OBITUARY NOTICES OF FELLOWS DECEASED.

JAMES APJOHN, M.D., was Professor of Chemistry in the University of Dublin from 1850 to 1875. He died on the 2nd of June, 1886, at Southill, Blackrock, co. Dublin, in his 91st year. Dr. Apjohn was born at Sunville, co. Limerick, on the 1st of September, 1796, and, having received his elementary education at the Tipperary Grammar School, he entered Dublin University in 1814. After a distinguished undergraduate course, he took his Arts degree in 1817, and in 1821 obtained the M.B. Sixteen years later he proceeded to the M.D. degree. Apjohn's love for experimental science seems to have been kindled during his medical studies, and after graduating he devoted himself almost exclusively to the pursuit of chemistry and physics. About 1824 several eminent physicians and surgeons—including Groves, Marsh, Jacob, and Cusack—decided to establish a new medical school at Parke Street, in Dublin, and in the following year Apjohn joined the staff of the new school as lecturer in chemistry. Here he acquired considerable reputation as a lecturer, and three years later he was transferred to the newly-established Chair of Chemistry in the College of Surgeons' School, which he held until 1850, when he was appointed to the University Chair of Chemistry on the death of Dr. Francis Barker. Apjohn's official connexion with the University began, however, in 1841. About that time the Board of Trinity College founded an Engineering School, and appointed Apjohn to the Chair of Applied Chemistry and Mineralogy—an office which he continued to hold when he succeeded Barker in 1850. On Dr. Apjohn's retirement from professorial work, Mineralogy was transferred to the Chair of Geology in the University, and Applied Chemistry was permanently attached to the Chair of Chemistry.

The principal scientific work of Dr. Apjohn was rather physical than chemical. The general study of hygrometry had a special attraction for him, and of the forty-nine scientific papers named in the Royal Society's Catalogue, a large proportion relates to that subject. In the course of his work on the theory of the wet bulb hygrometer, he arrived at the expression well known as "Apjohn's Formula" for ascertaining the dew point.

The study of hygrometry led to much interesting work on the specific heat of gases, and in 1837 Apjohn received the Cunningham

Medal from the Irish Academy for his paper "Upon a New Method of Investigating the Specific Heats of the Gases." The method consisted in noting the fall in temperature suffered by the wet bulb thermometer when immersed in the perfectly dry gas, whose specific heat was required. From 1838 onwards Dr. Apjohn devoted less attention to physical work than to mineralogical chemistry. He was a frequent contributor to the literature of the latter subject. In 1838 he analysed and described a mineral from Algoa Bay, South Africa, which proved to be a somewhat effloresced manganese alum, which has since been named "Apjohnite." In 1840 he described a mineral found at Kilbricken, co. Clare, which is closely related to geocronite, but is non-arsenical. Again, in 1852 he was concerned in the description, under the name of "Jellettite," of a yellowish-green garnet found near Zermatt, Monte Rosa, by Dr. Jellett, the present Provost of Trinity College. Papers on the relations of pyrope, of pennine, and on Mexican hyalite are also to be found amongst his contributions to mineralogy.

Dr. Apjohn contributed to the "Cyclopædia of Practical Medicine" the articles on electricity, galvanism, toxicology, and spontaneous combustion, and it is stated that the latter article supplied Dickens with the facts on which he founded his account of Krook's death in "Bleak House."

As the representative of the University of Dublin in the General Medical Council, Dr. Apjohn took a prominent part in the production of the "British Pharmacopœia." Almost every chemical process and test described in the first edition of the "Pharmacopœia" was carefully examined in the Trinity College Laboratory, and much of the success of the work was due to Apjohn's laborious revision in detail.

He was elected to the Fellowship of the Royal Society in 1853; he was a Vice-President of the Royal Irish Academy; and at the time of his death was second on the roll of Fellows of the King and Queen's College of Physicians.

Dr. Apjohn was widely esteemed throughout his long life as a thorough and earnest worker, a singularly lucid and able lecturer, and an upright and honourable man.

J. E. R.

William Benjamin Carpenter was born at Exeter in 1813, and was the fourth child and eldest son of Dr. Lant Carpenter, a Unitarian minister. His sister, Mary Carpenter, who died a few years since, achieved the most important work as a philanthropist, in relation to the treatment of prisoners and to questions affecting our Indian fellow-subjects, and will be remembered by future generations with no less gratitude than her brother.

In his childhood Dr. Carpenter received an excellent education,

comprising both classics and the principles of physical science, at the school established by his father at Bristol, and it was his intention to adopt the profession of a civil engineer. He was, however, persuaded to accept the opportunity offered by a medical practitioner, Mr. Estlin, of Bristol, and to enter on the study of medicine as apprentice to that gentleman. Shortly after this he was sent, as companion to one of Mr. Estlin's patients, to the West Indies, and on his return from this visit he entered, at the age of twenty, the medical classes of University College, London. After passing the examinations of the College of Surgeons and the Apothecaries' Society he proceeded to Edinburgh, where he graduated as M.D. in 1839.

His graduation thesis on "The Physiological Inferences to be deduced from the Structure of the Nervous System of Invertebrated Animals" excited considerable attention, especially on account of the views which he advanced as to the reflex function of the ganglia of the ventral cord of Arthropoda.

From the first Dr. Carpenter's work showed the tendency of his mind to seek for large generalisations and the development of philosophical principles. He was a natural philosopher in the widest sense of the term—one who was equally familiar with the fundamental doctrines of physics and with the phenomena of the concrete sciences of astronomy, geology, and biology. It was his aim, by the use of the widest range of knowledge of the facts of Nature, to arrive at a general conception of these phenomena as the outcome of uniform and all-pervading laws. His interest in the study of living things was not therefore primarily that of the artist and poet so much as that of the philosopher, and it is remarkable that this interest should have carried him, as it did, into minute and elaborate investigations of form and structure. Although some of his scientific memoirs are among the most beautifully illustrated works which have been published by any naturalist, yet it is noteworthy that he himself was not a draughtsman, but invariably employed highly skilled artists to prepare his illustrations for him. Yet we cannot doubt that the man who, with his dominant mental tendency to far-reaching speculations, yet gave to the world the minute and ingenious analysis of the beautiful structure of the shells of Foraminifera, had an artist's love of form, and that the part of his life's work (for it was only a part among the abundant results of his extraordinary energy) which was devoted to the sea and the investigation of some of its fascinating living contents, was thus directed by a true love of Nature in which ulterior philosophy had no share.

Two books, Dr. Carpenter has told us, exerted great influence over his mind in his student days: they were Sir John Herschel's "Discourse on the Study of Natural Philosophy" and Lyell's "Principles of Geology"—that great book to which we owe the even greater books

of Charles Darwin. Taking the "Principles" in some way as his model, Dr. Carpenter produced in 1839 his first systematic work, under the title "Principles of General and Comparative Physiology, intended as an Introduction to the Study of Human Physiology and as a guide to the Philosophical Pursuit of Natural History." Admirable as was the execution of this work in many ways, its great merit lay in the conception of its scope. It was in fact the first attempt to recognise and lay down the lines of a science of "Biology" in an educational form. Carpenter's "Comparative Physiology" is the general or elementary "Biology" of the present day—traced necessarily upon the less secure foundations which the era of its production permitted, viz., one year only subsequent to the date of Schwann's immortal "Microscopical Researches."

For five years Dr. Carpenter remained in Bristol, commencing medical practice and marrying in 1840; but in 1844, feeling a distaste for the profession of medicine, he moved to London in order to devote himself entirely to a literary and scientific career. He was encouraged to take this step by the success which his "Comparative Physiology" obtained, a second edition having been called for within two years of the publication of the first. He was appointed Fullerian Professor of Physiology in the Royal Institution during his first year in London, and Professor and Lecturer at University College and at the London Hospital, whilst he was also elected a Fellow of the Royal Society.

In 1851 Dr. Carpenter became Principal of University Hall, the residential institution attached to University College, where he remained until 1859. During this period he remodelled his treatise on Physiology, issuing the more general biological portion as "Comparative Physiology," whilst that portion dealing with the special physiology of man and the higher animals appeared as his well-known "Human Physiology," which subsequently ran through many editions. The "Human Physiology" is remarkable in the first place for the chapters on the physiology of the nervous system, and especially for the theories enunciated with regard to the relations of mind and brain, and the attempt to assign particular activities to particular portions of the cerebral structure. In arriving at his conclusions Dr. Carpenter had to depend on arguments drawn from the facts of comparative anatomy and of diseased or abnormal conditions in man. There is no doubt at the present day of the acuteness which he displayed in his treatment of the subject, and of the truth in a general way of the results which he formulated. Experiment and a wider range of observation have to some extent corrected—but on the whole rather extended and confirmed—the doctrines of the early editions of the "Human Physiology" in regard to this subject, so that he was able only a few years since to separate this portion of the work and issue it as a separate book, the "Mental Physiology," in which is contained by far

the most complete, consistent, and readable account of the phenomena of mind, and their relation to the actual structure of the brain, which exists. Such topics as Instinct, Mesmerism, Somnambulism, Unconscious Cerebration (his own phrase), &c., are discussed in a masterly way, and with an abundance of illustration and knowledge which renders the work one of the greatest value even to those who may differ here and there from its theoretical conclusions.

About the period of his removal to London Dr. Carpenter began to occupy himself with the minute study of the structure of the calcareous shells of the Mollusca—being led thereto by a desire to compare the results of the operation of living matter upon distinctly mineral compounds (such as carbonate of lime), by way of comparison and in illustration of the rapidly accumulating knowledge of cell-structure in the softer parts of living things. This study, which resulted directly in some valuable contributions to our knowledge of the structure of shells, shown by these researches to be far more complex than had hitherto been supposed, led on the one hand to Dr. Carpenter's permanent identification with the pursuit of research with the microscope, and on the other hand to those admirable investigations of the structure and law of growth of the shells of the minute Protozoic Foraminifera which constitute his most weighty contribution to the special literature of science. His microscopic studies bore fruit in the publication of "The Microscope and its Revelations," the sixth edition of which was issued in 1881. The studies on the shells of Foraminifera were continued throughout his life, being published in four memoirs in the "Philosophical Transactions," and in a richly illustrated monograph produced by the Ray Society in 1862, whilst the last of his memoirs in the "Philosophical Transactions" was that on Orbitolites bearing date so late as 1882. It was on this subject that Dr. Carpenter was busy at the time of his death, having during the past few years accumulated a wealth of material and drawings in support of his contention that the *Eozoon canadense* discovered by Logan in the Laurentian rocks of Canada exhibits the distinctive structure of the shell-substance of the higher Foraminifera. The material relating to Eozoon has been placed by Dr. Carpenter's executors in the hands of Mr. Rupert Jones, who has undertaken to prepare it for publication.

At the age of forty (1853), what with his larger and smaller books, his original researches, his lectures on medical jurisprudence at University College, and numerous popular lectures on scientific topics, Dr. Carpenter's life was unusually laborious and productive.

In 1856 he was appointed Registrar of the University of London, and for twenty-three years administered the onerous duties of that office in such a way as to contribute in no small degree to the success of the University, and above all to the maintenance of the high

character of its degrees and the ample recognition of the study of natural science for which the University is now distinguished.

He was able now to give a larger amount of time than formerly to his original investigations, and, in his summer holidays at Arran and elsewhere, commenced, amongst other studies, those researches on the structure and development of the beautiful little feather-star, which were from time to time published in the "Philosophical Transactions," and led to his association with Wyville Thomson, and thus to the deep-sea explorations of the "Lightning," and subsequently of the "Challenger."

Carpenter's memoirs on Comatula give a very full and beautifully illustrated account of the structure of the skeleton of the feather-star, but for many years the view which he entertained with regard to the nature of the axial cord which runs through the segments of the arm-skeleton of that animal was regarded by all other observers (with scarcely an exception) as erroneous. Dr. Carpenter considered these cords as nerve-cords, and in the Easter vacation of 1876 he made a special visit to the marine laboratory erected by Dr. Dohrn at Naples, in order to test his views by the repetition, on an extensive scale, of experiments which had already appeared convincing to his mind. These experiments, and others since carried out by younger naturalists, have at length fairly established the view for the truth of which the veteran observer had long contended.

In December, 1875, Dr. Carpenter had communicated to the Royal Society the outlines of his work on the soft parts of *Antedon* (*Comatula*) *rosacea*, and on returning from Naples he communicated a supplemental note to the Society on the subject of the nervous system of that animal ("Roy. Soc. Proc.," vol. 24, 1876, p. 451). He lived to see his conclusions, first formulated in 1865 ("Phil. Trans.," vol. 156, p. 705), fully confirmed by the experiments of Marshall ("Quart. Journ. Micro. Sci.," vol. 24, 1884) and by those of Jickeli of Jena ("Zool. Anzeiger," No. 170, 1884). Important evidence in favour of these conclusions was also furnished by the anatomical investigations of Dr. P. Herbert Carpenter on the allied genus Actinometra ("Journal of Anatomy and Physiology," 1876). M. Ed. Perrier of Paris, who had strenuously opposed Dr. Carpenter's conclusions, was thus led to renewed observations and to a complete acceptance of their correctness ("Comptes Rendus," July, 1883, p. 187), whilst the most careful student of Echinoderm anatomy among German zoologists, viz., Dr. Ludwig, who had also previously opposed these conclusions, has now endorsed them. Thus in the "Roy. Soc. Proc.," vol. 37, 1884, p. 67, Dr. Carpenter was able to give a complete history of the question, showing how the opposition on theoretical grounds to the view that the axial cords of Comatula were nerve-cords, had gradually given way before an appeal to observation and experiment. This

record of the final triumph of the view which he had originated and so long laboured to establish was the last scientific paper published by Dr. Carpenter.

The deep-sea explorations which Dr. Carpenter, assisted by Professor Wyville Thomson, arranged, and for which he succeeded in obtaining the aid of ships of the Royal Navy, were designed not merely to search for organisms in the great depths of the ocean, but especially to study the ocean currents both deep and superficial, Dr. Carpenter having a strong desire to enter upon the explanation of the great physical phenomena presented by the ocean. He himself took part in the earlier expeditions in 1868 and subsequent years, and though unable to leave the ties which bound him to home, so as to join the "Challenger" Expedition, yet he closely watched the results then obtained, and embodied the whole of his observations, and those reported from the "Challenger," in some extremely suggestive and important memoirs and lectures on ocean circulation. These are as follows:—Reports in the "Proceedings of the Royal Society" on the several cruises of the "Lightning" ("Roy. Soc. Proc.," 1868), "Porcupine" (*ibid.*, 1869–70), "Shearwater" (*ibid.*, 1871), and "Valorous" (*ibid.*, 1875); a series of memoirs in the "Roy. Geograph. Soc. Proc.," 1871, 1874, 1875, 1877; lectures delivered to and printed by the Royal Institution of London and the United Service Institution; articles in the "Contemporary" and the "Nineteenth Century" Reviews.

The more general philosophical views held by Dr. Carpenter, and his conceptions in regard to those topics where science touches religion, may be gathered from a series of articles published by him in the "Modern Review" during the years 1880–84, the titles of which are as follows:—"The Force behind Nature," "Nature and Law," "Charles Darwin; his Life and Work," "The Doctrine of Evolution and its Relations to Theism," "The Argument from Design in the Organic World."

In 1879 he retired from the Registrarship of the University of London with a well-earned pension, and was at once chosen as a member of the Senate of that body. He now devoted himself with unabated vigour to the prosecution of his studies on Foraminifera and on Comatula, and to more theoretical matters, such as ocean-currents, and the explanation of the frauds of spirit-mediums. Though released from the duties of office, he was still a constant attendant at the Senate of the University, he rarely missed a meeting of the Royal Society or one of the annual gatherings of the British Association, and, besides undertaking the administration of the Gilchrist Trust, delivered many lectures in all parts of the country himself—both independently and as an emissary of the trustees. The scheme of lectures and scholarships instituted by the Gilchrist trustees, which

is effecting important educational results in natural science among classes of society excluded from regular University teaching, is Dr. Carpenter's work. He wrote at this time in the interest of the public health some admirable articles on vaccination, as in earlier life (1849) he had from a similar point of view treated the subject of alcoholic liquors, and had urged the arguments for total abstinence. When past seventy years of age he did not shrink from a journey to the United States, where he spoke and lectured with unflagging vigour. The last public movement in which he took an active part was the foundation of the Marine Biological Association, of which he was a Vice-President, and which is about to carry out, by means of its laboratory on Plymouth Sound, a suggestion which is traceable to his own proposition for the thorough exploration and study of Milford Haven.

The abundant and noble achievements of Dr. Carpenter's public and scientific career did not pass without recognition in the form of awards and titles. He received in 1861 one of the Royal medals awarded by the Council of the Royal Society, and in 1883 the Lyell medal of the Geological Society. In 1871 he was made an honorary LL.D. of the University of Edinburgh, and in 1872 he was President of the British Association for the Advancement of Science when it met at Brighton. In 1873 he was elected Corresponding Member of the Institute of France, and on his retirement from his official position at the University of London in 1879 he was nominated C.B.

It is impossible to do justice to Dr. Carpenter's character as a scientific man in a few lines: here no attempt has been made to do more than indicate in something like chronological order and connexion of subjects the vast amount of work which he accomplished.

Upon the present writer, whose father was his fellow-student at University College, and who has enjoyed since boyhood the privilege of his friendship, Dr. Carpenter always produced the most vivid impression of a man of indomitable energy, who had accepted as the highest duty and keenest delight of his life the promotion, whether by advocacy or by research, of true knowledge. The tenacity and vigour with which he was wont to expound his views on such matters of research as at the time occupied his thoughts, and the importance and respect which he assigned to all genuine research, were evidences of an earnest and just nature which evoked sympathy and esteem in all men of kindred pursuits.

In reference to Dr. Carpenter's private life and tastes, the following extract from a weekly journal states, with the authority of a member of his own family, what might, in its absence, have been here less completely indicated. The journal to which we are thus indebted is an organ of the Unitarian Church, of which body Dr. Carpenter was, throughout life, an active and orthodox member, a fact which may or

may not be brought into connexion with the fact of his incomplete acceptance of the leading doctrines of Darwinism.

"He was well versed in literature, and turned for refreshment in hours of weariness to his favourite Scott. Political memoirs of his own time were read with the keenest relish, for he had early learned from his father, Dr. Lant Carpenter, to take a high view of a citizen's obligations, and the Bristol riots, which he had witnessed, made a life-long impression upon him. A brief sojourn in Italy called forth a susceptibility to the enjoyment of art which was a surprise even to himself; and in music, from the time that he had taught himself as a young man to play on the organ, he found unfailing recreation. Nature, likewise, in her vaster as well as her microscopic forms, was for him full of charm and delight, and from every excursion he carried back memories which remained singularly vivid and distinct. In society his immense stores of information, his sympathetic interest in others, his thorough enjoyment of humour though he felt unable to originate it, made him a genial and ever-welcome companion, while his friends learned how strong a confidence might be placed in his faithfulness. Many young men found unexpected help and encouragement in him, and he rejoiced when he could open a way to those who were involved in the struggles through which he had himself once passed. The dominant conception of his life—as was fitting in one of Puritan descent—was that of duty. And if this sometimes took austere forms, and led him to frame expectations which others could not always satisfy, an enlarging experience mellowed his judgment and enabled him to apprehend their position from their point as well as his own. Released from the pressure and strain of earlier life, he was able to give freer play to his rich affections; and in his own family they only know what they have lost who will never again on earth feel his support as husband and father, brother and friend."

E. R. L.

William Willoughby Cole, third Earl of Enniskillen, was born on the 25th of January, 1807, succeeded to the title and estates in March, 1840, and died at Florence Court, co. Fermanagh, on Friday, the 12th of November, 1886, after only a few days' illness. He sat as Baron Grinstead in the House of Lords.

Lord Enniskillen was educated at Harrow and at Christ Church, Oxford, but never graduated. While at Oxford he devoted much time and attention to Geology and Palæontology, assiduously attending the lectures delivered by the Rev. Dr. Buckland.

In conjunction with the late Sir Philip de Malpas Grey Egerton, his friend and college companion, Lord Enniskillen commenced collecting organic remains in the neighbourhood of Oxford and other parts of the British Islands; together they ultimately succeeded

in obtaining a most extensive, complete and valuable collection of Fossil Fishes; probably the largest in the world. From that period until the death of Sir Philip Egerton they were joint collectors, scrupulously dividing their acquisitions, and that so industriously, that nearly the same species occurred in each cabinet; it was owing to this union of partnership that the two collections were so intimately interwoven, and for the interest of Ichthyic Palæontology inseparable; hence their subsequent possession by the nation, and united preservation in the galleries of the British Museum of Natural History, Cromwell Road.

Three years previous to Lord Enniskillen's death (1883), that portion contained in the Florence Court Collection was purchased by the trustees of the British Museum, through a special grant from the Treasury.

Lord Enniskillen* and Sir Philip Egerton, after leaving Oxford, travelled through much of Germany, Switzerland, and Italy, solely for the purpose of studying and collecting one group of the Vertebrata, and to this large division of the animal kingdom they appear always to have restricted their researches; their continental journey was also undertaken to still more perfect their knowledge of stratigraphical Geology, in connexion with their palæontological researches; how completely this was continued, and carried on until both our distinguished Fellows were removed by death, is fully exemplified by the union of the two great collections—or that of Florence Court and that of Oulton Park—now arranged together in the galleries of the British Museum of Natural History.

Lord Enniskillen also particularly examined the caves of Germany, Belgium, &c., obtaining from Gailenreuth, Kuhloch, and Engis, a rich series of bones illustrating the remains of extinct Mammalia, especially those of the lion, mammoth, rhinoceros, hyæna, and reindeer.

At home and abroad every locality and geological horizon yielding the remains of fish attracted Lord Enniskillen's attention, who never failed to secure every good as well as new form for his Florence Court Collection, duplicates whenever they occurred being also added to the Oulton Park Museum by Sir Philip Egerton.

This dual possession and study of Fossil Ichthyology arose through their intimate acquaintance in 1830 and subsequent years with Agassiz, who impressed upon them the importance of confining themselves to one line or branch of research; the result of which has been the formation of these two unrivalled collections of Fossil Fish, the history of which, through the works of Agassiz and Sir Philip Egerton, has greatly enriched the literature of this extensive division in Zoology, especially as regards structure and distribution.

* Then Viscount Cole.

Lord Enniskillen never published any particulars of, or described any species of Fossil Fishes, but the Florence Court MS. catalogue was kept with the most scrupulous care, every specimen being recorded with all details essential to the zoological position, stratigraphical and geographical history of the species in so great a collection; and this was carried out in every detail.

This applied not only to the Florence Court catalogue, but also to the almost *duplicate* volume of the Oulton Park Collection, kept with the same care by Sir Philip Egerton; so that the enumeration of species contained in one, without reference to the other, would be incomplete and unsatisfactory.

Lord Enniskillen paid considerable attention to Archæology, especially that relating to Ireland, and was one of the first to call attention to the lake dwellings in that country.

Lord Enniskillen's public services were great, as also indeed had been those of the long line of his ancestors through nine generations, ever since their settlement in Ireland in the year 1612. He sat as M.P. for Fermanagh from the year 1831 to 1840; was Colonel of the Fermanagh Militia from 1834 to 1875, and Hon. Colonel from 1875, and for more than fifty years leading member of the Orange Society, Grand Master of the County of Fermanagh, Grand Master of Ireland, and Imperial Grand Master. He was also one of the Trustees of the Hunterian Museum. He received the honorary degree of D.C.L. from the University of Oxford, and that of LL.D. from the University of Dublin and the University of Durham.

Lord Enniskillen was elected F.R.S. in the year 1829, and was thus a Fellow of our Society for fifty-seven years.

R. E.

Thomas Andrews was born at Belfast on the 19th December, 1813. His father was a linen merchant in good position. He received his early education at the Belfast Academy and at the Royal Academical Institution of Belfast. He then went to Glasgow to study chemistry under Professor Thomas Thomson, whose laboratory was then one of the very few places in this country where systematic instruction in *real* chemistry was regularly given to students. He continued his studies in Trinity College, Dublin, where he distinguished himself both in Science and in Classics; and, after spending some time in Dumas' laboratory in Paris, went to Edinburgh, where he took the degree of Doctor of Medicine in 1835. Returning to Belfast, he devoted himself to the practice of medicine, in which he was very successful. In 1845 he was the first Lecturer on Chemistry in the Royal Belfast Academical Institution, but held this office for a short time only. In 1845 the Queen's Colleges were founded and Andrews was appointed Vice-President of the Belfast College. With this office

there was conjoined, when the preliminary arrangements had been made, that of the Chair of Chemistry. He held these offices till 1879, when the state of his health induced him to resign them, and to retire almost completely from active work. He continued to take a keen interest in the progress of Science till his death on the 5th November, 1885.

He was elected a Fellow of the Royal Society in 1849, he was an Honorary Fellow of the Royal Society of Edinburgh, and a Corresponding Member of the Royal Society of Göttingen. He received honorary degrees from various Universities.

He presided over the Chemical Section of the British Association at Belfast in 1852, and again at Edinburgh in 1871, and was President of the Association at the Glasgow Meeting in 1876.

In 1842 Dr. Andrews married Jane Hardie, daughter of Major Walker of the 42nd Highlanders. He is survived by Mrs. Andrews, by three daughters and by two sons, the elder of whom is Major in the Devonshire Regiment, and the younger a member of the Irish Bar.

Dr. Andrews was deeply interested in public affairs, but very rarely took an active part in politics, and was quite free from party spirit. His only writings bearing in any way on political matters are 'Chapters of Contemporary History.' The first, entitled "Studium Generale," and published in 1867, is a historical and critical discussion of the function of a University, with special reference to the Queen's Colleges. The second, "The Church in Ireland," was published in 1869.

Of Dr. Andrews' strictly Chemical papers we may mention one on the blood of cholera patients, in which he showed that it differs from normal blood only by having a smaller proportion of water; one on galvanic cells with strong sulphuric acid as the exciting liquid, and one on the presence of metallic iron in basaltic and other rocks. Much more important than these careful and interesting papers is his great work on Ozone. This mysterious body had been the subject of investigations by its discoverer, Schönbein, and also by Marignac. De la Rive, Berzelius, Williamson, Fremy and Becquerel and Baumert, but its real nature was still unknown, it was not even certain that a number of different substances had not been confounded under the name. That ozone, however prepared, contained oxygen, and was a powerful oxidising agent was certain, but it was not clear that it did not, sometimes at least, contain hydrogen also. Andrews attacked the problem with characteristic energy and straightforwardness. By a series of experiments, in which it is difficult to say whether the ingenuity, the perfect fitness for their purpose, or the wonderful simplicity of the methods used is to be most admired, he proved that "ozone, from whatever source derived, is one and the same body, having identical

properties and the same constitution, and is not a compound body, but oxygen in an altered or allotropic condition."

This work was continued by Andrews and Tait, and the results were published in the 'Philosophical Transactions' under the title "On the Volumetric Relations of Ozone and the Action of the Electrical Discharge on Oxygen and other Gases." The theory of the constitution of ozone now universally held is clearly indicated in this paper, although its apparent improbability deterred the authors from discussing it fully.

But by far the most interesting and peculiar part of Dr. Andrews' work is to be found in his investigations in the borderland between Chemistry and Physics. There his special ability, his power of arranging experiments, of devising pieces of apparatus suited to the particular purpose at the moment in view, of detecting sources of error and providing simple effective means of avoiding them, and of doing all this himself with the least possible help from the instrument maker, comes into remarkable prominence. The apparatus with which most of his work was done was made with his own hands, and when, for instance, he wanted a casting, he personally superintended the minutest details. This directness of his work, and his habit of working alone, made him somewhat intolerant of assistance, as it made him independent of it. The only exception to the solitariness of his scientific work, a very notable exception, is the investigation of Ozone, carried out in conjunction with Professor Tait. His researches on the heat developed in chemical actions, for one of which he received in 1844 one of the Royal Medals, and for the other in 1850 one of the prizes given by the French Academy of Sciences, and that on the continuity of the liquid and gaseous states, partly contained in his Bakerian Lectures, and partly communicated posthumously to the Society, were done strictly alone. If this independence and individuality limited the amount of work done by him, it has the compensating advantage that we know that every analysis and every observation published by him were actually made with his own hands and eyes, so that a reader of his paper is as nearly as possible in as good a position to judge as to the soundness of his conclusions as if he had performed the experiments himself. In reading his papers we are transported at once to the laboratory; without wearisome repetition we have all the details before us, and we can follow every step of his argument as if we had been present at every experiment on which it was founded.

The investigation into the heat given out during chemical action was begun while he was still engaged in medical practice; this work at once established his position as a genuine scientific discoverer, and introduced him to the chemists and physicists of Europe.

But the work which will always be most closely connected with his name is the great investigation into the relation of temperature, pres-

sure and volume of carbonic acid, communicated to this Society in the Bakerian Lectures of 1869 and 1876.

He showed that for temperatures below about 30·9° C. as the pressure is increased we come to a point where condensation occurs, where the gas is converted into a liquid. At this pressure there are two limiting values of the volume, one when all the substance is vapour, and one when it is all liquid. Between these the substance is partly vapour and partly liquid, the distinction between the two being visible, as the liquid and the vapour refract light differently, and are separated from one another by a distinct meniscus. As the temperature approaches 30·9° the abrupt change of volume on condensation becomes less and less in amount, above that temperature (the *Critical Temperature* of carbonic acid) there is no abrupt change of volume, and no visible condensation. Near 30·9°, but above it there is a rapid, but not abrupt, change of volume; as the temperature rises this rapid change of volume becomes less and less marked, and the isothermal approximates more and more to the hyperbolic form. This extraordinary character of the isothermals—discontinuous below a particular temperature, continuous above it—led Andrews to the remarkable discovery which gives the title to his Lectures, "The Continuity of the Gaseous and Liquid States of Matter."

If we represent the relation of temperature, pressure and volume by means of a surface, where the rectangular co-ordinates x, y, and z correspond to p, t, and v (as was done by Professor James Thomson to illustrate Andrews' work), we see that there is what may be called a cliff, points at the top of which correspond to the substance at the condensing point, but all in the state of vapour, while points immediately below them, at the base of the cliff, correspond to the substance just condensed and all in the state of liquid. The cliff becomes less and less high as x and y increase, and vanishes at the place corresponding to the critical point. From a point on the slope above the cliff we can pass to a point on the slope below, either by dropping down the vertical face or by going round the end of the cliff. To quote Andrews' words ". . . . the author has made carbonic acid pass, without breach of continuity, from what is universally regarded as the gaseous to what is, in like manner, universally regarded as the liquid state. As a direct result of his experiments, he concludes that the gaseous and liquid states are only widely separated forms of the same condition of matter, and may be made to pass into one another by a series of gradations so gentle that the passage shall nowhere present any interruption or breach of continuity. From carbonic acid as a perfect gas to carbonic acid as a perfect liquid, the transition may be accomplished by a continuous process, and the gas and liquid are only distant stages of a long series of continuous physical changes. Under certain conditions of temperature and pressure, carbonic acid finds

itself, it is true, in a state of instability, and passes, without change of pressure or temperature, but with evolution of heat, to a condition which, by the continuous process, can only be reached by a long and circuitous route."

Like most great discoveries, this had been to a certain extent foreshadowed. In 1822 Cagniard de la Tour observed that certain liquids —ether, alcohol, water—when heated in hermetically closed tubes, were apparently totally changed into vapour occupying from two to four times the original volume of the liquid. In 1823 Faraday succeeded in condensing to liquids a number of substances previously known in the gaseous state only.

Shortly afterwards Thilorier obtained solid carbonic acid, and observed the very rapid expansion of liquid carbonic acid when heated. In 1845 Faraday published a very remarkable paper in the 'Philosophical Transactions' on the liquefaction and solidification of gases. He there pointed out that as different liquids assume the Cagniard de la Tour state at different temperatures, so the gases which had not been condensed—oxygen, hydrogen, nitrogen, &c.—might be supposed to have that point below the lowest temperature he had applied (that of a bath of solid carbonic acid and ether *in vacuo*), and therefore to be incapable of condensation to a liquid by any pressure unless the temperature were much further lowered.

Faraday conjectured from the results of experiment that the Cagniard de la Tour state occurred in the case of carbonic acid about 90° F., a value surprisingly near that experimentally proved by Andrews.

But what others had seen obscurely or partially, or had inferred, Andrews made clearly visible in its entirety, and many physicists and chemists can testify to the startling character of the revelation made by the publication of his discovery. It is in fact after the discovery has really been made that the historian begins to look for foreshadowings, and we are perhaps somewhat inclined to interpret these early indications in the light of the later, more definite knowledge, but the unanimous verdict of the scientific world is that the discovery of the continuity of the liquid and gaseous states belongs to Andrews and to him alone.

Dr. Andrews was loved by all who knew him. Warmly hospitable, he was personally almost stoically temperate, allowing himself the minimum of rest, of food, and of sleep. While in theological, as in all other matters, he thought for himself, he was a consistent and orthodox Christian and a loyal member of the Church of Ireland.

A. C. B.