demonstration may be more or less compactly constructed."

There can be no doubt that Clausius was the first to throw a clear light upon the then dark and doubtful foundations of Carnot's theorem. Sir William Thomson writes of this in 1851, "the merit of first establishing the proposition upon correct principles is entirely due to Clausius."

As Professor Willard Gibbs says, "Rankin was attacking the problem in his own way with one of those marvellous creations of the imagination of which it is so difficult to estimate the precise value." The question of the amount of mechanical effect to be derived from heat, he further says, "was completely answered, on its theoretic side, in the memoir of Clausius, and the science of thermodynamics came into existence." "It might be said, at any time, since the publication of that memoir, that the foundations of the science were secure, its definitions clear, and its boundaries distinct." To Clausius then be the honour of making a science of Thermodynamics.

Clausius' subsequent work in this line consists essentially in working out the results of the law he discovered, and in investigating its foundations on general dynamical principles applied to molecular physics. In working out the results of his law he explored in two directions. He applied his discovery to work out the theory of the steam engine, and of many known phenomena, and also to discover properties of matter revealed by his analysis. This latter line is contiguous with his exploration of the dynamical foundations of the theory of heat. His analysis revealed the existence of eutropy as a property of matter, a property for which mankind has no sense, such as exists for feeling temperature, and which consequently escapes attention, and is most difficult of apprehension; so difficult, indeed, that although fundamentally as important as temperature in the theory of steam engines, its existence is ignored by all except the very foremost amongst those who study the working of steam engines. Clausius has left little to be done in the theory of heat engines except to work out, in the lines he has laid down, the details that experiments may prove to be most important. Clausius applied his theory to investigate the laws of specific and latent heat, of saturated steam, of the relations of heat and electricity in conductors, in thermopiles, and in electrolytes, and to the laws of radiant heat. He showed that radiant heat was no exception to the law that heat flows of itself from hot to cold bodies, and so proved the futility of the ingenious suggestion that the death of the universe by the degradation of energy might be avoided by the reconcentration of heat radiations by reflection from the confines of the ether. He showed that the radiating power of black bodies in various media was proportional to the square of the refractive index of the medium, which involves a corresponding law of radiation of electromagnetic energy.

In all these applications his attention was constantly directed to the underlying molecular motions which explained the phenomena on dynamical principles. It was in this connexion that he investigated the dynamical foundations of the Second Law of Thermodynamics and the molecular theory of gases and of electrolysis.

In quite an early investigation he had been dominated by the conception that heat in a body can be considered as separated into two parts, one the kinetic energy of atoms, and the other the potential energy of forces between atoms. His later investigations were elaborations of these conceptions by the application of statistical methods, and by mathematical analysis of the highest order. He showed that the heat in a body could be expressed as the product of two factors, one proportional to the mean kinetic energy of the atoms, and the other depending on the mass, velocity, and period of their motions. These factors may be identified with temperature and entropy, and so furnish a dynamical basis for the theory of heat. Involved in these investigations was the Theorem of the Virial, which is so important in the dynamics of stationary motion. His theory is in accordance with much that we know, though it neglects radiation, and forces between molecules depending on their motions and positions, which may be systematically different before and after collision. With the ether among the molecules it is almost impossible but that some such forces exist, while the success of dynamical theories that neglect them seems to show that their effect cannot be very great.

While Clausius was elaborating these general results, he attacked the simpler case of the molecular theory of gases. That the properties of gases were in some way due to the motions of their molecules was a hypothesis as old at least as Bernoulli, but it was Clausius who raised it to the rank of a theory, and he has been described by Clerk Maxwell as the principal founder of the science. He showed how Boyle's and Dalton's laws followed from the theory, and how they were approximate; he proved the existence of intramolecular energy, and the necessity for Avcgadro's law, and for the equality of mean energy of translation; and, insisting on the necessity for two atoms in a molecule, hastened the advent of the change in atomic weights which chemists were adopting; he investigated the length of the mean free path of a molecule, and the rates of diffusion and conductivity of heat in gases.

In connexion with the molecular theory of matter, Clausius had as early as 1851 investigated some of the laws of evaporation, and had shown that the law of corresponding temperatures that Groshans modified from Dalton involved the law that at any given pressure the latent heat of vaporisation per unit volume of many substances was the same. After Van der Waals' memorable paper on the continuity of the liquid and gaseous states, Clausius published an elaborate investigation of this subject, in which he developed the application of a rather complicated formula, and showed that it represented the experiments throughout an enormous range with wonderful accuracy. There is a measurable departure from the law in calculating the compressibility of the liquids. To facilitate the application of this formula, Clausius invented and calculated the values of a special transcendental.

Electricity and magnetism attracted Clausius' attention from time to time, at first in connexion with heat and molecular physics, and afterwards with reference to the theory of electrokinetic actions. In 1858 he developed the theory that the molecules in electrolytes are continually interchanging atoms, and that the effect of electric force is to direct the interchange and not to cause it. It seems, however, possible that as synchronous systems near the solar system might break it up, while asynchronous ones might not, so a polarisation of the atomic motions in a liquid might result in a proportionate breaking up of the molecules which before this introduced regularity were stable. In reply to Hittorff's objection that gases should obey Ohm's law, Clausius answered that there were too few molecules. This can hardly be considered conclusive in presence of electrolytic conduction in very dilute aqueous solutions. His theory, however, explains almost all the known facts of electrolysis, and has been extended by others to explain many other phenomena with most remarkable success. He investigated electric osmosis, and hints that it is produced by electric forces due to charges over the surfaces of the pores in the diaphragm. He remarked that the resistance of pure metals is proportional to their absolute temperature.

His electrokinetic theory, founded on a theory of action at a distance between electrical elements moving in conductors, led to the conclusion that the action between the elements must depend on their absolute velocity and not on their relative velocity. This practically postulates a medium with reference to which the elements move, and by which the actions are propagated.

With the great development of electrodynamics as a machine for applying energy to do man's work, Clausius repeated his exploration of the theory of the steam engine, that great machine for applying heat energy to do work, and investigated on broad principles the theory of dynamos. Some of his work in this direction is superseded by the rapid development of the science and its applications, but his insight into the problem is evidenced by his having been one of the first to notice hysteresis, which he describes as the forces resisting magnetisation being like friction.

It is to be regretted that in his electromagnetic theory Clausius was led by the algebraic methods of Weber rather than by the geometrical insight of Faraday, or by some mechanical theory, such as directed his steps in thermodynamics. If his constructive genius had been here well directed, there might now exist a satisfactory theory of electromagnetic action; he might have founded the theory of ether as well as of gas; he had genius enough to do it.

Though not himself an experimentalist, he valued and was eminently able to criticise and use the results of experiment. He had that clear grasp of natural phenomena which leads to a right interpretation of them, and that concrete practical conception of them that leads to a continual reference back of the interpretation to experimental numerical verification. He was a noble example of the spirit that devotes itself to directly benefiting mankind, and that does not waste time on petty elaborations of pretty problems. He was in the highest sense practical, his work is eternal, and his memory will live as long as mankind reveres its benefactors.

G. F. F. G.

Sir William Gull died on the 28th day of January, 1890, at his house in Brook Street, in his 74th year. His was one of the many distinguished names which refute the imputation of dulness upon the Eastern counties. He was born in the north-east corner of Essex, at one of the many villages which retain the old English name of Thorpe. While he was still a child his father died, and he was dependent for his education upon his mother's character and his own exertions. While teaching in the village school, he attracted the attention of the late Mr. Benjamin Harrison, for many years the Treasurer of Guy's Hospital, and the wise ruler of its Medical School. Thorpe-le-Soken lay in the midst of the Essex estates of the Hospital, and the Treasurer performed all the duties of a good landlord. Telling the friendless youth, "If you will help yourself I will help you," he brought him up to London, and gave him employment in transcribing Museum catalogues, and other clerical work in the Hospital counting-house. While thus employed Gull matriculated at the University of London in 1838, and by the Treasurer's influence was admitted to attendance on the courses of lectures at Guy's. His industry and talents procured him an honourable degree in 1841. Dr. Quain, who graduated the year before, Sir Edmund Parkes, who passed in the same year, and Sir Alfred Garrod and Dr. George Johnson, who followed in 1842, all became like him Fellows of this Society, and all, with the exception of the lamented Parkes, survive him.