

OBITUARY NOTICES.

WILLIAM HENRY PERKIN.*

BORN MARCH 12TH, 1838 ; DIED JULY 14TH, 1907.

SIR WILLIAM HENRY PERKIN, whose death occurred on July 14th, 1907, was born in London on March 12th, 1838. He was the youngest son of Mr. George Fowler Perkin, a builder and contractor, who died in 1865 at the age of 63. The younger Perkin received his early education at a private school, and was afterwards sent to the City of London School, where it may be said that his inborn talent for chemistry as a science first took definite form through the encouragement of the late Thomas Hall, who was at that time one of the class masters in the school. Science at that period apparently did not form a recognised part of the educational curriculum, since Mr. Hall had to take the time for giving two weekly lectures on chemistry and natural philosophy out of the dinner interval. The schoolboy Perkin attended these lectures with the greatest delight, often sacrificing the midday meal in his enthusiasm, and was soon promoted to the, to him, proud position of being allowed to prepare the experiments, and help Mr. Hall with the demonstrations during the lectures.

It is evident that in the case of Perkin, as is so generally the case with those who leave their mark upon any branch of science, the particular specialisation of faculty and disposition indicative of inherent ability revealed itself at a comparatively early age, and it is certainly a fortunate circumstance that at this critical period of his career he should have fallen under the influence of Mr. Hall, who was himself a pupil of Hofmann's, and who, according to all accounts furnished by contemporaries, must have been highly inspiring as a teacher of science. Perkin has quite recently placed upon record the history of his early life in the following passage:—

“As long as I can remember, the kind of pursuit I should follow during my life was a subject that occupied my thoughts very much. My father being a builder, the first idea was that I

* This notice has been compiled from those previously published by the Royal Society and the Society of Dyers and Colourists.

should follow in his footsteps, and I used to watch the carpenters at work, and also tried my hand at carpentering myself. Other things I noticed led me to take an interest in mechanics and engineering, and I used to pore over an old book called 'The Artisan,' which referred to these subjects and also described some of the steam engines then in use, and I tried to make an engine myself and got as far as making the patterns for casting, but I was unable to go any further for want of appliances. I had always been fond of drawing, and sometimes copied plans for my father, whose ambition was that I might be an architect. This led me on to painting, and made me think I should like to be an artist, and I worked away at oil-painting for some time. All these subjects I pursued earnestly and not as amusements, and the information I obtained, though very elementary, was of much value to me afterwards. But when I was between twelve and thirteen years of age, a young friend showed me some chemical experiments, and the wonderful power of substances to crystallise in definite forms, and the latter especially struck me very much, with the result that I saw there was in chemistry something far beyond the other pursuits with which I had previously been occupied. The possibility also of making new discoveries impressed me very much. My choice was fixed, and I determined if possible to become a chemist, and I immediately commenced to accumulate bottles of chemicals and make experiments."

It was at this period that Perkin entered the City of London School, and, as he has told us in the passage just quoted, with a distinct bias towards chemistry as a career. This decision appears to have caused his father some disappointment, as at that time chemistry as a profession offered but few attractions, and it was only through the intercession of Mr. Hall that he was allowed, at the age of fifteen, to enter the Royal College of Chemistry as a student under Hofmann in the year 1853. His special ability must have revealed itself also to the eminent professor who was at the head of that institution, for he soon passed through the ordinary course of training, consisting of qualitative and quantitative analysis and gas analysis, and, by the end of his second year, had, under Hofmann's guidance, carried out his first piece of research work. In describing this period of his career in a speech delivered in New York in October, 1906, Perkin significantly added with respect to the ordinary curriculum which all students of the Royal College of Chemistry went through at that time:—"This I looked upon only as a preliminary part of my chemical acquirements and not, as many used to and some still do, as a full equipment. Research was my ambition. . . ."

For a youth with these proclivities, no more inspiring influence existed in this country than that exercised by Hofmann in the research laboratory in Oxford Street, and at the age of seventeen we find Perkin, who had by then proved his capabilities, enrolled as honorary assistant to the Professor. In that laboratory the first serious insight into research methods was acquired, and it is of particular interest to note that his initiatory work, instigated by Hofmann, was in connexion with the hydrocarbon anthracene, a substance which, a few years later, served as the starting point in one of the most brilliant synthetical achievements in scientific and industrial chemistry, with which the name of Perkin will be always associated. No less interesting is the circumstance that this first research, although, for reasons which are now readily intelligible, ending in negative results, in no way daunted the ardour of the young investigator, who, in later life, frequently declared that his first efforts at getting definite products from anthracene were of invaluable service to him when he again took up the study of this hydrocarbon from the scientific and technical point of view. The problem set by Hofmann was, in fact, not solved until more than a quarter of a century after Perkin's first attempt, and then by a very indirect method. The general subject which, among others, was under investigation in the Oxford Street laboratory at that time was the production of organic bases from hydrocarbons by the reduction of the nitro-derivatives. Anthracene, then known as "paranaphthalene," had not been brought within the range of these experiments, and the task of isolating the hydrocarbon from coal-tar pitch with the view of nitrating the pure substance was entrusted to Perkin, whose difficulties in attempting on a laboratory scale to achieve a result which is only satisfactorily accomplished on a factory scale are readily imaginable. However, the aid of the tar distiller was invoked, and a supply of the raw anthracene obtained from the Bethels Tar Works, but the pure hydrocarbon could not be nitrated, and so the desired amine corresponding with aniline could not be obtained. As a matter of fact, Perkin had unwittingly produced, by the action of nitric acid on anthracene, the parent substance of alizarin, anthraquinone, although his analyses failed to reveal the nature of the compound, because at that time an erroneous formula had been assigned to the hydrocarbon by its discoverers, Dumas and Laurent. Other (haloid) derivatives of anthracene prepared during the research for a similar reason failed to give intelligible results on analysis, and the young investigator was therefore given another piece of work, namely, the study of the action of cyanogen chloride on naphthylamine, this being a part of a general research on the

action of cyanogen chloride, etc., upon organic bases, which had, for some time, been going on under the auspices of Hofmann. This second investigation was brought to a successful issue and communicated a year later to the Chemical Society of London, which then held its meetings at a house in Cavendish Square.

Perkin's first successful research was thus completed in 1855 and appeared in the *Journal of the Chemical Society* in 1856 (9, 8; also *Annalen*, 98, 238), from which time, throughout the whole period of his career, this Society received and published practically the whole results of his scientific labours.

The compound described by Perkin in his first paper as "menaphthylamine," in accordance with the nomenclature of the period, is the α -dinaphthylguanidine of modern chemistry. But one naphthylamine was known at that time, and the possible existence of a second modification could not, in the existing state of chemical theory, have been foreseen. That the work and the worker found favour in the estimation of Hofmann is shown by the circumstance that on its completion he was promoted from the position of honorary assistant and made a member of the research staff, his colleague being Mr., now Professor, Arthur Herbert Church, with whom Perkin formed a friendship which lasted throughout his life. It was at this period of his career that he made that discovery of the dyestuff mauve, which for a time diverted his attention from pure to applied science, although, as is now well known, the cause of pure science was advanced at a later period by this discovery to an extraordinary degree, and in many directions quite unforeseen at the time. The story of the discovery of the first coal-tar colouring matter has been frequently placed upon record, and the fiftieth anniversary was made the occasion for an international celebration in London, in July, 1906, when Perkin became the central figure and received the homage and congratulations of chemists and technologists from every part of the world. Seldom, if ever, in the history of science has the discovery of one chemical compound of practical utility led to results of such enormous scientific and industrial importance as this accidental preparation of mauve in 1856. The details of the working out of the manufacturing process and of the methods for utilising the dyestuff belong to the history of applied science, but since the discovery was the outcome of purely scientific antecedents, and its achievement a matter which materially affected Perkin's career, it is necessary to recapitulate this chapter of his activity in the present notice.

The remarkable zeal which Hofmann's young assistant must have thrown into his work is well revealed by the circumstance

that even the activity of the Oxford Street laboratory failed to satisfy his craving for research. He was at that time kept at work on the investigations prompted by that illustrious professor whose resourcefulness appeared to be inexhaustible, and had little or no time for working independently. He accordingly fitted up, in 1854, a part of a room as a laboratory in his own home,* and there carried on his researches after the day's work at the College was over and during the vacation. It is of considerable interest to note that even at this early period his work brought him into contact with colouring matters, for, having secured the co-operation of his colleague, Mr. Church, one of the first pieces of work which they took in hand was the investigation of the products of reduction of dinitrobenzene and dinitronaphthalene. From the latter there was obtained a coloured substance which, in accordance with the prevailing views concerning the nature of such compounds, was named "nitrosonaphthyline," and a brief account of it was given to the Royal Society by Hofmann on February 6th, 1856 (*Proc. Roy. Soc.*, **8**, 48), the complete description being afterwards published in the names of Perkin and Church in the *Journal of the Chemical Society* (*Quart. Journ.*, 1857, **9**, 6). The interest attaching to this colouring matter is that it was the first representative of the large and important group of azo-dyes derived from naphthalene ever manufactured, although its true nature was, of course, at first unknown to its discoverers, and even its ultimate composition was not accurately established at the time, because, seven years later, when Perkin and Church resumed the study of the compound, they found that it contained no oxygen, as had at first been supposed, and that it could be made more conveniently by the action of a nitrite on a salt of α -naphthylamine in the presence of alkali. The substance was re-named, in accordance with current notions, "azodinaphthylidiamine," and the amended results published by the Chemical Society (*Journ. Chem. Soc.*, 1863, **16**, 207). A patent was also secured (No. 893 of 1863) † and the substance had a limited use as a dyestuff. The azodinaphthylidiamine of 1863 is the α -aminoazonaphthalene of modern chemistry, and, it may be added, is of no importance in tinctorial industry at the present time.

The discovery of a compound which happened to be a colouring matter was at this stage of Perkin's career an accidental circumstance, as was, in fact, the discovery of mauve, which was made

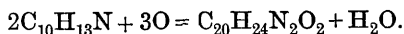
* His father's house was at that time known as "King David's Fort," Shadwell, E. The name is still preserved in King David's Lane.

† It has been pointed out by Caro (*Ber.*, 1891, **24**, Appendix, p. 3) that this patent is the first claiming the production of a sulphonated azo-colour.

in this same rough home laboratory about the same time, namely, the Easter vacation of 1856. In view of the widespread notion that discoveries of industrial value are invariably the result of researches directed solely towards this practical end, it may be of interest to place once again upon record the statement that the first coal-tar colouring matter was discovered by Perkin as the outcome of as distinct a piece of pure scientific research as was possible in the light of the theoretical conceptions of that period. It must be borne in mind that in 1856 organic chemists had practically nothing to guide than in expressing the formulæ of compounds but the ultimate composition derived from analytical results. It is true that the possibility of different substances having the same ultimate composition had, since the time of Wöhler and Berzelius, received recognition among chemists, but these early ideas concerning isomerism had not yet given birth to those definite conceptions of chemical structure which at a later period resulted from the application of the doctrine of valency. Thus in 1856 it was scientifically legitimate to set out from the assumption that a natural product might be synthesised if the elements composing it could be brought into combination in the right proportions. Many attempts to produce natural compounds artificially had been made on this principle since the fundamental synthesis of urea from ammonium cyanate by Wöhler in 1828, and although no success in the way of the desired syntheses can be recorded, there can be no doubt that many indirect results of lasting importance to chemical science were arrived at in this way. The discovery of mauve by Perkin is an example of such an indirect result which at first ranked as an industrial success only, and, it may now be said fortunately, for a time diverted the energies of its discoverer from the field of pure science to that of chemical industry.

In so far as the discovery of mauve is attributable to scientific as distinguished from purely technical research, it may be pointed out that in accordance with the prevailing belief that a synthetical product, if of the same empirical formula, would prove to be identical with the natural compound, Hofmann, as far back as 1849, had, as Perkin himself indicates in the Memorial Lecture (*Trans.*, 1896, 69, 603), suggested the possibility of synthesising quinine from naphthalene, the ground for this suggestion being that the base "naphthalidine" (=naphthylamine) was at that time supposed to differ from quinine only by the elements of two "equivalents" of water, so that if the hydration of the base could by some means have been effected, quinine might be expected to be the result ("Reports of the Royal College of Chemistry," 1849, Introduction, p. 61). Ideas of this order were prevalent in the chemical world

about the middle of the nineteenth century, and Perkin has told us how, imbued with these notions, he was "ambitious enough to wish to work on this subject of the artificial formation of natural compounds" (Hofmann Memorial Lecture, *loc. cit.*). Following the method then in vogue, he came to the conclusion that the most likely generator of quinine would be allyltoluidine, since two "equivalents" of this compound, by taking up oxygen and losing hydrogen (in the form of water), would give a substance of the formula of quinine:



The experiment was tried, a sale of allyltoluidine being oxidised by potassium dichromate, but, instead of quinine, a "dirty reddish-brown precipitate" was obtained. This result, negative in one sense, still appeared of sufficient interest to the young investigator to be worth following up, and he repeated the experiment with a salt of the simpler base aniline, obtaining in this case a very dark-coloured precipitate, which, on further examination, was found to be a colouring matter possessed of dyeing properties. Thus was discovered the first of the coal-tar dyes, the subsequent and rapid development of which, from a laboratory curiosity into a technical product, brings into strong prominence the extraordinary combination of energy, skill, and resourcefulness inherent in this youth, who at the time was not much over seventeen years of age. The very fact of his continuing the investigation of what the majority of contemporary chemists would have discarded as an unpromising "Schmier," may be taken as an indication of his originality, for it must be remembered that, at that time, the main object of research in organic chemistry was to obtain definite crystalline compounds, and the formation of non-crystalline, and especially of coloured, amorphous products was considered as an indication of the failure of a reaction. This view of research method was particularly upheld in Hofmann's laboratory, and, as has frequently been pointed out by many critics of the too-rigid enforcement of this method, there can be no doubt that the discovery of the coal-tar dyes was considerably retarded by the liberal use of animal charcoal as a decolorising material. Hofmann himself, for example, is well known to have prepared rosaniline in 1858 incidentally as a by-product in the course of his study of the reaction between carbon tetrachloride and aniline, although, so far as concerned the main objects of his research, he regarded it as an impurity. To Perkin must be given the credit of having the courage to break through the traditional dislike of investigating coloured, resinous-looking products, an achievement which, in the

case of mauve, may, perhaps, be attributed to that rare combination of the scientific and artistic faculties which he was known to possess. The fact that his new product on purification gave a compound which at that time would be considered as imparting a beautiful shade of colour to fabrics when used as a dye, may fairly be claimed to have appealed to his æsthetic sense, and to have lured him on with his research, independently, at first, of immediate practical developments. Professor A. H. Church, his colleague and co-worker, has supplied the following statement with respect to this period of his career:

"It was, I think, in October, 1853, that William Henry Perkin entered the Royal College of Chemistry, and was assigned the next bench to mine in the front of the building, looking out upon the street. One year before this date I had gone through my novitiate, and had been awarded what was called a scholarship—still receiving instruction and attending the lectures, but paying no fees. Indeed, I had been carrying out from time to time some minor researches suggested by Dr. Hofmann. Perkin and I soon found we had several interests in common. We were both given to painting, and were amateur sketchers. I was introduced to his home at King David's Fort, and we began painting a picture together. This must have been soon after the Royal Academy Exhibition of 1854, when I had a picture hung. I was nearly four years Perkin's senior, but was soon impressed by his mental activity and his devotion to work.

"I remember the epoch-making experiment in which mauve was first discovered. He repeated it in my presence for my particular benefit. I distinctly recollect strongly urging him to patent his invention. Shortly after this date I left the college for Oxford, but Perkin and I were in frequent communication, and sometimes worked together after I had taken my degree in 1860, and until my appointment in 1863 to the chair of chemistry at the Royal Agricultural College.

"During the year 1855, and the spring of 1856, Perkin and I were no longer working in the same laboratory, for I had been given a bench in the professor's private laboratory on the ground floor, and was engaged in carrying out some of his most important researches of that period."

The history of the technical development of this discovery has been narrated by Perkin in his Hofmann Memorial Lecture of 1896, and it is only necessary to go through that account in order to realise the magnitude of his achievement. A youth of about eighteen, undaunted by the discouragement of his professor, the greatest living master of organic chemistry, had determined to

work out his discovery on a manufacturing scale, with no experience or training as a manufacturer himself, and with no precedent to guide him in the construction of plant for carrying on operations, which had, up to that time, never been conducted on more than a laboratory scale. Hofmann's opposition to his young assistant's leaving the paths of pure science, and embarking upon what, no doubt, appeared to his maturer judgment a most risky undertaking, is quite understandable, and fully justifiable. Everything in connexion with the new industry had to be worked out from the very beginning—the methods for the isolation and preparation of the raw materials, as well as the manufacture of the new dyestuff, and the prejudices of the dyers and printers against innovation had also to be overcome. With all this responsibility ahead of him, Perkin, encouraged, no doubt, by the favourable report concerning the dyeing qualities of his new product furnished by certain practical dyers, and especially by Messrs. Pullar, of Perth, formally resigned his position at the Royal College of Chemistry, and boldly entered upon his career as an industrial chemist. He has touchingly placed upon record his indebtedness to his father, who, although, as already stated, at first inclined to be adverse to his taking to chemistry as an occupation, had, at the time of the discovery of mauve, so much confidence in his son's ability that he threw in his lot with the new venture, and devoted the greater part of his life's savings to the building of a factory, for which a site had been secured at Greenford Green, near Sudbury, at which latter place Perkin afterwards resided. His elder brother,* Thomas D. Perkin, who, during the summer vacation of 1856, had assisted in making mauve in the laboratory on a somewhat larger scale, in order to supply specimens for testing by the dyers, also joined in the undertaking. A patent was secured (No. 1984, August 26th, 1856), and the building of the works commenced in June, 1857, and six months later the new dyestuff, under the name of "Aniline Purple," or "Tyrian Purple," was being manufactured in sufficient quantity to supply one of the London silk dyers.† The subsequent development of this precursor of the coal-tar dyes forms an interesting and, indeed, a romantic chapter in the history of applied science. Its reputation spread rapidly; from silk dyeing its application was extended to cotton dyeing and to calico printing, and at every stage of a career which may be fairly described as triumphant, the master hand of William Henry Perkin can be detected. Now we find him working out processes for the manu-

* Born 1831, died 1891.

† The name "Mauve," by which it was afterwards generally known, was given to the dyestuff in France.

facture of nitrobenzene and aniline on a scale never before attempted, then we learn of his introducing improvements into the methods of silk dyeing on the large scale, and of his discovering suitable mordants for enabling the dyestuff to be applied to cotton fibre both by dyers and calico printers. Well may it be said in Perkin's own words: "In fact, it was all pioneering work." *

In spite of these splendid pioneering efforts, however, it seems that the recognition of the value of the product at first took place but slowly in this country, and it was not until it had been taken up in France that its merits for tinctorial purposes became generally recognised. In a private communication addressed to the writer of this notice on April 3rd, 1906, Perkin states: "The value of the mauve was first realised in France, in 1859. English and Scotch calico printers did not show any interest in it until it appeared in French patterns, although some of them had printed cloth for me with that colour." The "Société Industrielle de Mulhouse," it may be added, awarded him a silver medal for his discovery in 1859, and afterwards a gold medal.† It is of interest to note also that a paper was read by him at the Leeds meeting of the British Association in 1858, under the title, "On the Purple Dye obtained from Coal Tar" (Reports, 1858, p. 58), when specimens of the substance and fabrics coloured by it were exhibited. No more appropriate place than this town, in the centre of one of the chief seats of the tinctorial industry in Great Britain, could possibly have been selected for bringing the discovery under the notice of chemists and technologists. Sir John Herschel was President of the Chemical Section, and, by a remarkable coincidence, in the opening address of the President of the Association, Professor (afterwards Sir Richard) Owen, there occur the following passages *à propos* of the general progress of organic chemical synthesis: "To the power which mankind may ultimately exercise through the light of synthesis, who may presume to set limits? . . . Already, natural processes can be more economically replaced by artificial ones in the formation of a few organic compounds. . . . It is impossible to foresee the extent to which chemistry may ultimately, in the production of things needful, supersede the present vital agencies of nature." This pronouncement at the meeting when the first of the coal-tar colouring matters was exhibited—a

* Speech at the Jubilee Banquet in New York, October 6, 1906. See also the Hofmann Memorial Lecture, *loc. cit.*, p. 609.

† The impetus given to the new colouring matter through French influence was also referred to by Perkin in his reply to Professor Haller at the Jubilee Meeting in 1906 (Report, p. 11); see also *Journ. Society of Dyers and Colourists*, April, 1907, p. 106.

discovery which laid the foundations of an industry which now supplies as tar products the colouring matters of madder and indigo—may be looked upon as prophetic.

The influence of this inaugural work by Perkin upon the subsequent history of the industry is too well known to need recapitulation. It is only necessary to point out that the introduction of aniline—at that time a mixture of homologues—into the market soon led other investigators to enter the field of colour chemistry, and new dyestuffs made their appearance in rapid succession, the most noteworthy after mauve being magenta, which was discovered as a technical product in 1859 by Verguin, and manufactured for a short period by his process* by the firm of Renard Frères et Franc, of Lyons. In fact, the stream of competition in the course of a few years turned against the original mauve, the demand for which gradually fell off as other colouring matters of a similar or brighter hue were introduced. The consideration of chief interest in connexion with Perkin's successful venture into the domain of applied chemistry is, however, from the present point of view, the influence which his work in this field exerted upon pure science. That it has exerted an enormous influence is now generally recognised, and a critical examination of the course of development of the industry will show that the gain by chemical science has been of a twofold character—a direct and an indirect gain.

In the first place, as the direct result of introducing into commerce in large quantities organic chemical products which had before been but laboratory curiosities, a great stimulus was given to research, and chemical workers of the highest repute took up the investigation of the new products, both raw materials and colouring matters. As an indirect consequence, also, many new compounds of industrial value were discovered incidentally in the course of manufacturing operations conducted on the large scale, and these, with the colouring matters which from time to time appeared as novelties, furnished endless subject matter for research, the results so obtained often proving of the greatest scientific importance. Not the least interesting circumstance in connexion with this chapter of chemical history is the fact that Hofmann himself soon entered the field of tinctorial chemistry, to which he made many contributions of the utmost value both from the scientific and technological point of view. He was, in fact, for many years recognised as the leading scientific authority on coal-tar colouring matters, and many of his discoveries were practically

* By heating crude aniline (*i.e.*, aniline containing toluidine) with stannic chloride.

utilised in the factories. Then, again, there can be no doubt that the success of the new industry and the succession of important scientific discoveries which followed its development attracted large numbers of students into the chemical schools, and many gifted and active workers were by this means drawn as recruits into the ranks of scientific chemists. It is, indeed, not going too far to say that the discovery of the coal-tar colouring matters brought about such a revival in the study of organic chemistry, and particularly in that of the so-called "aromatic" series, that when the epoch-making conception concerning the constitution of these compounds had been given to the world by Kekulé in 1865, the rapid extension of the "benzene theory" was enormously facilitated by the resources which the new industry had given to pure science. If it is true that the new theory materially advanced the cause of the industry, it is no less true that the industry contributed to the advancement of the theory, the verification of which might have been delayed for a generation or more without such support. No better illustration of the interdependence of science and industry has ever been given to the world than this particular example of the action and reaction between theoretical and applied chemistry.*

The success of the new industry not only reacted upon the science of chemistry in the way indicated, but it may be claimed that, contrary to Hofmann's forebodings, it proved in the long run beneficial in every way to Perkin himself, and through him to that science to which he devoted his life. He has told us that when, being fully convinced of the value of mauve, he announced his intention of leaving the College of Chemistry and taking up the manufacture of the new colouring matter, he determined not to allow the manufacturing career to check his research work, and nobly did he adhere to his resolution. His published papers show that in spite of all his technical work the stream of original investigation was never allowed to stagnate. Only a year after the starting of the Greenford works, namely, in 1858, in conjunction with Duppa, he discovered that aminoacetic acid or "glycocoll," a compound which up to that time had only been prepared by the

* The consideration of the later important influence upon other branches of science arising, often in most indirect and unforeseen ways, from the applications of coal-tar products to such subjects as bacteriology, histology, therapeutics, photography, etc., would swell this notice to an inordinate extent. Although results of incalculable value have been achieved in these fields, Perkin himself is not particularly identified with any of the lateral developments of his initial pioneering labours. References to this aspect of the subject were made in some detail at the Jubilee celebration in 1906. (See the official Report published by the Memorial Committee, and also a paper by Dr. Hugo Schweitzer in *Science*, No. 616, October 19, 1906, p. 481.)

decomposition of natural products, could be obtained by heating bromoacetic acid with ammonia.* A general survey of his work during his connexion with the coal-tar colour industry, which ceased in 1874, brings out very clearly the double line of thought which during that period actuated his research work. Concurrently with the investigation of the dyestuffs, he carried on researches in other departments of organic chemistry which had at that time no relations with tinctorial chemistry. Thus we find that by 1860 he, in conjunction with Duppa, had discovered the relationship between tartaric and fumaric-maleic acid, and had effected the synthesis of racemic acid from dibromosuccinic acid, a line of work which was followed up with signal success (Perkin and Duppa, *Annalen*, 1860, **115**, 105; *Quart. Journ. Chem. Soc.*, 1860, **13**, 102; Perkin, *Journ. Chem. Soc.*, 1863, **16**, 198; Perkin and Duppa, *Annalen*, 1864, **129**, 373; Perkin, *Proc.*, 1888, **4**, 75). About 1867 he must have commenced those researches on the action of acetic anhydride upon aromatic aldehydes which led to such important developments, and culminated in that beautiful method of synthesising unsaturated acids now known as the "Perkin synthesis." The first paper of this series bore the title, "On the Action of Acetic Anhydride upon the Hydrides of Salicyl, Ethylsalicyl, &c." (*Journ. Chem. Soc.*, 1867, **20**, 586), and as the outcome of this work the synthesis of coumarin, the odorous substance contained in Tonka Bean, etc., was announced the following year ("On the Artificial Production of Coumarin and Formation of its Homologues," *Journ. Chem. Soc.*, 1868, **21**, 53 and 181). The production of a vegetable perfume from a coal-tar product was thus first made possible by Perkin, and the continuation of this work, after his retirement from the industry, led to his celebrated discovery of the synthesis of cinnamic acid from benzaldehyde, an achievement which subsequently, in the hands of Adolf v. Baeyer and H. Caro, made possible the first synthesis of indigo from tar products.† It is of interest to note also that while still in the coal-tar colour industry he took part in the discovery of synthetical methods for producing glyoxylic acid from dibromoacetic and

* Perkin and Duppa, *Annalen*, **108**, 112. This discovery is specially referred to, not only as illustrating Perkin's extraordinary activity during this busy period, but also because the compound is the type of a large group of amino-acids which of late years have become of extreme importance owing to their relationship to the proteins, as shown by Emil Fischer and his co-workers.

† "A Preliminary Notice of the Formation of Coumarin, Cinnamic Acid, and other similar Acids," *Chem. News*, 1875, **32**, 258; "On the Formation of Coumarin and of Cinnamic and of other Analogous Acids from the Aromatic Aldehydes," *Journ. Chem. Soc.*, 1877, **i**, 388.

bromoglycollic acids, thus giving the first insight into the constitution of glyoxylic acid, a result of considerable significance in view of the important part attributed by many modern chemists to this acid in the photosynthetic processes going on in growing plants (Perkin and Duppa, *Journ. Chem. Soc.*, 1868, **21**, 197).

The research work done during Perkin's colour-making period was carried on in a laboratory in a house just outside the Greenford factory, where also the scientific investigations in connexion with the colouring matters were conducted, the double line of work already indicated being revealed by the papers published during that period. It has not been considered necessary to give a complete list of these papers in the present notice, but it will be of interest to call attention to the fact that the purely scientific study of the colouring matters undertaken at this time centred round his early discoveries. It was in this new laboratory at Greenford that he and Church continued the investigation of "azodinaphthylidiamine" already mentioned, and discovered a method for resolving this compound by complete reduction, thus introducing a process which is still the standard one for determining the constitution of azo-compounds, and at the same time leading to the isolation of the first diamine derived from naphthylamine (*Journ. Chem. Soc.*, 1865, **18**, 173). Nor did he allow his scientific interest in his first discovered dyestuff to flag, for one paper on mauve from the purely chemical point of view was published during his connexion with the industry and another after his retirement in 1874.*

In 1868 it was shown by Graebe and Liebermann that the colouring matter of the madder, alizarin, one of the most ancient of vegetable dyestuffs and a substance of immense value for tinctorial purposes, was a derivative of the coal-tar hydrocarbon anthracene, and not, as had up to that time been believed, a derivative of naphthalene. The synthesis of this compound was effected by Graebe and Liebermann in that year, and patents for its manufacture from anthracene secured in Germany and in Great Britain, this being the first instance of a natural vegetable colouring matter having been produced artificially by a purely chemical method. This discovery had a great influence upon Perkin's career as an industrial chemist, and may, indeed, be considered to have marked a new phase of his activity in this field. There was no

* "On Mauve or Aniline Purple," *Proc. Roy. Soc.*, 1863, **12**, 713 (abstract); 1864, **13**, 170 (full paper). "On Mauveine and Allied Colouring Matters," *Trans.*, 1879, **35**, 717. In 1861 he lectured before the Chemical Society on the new coal-tar colouring matters, on which occasion, he has told us, Faraday was among his auditors and congratulated him at the end of the lecture.

living worker in this country at that time besides Perkin who so completely combined in himself all the necessary qualifications for taking advantage of such a discovery. Imbued with the spirit of his early ambition to produce natural compounds synthetically, with more than a decade's experience as a manufacturer, with the resources of a factory at his disposal, and, not least, with special experience of anthracene as the very substance upon which, at Hofmann's instigation, he commenced his career in research work, it can readily be understood that Graebe and Liebermann's results should have appealed to him with special significance. The first patented process of the German discoverers was confessedly too costly to hold out much hope of successful competition with the madder plant, requiring as it did the use of bromine. Perkin at once realised the importance of cheapening the process by dispensing with the use of bromine, and undertook researches with this object. As a result, the following year (1869) witnessed the introduction of two new methods for the manufacture of artificial alizarin. In one of these processes dichloroanthracene was the starting point, and in the other the sulphonic acid of anthraquinone, the first being of special value in this country owing to the difficulty of obtaining at that time "fuming" sulphuric acid in large quantities. The second process, which is the one still in use, had quite independently been worked out in Germany by Caro, Graebe, and Liebermann, and patented in England practically simultaneously with Perkin's.* The subsequent industrial development of this brilliant achievement has now become historical; the artificial alizarin has completely displaced the natural colouring matter, and madder growing as an industry has become extinct. It is of interest, as showing the growth of the new industry, to reproduce Perkin's statement in 1876:

"The quantity of madder grown in all the madder-growing countries of the world, prior to 1868, was estimated to be 70,000 tons per annum, and at the present time the artificial colour is manufactured to an extent equivalent to 50,000 tons, or more than two-thirds of the quantity grown when its cultivation had reached its highest point" (Presidential Address to Section B of the British Association, Glasgow, 1876, "Reports," p. 61).

The development of this branch of the coal-tar industry in the Greenford Green Factory has also been recorded by Perkin:

"Before the end of the year (1869) we had produced 1 ton of this colouring matter in the form of paste; in 1870, 40 tons; and in 1871, 220 tons, and so on in increasing quantities year by

* The patents are, Caro, Graebe, and Liebermann, No. 1936, of June 25, 1869, and W. H. Perkin, No. 1948, of June 26, 1869.

year . . . up to the end of 1870 the Greenford Green Works were the only ones producing artificial alizarin. German manufacturers then began to make it, first in small and then in increasing quantities, but until the end of 1873 there was scarcely any competition with our colouring matter in this country" (Hofmann Memorial Lecture, Trans., 1896, 69, 632).

This brilliant achievement in technology again served to bring out the purely scientific spirit which animated all Perkin's work. The chemical investigation of anthracene derivatives was carried on concurrently with the industrial development of the factory process, and also after his retirement, about a dozen papers on these compounds having been published between 1869 and 1880. The discovery of a practical process for the manufacture of alizarin thus led to the utilisation of another coal-tar hydrocarbon anthracene, which had up to that time been a waste product, and the methods for isolating and purifying this substance had, as in the case of benzene, etc., to be worked out in the factory. All the difficulties inseparable from large-scale operations with new materials were successfully surmounted by Perkin; the increasing demand for artificial alizarin taxed all the resources of the factory, and by 1873, when the necessity for introducing enlarged plant became imperative, advantage was taken of the opportunity for transferring the works to the firm of Brooke, Simpson, and Spiller, the successors to the firm of Simpson, Maule, and Nicholson, which had co-operated with Perkin in the early days of the mauve manufacture. The later history of the works is referred to in the technical portion of this notice.

On completion of the sale of the Greenford Green Works in 1874, Perkin retired after eighteen years' connexion with the industry. In view of the enormous development of this branch of manufacture in later times, it is of interest to recall the circumstance already mentioned that the whole output of the original factory, both in number and quantity of products, would appear quite trivial in comparison with that of one of the great German factories now in existence—a fact which only serves to emphasise the extraordinary fertility of the seed originally planted by Perkin, whose labours as a technologist led, as a practical issue, to the acquisition of sufficient means to enable him to withdraw altogether from the industrial side of chemistry at the comparatively early age of 36, while still in the prime of life. By many who have watched the decadence of the coal-tar colour industry in this country, he has been blamed for cutting himself so soon adrift from his own offspring. There is no doubt that the life of the industry here would have been prolonged if he had kept in touch with it, but it must not

be forgotten that at the time of his retirement he left things in a very flourishing condition. Other factories had developed into successful establishments, and Great Britain was well to the front in this branch of manufacture. Neither Perkin nor his contemporaries could have foreseen in 1874 that our position would later be so successfully assailed by foreign competitors. To a man with his most moderate personal requirements, and with the ardour of the original investigator unquenched, the means of retirement—modest enough as compared with the fortunes accumulated by modern successful manufacturers—simply meant the opportunity of giving practical effect to that resolution concerning his mission as a research chemist which he had formed as a youth, which he had adhered to throughout his industrial career, and which it was his desire to carry out untrammelled by business distractions throughout the remainder of his working period.* Industry may, and no doubt did, lose by his decision, but science gained by thirty years of his activity from the period of his retirement down, practically, to the end of his life.

The contributions to chemical science which proceeded from Perkin's laboratory after 1874 have, to some extent, been referred to. After his connexion with the Greenford Green Factory had terminated, he had a new house built at Sudbury, converting the adjacent house in which he had previously resided into a laboratory, and it was here that from 1875 he continued his investigations of those colouring matters with which his manufacturing experience had brought him into contact, such as mauveine, the anthracene derivatives, etc. In 1881 he first drew attention to a certain physical property of some of the compounds which he had prepared, namely, their magnetic rotatory power, which observation diverted his activity into an entirely new channel. On further development in his hands this method became a powerful weapon in dealing with questions of chemical constitutions, and the remainder of his life was more or less devoted to its elaboration. As Perkin's name must always be intimately associated with this chapter of physical chemistry, it will be of interest to place upon record his earliest observation. In a paper entitled "On the Isomeric Acids obtained from Coumarin and the Ethers of Hydride of Salicyl" (*Trans.*, 1881, **39**, 409), he describes the methyl ether of "*α*-methylorthoxyphenylacrylic acid," which he had first prepared in 1877, and in this paper occurs the statement:

* "The great importance of original research has been one of the things I have been advocating from the commencement of my chemical career, in season and out of season."—From a speech by Perkin at the Jubilee Banquet in London, on July 26, 1906.

“ A determination of its magnetic rotary power gave for the yellow ray 2.334, water being taken as 1. Test observations were made at the same time with water and carbon bisulphide, and gave results very nearly identical with those obtained by Becquerel” (*Ann. Chim. Phys.*, 1877, [v], **12**, 22; *loc. cit.*, p. 411).

It is not difficult to follow, at least conjecturally, the mental process by which Perkin was enabled to foresee that this property might be utilised for investigating the constitution or structure of chemical molecules, a subject which even at that time was beginning to bristle with difficulties and ambiguous results when handled by purely chemical methods. He had for precedent the success which had attended the study of other optical properties of organic compounds, such as ordinary (not induced) rotatory power, dispersion, refractivity, etc., and he threw himself seriously into this line of work, armed with the skill of an accomplished experimenter, and with that true instinct as a chemist which enabled him to deal with his materials in such a manner that his results at once commanded complete confidence, in spite of the circumstance that this kind of work was for him a totally new departure. In 1882 he published a preliminary paper on the application of this method, and a complete account in 1884.*

From that time onwards the Chemical Society received and published constant instalments of his work, the fertility of the method being shown, not only by the long list of papers published in his own name, but also by the numerous observations recorded in the papers of other workers, to whose service his apparatus and his observational powers were frequently and ungrudgingly devoted. His achievements in this field are well summarised in a letter from Professor J. W. Brühl, of Heidelberg, himself one of the pioneers in the application of optical methods for the determination of chemical constitution, sent to the writer of this notice for transmission to Perkin on the occasion of the Jubilee celebration in 1906: “ Availing yourself of the marvellous discovery of your great countryman, Michael Faraday, you undertook to investigate the relations between the chemical composition of bodies and their magnetic circular polarisation—that is to say, one of the general properties of all matter. Before you began work there was little, almost nothing, known of this subject, certainly nothing of practical

* “ On Rotatory Polarisation by Chemical Substances under Magnetic Influence,” *Trans.*, 1882, **41**, 330. “ On the Magnetic Rotary Polarisation of Compounds in Relation to their Chemical Constitution; with Observations on the Preparation and Relative Densities of the Bodies examined,” *ibid.*, 1884, **45**, 421. This last paper, which occupies 60 pages of the volume, contains a full description of the apparatus and method of observation.

use to the chemist. You created a new branch of science, taught us how, from the magnetic rotation, conclusions can be drawn as to the chemical structure of bodies, and showed that the magnetic rotation allows us to draw comprehensive and certain conclusions as to the chemical constitution of substances, just as we may from another general physical property, viz., refraction and dispersion. And by showing that both these physical methods of investigation lead to completely harmonious results, you did essential service to both the branches of study, and also to chemistry, which they are destined to serve."

This last statement by Brühl, which relates to one of the most interesting results of the study of magnetic rotation, has reference to a development of Perkin's work which brought him into association with the late John Hall Gladstone, the pioneer and leading authority in this country at that time on the relations between refractive and dispersive power and chemical constitution. The correspondence between the results arrived at by these two optical methods forms the subject of a joint paper by Gladstone and Perkin published in 1889.* Eighteen years later Perkin's last paper, to which attaches the melancholy interest that it was read before the Chemical Society on April 18th, 1907, only a few months before his death, bears the title: "The Magnetic Rotation of Hexatriene, $\text{CH}_2\cdot\text{CH}\cdot\text{CH}\cdot\text{CH}\cdot\text{CH}\cdot\text{CH}_2$, and its Relationship to Benzene and other Aromatic Compounds: also its Refractive Power" (Trans., 1907, **91**, 806).

Although, as already stated, the latter part of Perkin's life was devoted mainly to his work on magnetic rotation, he published also during this period a few papers relating to other subjects, among which perhaps the most notable is his contribution to the subject of low temperature combustion, entitled "Some Observations on the Luminous Incomplete Combustion of Ether and other Organic Bodies" (Trans., 1882, **41**, 363). The writer of this notice well remembers the keen interest with which the experiments were followed in the darkened meeting-room of the Chemical Society at Burlington House when this paper was read. In view of the

* "On the Correspondence between the Magnetic Rotation and the Refraction and Dispersion of Light by Compounds containing Nitrogen," Trans., 1889, **55**, 750. The correspondence between Perkin and Gladstone during this period has been placed at the disposal of the writer by Miss Gladstone. The letters are interesting as showing the extreme conscientiousness in every detail with which Perkin carried out his work. The results are embodied in the above paper, and a further contribution by Perkin was published two years later, under the title, "The Refractive Power of certain Organic Compounds at different Temperatures," Proc., 1891, **7**, 115. In his later papers he dealt with refractivity as well as magnetic rotation (Trans., 1896, **69**, 1; *ibid.*, 1900, **77**, 267, etc.).

modern revival in the scientific study of the chemical mechanism of combustion, it is of importance that Perkin's observations should not be allowed to fall into oblivion.

It has been claimed in a previous part of this notice that Perkin's entry into the domain of chemical industry was no real loss, but actually a gain to pure science. His published papers, considered in detail, show that his contributions to "colour chemistry" are far outweighed by his work in other fields. In fact, the extension and completion of the investigation of the dyestuffs of his industrial period is due to other workers, and Perkin's achievements in this direction are, on the whole, more of a technological than of an abstract scientific character, the constitution of most of the colouring matters having been subsequently worked out chiefly by the group of brilliant Continental investigators attracted by the success of the new industry, and stimulated by the rapid development in chemical theory then going on in Germany.* But although Perkin has overshadowed his own achievements as a "colour chemist" by his subsequent career, the whole success of his life, and the inestimable gain which chemical science has derived from his labours, must be directly attributed to his industrial undertakings, for it may safely be asserted that had he not been rendered independent by the success of the Greenford Green Factory, he would never have found an opportunity for that continuous devotion to research which is so essential for the achievement of results of lasting value. Having determined in early life to adopt chemistry as a career, he would of necessity have been compelled to become either a manufacturer or to have entered an educational establishment. In the former capacity he would, no doubt, have succeeded, but in any subordinate post he might have spent long years before acquiring independence. As a teacher his prospects of making a position at the time of his connexion with the Royal College of Chemistry were most slender. There were but very few posts which he could have filled; originality as an investigator was of minor importance as a qualification for the teaching profession, and the stamp of university training was generally considered absolutely essential for holding any important appointment in that profession. Perkin in any minor teaching post would have been lost to science. Happily the comparatively rapid financial success of his early discoveries placed him in that category which comprises such names as Cavendish, Herschel, Joule, Murchison, Spottiswoode, Lyell, and

* For example, the constitution of mauveine was established broadly by O. Fischer and Hepp about 1890; that of the colouring matters of the rosaniline group (magenta, methyl-violet, etc.), by E. and O. Fischer, about 1878, and that of safranine about 1883 by Nietzki.

Darwin—representatives of that band of independent devotees of science who have more than any other class helped to maintain the prestige of this country. Truly may it be said that to a man of his temperament success as a manufacturer meant salvation as an original worker.

Reviewing Perkin's scientific work as a whole, its chief characteristic is its solidity. His mind was not of that order which readily entered into the region of speculation; he was a typical representative of that school of chemists to whom the conscientious accuracy of experimental facts is of primary importance—the school which has laid those solid foundations of chemical science upon which all superstructures of theory must be erected. It is for this reason that it may be predicted with certainty that his work will live in the history of modern chemistry whatever changes in theoretical conceptions the future may have in store. He himself witnessed with the progress of the science radical changes in the views of chemists concerning the mechanism of the reactions or the nature of the compounds which he had discovered. With true philosophic spirit he accepted the evidence of other workers and welcomed the legitimate development of his own discoveries. Whatever modification of theory may have been rendered necessary by the accumulated labours of the great and ever-growing army of investigators which he lived to see following the tracks which he had been the first to tread, it may be safely asserted that his own early footprints have been, and always will be, ineffaceable.

Perkin was by disposition a man of extreme modesty and of a most retiring nature. His devotion to science and the domesticity of his character accounted so completely for his time that, beyond participating in the administrative work of the scientific societies with which he was connected, he took but little part in extraneous affairs. He was not particularly of a business turn of mind in the commercial sense, and during his industrial career his brother Thomas was the chief man of business connected with the factory. One line of work distinct from his purely scientific occupations is, however, worthy of special record, because it enabled him to exert some influence in the cause of technical and scientific education. His family had for a long period been connected with the Leather-sellers' Company, and through this connexion he was enabled to promote the cause of chemical research and also to become, as the representative of his Company, a member of the governing body of the City and Guilds of London Institute, whose meetings he attended with considerable regularity, although, unless specially appealed to, he seldom took part in the discussions at the Council

table. But his influence in the City of London, although unobtrusive, was of a most beneficial character, and every movement for the promotion of science and of scientific education was certain to receive his support. His special knowledge of the requirements of the chemical technologist and his sympathy with the teaching staffs have contributed in no small degree to promote the cause of sound chemical education in London through the City and Guilds Institute. As an illustration of the modesty of his character, it may be of interest to relate that many of his colleagues in the City were unaware, until the Jubilee of 1906, that the William Perkin who sat at their meetings was the same man who, half a century before, had laid the foundations of a great industry. The following details concerning his connexion with the Leathersellers have been supplied by the late Mr. W. Arnold Hepburn, the Clerk to the Company:

“ William Henry Perkin, son of George Fowler Perkin, was made free by patrimony, November 13th, 1861.

“ George Fowler Perkin, son of Thomas Perkin, was made free by patrimony, February 4th, 1829.

“ Thomas Perkin, apprenticed to Isaac Roberts, March 16th, 1772, was made free by servitude, July 7th, 1790.

“ William Henry Perkin served the office of Steward, 1881-2; 4th Warden, 1885-6; second Warden, 1895-6; Master, 1896-7.

“ During the Mastership of Dr. Perkin in 1896 the Company, at his instance, resolved to found a Research Fellowship in Chemistry as applied to Manufactures, tenable at the Central Technical College of the City and Guilds Institute, and to grant £150 a year in support thereof.”

A portrait of Perkin in his robe as LL.D. of the University of St. Andrews, painted by Henry Grant in 1898, is on the wall at the Leathersellers' Hall in St. Helen's Place.

Although his single-minded devotion to his researches and his retiring nature caused Perkin to remain in comparative obscurity from the point of view of the general public, his real worth was well known to, and received frequent recognition from, his scientific colleagues. In this respect his history is that of the majority of active workers in the field of science in this country who do not wield the pen as *littérateurs*, or whose achievements are not of a sufficiently startling kind to create public notoriety. With the passing of the generation which witnessed the interest aroused by the discovery of mauve, and which was fanned into temporary excitement by the sensational accounts circulated by the news-

papers of the period, the memory of Perkin faded from the public mind. To most of his fellow countrymen the memorable international gathering in London in 1906 came as a revelation that they could claim as their compatriot the man whom all the nations had sent their representatives to honour as an individual, and in celebration of the fiftieth anniversary of the discovery of the first of the synthetic dyestuffs.

Perkin was elected into the Royal Society in 1866; he served on the Council in 1879–81, and again in 1892–94. In 1893–94 he was made one of the Vice-Presidents. He joined the Chemical Society in 1856, served on the Council in 1861–62, and in 1868–69; was Secretary from 1869 to 1883, and President from 1883 to 1885. By way of academic distinctions he received the degree of Ph.D. from the University of Würzburg in 1882; the degree of LL.D. from the University of St. Andrews in 1891; and was made a D.Sc. of Victoria University in 1904. In connexion with the Jubilee of 1906, the University of Heidelberg conferred upon him the degree of Ph.D., the Munich Technical High School awarded him the diploma of Dr. Ing., and the same year the Universities of Oxford and Leeds gave him the degree of D.Sc. During his subsequent visit to America in the autumn of 1906, in connexion with the celebrations organised in that country, he received the degree of D.Sc. from Columbia University, and LL.D. from the Johns Hopkins University, of Baltimore, the latter degree having been most appropriately conferred by his chemical colleague, President Ira Remsen.

He was President of the Society of Chemical Industry in 1884–85, at the time of his death was President of the Society of Dyers and Colourists,* and had recently accepted office as President of the Faraday Society. In 1884 he was made an Honorary Foreign Member of the German Chemical Society. Following the early recognition of his technological work by the "Société Industrielle de Mulhouse," already referred to, he received from the Royal Society a Royal Medal in 1879, and the Davy Medal in 1889; from the Chemical Society the Longstaff Medal in 1888; from the Society of Arts the Albert Medal in 1890; from the Institution of Gas Engineers the Birmingham Medal in 1892, and the Gold

* In honour of the founder of the industry this Society has established a Perkin Medal "for inventions of striking scientific or industrial merit, applicable to, or connected with, the tinctorial industries." Perkin's last official act in connexion with this Society was to accompany a deputation to the Dyers' Company asking the latter to contribute towards the foundation of a prize for the encouragement of research in tinctorial chemistry. The American Memorial Committee also founded a Perkin medal for American chemists in 1906 in connexion with their Jubilee Celebration in New York.

Medal of the Society of Chemical Industry in 1898. At the Jubilee Celebration in 1906, Professor Emil Fischer, on behalf of the German Chemical Society, presented him with the Hofmann Medal, and Professor Haller, on behalf of the Chemical Society of Paris, with the Lavoisier Medal.

The influence which Perkin has exerted upon this generation is not to be measured solely by his achievements in pure and applied chemistry. His life was noble in its simplicity, and his single-minded devotion to his work, combined with a character known to be religious in the highest and best sense of the term, will bequeath to posterity an enduring example of humility in the face of success which would have marred many men of smaller moral calibre. The financial success of his early manufacturing experience was turned to account simply as a means of advancing science, and no distinction which he ever gained throughout a career which culminated in 1906, when the King conferred upon him the honour of Knighthood, and when the nations of the world assembled to render him homage, had the slightest influence upon the modesty and gentleness of his disposition. It was his personality that caused him to be revered in his domestic circle, and to be beloved by all who enjoyed the privilege of his friendship. Two of the addresses presented at the Jubilee meeting in 1906 give striking expression to the universal esteem in which he was held as a man:

“But however highly your technical achievements be rated, those who have been intimately associated with you must feel that the example which you have set by your rectitude, as well as by your modesty and sincerity of purpose, is of chiefest value.” (From the address presented by the Chemical Society.)

“You have given to science the allegiance of a noble life, and you have not allowed the seductions of wealth to abate the loyalty of your devotion to truth and knowledge. This is an example for which the age owes you unstinted thanks. . . . Amid these varied activities it is pleasant to know that you have cultivated the full humanity of life. Music and art have found in you a devoted disciple, and in the family and social relationship of life you have shown that science gives a truer interpretation of, and a deeper meaning to, all that is sacred and good in the heart of man.” (From the address presented by the Society of Dyers and Colourists.)

Perkin was twice married, his first wife being a daughter of the late Mr. John Lisset; some years after her death he married the daughter of Mr. Herman Mollwo. Lady Perkin, three sons, all of whom have made their mark as chemists, and four daughters survive. Two of his sons, William Henry and Arthur George, were elected into the Royal Society in 1890 and 1906 respectively, and

it was always a source of great satisfaction to him to know that all his sons were following in his footsteps. In his general mode of life Perkin was a man of extreme frugality, robust and active to the last. To one of his retiring habits the strain accompanying the Jubilee celebrations in 1906 and the subsequent ordeal of his American tour must have been considerable, but he bore all the excitement and fatigue without the least indication of discomfort. Literally he died in harness; a few months previously he had read his last paper before the Chemical Society, and he was looking forward to being able to resume his research work quietly and uninterruptedly after the distractions of 1906. The illness which brought his noble and useful life to an end, which, in view of his activity, cannot but be regarded as premature, did not at first reveal any serious symptoms. The writer of this notice was with him a few hours before his death, and although he complained of suffering pain he spoke hopefully of his condition and anticipated being soon able to leave his room. The illness proved, however, to be more serious than he or his family were aware of; a sudden change for the worse occurred, and on July 14th, 1907, he passed away in perfect peace and in the full tide of well-won honour.

TECHNICAL ASPECTS OF PERKIN'S DISCOVERY OF MAUVE.

In dealing with the technical development of Perkin's discovery it is of interest to consider in the first place the state of affairs with respect to the raw materials required for the manufacture of mauve. These were benzene, nitrobenzene, and aniline.

Benzene was discovered by Michael Faraday, in 1825, as a component of the liquid obtained by the compression of oil-gas. Twenty years later Hofmann found this hydrocarbon in coal-tar, and proved its presence by preparing from it nitrobenzene and aniline, the latter being identified by the usual tests. The occurrence of benzene in coal-tar was thus known in 1845, and in 1848 one of Hofmann's brilliant young students at the Royal College of Chemistry, Charles Blachford Mansfield, at the instigation of his illustrious master, undertook a systematic study of coal-tar, with a view to the isolation and identification more especially of the "neutral liquid oils," of which he tells us in his paper published by the Chemical Society in 1849 we had at that time "no precise information." When Mansfield took up this work, a few definite compounds were known to exist in this tar, notably naphthalene, which had been isolated by Garden in 1820, and certain acid and basic substances, such as phenol (carbolic acid), aniline (kyanol), quinoline (leucol or leucoline), and pyrrole, all of which had been

isolated by Runge in 1834. Anthracene, under the name of "paranaphthaline," was isolated by Dumas and Laurent in 1833, although it is now known that their original analysis, which assigned to this hydrocarbon 15 atoms of carbon, was erroneous. Chrysene and pyrene had also been indicated, but only superficially studied by Laurent in 1837. To the basic constituents, picoline was added in 1846 by Anderson.

Such was the state of knowledge when Hofmann set Mansfield to work upon the coal-tar hydrocarbons. The paper embodying his results is entitled, "Researches on Coal Tar. Part I.,"* and now, nearly sixty years after its publication, it can still be read with interest and profit. Its contents have become historic in connexion with the colour industry, and must rank with Runge's celebrated papers of 1834 (*Pogg. Annalen*, **31**, 65, 513; **32**, 308, 328) among the most important contributions to tar chemistry that preceded the foundation of that industry. The still devised by Mansfield for fractionally distilling the tar oils embodied the "reflux" principle of our modern rectifying columns. In the way of definite products he isolated and characterised benzene with considerable precision; he found that it could be purified by fractional distillation and by crystallisation at a low temperature. It is of interest to note in passing that the analysis of the hydrocarbon was made for him by Edward Chambers Nicholson, another of Hofmann's pupils, who at a later period played a very conspicuous part in connexion with the coal-tar colour industry of this country. Of the higher boiling-point hydrocarbons, he also isolated toluene and two of the higher homologues, which he was inclined to identify with cumene and cymene respectively. It is now known that the fraction which he considered to be cumene was xylene, and it is very doubtful whether cymene is contained in coal-tar at all. There can be no doubt that he had not individual compounds to deal with in the case of these higher homologues, and it was evidently his intention to have continued the investigation in this direction, as the paper is entitled "Part I."

Unfortunately, the author never lived to complete his work. A few years after the publication of this first paper, he met with an accident through the ignition of some hydrocarbons which he was distilling, and was burnt so severely that he died in the thirty-fifth year of his age. The late Mr. Robert Holliday informed the writer some years ago that Mansfield was at that time carrying on experiments in London with coal-tar hydrocarbons for their

* *Quart. Journ. Chem. Soc.*, 1849, **1**, 244. He gave a general account of his work at a Friday evening discourse at the Royal Institution on April 27th, 1849, which was published as a brochure entitled, "Benzole: its Nature and Utility."

firm in Huddersfield. The fatal accident occurred in a laboratory in the east part of London on February 17th, 1855.*

The total number of definite compounds actually known or suspected to be contained in coal-tar at the time of Mansfield's work was thirteen. Of these four were only conjectured to be present, and one, as we know, had been wrongly identified with cumene. What Mansfield did was to show conclusively that benzene could be obtained if required in any quantity from coal-tar "naphtha," that toluene was also a constituent of this naphtha, and that the higher homologues were there if wanted. There was something prophetic about this statement, which occurs in the introductory portion of his paper :

"It appears somewhat strange that, in this country, where coal-tar is so exceedingly plentiful, our chemists should have been contented with the discovery of naphthaline, and should have allowed others, less fortunate than ourselves in being able to command abundance of this almost national production, to inform us of the existence at our feet of vast quantities of aniline, of paranaphthaline (anthracene), and of other remarkable substances; and it appears, perhaps, no less singular that we should have failed as yet in applying them, when discovered, to the practical uses which they will no doubt some day claim."

Mansfield went further, however, than simply isolating and characterising benzene and toluene. In 1847 he described and patented a process for preparing nitrobenzene by the action of strong nitric acid (1.5 sp. gr.) upon benzene in glass or earthenware spiral tubes or other suitable form of apparatus cooled by immersion in water. Nitrobenzene must have been prepared in some quantity from coal-tar benzene about that time, since Hofmann, in whose work aniline played a very important part, refers to his having made this material by the reduction of nitrobenzene from this source. In his introductory remarks prefacing the volume of Reports of the Royal College of Chemistry (1849), which volume comprises Mansfield's paper, Hofmann says with respect to this :

"Nor is the sense of sight the only one which benzole promises to serve (referring to its use as an illuminant). By treatment with nitric acid the same volatile hydrocarbon yields a fragrant oil, the

* Prof. A. H. Church, F.R.S., informs the writer that Mansfield was then preparing specimens of benzene and its homologues and derivatives for the French International Exhibition. The accounts are not inconsistent; he may have been carrying on both lines of work, or Read Holliday's specimens may have been intended for the Exhibition. Unfortunately, the chief figures in this misfortune have all passed away. An obituary notice was published by the Chemical Society in 1855; *Quart. Journ.*, 8, 110.

odour of which is not to be distinguished from that of oil of bitter almonds; so that this perfume may now be procured from coal-tar in tons, if required, with the greatest facility and at a trifling cost." As a matter of fact, nitrobenzene, under the name of "essence de mirbane," had been introduced into commerce by C. Collas, of Paris, as a substitute for bitter almond oil, and was chiefly used for scenting soap, but this limited application of a tar product, although interesting historically, was practically of no importance from the industrial point of view. According to Bolley (*Handbuch der Chemischen Technologie*, Vol. V., Part II., p. 257, 1870), Collas must be credited with the use of a mixture of nitric and sulphuric acids, the modern process for nitrating benzene, although, for reasons not now obvious, he specifies the use of the "monohydrated" nitric acid.*

The "practical uses" which Mansfield had predicted for the coal-tar hydrocarbons began seriously in 1856 with Perkin's discovery of mauve, and the establishment of the Greenford Green factory in 1857 for the manufacture of this first of the coal-tar colouring matters. It must not be imagined that no use for coal-tar had been found up to that date. Tar distilling as an industry was carried on extensively, but the products were entirely applied to what may be described as coarse uses, such as timber preserving, an industry which had been founded by Bethell in 1838, and which led to a large consumption of the "creosoting" oils. The "naphtha" also was used as a solvent or for burning in lamps, and the pitch for coating surfaces of wood or metal which required protecting from corroding influences. It is interesting from the historical point of view to read in "A Journey through England and Scotland to the Hebrides in 1784," by a distinguished French author, Faujas de Saint Fond, of which a revised translation has recently been given by Sir Archibald Geikie (Glasgow: Hugh Hopkins, 1907), the following statement relating to the use of the crude tar for coating ships:

"The harbour of Leith, when we entered it, was full of vessels, English, Scottish, American, etc. I saw several vessels belonging to Glasgow and Leith which were coated over with bitumen or tar, extracted from pit coal at the manufactories of Lord Dundonald, who has introduced the making and using of this tar on a great scale in England. The vessels covered with it appeared of a fine shining black, which distinguished them from the others. Several ship-masters from the West Indies whom I questioned assured me that their vessels thus tarred arrived in the best possible condi-

* It is possible that he had in mind the old view of an acid as a combination of an "acid oxide" with water, that is, nitric acid as $N_2O_5 + H_2O$.

tion, and were free from worm-holes. Navigation is doubtless much indebted to Lord Dundonald, who has continued with the greatest perseverance to perfect this useful product of coal, and has done everything to bring it into general use in the country—no easy task when it involves the change of old habits." (Vol. II., pp. 220–221.)

Even at the time of Mansfield's work no coal-tar hydrocarbon had been utilised as a source of other chemical compounds, tinctorial or otherwise, and he himself, in describing the practical applications of benzene, refers only to its use as a solvent or an illuminant. Perkin's discovery thus created a demand for this hydrocarbon as a raw material in a new industry on a scale never before contemplated. Mansfield's experiments had prepared the way, but there had been no demand for benzene, and the tar distillers could not at first supply it in quantity or in a sufficient state of purity. It is of interest to know that the first supply of this material used by Perkin came from the Scotch tar distillery of Messrs. Miller and Co., of Glasgow.

Then came the difficulties connected with the nitration and the reduction of the nitrobenzene to aniline. Here, again, Mansfield had played the part of a pioneer, but his process was impracticable on the scale now required. Moreover, it was too costly, for it must be borne in mind that the new dye had to compete with the existing vegetable colouring matters, and on June 12th, 1856, Messrs. Pullar, of Perth, who had been testing the dyeing properties of mauve, had reported to Perkin that the discovery was a valuable one provided it did not "make the goods too expensive." It is needless to say that nitric acid of the strength used by Mansfield would have been a very costly material in 1856. In fact, nitric acid of sufficient strength to nitrate benzene could not be obtained in quantity at that period, and Perkin had to devise apparatus for nitrating with a mixture of sulphuric acid and sodium nitrate. His resourcefulness is well revealed by this passage quoted from his Hofmann Memorial Lecture in 1896: "At this time neither I nor my friends had seen the inside of a chemical works, and whatever knowledge I had was obtained from books. This, however, was not so serious a drawback as at first it might appear to be, as the kind of apparatus required, and the character of the operations to be performed, were so entirely different from any in use that there was but little to copy from.

"In commencing this manufacture it was absolutely necessary to proceed tentatively, as most of the operations required new kinds of apparatus to be devised and tried before more could be ordered to carry out the work on any scale." (Trans., 1896, 69, 606.)

After the manufacture of mauve had been started, the demand for the new dyestuff increased to such an extent that the resources of the Greenford factory were taxed to their utmost, and the assistance of another firm had to be called in for supplying raw materials. That firm was Simpson, Maule, and Nicholson, whose factory was at Locksfields, in the south of London. The Nicholson of the firm was that pupil of Hofmann's already referred to as having been a co-worker with Mansfield, and, under his energetic management, they not only supplied the firm of Perkin and Sons with some of the raw materials required, but later they also entered the colour industry, and in 1865 established the Atlas Works at Hackney Wick, the firm being transferred in 1868 to Messrs. Brooke, Simpson, and Spiller. Mr. William Spiller, formerly of this latter firm, has told the writer that he well remembers the early stages in the manufacture of nitrobenzene by their predecessors at Locksfields, where he was then working in association with the late Mr. E. C. Nicholson. The nitration was carried out in large glass "boltheads" arranged in series, as they had not then discovered that cast-iron vessels could be used. The scale of working was quite small as compared with the modern output from a large nitrating still, and they experienced the difficulty referred to by Perkin of obtaining a supply of pure benzene. The operation also was somewhat capricious, owing to the want of uniformity in the quality of the commercial "benzole," and to the absence of mechanical stirring. The cheapening of the process by the introduction of cast-iron stills with mechanical stirring gear did not take place until some time after the manufacture of mauve had been commenced in 1857. The plant in use was described and figured by Perkin in his Cantor Lectures, delivered before the Society of Arts in 1868, and has since been refigured in many works on technology, as it is practically the same in principle as that now generally in use.*

The next step, the reduction to aniline, had also to be worked out on the manufacturing scale. The laboratory method then generally in use was Zinin's, namely, hydrogen sulphide in presence of ammonia, a process obviously impracticable on the large scale. The use of metals, such as tin or zinc, in combination with acids, would have been both costly and unmanageable. Fortunately, however, Béchamp, in 1854, had found that iron and acetic acid

* A workman, James Underwood, in the employment of Simpson, Maule, and Nicholson, at Locksfields, during the early years of the colour industry, also remembers this manufacture of nitrobenzene in boltheads and the development to cast-iron stills. This last improvement is generally attributed to E. C. Nicholson. A figure of the earliest form of (horizontal) still is given by Perkin in his Cantor Lectures above referred to.

could be used for reducing nitro-compounds, and Perkin, who had been familiarised with this process in Hofmann's laboratory, applied it successfully for the manufacture of aniline.* That this was a task of considerable difficulty can be readily understood by those who are familiar with the violence of such "reducing" processes, unless properly controlled. It is, in fact, known that at first serious attempts were made to extract the minute quantity of aniline contained in the coal-tar oils directly by acid washing—a process which, it is needless to say, had soon to be abandoned on account of its cost and the impure state of the product. In the manufacture of aniline from nitrobenzene, the firm of Simpson, Maule, and Nicholson also co-operated with Perkin and Sons, and Mr. William Spiller has given the writer a graphic description of their early work at Locksfields when starting this branch of the industry. The reduction was carried out in iron vessels with removable still-heads, the vessel being at first uncovered, and the materials, nitrobenzene, iron turnings, and acetic acid, simply stirred up by a rod until the reaction showed signs of starting. The still-head was then immediately clapped on, and a workman mounted guard with water-hose ready to play over the still if the contents gave signs of boiling too violently. The cost of the acetic acid was a considerable item at that time, and they had to make their own acid by heating sodium acetate with sulphuric acid. It was soon found that hydrochloric acid could be used instead of acetic acid, and the introduction of stills with mechanical stirrers put this branch of the manufacture on a sure basis. It is perhaps hardly necessary to point out that the "aniline" of that period was a mixture of homologues, and very impure from the modern point of view.

And so the manufacture of the first of the "synthetic dyestuffs" was started at Greenford Green towards the end of the year 1857, and the genius of the founder had ample scope for exercise. Let it be borne in mind that the raw product obtained by oxidising crude aniline with sulphuric acid and potassium dichromate was what would now be called a "resinous mess." Processes for its purification had to be devised, and here again the resourcefulness of Perkin becomes manifest. With that true scientific spirit which dominated all his work, the investigation of his products and processes was always kept going. At first the crude product was collected on filters and washed with water to remove excess of aniline sulphate, then dried and powdered, and extracted with coal-tar "naphtha" until free from resinous impurities, then dried

* "Had it not been for this discovery the coal-tar colour industry could not have been started."—W. H. Perkin, Hofmann Memorial Lecture, *loc. cit.*, p. 607.

again and extracted with methylated spirit, and the filtered solution distilled until the dyestuff separated out. This method of purification was afterwards improved and cheapened by the omission of the naphtha treatment, as it was found that dilute methylated spirit extracted the colouring matter directly, and left the resin undissolved. The process was finally simplified by boiling out the colouring matter with water alone, and precipitating with an alkali so as to obtain the free base, which was then converted into acetate for use by the dyers.

The discovery and manufacture of mauve, with its train of consequences, must be regarded as constituting but a portion of Perkin's claim to our gratitude. In starting upon this work he had, against the advice of his illustrious master, Hofmann, broken away from the path of pure science and entered a field in which he was a novice. His whole future was bound up with the success of the undertaking, for his father had placed nearly his entire capital in the venture in order to establish the factory at Greenford Green. There was evidently something more to be done besides placing the new dyestuff on the market. The dyers and printers had to be convinced of its merits and taught how to use it. This task, by no means a light one, had also to be undertaken by Perkin, who, up to that time, had never been brought into contact with the tinctorial industries. It has frequently been mentioned that Messrs. Pullar, of Perth, were the first to give encouragement to the young inventor so far as concerned the dyeing properties of mauve. At their instigation it was tried for silk dyeing by Thomas Keith, silk dyer, of Bethnal Green, London, and he also reported favourably. But, as is generally the case with new departures, the step from the experimental to the practical scale was not made without encountering difficulties. It was found that on the large scale the dye "took on" unevenly, and caused a patchy appearance, so that a restraining material had to be added to the bath. The use of the soap bath for silk dyeing was the outcome of Perkin's association with a practical dyer, and Keith's dyehouse was the first in which mauve was used on the industrial scale.

Then with respect to wool and cotton dyeing, the same pioneering work had to be done. Perkin has told us that he and Mr. (now Sir) Robert Pullar had independently discovered the use of tannin and a metallic oxide as a mordant for cotton dyeing, and, in conjunction with Alexander Schultz, he had introduced the "insoluble arsenite of alumina" as a mordant. The calico printers in this country did not at first take kindly to the new colouring matter, and Perkin has often told the writer that the impetus to

this most important application of his discovery came from France. It appears that, owing to some technical oversight, the French patent was ineffective, and the French manufacturers accordingly began making the new dyestuff themselves. It was in France, in fact, that the term "mauve" was given. With the well-known skill of the French calico printers, beautiful designs in mauve were produced and sent over to this country, and this was more effective than any other cause in hastening the use of the dye for this purpose over here. Had it not been for this stimulus the success of the new factory would have been doubtful, for Messrs. Pullar had reported to Perkin that, in their opinion, unless the new dye could be used by the printers it would be questionable whether "it would be wise to erect works for the quantity dyers alone will require." * In summing up this part of his experience Perkin stated in 1896:

"Before the aniline purple could be introduced for dyeing woollen and mixed fabrics, some weeks were also spent at Bradford in finding out suitable methods of applying it.

"Thus it will be seen that, in the case of this new colouring matter, not only had the difficulties incident to its manufacture to be grappled with, and the prejudices of the consumer overcome, but, owing to the fact that it belonged to a new class of dyestuffs, a large amount of time had to be devoted to the study of its applications to dyeing, calico printing, etc. It was, in fact, all pioneering work—clearing the road, as it were, for the introduction of all colouring matters which followed, all the processes worked out for dyeing silk, cotton, and wool, and also for calico printing, afterwards proving suitable for magenta, Hofmann Violet, etc." (Hofmann Memorial Lecture, *loc. cit.*, p. 609.)

The success of the new industry had for its natural consequence the creation of a host of imitators. All kinds of oxidising agents were tried upon aniline and made the subjects of rival patents. The departure from the original patent was in some cases so slight that it is questionable whether in modern patent legislation the inventor's claim would not be dismissed as a "colourable imitation." Tabourin and Franc Bros. claimed aniline hydrochloride instead of sulphate; Beale and Kirkham in England, as well as Scheurer-Kestner, Depouilly and Lauth, Coblenz, and C. Phillips in France, claimed bleaching powder; Smith claimed chlorine

* "I distinctly remember the first time I induced a calico printer to make trials of this colour that the only report I obtained was that it was too dear, and it was not until nearly two years afterwards, when French printers put aniline purple into their patterns, that it began to interest English printers."—Perkin's Cantor Lectures, Society of Arts, December 7th, 1868, p. 9.

water, Greville Williams potassium permanganate, Kay manganese dioxide, David Price (attached to the firm of Simpson, Maule, and Nicholson) claimed lead peroxide, Dale and Caro cupric chloride, Stark and Guyot red prussiate of potash, and so forth. It is needless to point out that many of the products obtained by these inventors could not have been Perkin's mauve at all, and, as a matter of fact, not one of these rival processes was enabled to compete successfully with the original "bichromate" method. The yield was too small or the colour too difficult to purify, or the oxidising agent too expensive, although at that time the bichromate cost from 10d. to 11d. per pound. The only one of these processes which gave a good result was Dale and Caro's, but even this could not be worked so economically as the original process.

The introduction of mauve by the founder of, and pioneer in, this new development in manufacturing chemistry soon led to the further discovery of coal-tar colouring matters and to the establishment of other factories. For about a decade the manufacturing operations at Greenford were carried on successfully, and without any fresh discovery of very great importance, although Perkin's activity in the field of pure scientific investigation never ceased. Magenta was first made industrially by Verguin, in France, in 1859, and the firm of Simpson, Maule, and Nicholson soon began to manufacture this on the large scale by the arsenic acid process as well as other well-known colouring matters. Such was the development of the industry that, in 1862, the year of the International Exhibition in London, Hofmann gave a Friday evening discourse at the Royal Institution (*Chem. News*, 6, 90), from which it appears that the definite compounds which had been isolated from coal-tar, and which in Mansfield's list of 1848 consisted of thirteen, had then risen to about forty. It was for that Exhibition that Messrs. Simpson, Maule, and Nicholson prepared a crown of magenta crystals (acetate), which Hofmann exhibited during his lecture, the title of which was "Mauve and Magenta." The selling price of the new dyes at that time may be gathered from the circumstance that the purified solid mauve sold for about the same price as platinum, weight for weight, and the vat from which the magenta "crown" had been crystallised contained a weight of the acetate of that base valued at £8,000, the crystals adhering to the wire framework of the crown being valued at £100.*

The discovery and manufacture of magenta was undoubtedly,

* Some of the original crystals are now in the possession of Mr. William Spiller. A trade catalogue of the firm of Simpson, Maule, and Nicholson, placed at the writer's disposal by Dr. Cain, shows that in 1866 "Pure Roseine" was priced at 2s. 6d. per ounce.

after the production of mauve, the most important contribution to the industry made during the decade referred to. This discovery did not at first affect Perkin's operations; mauve still held its own, and in 1859 Perkin's brother Thomas, the business man of the establishment, patented on behalf of the firm a process for making magenta by oxidising crude aniline with mercuric nitrate.* This was an improvement upon the original stannic chloride process of Verguin, but it was dangerous, capricious, and expensive, and was very soon displaced by Medlock's arsenic acid process worked by Simpson, Maule, and Nicholson, and also, as the result of a celebrated lawsuit, by Messrs. Read Holliday and Sons, of Huddersfield. But although Perkin and Sons never made magenta in any quantity, the introduction of this dyestuff led to new and necessary developments in their factory. About five years after the foundation of the Greenford works, Hofmann, who had then enthusiastically entered the field of colour chemistry, found that magenta when ethylated or methylated gave rise to violet colouring matters, the manufacture of which was at once taken up by Simpson, Maule, and Nicholson.† Hofmann's Violets and certain phenylated rosanilines, discovered about the same time by Girard and De Laire, in France, and made here also by Simpson, Maule, and Nicholson, soon began to enter into competition with mauve.

It has not, I think, been sufficiently dwelt upon by any of the historians of the coal-tar colour industry that Perkin's pioneering discovery reacted upon itself, for there can be no doubt that the production of aniline on the large scale led to the discovery of processes for the manufacture of magenta, and it was the derivatives of the latter that first began seriously to displace mauve. The discovery by Lauth of colouring matters, such as methyl-violet, formed by the oxidation of the alkylated anilines and manufactured in France about 1866, brought into the field other competitors with the original mauve. The newer dyes were not so fast as mauve, but they were much more brilliant, and fastness soon gave way to brightness. The practical effect of these later developments made itself felt in the gradual decline in the demand for mauve, the use of which soon became very limited, and finally

* "Das Zinnchlorid wird durch das Quecksilbernitrat ersetzt, mit dem die Fabrikation auch in Deutschland ihre ersten, kräftigen Wurzeln fasst."—H. Caro, *Ber.*, 1892, **25**, 1031.

† The manufacture of methyl and ethyl iodide on the large scale was a remarkable achievement at the time. When the writer entered the Atlas Works, in 1877, the Hofmann Violets were still being manufactured, and the use of these colouring matters by English dyers continued for more than twenty years after that date. The violet is priced in the 1866 catalogue of Simpson, Maule, and Nicholson at 3s. per ounce.

died out altogether. As a flourishing branch of the colour industry it may be said that mauve did not complete ten years of its existence. But Perkin was enabled to keep the Greenford works going successfully in spite of the adverse influence of the new discoveries and the coming into existence of other factories. He introduced, in 1864, a very ingenious method for the indirect alkylation of magenta, which enabled their firm to compete with the other violet colouring matters then in the market. This method consisted in heating magenta base with methylated spirit—afterwards improved by substituting methyl alcohol—and the compound formed from turpentine oil and bromine in the presence of water. This “brominated turpentine” had long been known to chemists, and had been investigated by Greville Williams, but had never before been used for manufacturing purposes. The dyes thus made were introduced under the name of Britannia Violet of different shades of blueness, according to the degree of alkylation. It was at first thought that they contained the terpene radicle, although it was afterwards considered that they were of the same type if not identical with the Hofmann Violets, so that Perkin had really discovered an indirect method of methylation of a type unknown in chemistry at that time. Perkin’s process was very successful, although they were handicapped by having to purchase magenta base, which they did not themselves manufacture. But, on the other hand, brominated turpentine was cheaper as an alkylating agent than the methyl iodide used in the manufacture of Hofmann Violets.

After eleven years’ successful working at the Greenford Green factory with mauve and certain of its derivatives, the Britannia Violets, and a few other dyes which are given in the list on p. 2253, a new impetus suddenly came through the announcement, in 1868, that Graebe and Liebermann, in Germany, had discovered that alizarin, the colouring matter of the madder plant, was a derivative of the coal-tar hydrocarbon, anthracene, and not, as had formerly been supposed, a derivative of naphthalene. The German chemists, both of whom are happily still with us, found also that the compound could be prepared from anthracene, and thus was accomplished the first laboratory synthesis of a natural colouring matter.

The demand for another coal-tar hydrocarbon, anthracene, in large quantities and in a state of purity, necessitated further pioneering work. Supplies of the crude material had to be procured, the tar distillers had to be educated in the production of raw anthracene, and factory methods of purification had to be devised. All these requirements were met by the science and

skill of Perkin, then a young man just turned thirty years of age. The subsequent development of the artificial alizarin industry is too well known to need recapitulation in this notice. But there is one point in connexion with Perkin's work in this field which must not be forgotten, and that is the great importance of the dichloroanthracene process in this country at the outset of the new branch of the coal-tar colour industry.

The two processes discovered by Perkin were the anthraquinone process and the dichloroanthracene process. In the first of these the anthracene is oxidised to anthraquinone, the latter sulphonated by heating with strong sulphuric acid to a high temperature, and the sodium sulphonate converted into alizarin by alkaline fusion. The sulphonation by this process yields a mixture of mono- and di-sulphonic acids, and the final product is therefore a mixture consisting of alizarin, anthrapurpurin, and some flavopurpurin. This was the process first tried on the large scale by Perkin, as well as by the German manufacturers. The second process, which was patented here by Perkin a few months after the patenting of the anthraquinone process, namely, in November, 1869, sets out from dichloroanthracene, which is sulphonated by ordinary strong sulphuric acid and the product submitted to alkaline fusion as before. Now dichloroanthracene sulphonates more readily than anthraquinone, and as the product consists chiefly of a disulphonic acid of anthraquinone, the "artificial alizarin" obtained by this process consists mainly of anthrapurpurin with some alizarin and flavopurpurin. Alizarin gives bluer shades of colour than anthrapurpurin, so that although for certain purposes where bright red was required the mixture obtained by Perkin's second process possessed an advantage, for the production of the bluer reds the anthraquinone product had the advantage. Perkin met this difficulty to some extent by devising a method for separating his "alizarin" into "blue shade" and "scarlet shade," but this method was not easy to carry out on the large scale, and added to the cost of the final products.

For the first few years the Badische Company, which had acquired the Caro-Graebe-Liebermann patent, worked by mutual arrangement in combination with the Greenford Green factory, the latter having the monopoly of the English markets.* The Germans were using the anthraquinone process almost exclusively, this being the method still in use. When ordinary English oil of vitriol is used for sulphonating, a great excess of acid is necessary, and there is much loss owing to the high temperature, so

* The amicable arrangement between the German and English manufacturers was brought about through the mediation of Dr. Hugo Müller, F.R.S.

that the dichloroanthracene process from this point of view had the advantage. Moreover, when anthrapurpurin was the main object of manufacture, it was found that the product obtained by the dichloroanthracene process gave much purer shades than that obtained by the anthraquinone process.* It would have naturally occurred to Perkin in working out this last process to try fuming sulphuric acid as a sulphonating agent, and he did so with success, but this method, although giving better results in the way of yield and uniformity of product, was placed at a disadvantage here on account of the cost of the fuming acid. The advantages arising from this method of sulphonating are an increased yield on account of the lower temperature at which the acid does its work, and a product which consists mainly of the monosulphonic acid, and which therefore gives chiefly the true "alizarin" on alkaline fusion. Now Germany was, at that time, the only country in which the manufacture of fuming sulphuric acid was carried on, and this gave them a distinct advantage in working the anthraquinone process. Perkin has called attention more than once to the state of affairs in this country during the early life of the artificial alizarin industry, and his own statements may be quoted here:

"On account of the expense and difficulty in getting Nordhausen sulphuric acid imported into this country—few vessels liking it as a cargo—we commenced working with ordinary sulphuric acid. We usually employed four or five parts of this to each part of anthraquinone and heated the mixture to 270—280° C. . . . I find we employed this process principally in our works until the middle of June, 1870. We then began to work on a larger scale than we had hitherto done with dichloroanthracene, and carried both processes on for a time, but finding the latter the most economical, partially on account of the ease with which it yielded the sulpho-acids with ordinary sulphuric acid, we employed it almost exclusively after a time, although frequently making colouring matter by the other method.

"The large quantity of ordinary sulphuric acid which had to be employed to convert anthraquinone into the sulpho-acids, and the high temperature which had to be used, causing a certain

* Perkin, *The History of Alizarin, &c.*, 1879, p. 26. Dr. Caro informs the writer that since 1870 the Badische Co. employed also the dichloroanthracene process for the manufacture of a special kind of "alizarin," consisting chiefly of anthrapurpurin. It may be pointed out, also, that, owing to some peculiarity in the internal administration of the German Patent Laws at that time, the rights of Caro, Graebe, and Liebermann could not be secured in certain States, and so other manufacturers took up the artificial alizarin industry and entered into competition with the Badische Co. So far as the writer has been able to learn, the anthraquinone process was generally employed.

amount of destruction to take place, evidently showed that it was desirable to employ fuming sulphuric acid in this process. In this country we found it costly, but as it was more readily procurable in Germany, the manufacturers there used it. They were afterwards supplied with a very strong fuming acid from Bohemia, containing about 40 per cent. of sulphuric anhydride." (*The History of Alizarin, etc.*, 1879, pp. 24-25.)*

The same statement was repeated in substantially identical terms in 1896. Referring to the loss of anthraquinone when ordinary sulphuric acid is used, he says: "The means of overcoming this difficulty was to use fuming sulphuric acid, with which anthraquinone combined at a much lower temperature, but the only acid of the kind then made was the old-fashioned Nordhausen acid. We imported a quantity of this, and, of course, found it to work satisfactorily, but the difficulties and expense connected with the carriage and transport of this substance on account of its dangerous nature—supplied as it then was in large earthenware bottles—made it unsuitable for use in this country.

"The artificial alizarin we first made was produced by the anthraquinone process, the method still used for its manufacture, but the difficulty in preparing the sulphonic acid in those early days just referred to caused us to turn our attention to the second process I had discovered, in which dichloroanthracene was used. . . . Without this process the manufacture of artificial alizarin in this country could not have been carried on with much success in the early days of its manufacture." (Hofmann Memorial Lecture, *loc. cit.*, p. 631.)

The "contact," or "catalytic," process for producing sulphuric anhydride, introduced about the same time in this country by Messrs. Chapman, Messel and Co., and in Germany by the late C. Winkler, dates from 1875, so that Perkin's share in the founding of this great industry does not consist only in his having given us the practical methods for realising Graebe and Liebermann's synthesis in the factory, but in having devised a process which, so to speak, enabled the new industry to be nursed through its infancy in this country and without which it would probably not have survived that Continental competition which, as Perkin has told us, first began to make itself seriously felt about the end of 1873 (*History of Alizarin, etc.*, 1879, p. 31). By that time it was fully realised that a complete revision of the

* The use of Nordhausen acid for the anthraquinone process in Germany began about 1871; the introduction of the stronger acid referred to by Perkin in the above passage is generally attributed to Koch in 1873. Dr. Caro informs the writer that he has been unable to find the authority for this statement.

plant at Greenford Green had become necessary. It required enlarging and modifying in order to meet the successful competition arising from the development of the anthraquinone process in Germany, and a considerable expenditure of capital would have been necessary to carry out this work. But Perkin, whose ambition it had always been to be able to devote himself to pure science, and whose personal requirements were extremely modest, found that his manufacturing career had by then provided him with sufficient means to enable him to retire, and, rather than incur the responsibility of making a fresh start, he took advantage of the opportunity for withdrawing altogether from the industry. His career as a manufacturer terminated in 1874, the Greenford Green works having then been purchased by Messrs. Brooke, Simpson, and Spiller, which firm, soon afterwards, transferred them to Messrs. Burt, Bolton, and Haywood, who shifted the manufacture from Greenford Green to Silvertown, and ultimately from this firm the "British Alizarine Company" was developed, and is still at work. Perkin always wished it to be known that he considered the Silvertown works as the lineal descendant of the first coal-tar colour factory.

This sketch of the founding of the coal-tar colour industry is necessarily limited to the history of the Greenford Green factory. These works would now appear quite insignificant in comparison with one of the great German establishments, and the whole output of dyes during the seventeen years that Perkin was connected with them was not very great as measured by modern standards. Nevertheless, it may fairly be said that no single factory established in this country has ever given rise to such world-wide developments, both scientific and industrial. When it fell to the writer's lot to take part in the organisation of the jubilee celebration of 1906, it appeared desirable to place upon record the complete history of the Greenford Green factory as a colour-making establishment, and Sir Wm. Perkin was good enough to prepare the following list:

THE PRODUCTS MANUFACTURED AT GREENFORD GREEN, 1857-1873.

Mauve.—Large quantities manufactured.

Dahlia.—Ethylmauveine, $C_{27}H_{23}(C_2H_5)_4N_4, HCl$. Made about the same time as Hofmann's Violet [1863]. The colour was much admired, but being very expensive was not largely used (*Journ. Chem. Soc.*, 1879, **35**, 399).

Aniline Pink.—First found in washings from mauve, afterwards produced by oxidising mauve with lead peroxide. It is para-

safranine. Made about the same time as Dahlia (*Journ. Chem. Soc.*, 1879, **35**, 407). The researches were made many years before publication.

Magenta.—Prepared by a mercuric nitrate under a patent in my name; a communication from abroad. It was first obtained in crystals in this way (*Journ. Chem. Soc.*, 1862, **15**, 238–240. The research was made some years before publication). The process was dangerous, and not carried on very long.

Amidoazonaphthalene.—Used in a finely precipitated form as an orange, red, or scarlet pigment for calico printing, but not largely.

Britannia Violet (various shades).—Made from Magenta, the bromine compound of turpentine, and methylated spirit, or, better, purified wood spirit. At first thought to be a turpentine derivative, but afterwards found to be methylated rosanilines. Made in large quantities.

Perkin's Green.—This was an interesting compound made by treating Britannia Violet (blue shade) with acetyl chloride. The latter was made in large quantities from phosphorus trichloride and acetic acid. The phosphorus trichloride was made in cast-iron retorts with iron condensers from phosphorus and dry chlorine. The colouring matter was obtained in a crystalline condition, but was not investigated as to its constitution. It was rather extensively used for calico printing when Iodine Green was too expensive.

"*Alizarine*."—Produced very largely, chiefly by dichloroanthracene process. It consisted of anthrapurpurin and alizarin, chiefly of the former. These were also separated and sold as "Blue Shade Alizarine" and "Scarlet Shade," but we chiefly sold the mixture known as "Red Shade." Besides the above we made suitable mixtures of aniline salts, oxidising agents, and copper compounds for the production of Aniline Black on the fabric by calico printers. Also the colouring matters were made into "lakes" by processes of our own for paperhangings and lithographic and other printing inks in considerable quantities.

This list contains what may be regarded as Perkin's direct contribution to the colour industry as a manufacturer. It may not appear very imposing to us now, but we must read into it all that it means in order to appreciate its full significance. There must be taken into consideration the pioneering work in every direction that had to be done in order to accomplish these results. It must further be remembered that they were achieved at the outset by a youth of about 18, and brought to a successful termination in seventeen years by a young man 36 years of age, and that during the whole of that period, while the factory was actively at work,

a continuous stream of scientific research was kept going in his laboratory. The stupendous consequences of the initiation of this industry must also be borne in mind, and then the extent of our indebtedness to him will be fully realised.

By many who regard manufacturing industry from a narrow point of view, Perkin, as already stated in the previous part of this notice, has been censured for withdrawing so soon from the scene of his industrial operations. The reply to this charge is obvious. He had made a sufficient fortune for his modest requirements, and the seeds which he had sown were developing rapidly in this country. At that time (1874) German competition was only just beginning to make itself felt. The industry was flourishing here, and with respect to France it may be said that within a very short period of the founding of the Greenford Green factory, and especially from the time of the discovery of magenta, the industry was also in a prosperous condition. How thoroughly this branch of manufacture had its head centre in England during the few years following the opening of the Greenford works may be inferred from the fact that such men as Maule and (especially) E. C. Nicholson, both pupils of Hofmann's, had entered the industry; that in Manchester the firm of Roberts, Dale and Co. had secured the services of men like Caro and Martius, who later became pioneers in the German colour-making industry. Or, if we turn to the actual products, we find that in addition to those emanating from the firm of Perkin and Sons, Simpson, Maule, and Nicholson had secured the first really valuable process for making magenta, namely, the arsenic acid process of Medlock; that they had also secured the beautiful process of Girard and De Laire for phenylating magenta so as to convert it into blue and violet colouring matters, and that Nicholson, by his discovery of the method of sulphonation, had developed these into what were for many years the most important of all the coal-tar colouring matters. This firm had also introduced aniline-yellow (aminoazobenzene), the precursor of the basic azo-dyes, and phosphine (chrysaniline),* the first member of the acridine series. They were, moreover, the only manufacturers of the alkylated rosanilines under Hofmann's patent. Then the firm of Roberts, Dale and Co. were making picric acid, and had, through Caro, given to the industry the first induline obtained from aniline-yellow and aniline, as well as Manchester brown or Bismarck brown. This firm had also, through Martius,

* In the 1866 catalogue of this firm, already referred to, Aniline-yellow is priced at 2s. and "Phosphine" at 3s. per ounce. The Nicholson Blues were, at that time, sold only in solution, the price ranging, according to the brand, from 15s. to 30s. per gallon. Solid "Regina Purple" is priced at 15s. per ounce.

given us the dinitronaphthol known as Manchester yellow. Cyanine, or quinoline blue, the first representative of a group of colouring matters which have since become of great importance as special sensitisers for photographic purposes, was discovered the same year as mauve (1856) by Greville Williams, who was for some time chemist at the Perkin's factory, and who afterwards, with Messrs. E. Thomas and J. Dower, started the Star Chemical Works at Brentford. This country may also claim to have been the pioneer, through Crace-Calvert and Lowe, of Manchester, in the technical production of highly purified phenol.* The first successful method for printing on the fabric with aniline-black was discovered and patented in 1863 by John Lightfoot, of Accrington.

This was the state of affairs during Perkin's connexion with the industry, and, superadded to this manufacturing activity, was the supremely important fact that, until 1865, the great master, Hofmann, was among us, and that his laboratory at the Royal College of Chemistry had become a centre of active research in the chemistry of colouring matters which stimulated the industry and supplied chemists for the factories.† Nor must it be forgotten that Peter Griess, the founder of diazo-chemistry, was working over here during the greater part of the same period. It cannot be said that Perkin abandoned the ship in a sinking condition; on the contrary, she was steaming full speed ahead! For any scuttling that may have afterwards occurred he can in no way be held responsible.

ADDENDUM.

As the introduction of fuming sulphuric acid played such an important part in the early history of the artificial alizarin industry, it is of interest to append the following account kindly furnished by Hofrath Dr. Caro. It may be pointed out that the "contact" process for producing sulphuric acid dates from 1875,‡ and therefore subsequently to Perkin's retirement, so that it was

* The state of the industry here and in France five years after its inauguration at Greenford Green can be ascertained from Hofmann's report on the chemical exhibits at the International (London) Exhibition of 1862. It is not going too far to say that during its early years the coal-tar colour industry was essentially English and French.

† Hofmann left London in 1865. From that time until the creation of the Chair of Organic Chemistry at Owens College, Manchester, in 1874, to which Schorlemmer was appointed, there was no Professorship in this department of the science in this country.

‡ The patent of Messrs. Chapman and Messel is dated September 18th, 1875. Winkler's process was described in *Dingler's Polytechnisches Journal* for October, 1875. Dr. Messel gave a description of their process before the Chemical Society in April, 1876, but the paper was not published by the Society.

his successors who had the advantage of this new branch of manufacture:

“Previously to the publication of Clemens Winkler, the entire ‘Nordhausen Fuming Sulphuric Acid’ was manufactured by John David Starck in Bohemia (in several works near Pilsen), and was largely imported into England. It originally contained about 20 per cent. of the free anhydride. This acid was employed by Perkin in his first experimental manufacture in 1869 for sulphonating anthraquinone, and was afterwards in 1870 exchanged for ordinary sulphuric acid,* while we (the Badische Co.) commenced at this same period with the ordinary acid and gradually went on increasing its strength by adding fuming acid containing about 24 per cent. of free anhydride. I recollect that in 1873 we used chiefly a mixture of two parts of the said fuming acid with one part of the monohydrate. At the same time we studied carefully the effect of the increased strength of the sulphonating agent upon the separate production of the mono- and di-sulpho-acids of anthraquinone, and I believe that at the same time (1873) similar experiments were made by all German alizarin makers, particularly by Gebrüder Gessert and Co., at Elberfeld, and that in consequence of the superior results obtained by the action of stronger acid at a corresponding lower temperature a demand was created for fuming sulphuric acid of greater strengths than hitherto supplied. Thus John David Starck was led to manufacture the solid fuming sulphuric acid containing about 45 per cent. of the free anhydride. This was, I think, in 1873 or 1874. In 1875 we employed regularly the fuming acid of 45—50 per cent. of anhydride. In 1877 we went further in increasing the energy of the sulphonating action by the employment of fuming acid of from 68 to 72 per cent. of free anhydride, which we prepared by distilling the anhydride from one portion of fuming acid into another portion of fuming acid containing 45—50 per cent. of free anhydride. We also distilled the anhydride into the sulphonating mixture of anthraquinone with fuming acid. Immediately after the publication of Winkler, in 1875, we commenced experimenting with his synthetical process, and after having many times changed our experimental plant, we succeeded in manufacturing the fuming acid on a very large scale from 1877. At about the same time other manufacturers started the manufacture of fuming acid by the synthetical process.”

R. MELDOLA.

* See Perkin's statement (*ante*) quoted from his *History of Alizarin*, 1879.

ROBERT WARINGTON.

BORN AUGUST 22ND, 1838; DIED MARCH 20TH, 1907.

THE name of Robert Warington will ever be associated with one of the most important advances in the agricultural chemistry of the latter half of the nineteenth century, although his classical work on nitrification, which may be regarded as his life-work, bears but a small proportion to the total of that accomplished by him. He, no doubt, owed his chemical proclivities to his father—a Robert Warington also—who was a prominent figure amongst the chemists of earlier days. The elder Warington was one of the first chemical assistants at University College, and was subsequently appointed chemical operator to the Society of Apothecaries. He also was a Fellow of the Royal Society, and published several papers on chemical subjects; yet chemistry is more indebted to him for the part which he took in founding the Chemical Society than for the extent of his own original work. It was through his zeal and powers of organisation that this Society was founded in 1841, and the work which he did for it as its secretary during the subsequent ten years helped in no small measure to launch it on its prosperous career.

Robert, his eldest son, was born on August 22nd, 1838, in the parish of Spitalfields. His mother was a daughter of George Jackson, M.R.C.S., to whom science is indebted for several improvements in microscopes which have not yet been superseded, as well as for the invaluable ruled glass micrometer. The original dividing machine made by him for ruling the lines was still being used by a well-known optician in 1899, and is probably in use at the present time.

Very early in young Warington's life his parents took up their residence at the Apothecaries' Hall, and it was here, in the uncongenial atmosphere of the City, that he spent his childhood and youth. His constitution was naturally feeble, and a life in the heart of London, with but little exercise, and no companions of his own age to assort with, did not tend to strengthen it. All through life he had to contend with a lack of bodily vigour, which rendered his work doubly laborious to him. For his education he seems to have been chiefly indebted to his parents. While still quite young he studied chemistry in his father's laboratory, and had the advantage of attending lectures by Faraday, Brande and Hofmann.

In consequence of the unsatisfactory state of young Warington's health, his father sought to get him some employment in the country, and, with that object in view, applied to Mr. Lawes, with

whom he was acquainted, and for whom he had done some professional work. The outcome of this was that in January, 1859, the youth went to work in the Rothamsted Laboratory as Lawes' unpaid assistant. Here he remained for one year, devoting all his time to ash analyses, of which he had had no previous experience, and examining various methods for obtaining the most satisfactory results. Dr. Pugh and Mr. F. R. Segeleke were also working in the laboratory at that time, and they gave Warington valuable assistance in his work. Of the two series of analyses eventually completed, the first comprised those of the ashes of grass grown under different manurial treatment, the results of which were published in Lawes and Gilbert's "Report of Experiments with Different Manures on Permanent Meadow Land" (*J. Roy. Agric. Soc.*, 1859, **20**, 407), the second series was that of the ash of grain from Broadbalk Field. These latter analyses were never published, their place having been taken by more complete work on the same subject by Richter.

Although Warington left the Rothamsted Laboratory in January, 1860, his interest in the work there never ceased, and, until he resumed his connexion with Lawes a few years later, he devoted much of his time to studying the Rothamsted results, and was a frequent visitor to the laboratory.

His health having been somewhat re-established by his year's residence in the country, he returned to town, and continued to reside with his parents until 1862, spending his days at South Kensington, where he worked under Dr. Frankland as research assistant. But at the end of this period a further breakdown in health forced him again to seek a country life, and he betook himself to the Royal Agricultural College at Cirencester. Here he remained for four and a-half years, the first nine months of which were spent in doing analyses for Dr. A. Voelcker, and the remainder of the time in fulfilling the duties of teaching assistant under Professor Church.

It was during his residence at Cirencester that Warington published the first papers on scientific subjects which appear under his name. These were printed in the *Journal of the Chemical Society*. The earliest of them (1863) dealt with the quantitative determination of phosphoric acid. This was followed by two other short communications on kindred subjects, which preceded and prepared the way for his first work of importance—an investigation into the part played by ferric oxide and alumina in decomposing soluble phosphates and other salts, and retaining them in the soil. The results of this investigation are embodied in a series of four papers read before the Chemical Society, and are typical examples

of the careful work and close reasoning which characterised all Warington's researches. That ferric oxide acted as a fixing agent for soluble substances applied to a soil was already known, but the action was attributed to an indefinable physical attraction, which explained nothing. Warington proved, first by experiments with pure ferric oxide, and then with ordinary soil, that the action in the case of calcium phosphate was simply one of chemical decomposition, resulting in the formation of ferric phosphate, whilst in the case of other salts, such as carbonates, sulphates, nitrates, etc., the chemical character of the action was indicated by the fact that the iron did not retain the salt as a whole, but partially decomposed it, retaining the basic portion in excess over the acid portion.

Warington did not allow his work at Cirencester to sever his connexion with Rothamsted, and he offered to analyse three of the most important of the animal ashes which had been prepared there, on the condition that he might make use of the results thus obtained. He consequently received mixed ashes representing the whole bodies of a fat ox, a fat sheep, and a fat pig, and an abstract of the analyses made by him appeared in an article which he wrote for the second supplement to "Watts's Dictionary of Chemistry." The analyses, together with others by Richter, were also published by Lawes and Gilbert in the *Phil. Trans.*, 1883.

In 1864 Warington commenced lecturing to the students at Cirencester on the Rothamsted experiments, and went systematically through all the work which had already been published, together with many additions of as yet unpublished results which had been communicated to him by Lawes and Gilbert. A desire was expressed at Cirencester that these lectures should be published, and negotiations to that end were, consequently, opened with Lawes and Gilbert. The outcome of these was that Warington was to write a book on the Rothamsted investigations, Lawes guaranteeing him from pecuniary loss, but offering no remuneration. Lawes also reserved to himself the right to supply a preface to the book, on the ground that there would be previously unpublished matter incorporated therein. The writing of this book involved a large amount of labour, especially as, in studying the effect of manures in different seasons, Warington was led to recognise the almost paramount influence of the rainfall on the results, and its action in washing the nitrates out of the soil, an action up to that time unrecognised. For the purpose of examining this action more closely, he compared the results from the plots at Rothamsted with the temperatures and rainfalls supplied to him by Glaisher; at the same time he applied to Gilbert to furnish him with unpublished

data respecting the Rothamsted hay crops. Gilbert, however, objected to what now appeared to him in the light of a publication of Rothamsted results by others than Lawes and himself. Discussions ensued, the upshot of which was that the book remained in manuscript, and the seeds of an unfortunate dissension between Gilbert and Warington were sown. Some 120 pages of this book were written (and are still in existence), but Warington declined the pecuniary compensation which Lawes offered to him for his labour.

Leaving Cirencester in June, 1867, he became chemist to Lawes's manure and tartaric and citric acid factories at Millwall, where he remained until 1876. During these years he generally had a long conversation every week with Lawes on those problems in agricultural chemistry which happened to be under investigation at the time, and which were evidently more congenial subjects of discussion to both of them than the problems arising in the factory. Even these, however, were by no means lacking in interest, and at the conclusion of his engagement at Millwall in 1874, Warington remained in the laboratory there for two years longer, working on citric and tartaric acids, and ultimately publishing his results in a paper of 70 pages in the *Journal of the Chemical Society*. This paper was published with Lawes's approval, and it is noteworthy for the opinion expressed therein, that "the large amount of information acquired in the laboratories of our great manufacturing concerns might well be published without any injury to the individual manufacturer." Eighteen years later, when Warington had for a second time gone to work in Lawes's tartaric and citric acid factory, he published another paper dealing with these acids, and with the detection of the presence of lead in them. With this solitary exception, all Warington's subsequent work was on agricultural chemistry, and all of it was done in the Rothamsted laboratory.

While still at Millwall he had been writing a good deal on agricultural subjects—several articles for "Watts's Dictionary" and for the Agricultural and Horticultural Co-operation Association—and he had, moreover, as already mentioned, been in continual consultation with Lawes as to the Rothamsted results; he was naturally, therefore, prepared to receive Lawes's suggestion that he should go and work in the Rothamsted laboratory. The terms were all settled, and had readily been assented to by Warington; for, although they had involved a reduction of salary to two-thirds of that which he had been receiving at Millwall, he obtained a certain amount of freedom by way of compensation. He was to be at liberty to publish his own work in his own name, provided

that it made its appearance as Rothamsted work; but in cases where the work dealt with subjects which had already occupied the Rothamsted investigators, it was to be published in the joint names of Lawes, Gilbert and Warington. This arrangement, however, owing to some unforeseen difficulties, was not carried out; and it was not until after a delay of two years that Warington went to Rothamsted (in 1876), under an agreement for a year only, to work simply as Lawes's private assistant. The engagement was subsequently extended, and all his results were published, either in his own name or in the names of Lawes, Gilbert and Warington.

Before removing to Harpenden he went to work at the laboratory at South Kensington in order to learn water and gas analysis under Frankland's assistant, some of the Rothamsted soils being sent to him for practising determinations of nitrogen. While there he devised a method of extracting soils by the vacuum pump, which method has since been largely used at Rothamsted. In the autumn of the same year (1876) he made a short tour among the German experimental stations, and then took up his residence for good at Harpenden.

The construction of a gas analysis apparatus (under Frankland's direction) for the Rothamsted laboratory, occupied a considerable time, and, pending its completion, Warington made a study of the indigo method of determining nitric acid. This method, as generally used, he found to be full of sources of error. The principal of these he succeeded in correcting, and, with the method of determination thus rendered trustworthy, he proceeded to determine regularly the nitrates in the drainage-water from the various wheat plots in Broadbalk field. The chlorides were determined at the same time. No such systematic work had been previously done, whilst the methods of sampling which had been adopted when any analysis had to be made had been faulty. Warington now altered these methods, so that the samples analysed should faithfully represent the average composition of the drainage-waters.

Having examined the indigo method for determining nitric acid, he next examined the Crum-Frankland method by agitation with mercury, and subsequently the method of Schlessing, modified, however, in such a way that the nitric oxide produced was determined by gas analysis. The exhaustive examination of these methods of analysis are described in a series of papers published in his own name in the *Journal of the Chemical Society* and elsewhere, extending down to 1882. The modified Schlessing method was the one which he finally adopted, and with it he began a long

series of determinations of nitrates in soils, and in mangels, swedes and potatoes.

Having satisfied himself as to the methods of nitrogen determination, he next turned his attention to those for the estimation of carbon, and having examined the permanganate and the dichromate methods, and found them wanting, he finally adopted the combustion method, which proved to be thoroughly satisfactory, provided that carbonates were entirely removed by prolonged treatment with sulphurous acid. In this work he was assisted by Mr. W. A. Peake, and the results were brought before the Chemical Society in the names of Warrington and Peake.

Warrington's results from the examination of the rain and drainage water, together with results previously obtained at Rothamsted, formed the subject of a very long report published in the names of the three investigators in the *Journal of the Royal Agricultural Society* for 1882. The subject, however, continued to occupy Warrington's attention long after this date, and we find a report on the subject in the three joint names in 1883, and papers by Warrington alone in 1889 and 1887. The last-mentioned paper is an important contribution (*Trans.*, 1887, 51, 500) to the study of well-waters, and deals with the wells in the chalk formation on which Harpenden is situated. In later years (1904) Warrington was enabled to give these results a practical bearing on the supposed contamination of the Harpenden water supply, and he saved the community, at any rate, for a time, from adopting an expensive and, apparently, quite unnecessary system of sewerage.

So far Warrington's work, as here described, consisted largely of examining and perfecting methods of analysis for use in agricultural research. For this work the precision of his nature, and the carefulness of his manipulation, pre-eminently fitted him, and most of the methods of analysis which he elaborated have been accepted as standard methods, which promise to remain in use for many years to come. The remainder of his work, however, is that by which he made his name, and if a strictly chronological sequence of events had been followed it should have been mentioned earlier in this notice, for it was in 1877 that he began to study nitrification, and this subject occupied the foremost place in his mind until 1891, when his opportunities for pursuing the subject ceased. During this period he published about ten papers on the subject, all in his own name, the principal of which were four communications to the Chemical Society, bearing the title "On Nitrification," Parts I to IV.

That the natural conversion of ammonia into nitric acid was

the work of an organism had been suggested by A. Müller as early as 1873, but it had been reserved for Schloësing and Müntz to establish definitely that this was the case. In 1877 they showed that, when sewage was allowed to percolate through a column of sand and limestone, the nitrification which occurred during its passage could be prevented by the presence of a sterilising agent, such as chloroform vapour, and after such sterilisation, the activity of the sand could be resuscitated by inoculating it with a few particles of vegetable mould. Questions affecting the problems connected with nitrogen in the soil had naturally been amongst those to which the Rothamsted investigators had, from the first, devoted themselves, and, consequently, they at once set to work to examine such an important observation as that of Schloësing and Müntz. A complete verification of it was obtained by Warington, operating with garden soil only, and using a solution of ammonium chloride instead of sewage; and he was enabled to add the additional information that nitrification occurred only in the dark. This paper appeared within a year of that of Schloësing and Müntz. Two and a-half years later he published a second paper, which added considerably to the facts already established. He showed that the nitrifying organism, besides requiring darkness in order to do its work, must also be supplied with food for its growth—potash, lime and phosphorus—and, moreover, that all liberation of free acid must be prevented, by the presence of some salifiable base, such as calcium carbonate. He found, also, that after the introduction of a small quantity of active soil or solution into a liquid capable of nitrification, no action occurred until a certain time had elapsed, this period of incubation being probably due to the organisms having to multiply to a certain extent before they become sufficiently numerous to produce recognisable results. An increase of temperature was found to favour the action up to a certain point, and it was shown that various vegetable moulds and known bacteria were not the organisms to which nitrification could be attributed. Many difficulties, however, still remained to be cleared up, notably the want of uniformity of the action, which resulted in the production of nitrates in some instances, and nitrites in others. We now know that the process is performed by two quite distinct organisms, and that their nutrition is, in some respects, wholly different from that of any other organism hitherto studied; but until this knowledge had been gained, work on the subject was singularly difficult, and the results were very perplexing.

Warington's third paper on nitrification added considerably to our knowledge of the circumstances attending the action, and established the fact that the organisms are almost entirely confined

to the first nine inches of ordinary soil. The distribution of the organism in the soil was dealt with still more exhaustively in a subsequent communication in 1887.

The prize coveted by the workers on this subject was, however, the isolation of the organism itself; and to prepare himself for this task, Warington went to London for a time, in 1886, to learn bacteriology under Dr. Klein at the Brown Institution. From Dr. Klein he obtained a large number of pure cultures of various bacteria, and all these, as well as others obtained from his own experiments with soils, he examined as to their behaviour towards ammonia and nitrates, and also as to their mode of growth on skim-milk. The results were brought before the Chemical Society, and proved that none of the bacteria, except the nitrifying organism itself, possessed any appreciable power of nitrification. The majority of the organisms examined, however, were active denitrifiers. Denitrification—whereby nitrates are converted into nitrites, oxides of nitrogen, or even nitrogen gas—was, at this time, a well recognised work of micro-organisms, but was one which naturally enhanced to a considerable extent the difficulties met in elucidating the reverse phenomenon of nitrification. Warington's work added a good deal to our knowledge of the subject, and showed that denitrification is a property actively exhibited by a large number, but by no means by all, micro-organisms, and that in a soil it becomes complete, before the nitrifying organisms begin their task of reversing the reaction. An excellent account of the denitrification of farmyard manure was subsequently written for the *Journal of the Royal Agricultural Society* (1897, **8**, Part IV).

Warington's work on nitrification was amply sufficient to establish the fact that the oxidation of ammonia in the soil was the work of an organism, but that organism seems to have been isolated first by Schlœsing and Müntz in 1879, although the method which they adopted left, at the time, considerable doubt as to its real identity. But even the isolation of this organism did not solve the whole problem: there was still the independent formation of nitrites and nitrates to be accounted for; and it was here that Warington's work was most conducive to a solution of the difficulties, for he succeeded in proving that one organism alone could not be held accountable for the various phenomena observed, and that two different organisms must be concerned in the process of nitrification. His success all lay in the chemical aspects of the subject. He was the first to obtain (1879) liquid cultures which converted ammonia into a nitrite, and preserved this power in all sub-cultures, but which was incapable of producing any nitrate; and shortly afterwards (1881) he obtained cultures which were able to convert

nitrites into nitrates, but were unable to oxidise ammonia. This was a practical separation of two distinct organisms, but at the time Warington did not grasp the true meaning of his results, and he associated the change from nitrites into nitrates with a white growth which appeared floating in the liquid, but which really had nothing to do with it.

In 1890, after the work of others had resulted in the isolation of the nitrous organism (that which converted ammonia into nitrites), Warington returned to the subject; and found that the white surface organism could not be held accountable for the conversion of the nitrites into nitrates. He eventually succeeded in isolating the organism which really produces this change, and obtained a nearly pure culture of the nitric organism. At the same time he showed that organic carbon is not necessary for the growth of these organisms, as he had previously imagined, but that they can obtain their carbon from carbonates. These results were published in his fourth paper on nitrification (1891), and were communicated to the Chemical Society only a few days before Winogradski made a similar communication to the French Academy. Winogradski, however, had pushed the matter somewhat further, having obtained the organisms in bodily form, and having shown how they could be cultivated on solid media, a problem which had baffled Warington and other investigators. Warington, therefore, had to share his final hard-won success with another.

The practical results of nitrification in the soil were being investigated while the search for the organism was still in progress, and Warington began a long series of determinations of nitrates in the Rothamsted soil, the first results of which were published as a lecture given before the Society of Arts, for which he was awarded a silver medal.

The quarrels even of eminent men are generally better left to bury themselves in oblivion, but we should hardly be doing justice to Warington if we were to pass over in silence the circumstances which made his work so arduous to him, and finally brought it to a premature conclusion. Indeed, there is so much that is pathetic, and even grand, in the unfortunate disagreement which arose and became intensified between Gilbert and Warington, that a brief allusion to the subject cannot lessen our appreciation of either of them. That two of the greatest of England's agricultural chemists should be at variance with each other may afford no subject for wonder, but what must surprise the layman is that in spite of this strong personal disagreement these two should for years continue to work under the same roof, on the same subjects, publish-

ing their results as joint productions. No mere forbearance (of which there was much), no mere love of gain (of which there was none), could have effected this; it was the love of science, pure, simple and unselfish, which could alone accomplish such a task, and obtain a mastery over the more human passions.

When, in 1889, Lawes resigned his active control to the present Committee of Management, it was evident that the work of the station could no longer be carried on in this painful state of tension, and, all attempts at accommodation having failed, the Committee were reluctantly forced to decide that Warington's work there must terminate. This was in June, 1890, and it was arranged that he was to leave in the following January. Having, however, in the meantime, reached a very interesting stage in his work on the nitrifying organism, he petitioned to be allowed to stay on, without remuneration, until June of 1891. This petition was granted, and before that date he succeeded in bringing the work on hand to a successful termination.

Throughout all the trying circumstances of these years Lawes showed an undeviating friendship towards Warington, and Warington's feelings towards Lawes were those of love and veneration. Perhaps, however, the highest tribute which could have been paid to his rectitude and disinterestedness was paid when the Royal Society requested him to undertake the obituary notice of Gilbert. At first he declined, and ultimately consented, only on the understanding that what he wrote should be revised by those who could have no personal bias in the matter, his one fear being—as he told the present writer in the last conversation which he had with him—that his own feelings might unconsciously lead him to do insufficient justice to his subject. That the performance of this kindly office must have gone far to soften the recollection of past animosities we may feel assured, and before the end came there was but little of bitterness left in the mind of the survivor. All three great workers now lie at rest in the same quiet country churchyard, their united work in the cause of scientific agriculture forming the most fitting and enduring monument of their labours, for its importance becomes every day more and more evident with the development of the superstructure which is being raised upon it.

Although Warington's original work in agricultural chemistry was brought to a close on his severance from Rothamsted, much useful work remained for him to do. The Committee of Management appointed him American lecturer under the Lawes Trust, and he consequently proceeded to the United States to perform his functions. The six lectures which he there delivered dealt chiefly

with the subject of nitrification, illustrated by his own work at Rothamsted. They were published by the United States Department of Agriculture.

On his return to England, Sir John Lawes invited him to carry out an investigation at his tartaric and citric acid factory at Millwall, on the contamination of these acids by the lead of the vessels used in their preparation. This Warington undertook, and he succeeded in finding a method for obviating the evil. He obtained, in addition, an excellent method for the accurate volumetric determination of lead in the acid. This formed the subject of a communication to the Society of Chemical Industry in 1893, the last communication of any investigation made by him.

In 1894 he was appointed one of the examiners in Agriculture under the Science and Art Department, and in the summer of the same year he was elected Sibthorpe Professor of Rural Economy at Oxford for three years.

The papers, other than those on original investigations, which Warington wrote, are numerous, and are all characterised by a lucidity of expression and precision of argument which renders them specially valuable. One of the most useful of his writings is, undoubtedly, a little volume entitled "The Chemistry of the Farm." The amount of appreciation with which it has been received, and the good which it has done, may be measured by the fact that it is now in its fifteenth edition, and is accepted as the text-book on the subject throughout the world, and as a model of what a text-book of that sort should be.

Warington continued to reside in Harpenden until the end. His habits and tastes did not predispose him to take any active part in village management, but whenever he thought that his knowledge might be of service to the community, he did not hesitate to give what assistance he could.

Educational or charitable work, however, always enlisted his sympathies and engaged his active support; whilst his strong religious convictions, guided by his clear judgment and absolute sincerity, rendered his church and philanthropic work peculiarly valuable. He certainly had an unusually high sense of public duty, and persistently throughout life did what he could to make his fellow-creatures better and happier. Missionary work always held a prominent place in his heart, as also did the training of the young, whether in religious or secular subjects, and during the last few years of his life much of his time and care was devoted to the Church day-schools. He was greatly interested in all work amongst the poor and needy, and was a liberal supporter of any organised charity which appealed to his judgment. Partly owing

to his isolated boyhood and youth, and partly to his lack of robust health, life went harder with him than it otherwise would have done, for the characteristics thus developed stood in his way, and often prevented his gaining the sympathy and appreciation which he was so ready to give to others.

Warrington was elected to the Chemical Society in 1863, and to the Royal Society in 1886. He served for two periods on the Council of the Chemical Society, and for one period as vice-president. For many years he was on the Library Committee of this Society, and did much useful work for the Fellows during the reorganisation and cataloguing of the books. For this his extensive acquaintance with chemical literature rendered him specially fitted.

Warrington was married twice. His first wife was a daughter of G. H. Makins, M.R.C.S., formerly chief Assayer to the Bank, and one of the Court of Assistants at the Society of Apothecaries. His second wife was a daughter of Dr. F. R. Spackman, who had for many years been medical practitioner at Harpenden. He has left five daughters by his first wife. In 1906 his health gave way, and he had a serious illness which necessitated a very difficult and dangerous operation. For this he prepared with singular equanimity and courage. The operation was successful; but though he nominally recovered from it, he never regained his strength, and eleven months afterwards (March 20th, 1907) he passed away.

SPENCER U. PICKERING.

AUGUST DUPRÉ.

BORN SEPT. 6TH, 1835; DIED JULY 15TH, 1907.

AUGUST DUPRÉ was born at Mainz on September 6th, 1835, and died at his residence, Mount Edgcumbe, Sutton, Surrey, after some weeks' illness, on July 15th, 1907, in his seventy-second year. He was the second son of J. F. Dupré, a merchant and citizen of the then Freie Reichsstadt of Frankfurt-am-Main, and his birth was entered in the register of the "Freie Französische Gemeinde" of that city. On his father's side Dupré traces his descent in a direct line from Cornelius Dupré, a French Huguenot who left France in 1685, after the suspension of the Edict of Nantes, and settled in the Palatinate, and who distinguished himself later as an officer in the army of Prince Eugene. Dupré's mother was also of Huguenot descent. His family was, therefore, originally French,

but by intermarriage had become practically German in the course of a hundred and fifty years.

Dupré had a somewhat varied school education, which he completed at the Polytechnic schools of Giessen and Darmstadt, and entered as a student of the University of Giessen in 1852, at the age of seventeen. There he studied chemistry under Professor Will, also attending the lectures of Kopp and others. From Giessen he proceeded to Heidelberg in 1854, Bunsen and Kirchhoff being among his teachers, and there he finally took his degree of Doctor of Philosophy in 1855, being barely twenty years old. It is interesting to note that fifty years later, in 1905, the University renewed his Diploma (Goldenes Doctor-Jubiläum) in recognition of his scientific work. Among his fellow students at Giessen and Heidelberg who became famous in later life were Harley, Matthiessen, Roscoe, and Volhard.

In the autumn of 1855 Dupré proceeded to London and became assistant to Odling, whom he accompanied to Guy's Hospital, remaining with him until 1863.

In 1864 he was appointed Lecturer on Chemistry and Toxicology at the Westminster Hospital Medical School, in succession to his elder brother, Dr. F. W. Dupré, who had given up the appointment in order to take up mining in the then recently discovered salt deposits at Stassfurt, in connexion with which he is now so well known.

August Dupré remained in London for the rest of his life, and became a naturalised English subject in 1866. He resigned his appointment at the Westminster Medical School in 1897, after thirty-three years' tenure, but during the last ten years, owing to pressure of consulting work, he had practically handed over the lectureship to the writer, who was associated with him as Assistant-Lecturer from 1885. From 1897 until his death in 1907 he continued to practise as consulting chemist, both privately and in connexion with several Government Departments, at his private laboratory in Edinburgh Mansions, Westminster.

Soon after he left the University Dupré began to publish various scientific papers, and, owing doubtless to this fact and the reputation for ability which he enjoyed in his own immediate circle, it was not long before he obtained several other public appointments in addition to the lectureship at Westminster.

Thus in 1871 he was appointed Chemical Referee to the Local Government Board, and about this time he was first consulted by Sir Vivian Majendie, then Colonel Majendie, Chief Inspector in the Explosives Department of the Home Office, to which Department he shortly after became permanently attached as Consulting

Chemist. In 1873 he became Public Analyst for Westminster, which post he held until 1901. In 1874 he was appointed Lecturer on Toxicology at the London School of Medicine for Women, an appointment in which he always showed the keenest interest and which he held until 1901.

He was also consulted by the Board of Trade, the Treasury, and the late Metropolitan Board of Works.

In all these appointments and consultations he may be said to have distinguished himself brilliantly by his rapid and thorough grasp of the problems in hand, his marked originality, his extreme conscientiousness, his intense enthusiasm, and his infinite capacity for taking trouble. He rapidly rose to eminence.

In 1875 he was elected a Fellow of the Royal Society. In 1877 he became President of the Society of Public Analysts. From 1871 to 1874 he sat on the Council of the Chemical Society. In 1885 he was made a Vice-President of the Institute of Chemistry. In 1886 he was elected Examiner in Chemistry to the Royal College of Physicians, and again in 1892.

In 1888 he was appointed a Member of the War Office Committee on Explosives, in 1891 an Associate Member of the Ordnance Committee, and in 1906 a Member of the Ordnance Research Board.

His earlier work for the Local Government Board, beginning in 1871, was largely analytical, but in 1884, 1885, and 1887 he made a series of investigations in connexion with the purification of water supplies by aëration and by the agency of bacteria, which must certainly rank as original researches of high merit and which undoubtedly have assisted greatly in the evolution of the most modern methods of treating sewage. They are published in the Medical Officers' Reports of the above dates, but are probably not widely known in the present day.

In conjunction with Abel, Dibdin, Keates, Odling, and Voelcker he advised the late Metropolitan Board of Works as to the condition of the Thames in 1878, 1882, and 1883, and in 1884 made numerous experiments in conjunction with Mr. Dibdin on the treatment of London sewage on a large scale. This work is referred to at great length in the Report of the Royal Commission on Metropolitan Sewage Discharge in 1884. He was a Member of the Departmental Committee on White Lead in 1893, and gave evidence before numerous other Royal Commissions.

Of all this Government work, it was the Home Office appointment which mainly occupied him. When, in 1871, he was first consulted by the Explosives Department, the manufacture in England of dynamite and guncotton had but recently commenced,

and these two were practically the only high explosives known at that time. Much had to be done on the part of the Government in connexion with the safe manufacture, storage, transport, and use of these explosives, and the rapid development of the industry necessitated the introduction of the Explosives Act of 1875. In 1876 the authorised list of explosives comprised twelve kinds only, but in 1907 it had risen to 182. In addition, during this period, 108 explosives had been passed by the Home Office after examination by Dupré, and over one hundred had been rejected by his advice. He thus investigated, during a period of thirty-six years, nearly four hundred entirely new explosives of the most varied composition, and further examined, at frequent intervals, all explosives imported into England as to safety. In the course of this work he had often to evolve original methods of analysis or of testing for safety, and in this latter direction especially he rendered great services to the Government and, indirectly, to the public.

It was also part of his duty to assist H.M. Inspectors in investigating the causes of various accidental explosions in factories and elsewhere, which occurred from time to time. His work, therefore, involved heavy responsibilities, and sometimes serious personal risks, notably during the Fenian outrages in 1882-83, when he had to examine several "infernal machines," and on the occasion of the Birmingham scare in 1883, when he superintended and himself assisted in the conversion of several hundred pounds of impure nitro-glycerine (which had been secretly manufactured in the heart of Birmingham) into dynamite, and so averted what might have been a terribly disastrous explosion. He was highly commended in the House of Commons by Sir William Harcourt, then Home Secretary, in connection with this "prompt and courageous action," and by Sir Vivian Majendie in the 8th Annual Report of the Inspectors of Explosives in 1883. As late as 1907 he devised a new method of testing for infinitesimal traces of mercury in explosive compounds. His private consulting work was also considerable, and he was engaged in many important law cases as a scientific witness.

It might well be supposed that these responsible undertakings engrossed him entirely, but this was far from being the case. During the first twenty years of his appointment at the Westminster Hospital Medical School he gave great attention to his lectures and to the practical teaching of chemistry. His lectures were always very fully illustrated with experiments, which year after year seemed to give him renewed pleasure to perform, and although not very easy to follow, he was always extremely interesting owing

to the mass of information he had ever ready to hand. In 1886 he published, in conjunction with the writer, then recently appointed Assistant-Lecturer, "A Manual of Inorganic Chemistry," which had some success, and which reached its third edition in 1901. This book was dedicated to Professor Will, of Giessen, whom he always spoke of with the highest admiration and reverence as a great teacher.

The subject of toxicology, on which, as already said, he also lectured both at Westminster and at the London School of Medicine for Women, had always specially interested him, and he became known and was not unfrequently consulted as a toxicologist. He was brought into particular prominence in connexion with the celebrated Lamson case in 1881.

As an instance of the thoroughness of his work, the writer well remembers Dupré tasting sixteen quinine powders which had been prepared for the unfortunate victim in this case, and his almost immediately experiencing the now familiar and somewhat alarming physiological effect of the aconitine which he found in the last powder. He was associated in this case with Sir Thomas Stevenson.

It has already been mentioned that very soon after leaving the University Dupré began to publish scientific papers, and it seems surprising that amid such varied occupations he found time to work out so many original problems. His papers amount to no less than thirty-four in number between 1855 and 1902. Of these, five papers are included in the Proceedings and Transactions of the Royal Society between 1866 and 1872. The first, in 1866, with Dr. Bence Jones, on "Animal Quinoidine," may be said to have anticipated the later important researches of Selmi and others on Ptomaines. Another, in 1871, dealt ably with the Elimination of Alcohol in the human subject, a problem then arousing much interest. The remaining four papers, published between 1868 and 1872, some of the work being done in conjunction with the late Mr. F. J. M. Page, rank, perhaps, as his best efforts, treating of the specific heat and other characters of various aqueous mixtures and solutions, notably of mixtures of ethyl alcohol and water, in the course of which he made the remarkable observation that mixtures of these last two substances up to 36 per cent. of ethyl alcohol had a specific heat sensibly higher than that of water itself.

In the Journal of the Chemical Society are found eight papers between 1867 and 1880. One on the Synthesis of Formic and Sulphurous Acids, four on the Various Constituents of Wine, including compound ethers, one on the Estimation of Urea with Hypobromite by means of an ingenious apparatus now so universally em-

ployed, and two, in conjunction with the writer, on a New Method of Estimating Minute Quantities of Carbon, which was included by the late Dr. E. Frankland in his well-known work on Water Analysis.

Between 1877 and 1883 he read no less than thirteen papers before the Society of Public Analysts dealing with the analysis of foods or water, and most of the methods evolved by him in these publications are still used or have given rise to improved operations, notably those dealing with butter fat, fusel oil in whiskey and other spirits, alum in flour and bread, foreign colouring matters in wine, and methods of water analysis.

He published only two papers on Explosives, to which he had given such great attention, before the Society of Chemical Industry, and these as late as 1902. As a matter of fact, however, much original work was done by him in this branch of chemistry, some of which appears in the Annual Reports of H.M. Inspectors of Explosives, while again much could not be put forward owing to his official connexion with the Home Office.

His earliest papers, published between 1855 and 1862, are six in number, and deal with volumetric methods and spectrum analysis (conjointly with his brother, Dr. F. W. Dupré), the iodic test for morphia, and the presence of copper in plant and animal tissues, this last in conjunction with Odling.

To the chemistry of wine, as will be seen from the above summary, he devoted a good deal of attention, and was joint author with Dr. Thudichum of a work entitled "On the Origin, Nature, and Varieties of Wine," published in 1872, in which a considerable amount of original analytical work is embodied.

Dupré married, in 1876, Miss Florence Marie Robberds, of Manchester, and leaves a family of one daughter and four sons, two of whom, Frederick and Percy, are now carrying on his work for the Home Office. He was of a striking personality, of medium height, but very powerfully built, with a massive head and brow, and must have possessed an iron constitution. As a young man he was a skilled fencer and swimmer. He was of somewhat excitable temperament, but had a most kindly disposition. Although not a fluent speaker, he was impressive from his obvious sincerity, and the thorough knowledge he displayed. He therefore made an excellent expert witness, and was more than once complimented in Court on his straightforward evidence. In controversy he was unsparing where facts were concerned, and at times intensely sarcastic.

Although almost wholly devoted to chemistry, his mind found many other outlets. He was a great student of history, and his quite remarkable memory was frequently exemplified in conversa-

tion on this subject. He was also exceptionally well read in general as well as in scientific literature, both English and German, and amassed a large collection of books. Among other hobbies he pursued astronomy and photography. His mind, indeed, seems rarely to have been idle; he had a perfect passion for work, and, except for a few weeks' holiday annually, he never relaxed. There is little doubt that at one time, about 1891, he overstrained his brain, and was obliged for some months to take a complete rest, which, fortunately, restored him to renewed energy. Like many great men, he was of a modest and retiring nature, and probably but few of his contemporaries have realised the magnitude and variety of the work he accomplished during fifty years of almost unceasing activity.

H. WILSON HAKE.

JOHN CLARK, PH.D., F.I.C.

BORN 1844; DIED JULY 9TH, 1907.

DR. CLARK was born in 1844, being the only son of John Clark, a solicitor of eminence in the City of Glasgow. He received his education in the classics at Glasgow University, and during his period of study there acquired a taste for chemistry and became a pupil in the laboratory of the late Dr. Frederick Penny, who was successor to Graham, Ure, and Gregory in the Chair of Chemistry of Anderson's College, now incorporated in the Glasgow and West of Scotland Technical College. He subsequently proceeded to the University of Göttingen, where he worked with Fittig and Wöhler, gaining the degree of Doctor of Philosophy for a dissertation on amidovalerianic acid. He also studied for a session at Heidelberg under Bunsen, and afterwards worked in Paris for nine months in the laboratory of Prof. Payen at the Conservatoire des Arts et Metiers. At the still early age of twenty-three he returned to Glasgow, where he was for three years senior assistant at the Andersonian College to his old teacher, Penny, acting as his substitute during the illness which ended in Penny's death. In 1870 he joined his friends, Mr. Tatlock and the late Dr. Wallace, in forming the widely-known firm of Wallace, Tatlock and Clark, who, in addition to their analytical practice, carried on a very successful private school of technical chemistry. For some years Dr. Clark also lectured on chemistry in the Medical School of the Royal Infirmary at Glasgow. In 1888 the original partnership was dissolved by the retirement from the firm of Mr. Tatlock, who estab-

lished the separate practice which he still carries on in conjunction with Mr. R. T. Thomson; and the death of Dr. Wallace left Dr. Clark in sole charge of the laboratory of the original firm at 138, Bath Street, until his son and survivor, Mr. R. M. Clark, became qualified, a few years since, to join his father in partnership.

Dr. Clark's contributions to chemical literature were many, being almost wholly directed to the practical advancement of analytical chemistry. In the *Analyst* only one paper appears to have been published, namely, one on the "Composition of Dutch Butter," 1901.

In the *Journal of the Chemical Society* he published the following papers:—"Estimation of Phosphoric Acid with Nitrate of Silver," 1888; "Separation of Arsenic, Antimony, and Tin," 1892; "The Use of Sodium Peroxide as an Analytical Reagent," 1893; "Fleitman's Test with Arsenic Acid," 1893; "Improvements in Reinsch's Test for Arsenic," 1893.

In the *Journal of the Society of Chemical Industry*:—"Composition of Tobacco," 1884; "New Method of Estimating Sulphur in Pyrites," 1885; "New Method of Estimating Arsenic in Pyrites," 1887; "Alloys of Aluminium," 1887 and 1891; "Transvaalite, a New Cobalt Mineral," 1890; "Analysis of Copper, &c.," 1900; "Separation of Bismuth from Lead," 1900; "Direct Estimation of Arsenic in Minerals, Metals, &c.," 1891; "Estimation of Chromium in Steel," 1892; "Estimation of Chromium in Ferro-Chromium and Steel," 1892; "Determination of Arsenic in Alkaline Solution," 1893; "Estimation of Nickel and Zinc as Phosphate," 1896; "Estimation of Antimony in Ores and Metals," 1896.

In the *Journal of the Philosophical Society of Glasgow*:—"Action of Phosphuretted Hydrogen on the Animal Organisms," 1879; "Volumetric Process for the Estimation of Cobalt and Nickel," 1883; "A New Process for the Estimation of Nickel and Cobalt," 1883.

In the *Chemical News*:—"Estimation of Chromium," 1871.

Among the public appointments he held were the Public Analystships for the counties of Lanark and Renfrew, and the burghs of Ayr, Kilmarnock, Girvan, Dumbarton, Kinning Park, Motherwell, Partick, Barrhead, Paisley, Renfrew, and Dornoch, and for the City of Glasgow, the last-named appointment being held conjointly with Mr. Tatlock and Mr. Harris.

At the time of his death Dr. Clark was President of the Association of Public Analysts of Scotland, as well as of the parent Society of Public Analysts, and a member of the Council of the Institute of Chemistry, and he had filled the office of Chairman of the Scottish Section of the Society of Chemical Industry.

His acquisition of French and German at an early age enabled him to read, write, and speak these languages with facility, and to keep himself abreast of the chemical literature of the Continent.

Although fully occupied in his professional life, he found time and opportunity for physical recreation of various kinds, golfing, bowling, and angling, in all of which he excelled, and in this capacity received presidential honours from the clubs and associations with which he was connected. During his German University student days he was a sufficiently orthodox student to earn the reputation of a keen duellist, and in moments of early reminiscence he was still proud of the scars which constituted the lasting trophies of this mimic but sanguinary warfare. His adventures in this direction must be put down to his love of sport rather than to any natural tendency to quarrel, for his disposition was one of the kindest and most genial, and his bright face and physically handsome presence will be long missed in the circles in which he personally moved. Few, probably, have gained greater respect than he commanded, both within his profession and in the eye of the public, and the loss of his friendship, as well as of his ever-ready advice and assistance, will be widely felt.

R. R. TATLOCK.

FREDERICK JAMES MONTAGUE PAGE.

BORN JUNE 27TH, 1848 ; DIED AUG. 16TH, 1907.

FREDERICK JAMES MONTAGUE PAGE was born at Chelmsford on June 27th, 1848, being an only child. When he was eight years old he came to London with his parents, and in due course entered the City of London School, at that time in Milk Street. While there, he carried off many prizes and medals, and obtained the "John Carpenter" Scholarship. In 1866, when eighteen years of age, he gained an exhibition to the Royal School of Mines, where he studied under Huxley, Tyndall, Frankland, and Percy. The following year he was first in chemistry and in physics, and at the close of his three years' training, 1869, he took the associateship of the Royal School of Mines, again passing first in chemistry and first in physics. He took his final B.Sc. London in the same year, having passed the preliminary (first class) in 1868 with honours in chemistry and "natural philosophy."

His first appointment on leaving the Royal School of Mines was that of assistant gas examiner to the Corporation of the City of London, but in 1870 he went to Dr. Thudichum as his assistant, where he was occupied for about three years in chemical research

undertaken for the Medical Department of the Privy Council. In 1873 he left Dr. Thudichum to become the assistant of Dr. Burdon Sanderson, first at the Brown Institute and subsequently at University College, remaining with him until the year 1883, when he was appointed lecturer in physics and demonstrator in practical chemistry to the London Hospital—appointments he held at the time of his death. During the winter of 1879 and 1880 he delivered courses of lectures on physics and chemistry at the Royal Gardens, Kew, and from 1880 to 1906 he gave lectures on chemistry and physics at the establishment of the well-known tutors, Messrs. Wren and Gurney. He was for two years assistant examiner in physiology at London University, and also held an examinership at the Society of Apothecaries.

Page was with the writer of this obituary at the Birmingham meeting of the Society of Chemical Industry in July, 1907, and then seemed to be in bad health, but put aside the suggestion that he should consult a medical man. In August he went to Weymouth for a holiday, and, being an excellent swimmer and fond of the sport, he went into the sea, but became unconscious and was brought ashore. He was attended by three resident physicians, and his colleague, Dr. Head, of the London Hospital, also came down to see him, but he never recovered consciousness, and died of cerebral hæmorrhage on August 16th, 1907, ten days after the attack.

His contributions to science were more physiological than chemical; amongst them are a paper "On the Specific Heats of Mixtures of Ethyl Alcohol and Water," published in the *Phil. Trans.*, 1869, p. 591, in collaboration with Dr. A. Dupré; one "On the Influence of Surrounding Temperature on the Discharge of Carbonic Acid in the Dog"; and four papers in conjunction with Sir Burdon Sanderson, one being "On Mechanical Effects and on the Electrical Disturbance Consequent on Excitation of the Leaf of *Dionæa muscipula*," *Proc. Roy. Soc.*, 1877, **25**, 4, and the others published in *Proc. Roy. Soc.*, 1877, **25**, 411; 1878, **27**, 410; 1880, **30**, 373; and in *J. Physiol.*, **2**, p. 384, "On Excitatory Processes on the Ventricle of the Heart of the Frog." His only contribution to our Journal was in 1876, i, p. 24, describing a simple gas regulator for thermostats. In conjunction with Dr. Luff he produced a "Manual of Chemistry" and also a text-book on "Elementary Physics."

He served on the Council of the Chemical Society, and five times on the Council of the Institute of Chemistry. He was also a member of the Society of Chemical Industry and of the Physiological Society.

He was an enthusiastic musician, no mean performer on the piano, and in his younger days had a fine tenor voice—this was sweet and sympathetic even up to the time of his decease.

He was a staunch Churchman, and member formerly of the choir of St. Martin's-in-the-Fields, and subsequently of St. Peter's, Eaton Square. He loved "part singing," and was for many years a member of the well-known "Moray Minstrels" and also of the "City Glee Club," of which he had been elected president shortly before his death. He was a member of the John Carpenter Club, holding the office of president in 1902.

As a man, all those who knew him well held him in high esteem, he was ever ready to do a kindness, and that not merely to his intimate friends; his genial manner, ready wit, and sterling good sense will long live in the memory of many of us.

C. E. G.

SIR DAVID GAMBLE, BART., K.C.B.

BORN FEB. 3RD, 1823; DIED FEB. 4TH, 1907.

SIR DAVID GAMBLE, Bart., K.C.B., was born on February 3rd, 1823, in Dublin. His father, Josias Christopher Gamble, was descended from an Ayrshire family, which removed to Lisbellaw, near Enniskillen, in 1620. Jos. C. Gamble removed with his family to Lancashire in 1828 to find a suitable site for chemical works. This he found at St. Helens, on the banks of the St. Helens Canal.

David Gamble went to school at Cowley Hill, St. Helens, kept by a Mr. Morley, and afterwards at Runcorn. On leaving school he studied chemistry at University College, London, under Thomas Graham, and afterwards at the Andersonian Institution, Glasgow. While in Glasgow he made the acquaintance of the Tennant family, with whom the firm had business relations. In 1842, at the age of nineteen, he joined his father's firm, which then became Jos. C. Gamble & Son.

Mr. Gamble was preparing bleach at the Gerards Bridge Works, but the anxieties connected with the disputed validity of one of his patents, added to the claims continually made by landowners and agriculturists on account of damage done by escaping hydrochloric acid, had so told on his health that David on coming into the firm almost immediately assumed charge. In 1846 the firm was Gamble, Son and Sinclair, and very soon afterwards became again Jos. C. Gamble & Son. At this time they manufactured alum, as well as the products usually made at alkali works. The firm was one of the first and largest to manufacture Epsom salts on a large

scale from carbonate of magnesia imported from Greece. This was, about the 'sixties, much used for weighting calico.

David Gamble married Elizabeth Haddock, in 1847, and resided near to the works, ultimately building the mansion "Windlehurst" in 1860. His eldest son, Josias Christopher Gamble, the second baronet, who died soon after succeeding to the title, joined the firm in 1867, which was at that time the first to carry out Weldon's process for the recovery of manganese on a large industrial scale. The firm was now Jos. C. Gamble & Son. They were also one of the first to make potassium chlorate on a large scale, and about 1869 they bought the Hardshaw Brook Works, where they manufactured chiefly saltcake, bleach, and potassium chlorate. They also manufactured for a short time chlorates of barium, aluminium, etc. The firm carried on operations on a very large and important scale with increasing success, and when the United Alkali Co., Ltd., was formed, in 1890, there was some difficulty in inducing Messrs. Jos. C. Gamble and Son to join. However, in 1891 they joined the United Alkali Co., which thus secured a practical monopoly in Great Britain of alkali manufacture and kindred industries.

Sir David Gamble was one of the most active members of the committee which raised funds for the establishment of the Volunteer force in St. Helens in 1859 and 1860. He was captain of the first company, and as the force grew he was promoted to be major; in which capacity he served so earnestly and with so much skill that this force became one of the best equipped and trained units in the country. Ultimately he became lieutenant-colonel. It was his generosity which provided a drill-hall and parade-ground; in short, he provided in every way for the efficiency of the 47th Lancashire Volunteers during the twenty-seven years that he was its commanding officer. He retired in 1887, becoming honorary colonel. He was also very fond of the sea, which he enjoyed in his own yacht. He was a leading member of the Royal Mersey Yacht Club for forty-nine years, becoming vice-commodore in 1873 and commodore in 1882, a position which he retained until his death in 1907. Residing as he did near St. Helens, in the midst of a community almost entirely engaged in manufactures, he paid a great deal of attention to organising and improving the condition of the town and its inhabitants. Taking a leading part in obtaining the Improvement Act, 1845, he became Chairman of the Improvement Commissioners, and when in 1868 St. Helens was incorporated, Colonel Gamble became the first mayor, a position to which he was re-elected twice in successive years. He was also mayor in 1882-3, and again in 1886-7.

On the occasion of Queen Victoria's Jubilee in 1887 he was made Commander of the Bath. He was created a baronet in 1897 and K.C.B. in 1904.

Sir David Gamble took a leading part in the foundation of the University College, Liverpool, which afterwards became the University of Liverpool. He not only contributed liberally and repeatedly to its funds, but devoted time and attention to its interests as a member of the Court of Governors as well as privately. His interests were not confined to the Chemical Department, although to it he was on many occasions a good friend. He was always willing in the most courteous way to listen to appeals, whether for help or advice, and many important advances were due in great measure to his wisdom, his sympathy, and his generosity.

In 1868 Sir D. Gamble built the Windle Schools at Cowley Hill, St. Helens. He was a governor of Cowley Schools, and promoted the extension of these schools, and also built and equipped a high-class technical school and free library for St. Helens, known as the Gamble Institute.

During sixty-four years of active industrial and public life, Sir David Gamble was characterised by the great consideration and courtesy which he extended to everyone with whom he had to do either in a public or private capacity. Possessed of great ability, he spent his energies more for others than for himself. His thoughtful care for the workpeople around him led him into schemes for their benefit far too many to be enumerated. His work and gifts were bestowed in the most unostentatious manner. Besides his activity in the public service as a magistrate and otherwise, his business ability made him a valued director of Parr's Bank from its foundation, and of other companies. He was a partner in iron works at Ditton. He and Mr. Henry Deacon built and started the works at Widnes which became the Tharsis Sulphur and Copper works there.

And when, on February 4th, 1907, the day after his eighty-fourth birthday, he passed away full of years and still active, the whole community of St. Helens, the County of Lancashire, and innumerable friends far beyond the boundaries of the county felt that they had suffered an irreparable loss.

J. CAMPBELL BROWN.