CHARLES WILLIAM SIEMENS, whose untimely death on November 19, 1883, we have to record, was born at Lenthe, in Hanover, on the 4th April, 1823.

His education was begun at the Gymnasium of Lübeck, from which he passed to the Polytechnic School of Magdeburg, and finished at the University of Göttingen. During his University course he had the advantage of studying the natural sciences under Professors Wöhler and C. Himly, from the latter of whom the Siemenses received the first impulse towards those investigations which led to their first invention—the electro-gilding process.

Leaving the University in 1842, at the age of nineteen, William Siemens entered upon the practical business of life by spending a year as pupil in the engine works of Count Stolberg, thus adopting the profession of engineer, in which in after years he attained such commanding eminence. It is interesting to observe that, at the very outset of his career, he showed how wide and all-embracing was his understanding of the word engineer, and of what an engineer should be. To his mind the word meant the practical development of the results of science, in order to minister to the wants and comforts of mankind; and he considered that an engineer must be able, if not himself an original investigator, at least to appreciate fully the conquests of science in the realm of Nature, and from his knowledge of ways and means to adapt the results so gained from time to time to the needs of life. His career shows how completely William Siemens realised this idea, and not only so, but establishes for him strong claims to rank as an able worker in the domain of pure science.

In 1843, when he was only twenty years old, William Siemens came to England to realise a joint invention of his own and his brother Werner in electro-gilding; and, persevering through the complication of difficulties naturally met with by a young man in a strange land, with little knowledge of its language, he succeeded in proving the usefulness of the invention, and getting it carried into practical effect through the wise and kindly appreciation of Mr. Elkington. Encouraged by this success, William Siemens returned a year later with his chronometric governor—an invention of remarkable beauty and ingenuity, in which, by the motion of a pivoted framework carrying an idle wheel geared to bevel wheels on two shafts in line, or geared to the outer and inner circumferences of concentric wheels, rotating in opposite directions on coaxial shafts, the movement of one wheel is caused to keep time with that of the other. We believe that, although the invention was not a commercial success, and is not generally known in this country as practically realised except in its application to regulate the motions of

chronoscopic instruments in the Royal Observatory at Greenwich, it may yet be destined to have large practical applications in engineering.

The process of anastatic printing, which was also the joint invention of William and his brother Werner, belongs to this period. As an evidence of the importance which was early accorded to this invention, it may be stated that it was considered worthy of being made the subject of a Friday evening lecture by Faraday at the Royal Institution in 1845. Siemens himself, in a lecture delivered by him at Birmingham on 20th October, 1881, referring to this invention, states that the favourable notice taken of it by Faraday "obtained for me an entry into scientific circles, and helped to sustain me in difficulty."

Another of William Siemens' early inventions was his water-meter, which exactly met an important practical requirement, and has had a splendid thirty years' success. It applied curiously subtle hydraulic principles, which, even irrespectively of the practical value of the instrument, are of great interest. Imagine a Barker's mill running absolutely unresisted. The discharged water must have approximately zero absolute velocity on leaving the nozzles; in other words, its velocity relatively to the nozzles must be approximately equal to the contrary absolute velocity of the nozzles. Hence the machine will rotate in simple proportion to the quantity of water passing through it. By an extension of similar considerations, it is easy to prove that if the wheel, instead of being unresisted, is resisted by a force exactly proportional to the square of its angular velocity, its velocity must still be proportional to the quantity of water passing through it per unit of time. Thus, provided this law of resistance is maintained, the whole angle turned through by the wheel measures the whole quantity of water that has passed. Now think of the difficulties which Siemens had to overcome to apply this principle. What has been roughly called a Barker's mill, must be completely inclosed in the supply water-pipes, its nozzles discharging into water, not into air. It must be of very small dimensions to be convenient for practice, and its bearings must be kept oiled to secure, not only that it may not be injured by the wear of running for years, but also that the constant frictional force of solid rubbing on solid may be as nothing compared to the resistance, proportional to the square of the velocity, exerted by the circumambient liquid upon a wheel with sharp edged vanes rotating in it. After a few years of trials, difficulty after difficulty was overcome, and the instrument did its work with the accuracy and convenience which met practical requirements. It was we believe the protection offered by the British Patent Law which, in the case of this very instrument, allowed Siemens to work it out in England, and so helped him eventually to find his home among us,

and to give us primarily the benefit of his great inventiveness in all directions; while the want of similar protection under German law at that time rendered it practically impossible for him to work out so difficult an invention in his own country.

In the foregoing we have selected those results of Siemens' inventive genius, not only on account of their position in time, or of the principles involved, but also, and perhaps mainly, because of the circumstances connected with them forming determining factors of such moment in his career. There is much in the lifework of such a man as Siemens, which while it might prove of great interest, and have some measure of importance in its bearing on his career as a whole, must yet of necessity be passed over in such a notice as this. We shall, therefore, here merely remark that during the ten years from his arrival in this country till about 1856, Siemens was employed on various engineering works. He was for some time engaged in railway work, and again in carrying out improvements at the famous calico printing works of Mr. Hoyle at Manchester.

William Siemens had early taken up the then new science of thermo-dynamics, and in 1847 he had already begun work on the regenerative principle—with which his name has since become indissolubly connected—in the employment of heat for the purpose of obtaining increased economy in its practical use. In that year he fitted up a regenerative steam-engine in the factory of Mr. Hicks at Bolton, and although the difficulties attending the use of superheated steam prevented the practical application of the invention, the importance of the principle embodied in it was recognised by the Society of Arts, who in 1850 awarded to William Siemens a gold medal "for his regenerative condenser." From papers contributed by him to various societies about this time—for instance, "On a New Regenerative Condenser as applied to High and Low Pressure Steam-engines," to the Institution of Mechanical Engineers in 1851; "On the Expansion of Isolated Steam, and the Total Heat of Steam," to the Journal of the Franklin Institute in 1852; and a most important paper "On the Conversion of Heat into Mechanical Effect," to the Institute of Civil Engineers in 1853 (for which he obtained the Telford Medal)—we see how persistently he clung to the problem of the better utilisation of heat. It was, indeed, at that time a conviction firmly fixed in his mind, that the various existing modes of using heat were wasteful and extravagant in the extreme, and he was continuously directing all his energies, not only to overcome the evil, but to convince others of its existence. The problem had always a fascination for him, and to the very latest pressed its claims upon his mind.

The great movement for smoke abatement, which has arisen within recent years, had his deepest sympathy, and his earnest labours on

its behalf during the last three years of his life may yet we hope have full effect. Just as those other wasteful modes of using heat yielded, as we shall see later, to Siemens' inventive genius persistently applied, so also, had he been spared to us, would this particular mode have had to yield in time.

Just nine days before his death, the writer of this notice had received a letter from Sir William Siemens, saying nothing of illness, but full of plans for the immediate future: chiefly an address to the Society of Arts, and the realisation at Sherwood of his method for the smokeless supply of heat to a steam-boiler, by the combustion of hydrogen, carburetted hydrogen, and carbonic oxide, obtained from the conversion into these gases of the whole combustible material of the coal, together with some hydrogen and oxygen from water, and oxygen from air, in his gas-producing kiln. "The producer will be in full operation at Sherwood by that time," were almost the last words received by the writer from his friend, kindly inviting him to come and see the new method in operation at the end of the current month. A short time before, in travelling home from Vienna, where they had been associated in the British Commission for the Electrical Exhibition, Sir William Siemens had told the writer that without waiting for a perfected gas-engine to use the products of combustion as direct motive agent, and so give the very highest attainable economy, he expected by using the gas from his producer as fuel for the fire of a steam-boiler, even on a comparatively small scale, like that of his appliances at Sherwood for electric lighting and the electric transmission of power, to be able to obtain better economy of coal for motive power than by burning the coal directly in the usual manner in a furnace under the boiler. And further, what is especially interesting to persons planning isolated installations for electric light, that he (Siemens) believed that the labour of tending the producer and boiler and steam-engine, would be on the whole considerably less than that which is required on the ordinary plan, with its incessant stoking of coal into the furnace under the boiler, as long as steam is to be kept up. There is something inexpressibly sad, even in respect to a comparatively small matter like this, to see the active prosecution of an experiment so full of interest and so near to a practical solution suddenly cut short by death.

In 1857 William Siemens, in conjunction with his younger brother and pupil, Frederick, commenced investigations with a view to using the principle of "regeneration" in the process of metallurgy. The result of their labours, in which it may be observed the elder brother had the greater share, was the regenerative gas furnace, certainly the most valuable and important of the many products of their genius which the Siemenses have given to the world. It was first practically applied, in 1861, within the works of the Messrs. Chance, of

Birmingham, to one of their glass-smelting furnaces, and proved a complete and undoubted success. As showing the saving to this industry alone, it may be observed that glass-smelting furnaces upon Siemens' principle are now in operation in which the fuel consumed is only 15 cwts. for every ton of glass produced, instead of 2 or 3 tons of fuel as was formerly the usual consumption for each ton of glass.

The great economy of fuel effected by the regenerative gas furnace, together with the great ease with which its high temperature could be maintained and regulated, soon led to its application in the production of iron and steel. In 1862 a paper by Siemens appeared in the "Chemical News" "On the Regenerative Gas Furnace as applied to Glass Furnaces, Puddling, Heating, &c.," and from that year the application of the regenerative principle to the processes of iron and steel making gained increasing attention from those concerned, having been very early adopted in the iron district of Lanarkshire in Scotland.

But Siemens did not rest content with the application of his regenerative gas furnace to the then known methods of iron and steel-making. With this new appliance he now turned his attention to the improvement of the methods of manufacture. His first attempt was in the production of steel on the open hearth according to the well-known experiments of Reamur, and in 1862 a practical trial of the arrangements devised by him to effect this was made at Tow Law by Mr. Charles Atwood, under a licence from William Siemens. This arrangement was found, however, to be faulty, and had to be laid aside. After one or two other disappointments, Siemens took the matter into his own hands, and in the famous sample steel works which he founded at Birmingham in 1865, he wrought out to a thorough practical success the process of steel making known as the Siemens Process, a subsequent improvement of which is the now well-known Siemens-Martin Process. Within three or four years after this the Landore Works, near Swansea, were organised on an extensive scale for the carrying out of this manufacture, William Siemens being here associated with Mr. Dillwyn, M.P., as the principal owners. The new material—mild steel—thus introduced, speedily proved its surpassing excellence for metallic structures in which strength and lightness were desired: while its manipulation was less difficult than that of iron on account of its greater ductility. Hence it at once began to displace iron in the construction of the highest class of steam-ships and marine steam-boilers, whilst of late years it seemed destined to altogether supplant iron as a material for the purposes of marine architecture and engineering. As an evidence of the extent to which these Siemens and Siemens-Martin Processes have been adopted, it may be

observed that amongst the very many licences which have been granted by the patentee, several of them have comprised hundreds of furnaces for various purposes. The total production of Siemens mild steel was over 340,000 tons in 1881 for Great Britain alone, while the Siemens furnaces in use here are approximately only one-third of those already set up in America and on the Continent.

The great things done by Siemens with gas produced in the manner referred to above, first in the gas glass furnace, described with glowing admiration by Faraday on Friday evening, June 20, 1862, in his last Royal Institution lecture, and more recently in connexion with the great and exceedingly valuable invention just referred to,—the Siemens process for making steel, by using the oxygen of iron ore to burn out part of the carbon from cast iron,—and still more recently in the heating of the retorts for the production of ordinary lighting gas, by which a large increase has been obtained in the yield of gas per ton of coal used, are achieved results which live after the inventor has gone, and which, it is to be hoped, will give encouragement to push farther and farther on in practical realisation of the benefits to the world from the legacy of his great inventions.

For his contributions in this department, towards the better application of science to the methods and processes of practice, William Siemens received many rewards and honours.

He received prize medals at the Exhibitions of 1851 and 1862, and a Grand Prix at the French Exhibition of 1867 for his regenerative gas furnace and steel processes. In 1874 he was presented with the "Royal Albert Medal," and in 1875 with the "Bessemer Medal" on account of his scientific researches and his inventions relating to heat and metallurgy, whilst only last week the Council of the Institution of Civil Engineers awarded him the Howard Quinquennial Prize for the advances he had made in the manufacture of iron and steel.

William Siemens has designated electricity "the youngest form of energy with which we are practically acquainted," and there is no doubt that to himself is due, in considerable degree, the great progress which has within recent years been made in its practical adaptation to various purposes.

It was in the early days of submarine telegraphy that Siemens entered the field of electric engineering, when the possibilities of ocean telegraphy were just coming into view, and it was therefore to this particular adaptation of electricity that he first applied himself. He took part in several of the early expeditions for cable laying in the Mediterranean and the Black Sea, acquiring there the practical experience, which helped him, in after years, in the arrangement and equipment of so many successful expeditions for a like purpose.

In 1858 the extensive telegraph works at Woolwich, now known as

Siemens Bros., were established by William Siemens in conjunction with Mr. Halske of Berlin, and the great undertaking so successfully carried out by this firm have more than a commercial interest. The scientific attainments, together with the wide experience and great inventive genius brought to bear by Siemens on the work entrusted to it, speedily succeeded in raising the firm to that eminence which it has ever since held. Alike in land as in sea telegraphic engineering, it has long held a first place, and while it would be out of place here to catalogue the various successes in cable laying and repairing of the Siemens firm, we may note that these include the North China, and Platino-Braziliera cables, the cables for the Indo-European lines, and no less than four Atlantic cables completed, and two new ones in progress at the time of Siemens' death. Many of the machines and processes now in use in the manufacture and maintenance of land and sea telegraph cables have been greatly improved, while some of them indeed owe their existence to William Siemens. One of these machines, the "Faraday," which is primarily a cable-laying and lifting machine, is a perfect monument of Siemens' practical genius. This vessel was designed by him in 1874 for the purpose of laying the Direct United States Cables, and was named the "Faraday" in grateful remembrance of that "master in science" to whom he owed so much.

It is remarkable that a ship capable of doing what no other ship afloat can do in the way of manœuvre, as has been proved by her success in the difficult and delicate operations of laying and lifting cables in depths of 2,500 fathoms, and of cable repairing in all seasons and all weathers, should have been the work of a landsman, born in the middle of Europe, who *early* made himself a sailor in cable-laying expeditions in the Mediterranean and the Black Sea, but whose life has been chiefly devoted to land engineering and science.

In the most recent advances that have been made in the application of electrical energy, William Siemens has been a pioneer, and it is in connexion with these that his name has become a household word. In the numerous and important inventions pertaining to this department of electrical engineering, to which the name applies, William Siemens has been associated with his brother Werner, and the world has profited largely by this brotherly co-operation of genius. More than a quarter of a century ago they brought out what is now known as the Siemens armature, which was shown at the London Exhibition of 1862, mounted between the poles of a multiple steel horseshoe magnet, and serving for the transmitter in an electric telegraph. That was what we may now call the one-coil Siemens armature. It suggested inevitably the mounting of two or more coils on the same iron core, in meridional planes at equal angles round the axis, and as nearly equal and similar in all respects as is allowed by the exigencies of completing the circuits with the

different portions of wire laid over one another, and bent to one side or the other, to avoid passing through the space occupied by the bearing shaft. The principle of electro-magnetic augmentation and maintenance of a current without the aid of steel or other permanent magnets, invented by Werner Siemens, and also independently by Wheatstone and S. A. Varley, was communicated to the Royal Society by William Siemens on February 14, 1867, in his celebrated paper on the "Conversion of Dynamical into Electric Force without the aid of Permanent Magnets." This paper is peculiarly interesting, as being the first scientific enunciation of that wonderful electro-magnetic principle, on which are founded the dynamo-electric machines of the present day. Soon after came the Paccinotti-Gramme ring, from which followed naturally the suggestion of the mode of connexion between the coils of a multiple-coil Siemens armature, described in the Siemens-Alteneck patent of 1873, and made the foundation of the Siemens dynamo as we now have it, whether as constructed by the Siemens firm, or with the modifications of details and proportions, valuable for many practical purposes, which have been contributed by Edison and Hopkinson. The evolution of the Siemens armature, as we now have it, in this splendid machine, from the rudimentary type which the writer saw a quarter of a century ago, is one of the most beautiful products of development by inventive genius, and is more like to the growth of a flower than to almost anything in the way of mechanism made by man.

It is unnecessary here to enter upon the consideration of the many new forms of apparatus for electric lighting given to the public by the Siemens firm, but we may perhaps mention the highly successful Siemens arc-lamp, and the various measuring instruments, particularly the Watt meter; this instrument being the realisation of a mode of estimating electrical energy or activity by a new unit—the "Watt"—suggested by Siemens in his Presidential Address to the British Association at Southampton in 1882. He at the same time suggested the "Joule" as a unit of heat or work, both of which units were at once adopted by electrical engineers as convenient practical units.

Just two months before his death Siemens witnessed the successful completion and formal opening for traffic of the Portrush and Bushmills electric tramway, one of the most splendid and interesting of his achievements. This railway, which is situated in the north of Ireland, and was the first of its kind in this country, now carries passengers on a 6½-miles line of steep gradients and sharp curves, at a good 10 miles an hour, solely by water-power of the River Bush, driving, through turbines, a 250-volt Siemens dynamo at a distance of 7½ miles from the Portrush end of the line.

We have seen how much the labours of William Siemens have contributed to make electricity subservient to the wants of mankind,

but, to show what to his mind were the possibilities of its future, we need only refer to the multifarious purposes to which electricity was applied at his country residence near Tunbridge Wells. There electricity might be found doing the great part of the actual work of the farm—sawing wood, and pumping water, and driving most of the various mechanical appliances on the premises. The very latest use to which it was here applied was for horticultural purposes. The electric light was used during the hours of darkness to continue the sun's work, in promoting the growth and ripening of plants and fruits, or, in other experiments, to compete with the sun in this work; the results in this latest application being made the subject of papers by Siemens, contributed to the Royal Society in March, 1880, and to the York Meeting of the British Association in 1881.

In the foregoing, we have sought to exhibit the life work of Sir William Siemens, not in its chronological order, but as viewed in the two departments "Utilisation of Heat" and "Utilisation of Electricity." Of the thirty-five papers which appear under his name in the Catalogue of Scientific Papers, and which do not include the last ten years of his life, all are with, perhaps, one not happy exception, more or less directly the result of his efforts in one or other of these directions. The exception referred to is his paper "On the Conservation of Solar Energy," contributed to the Royal Society, February, 1882, and embodied in an article, "A New Theory of the Sun," published in the "Nineteenth Century" of April, 1882; but even this may well be considered no exception, from its evident connexion with the principle of "Regeneration of Heat," and treating, as it does, of the sun imagined as a great regenerative gas furnace. Careful consideration of the circumstances, however, shows this view to be wholly untenable. While his papers are thus almost wholly of a practical nature, his work in the domain of pure science has been neither slight nor unimportant, because, in experimentally developing his inventions, his mind was ever on the alert, and hence his efforts towards the practical application of the results of science, in many cases, served to put these results in a clearer light.

Sir William Siemens has received recognition of his services to pure and applied science from the Emperor of Brazil, the Shah of Persia, and from France both under the Empire and the Republic, whilst in April last Her Majesty was graciously pleased to confer upon him the honour of knighthood. He was a member of nearly all the scientific societies of Great Britain; he was the senior member of council of the Institution of Civil Engineers; he was elected a member of the Royal Society in 1862, and has twice served on the council of that body. He has been President of the Institution of Mechanical Engineers, twice of the Society of Telegraph Engineers, of the Iron and Steel Institute, and last year, at Southampton, of the

British Association; whilst at the time of his death he was Chairman of the Council of the Society of Arts. He was made a D.C.L. of Oxford *honoris causâ* in 1870, an LL.D. of Glasgow in 1880, of Dublin in 1882, in which year the University of Würzburg also bestowed on him its honorary Ph.D. He was a corresponding or ordinary member of several learned societies in Europe and in America.

In private life Sir William Siemens, with his lively, bright intelligence always present, and eager to give pleasure and benefit to those around him, was a most lovable man, singularly unselfish and full of kind thought and care for others.

We shall conclude by quoting the closing lines of an article which appeared in the "Times" of November 21, 1883, "On the Life and Work of Sir William Siemens." They are words with which all who knew him or came in contact with him can fully sympathise, and they will, besides, serve to indicate the estimation in which he was held by the people of his adopted country:—"Those who knew him may mourn the kindly heart, the generous noble nature, so tolerant of imperfect knowledge, so impatient only at charlatanism and dishonesty; the nation at large has lost a faithful servant, chief among those who live only to better the life of their fellow-men by subduing the forces of nature to their use. Looking back along the line of England's scientific worthies, there are few who have served the people better than this her adopted son—few, if any, whose life's record will show so long a list of useful labours."

Jean Baptiste André Dumas was born at Alais, in the Department of the Gard, July 14, 1800.

The little town of Alais was almost unknown at the beginning of this century, being inhabited by only a few thousand souls. Nevertheless, young Dumas found there everything conducive to the expansion of a youthful intellect and to the development of a well-built frame.

A college which had then no lack of pupils fulfilled the requirements of the boy's early education, initiating him more especially in the study of Latin, so congenial to the classical traditions of the neighbourhood.

These associations could not but have had a tendency to direct the mind of young Dumas to the study of the past; but there were other influences, not less potent, continually calling him back to the present. Indeed, the town of Alais, by its unique situation, afforded opportunities of observing nature and the processes of adapting her products to the use of man, which proved not less attractive to the future Academician. Both in his speeches and writings he frequently refers with gratitude to these varied impressions of his early youth at Alais.

It would be difficult to imagine a happier complement to a classical education than the lessons taught at every step in this delightful country. Nor were they lost upon young Dumas, who at fourteen years of age, in addition to his rare attainments in classical literature, had acquired a rudimentary knowledge of the several natural sciences. Having made up his mind to enter the navy, he might at once have presented himself for examination, had it not been for an insufficient acquaintance with some branches of mathematics, in which, owing to the limited instruction given at the college, his information had hitherto remained of a very elementary character.

While Dumas was still preparing for his naval examination, the political events of 1814–15 obliged his family to renounce this project and to select a career for the youth which would entail less sacrifice.

Dumas accordingly entered as apprentice at an apothecary's in Alais. This position, in which he pursued his first practical studies, did not afford much opportunity for scientific progress, and the young man became soon impressed with a strong desire to give up this place and to quit his native town. This feeling, indeed, became so intense that his parents, moved by his evident distress, thought it best to accede to his wishes.

Soon after, in 1816, Dumas travelled on foot from Alais to Geneva, where he found everything to expand his ideas, to stimulate his emulation, and thus to prepare him for his future career. There were lectures on botany by M. de Candolle, on physics by M. Pictet, and on chemistry by M. Gaspard de la Rive. He had, besides, the superintendence of a tolerably large laboratory, belonging to the pharmacy of Le Royer, and formerly used for the courses of applied chemistry given by M. Tingry.

The pharmaceutical students, who frequently united in botanical excursions during the summer, started the idea of winter meetings for scientific studies. Seeing that Dumas had a laboratory at his disposal, it was suggested that he should give them a course of experimental chemistry. This was his *début* in the professorial career.

Meanwhile Dumas had become introduced to Gaspard de la Rive, to Theodore de Saussure, and to De Candolle, and each of these in his way began to take a warm and lasting interest in him; they encouraged his studies, and assisted him to the best of their powers in his pursuits. It was most likely at the instigation of his new friends that Dumas, reviving his early naval predilections, began seriously to think of, and to prepare for, an exploring expedition to some distant part of the world. A monograph on the Gentianeæ, chiefly written for the purpose of becoming familiar with the language and the ideas of botanical science, was a fruit of these aspirations.

But this was not to be his mission. Biot's great treatise, which for

half a century was to remain the standard text-book on physics, had just appeared, and Dumas had found, more especially in the first volume, plenty of subjects directing his attention to the art of experimenting, of making observations, of consulting nature, and of discovering the laws of her phenomena. The "Annales de Chimie" offered him, moreover, splendid models in the papers of Berzelius, Davy, Gay-Lussac, and Thénard. At the same time he studied with indefatigable zeal the works of Lavoisier, and the "Statique Chimique" of Berthollet.

Dumas was then eighteen years of age. It was about that time that he had the good fortune to make himself useful to one of the principal physicians of the town, a circumstance which contributed not a little to advance him in the circles in which he had hitherto lived. Dr. Coindet asked him to examine some carbonised sponges, and to ascertain more especially whether iodine was present in them. Having after some days received an affirmative answer, Dr. Coindet no longer hesitated to consider iodine a specific against goitre. Dumas was then asked to give his attention to the subject and to point out the preparations in which iodine might be most conveniently administered. He suggested tincture of iodine, potassic iodide, and iodised potassic iodide. Soon afterwards these new remedies were mentioned in a German journal published at Zurich, and it is in this connexion that the name of Dumas is first met with in scientific literature.

About that time Dr. J. L. Prévost, after an absence of several years, returned to Geneva. He had long been resident in Edinburgh and Dublin, devoting himself to comprehensive studies in the several departments of medicine. Among these was a particular examination of the physiological effects of digitalis, and he was naturally anxious to obtain the active principle of the plant free from all foreign matter accompanying it. He invited Dumas to join him in this inquiry. The problem to be solved consisted in successively removing all that appeared inert so as to concentrate the active constituent, which would ultimately remain in a state of purity. The chemical properties of this principle being unknown, the only means of estimating the concentration was to observe the effect of the concentrated substance upon animals. This slow and irksome process of elimination did not lead to any result; it is well known that the isolation of digitaline was not effected until some years later. But however unsuccessful, these joint labours gave rise to a far more fruitful collaboration.

Whilst studying together the physiology of Richerand, a work then in great repute, and the memoirs of Magendie, which were beginning to attract increased attention, the two friends resolved to engage in a series of chemico-physiological researches.

It seemed natural enough to commence these researches by a

renewed study of the blood, and they were soon able to publish a paper upon this subject. This appeared in the "Bibliothèque Universelle de Genève," and in the title Dumas still figures as *Elève de Pharmacie.* The results arrived at by the young inquirers for a long time satisfied the wants of science, and if our knowledge of the blood has been considerably expanded by many subsequent observers, the experiments of Prévost and Dumas have invariably served as a starting point for these inquiries.

It was about that time that the death of Princess Charlotte had excited a feeling of sorrow all over Europe. The pathological problem presented by this sad event induced the two experimentalists to resume the study of the transfusion of blood. This problem has since been frequently examined, but these renewed inquiries have added but little to the knowledge elicited by Prévost and Dumas' researches upon the subject.

A very important result at which they arrived was, moreover, the demonstration of the presence of urea in the blood of animals the kidneys of which had been removed. They inferred from this observation that the function of the kidneys is not to produce but to eliminate urea formed in the blood. Their experiments have been repeated by the most distinguished observers, among whom it suffices to name Gmelin, Tiedemann, and Mitscherlich, and the conclusions to which they led are therefore generally adopted by physiologists. We should not, however, leave it unmentioned that, during the last few years, some dissenting voices have been heard, and that some modern physiologists believe they have proved that urea is also generated by the kidneys. But if it should ultimately be proved, beyond doubt, that the kidneys, like many other organs, more especially the liver, have the power of producing urea, elimination of urea formed elsewhere would be still the principal function of the kidneys, although not the only one, as Prévost and Dumas have been led to believe from their experiments.

From the researches on blood Prévost and Dumas proceeded to the examination of the phenomenon of fecundation, the knowledge of which they considerably expanded. It deserves more especially to be noticed that, notwithstanding some previous observations by Swammerdam and Spallanzani upon the subject, modern physiologists are unanimous in recognising Prévost and Dumas as the discoverers of the phenomenon of segmentation in the ovum of the Batrachians. At the same time these investigators observed that at a certain stage of fecundation there escapes from the ovary of the Mammalia a limpid almost microscopic vesicle which enters the Fallopian tube, and proceeds to the uterus, where, when impregnated by the spermatozoids of the male, it is fixed, and, increasing in size and development, gives rise to the fœtus. Prévost and Dumas must

thus be looked upon as the precursors of C. E. Baer, whose classical researches on the genesis of the ovum in the Mammalia and in man appeared in 1827.

Simultaneously with their researches on blood and fecundation, Prévost and Dumas published several other physiological investigations not immediately connected with the main subjects of their studies. The urine and the organs of secretion of frogs successively engaged their attention. They also studied the phenomena accompanying the contraction of muscular fibre.

Lastly, Prévost and Dumas' suggestion as to the treatment of stone by electricity should not be left unnoticed. Their experiments showed that the current of a powerful battery is capable of destroying and dissolving the phosphatic calculi of the bladder, without its mucous membrane being materially affected. Although, at a subsequent period, these researches were continued and materially enlarged by the late Dr. Bence Jones, the author of this sketch has not been able to learn that the treatment indicated by these remarkable results has been successfully applied in surgery.

At this period, *i.e.*, in 1822, Dumas might have settled at Geneva, and many circumstances led him to think seriously of doing so. An incident, however, which happened at that time, and which at first sight seemed in no way likely to influence a well-matured plan of life, induced him within a few days to change his mind. He made the acquaintance of Alexander von Humboldt, who invited him to be his companion during a few days' stay at Geneva. The short intercourse with this extraordinary man suddenly expanded his aspirations.

The memorable hours he had spent with him had opened a new world to his mind. He had been more especially impressed with what he had told him of Parisian life, of the happy collaboration of men of science, and of the unlimited facilities which the French capital offered to young men wishing to devote themselves to scientific pursuits. He began to think that Paris was the only place where under the auspices of the leaders of physical and chemical science, with whom, he had no doubt, he should soon become acquainted, he might hope to find the advice and assistance which would enable him to carry out the labours over which he had been pondering for some time. His mind was soon made up—he must go to Paris.

Dumas' removal to Paris, which took place in 1823, brought the physiological labours in which he had been engaged along with Prévost to a conclusion. Though the separation from a friend, with whom he had been in daily intercourse for so many years, must have been deeply felt by the young *savant*, who had now to steer his course alone, he had the good fortune to become acquainted with three young men of about his own age, with whom he soon entered into friendly

alliance. These were Victor Audouin, the zoologist, well-known even at that time, Adolphe Brongniart, who had already published several important botanical papers, and Henri Milne Edwards, who had just terminated his medical studies and was working for his degree. The friendship of these three men, matured by daily intercourse and subsequently strengthened, if possible, by family ties, has ever been looked upon by Dumas as one of the most important acquisitions of his life, not only proving to him an inexhaustible source of the purest pleasures, but likewise materially assisting in shaping that successful career which has made the name of Dumas a household word in the mouths of chemists.

If a legitimate desire to become acquainted with the leading men of science of that day was one of the principal motives in determining Dumas to leave Geneva, his wishes were gratified far beyond his most sanguine expectations. Nothing could have surpassed the kindness with which the young aspirant was received by the very men to whom he had hitherto been looking up with mingled sentiments of reverence and awe. Indeed, a most kindly feeling of good fellowship towards youthful workers in the same field of inquiry was a noble feature in the character of nearly all men of science of that period. La Place, Berthollet, Vauquelin, Gay-Lussac, Thénard, Alexandre Brongniart, Cuvier, Geoffroy Saint Hilaire, Arago, Ampère, Poisson, all gave striking proofs of their desire to smooth the path of young investigators, and thus to promote the advance of science.

The place of Répétiteur de Chimie to Thénard's course of lectures in the École Polytechnique having become vacant at that time, Arago proposed Dumas for the office, and he was elected by the council of the school before he had become aware that he was a candidate. There was at that period in Paris an establishment for evening lectures on literature and science, resembling in a measure the Royal Institution of Albemarle Street, though the literary element predominated. The chair of chemistry at that institution, often called Lyceum, but better known by its later name of Athenæum, had become vacant, and Ampère succeeded in procuring the appointment for Dumas without having previously spoken to him on the subject.

From this moment, owing to the influence of his two illustrious protectors, the study of physiological questions receded more and more in the background, while his full energy was directed towards the solution of chemical problems.

Still many circumstances conspired which prevented Dumas from engaging much in scientific researches during the first years of his stay in Paris. His lectures at the Athenæum required a great deal of preparation; he was, moreover, in his capacity as assistant to Thénard's course at the École Polytechnique, assiduously practising the art of experimenting in public, in which he soon attained the

highest degree of proficiency. At the same time he founded (in 1824), with his friends Audouin and Brongniart, the "Annales des Sciences Naturelles," and also began to collect the materials necessary for the publication of his grand "Traité de Chimie appliquée aux Arts," the first volume of which appeared in 1828.

But if this period was for Dumas one of incessant labour, and often of the most strenuous efforts, it also enabled him to realise the most ardent of his aspirations. For some time Dumas had been intimate with the family of Alexandre Brongniart, the father of his friend Adolphe, and was not long before he became betrothed to Mdlle. Herminie Brongniart, the eldest daughter of the illustrious geologist. It was on February 18, 1826, that the matrimonial alliance was concluded which has been for more than half a century a source of the purest happiness for both consorts.

At the very commencement of his labours in the cause of organic chemistry Dumas had found himself face to face with a powerful rival in Germany, who, setting out by a curious coincidence from the same starting-point, the study of pharmacy, had entered the lists without passing through the physiological and natural history stages of his competitor. Liebig and Dumas have had, indeed, some strange encounters on the field of science. These encounters, to which we may have to refer hereafter, were occasionally rather violent, as might have been expected when two young and fiery champions, each persuaded of the justice of his views, were rushing at each other. Once or twice perhaps in the heat of battle an unguarded word might have sounded like personal provocation; but however fierce the aggression, the combatants never forgot that they were both fighting under the banner of truth, and the contest having been decided, the antagonists invariably separated with increased regard for each other.

But we must return to Dumas' early labours in the field of experimental investigation. They were by no means exclusively devoted to organic chemistry; indeed, one of his first researches, which riveted at once the eyes of the scientific world upon the young French chemist, was of a much larger scope. We allude to the classical paper, "On some Points of the Atomic Theory," which was published in the "Annales de Chimie et de Physique" for 1826, and in which the author soars to the very heights of chemical science. Whoever to-day, after a lapse of nearly sixty years, peruses this admirable memoir, which aims at the solution of old problems by new methods, cannot but gratefully acknowledge that a good deal of what has long since become common property, is rooted in its substance; but he will at the same time be astonished to perceive that many of our modern views, which we are in the habit of considering as the acquirement of the last few decades, had already found expression in this paper.

In glancing back at the results of this memoir in the light of our

present views, we perceive at once what a start the French chemist had gained on his contemporaries. "I am engaged in a series of experiments," he says, "intended to fix the atomic weights of a considerable number of bodies, by determining their density in the state of gas or vapour. There remains in this case but one hypothesis to be made, which is accepted by all physicists. It consists in supposing that in all elastic fluids observed under the same conditions, the molecules are placed at equal distances, *i.e.*, that they are present in them in equal numbers."

It is obvious that the author opens his inquiry with the very conceptions which form the basis of our present views in chemical philosophy; and it is only to be wondered at that the happy enlistment of Avogadro's ideas into the service of chemistry, which we owe to Dumas' initiatory sagacity, should for more than a quarter of a century almost have fallen into oblivion.

Having premised in lucid terms the general scope of his inquiry, Dumas proceeds to describe the several modifications of the well-known method of taking vapour-densities with which he has endowed science, and which went forth from his hands in such a state of consummate perfection that there has scarcely been room left for subsequent emendation.

The narrow compass of this sketch does not permit us to quote the numerous results communicated by Dumas in his paper; we will mention, however, that the determination of the vapour-density of chloride and fluoride of silicon elicited the view now held regarding the constitution of silicic acid, thus overthrowing the old formula of this compound upon which Berzelius had based his classification of silicious minerals.

There were other experimental researches of importance carried out by Dumas about this period. It had long been his intention to resume the study of the compound ethers, to which he had devoted considerable attention at Geneva. In conjunction with Boullay he proceeded to an elaborate investigation of nitrous, acetic, benzoic, and oxalic ethers. The composition of these substances was finally settled by accurate combustions and vapour-density determinations. They further elicited by unequivocal experiments the capital fact that the decomposition of compound ethers by alkalies gives rise to quantities of acids and alcohol, the joint weight of which is greater than the weight of the compound ethers submitted to experiment, and by accurately determining this difference they succeeded for the first time in establishing the nature of compound ethers on the solid foundation of experiment.

These investigations led to other inquiries teeming with most remarkable results, among which, those on the formation of oxamide, on chlorocarbonic ether, and on urethane may be specially

mentioned. Here, also, the splendid papers on wood-spirit and spermaceti, jointly published by Dumas and Peligot, deserve to be noticed, although they belong to a somewhat later period.

While the experiments on the ethers sketched in the preceding paragraphs were still going on, a strange incident directed the attention of Dumas to a perfectly different order of phenomena, the study of which occupied him for many years of his life, and ultimately led him to one of his finest conceptions, the theory of substitution. It is not generally known that it is to a *soirée* at the Tuileries that the origin of the substitution-theory must be traced. One evening the visitors at the palace were greatly incommoded by irritating vapours diffused throughout the apartments, and obviously arising from the wax candles burning with a smoky flame. Alexandre Brongniart, in his capacity of director of the porcelain manufactory at Sèvres, was looked upon as chemist to the king's household, and it appeared but natural that he should be consulted respecting this unpleasant incident. Brongniart intrusted his son-in-law with the task of investigating the suspicious candles, and Dumas was all the more inclined to engage in this inquiry, that he had already made some experiments in that direction, having been asked by a merchant to suggest a method of bleaching certain kinds of wax which resisted the ordinary processes, and thus remained unsaleable. Nor had Dumas any difficulty in supplying the explanation. The irritating vapours were chlorhydric acid, and it was thus obvious that the candle manufacturer supplying the palace had made use of wax bleached with chlorine, and that the chlorine-bleached wax had retained chlorine, which during the combustion of the wax was evolved in the form of chlorhydric acid. The origin of the inconvenience experienced at Charles X's *soirée* was thus satisfactorily explained, and its recurrence easily obviated. At the same time it was proved by experiment that organic substances when treated with chlorine are capable of fixing this element in quantities far too large to admit the assumption of its presence being an accidental contamination. A new field of investigation was thus opened, on which within a comparatively short time a harvest of results of startling novelty was reaped by Dumas.

It is well known that the researches suggested by the experiment above mentioned led to the view of chlorine being capable of replacing hydrogen, atom for atom, in organic compounds.

This view, diametrically opposed to the dualistic conception of the electrochemical theory of the time, was vehemently contested by Berzelius and his school, who exhausted the resources of argument, scorn, and even ridicule against them. Nevertheless, Dumas' ideas rapidly took root, and but a few years later substitutional conceptions began to prevail in the researches of the younger generation of

chemists. An additional impetus was given to the movement when it was joined by Laurent, who, though often so much at variance with Dumas, as to become, more especially in consequence of questions of priority as to certain collateral ideas, his declared opponent, has nevertheless, by amplifying the original conceptions and by presenting in his unremitting researches ever new and welcome illustrations of them, assisted more perhaps than any other chemist in the propagation of the theory of substitution.

We cannot, of course, attempt to examine the several experimental researches, extending over a considerable space of time and embracing a great variety of subjects, which served as scaffolding to Dumas when building up his substitutional and typical conceptions; all we can do is to allude in a few words to the experiments which furnished him with his principal illustrations.

Proceeding chronologically, we should have to refer in the first place to Dumas' experiments on cinnamon oil and cinnamic acid. Again, excellent illustrations of substitution are furnished by his work on olefiant gas and ordinary ether.

His examination of the action of chlorine upon alcohol, too, served to illustrate his theory; although in these experiments he was forestalled by Liebig, who by his researches had been led to the discovery of chloral and chloroform. But if Dumas lost the discovery of these two compounds, he had at all events the satisfaction of establishing their true composition, and of thus supplying the key to the correct interpretation both of the formation of chloral from alcohol and of its decomposition, first pointed out by Liebig, into formic acid and chloroform, when submitted to the action of alkalies.

But the inquiry, which more perhaps than any other has contributed to establish Dumas' ideas in the minds of chemists, is his splendid investigation of the action of chlorine upon acetic acid. The trichloracetic acid formed in this reaction retains all the characteristic properties of the mother compound, its salts and its ethers resemble those of acetic acid, and when Berzelius and the champions of dualistic views still endeavoured, by constrained interpretation, to prove acetic and chloracetic acid to differ in constitution, Dumas showed that even their metamorphoses are strictly analogous.

Among the numerous researches undertaken with a view of elucidating the theory of substitution, a joint inquiry of Dumas and Stas on the action of alkalies on alcohols and ethers must not be forgotten. They prove that the alkalies act as oxidising agents, hydrogen being evolved, whilst the acids belonging to the alcohols are simultaneously produced. Amylic alcohol, then just brought to light by Dumas and Cahours' researches, is thus found to yield valeric acid, up to that time obtained only from *Valeriana officinalis*.

A few years later Dumas returned once more to the acids generated

by the oxidation of the alcohols. But what on this occasion fixed his attention was the simple relation in which these acids stand to each other. For the first time, indeed, we hear of the series of fatty or aliphatic acids. The observations recorded by Dumas have greatly contributed to develop the classification of organic compounds in homologous series. A very important series of this kind was indicated by Dumas when, on this occasion, he showed that between formic and margaric acids not less than fifteen acids could be assumed to exist, differing from one another by a constant elementary difference, CH_2, of which nine at least were known at that time.

The number of elements with which organic chemistry works in building up her structures being so very limited, it was but natural that from the very first considerable attention should have been bestowed upon the quantitative analysis of organic substances; and that we find the very chemists who laid the foundation of organic chemistry also engaged in elaborating the methods for determining the organic elements. There are, indeed, no two chemists to whom we are more deeply indebted for the growth of our methods of analysing organic substances than Liebig and Dumas, and we are delighted that in the language of the laboratory their names remain associated with the processes they have introduced. We speak of Liebig's method of estimating carbon and hydrogen, and of Dumas' process for determining nitrogen.

Referring to the methods of determining the composition of organic substances, it is but natural that we should allude to the services which Dumas has rendered to organic analysis, by the revision jointly carried out with Stas of the atomic weight of carbon. This revision furnished the number 12 instead of 12·24, which was the number adopted by Berzelius. Dumas and Stas's investigation will ever be looked upon as a model for experimental researches, and their atomic weight of carbon, although it has still suffered a trifling modification by subsequent researches, has since been universally adopted.

The results arrived at in this inquiry naturally also led to a revision of the atomic weight of oxygen—in other words, to a revision of the composition of water—which appeared all the more desirable, since chemists at that period very generally began to use the atomic weight of hydrogen as the atomic unit instead of that of oxygen which had been previously employed. Experiments made by Dumas on a scale not hitherto attempted, and consisting in the reduction of large quantities of oxide of copper—from 300 to 900 grams were used—and determining the oxygen supplied by the oxide reduced as well as the water formed, showed the volume weight of oxygen to be exactly 16, and thus the fundamental numbers 1, 12, and 16 for hydrogen, carbon, and oxygen were acquired which for a long time satisfied the wants of chemists.

The corrections to which the experiments previously mentioned had led, as regards the composition of carbonic acid and water, suggested also a re-examination of atmospheric air. Dumas undertook this investigation in conjunction with his friend Boussingault. The method of analysis adopted was exclusively ponderal.

The composition of air thus arrived at by Dumas and Boussingault is—

	By weight.		By volume.
Oxygen	23	....	20·81
Nitrogen....	77	....	79·19
	100	....	100·00

The rectification of the atomic weight of carbon and the inquiries more immediately connected therewith must be looked upon as the prelude of Dumas's long series of researches on the atomic weights of the elements. They were mostly published at a later period (from 1858 to 1860). A few fragmentary statements must suffice to convey to the reader an idea of the magnitude and variety of these researches. They embrace not less than thirty elements, or about one-half of those then known; the number of experiments made for the purpose of fixing their atomic weight closely approach 200, so that on an average about six separate analyses were made in each case.

Among the researches carried out by Dumas in conjunction with other chemists we have still to notice those with Malaguti and Leblanc on the transformation of the ammonic salts and amides into the alcohol cyanides (nitriles), those with Cahours on the composition of the neutral nitrogenous substances in the vegetal and animal organism, those with Milne Edwards on the conversion of sugar into fat (wax) within the organism of the bee.

The last experimental inquiries published by Dumas are his researches on alcoholic fermentation (1872), and an interesting paper on the occlusion of oxygen in silver, which appeared as late as 1878.

Lucidity of exposition and grace of style are not necessarily associated with the gift of successfully interrogating nature. It happens but too frequently that the results of admirable inquiries are almost hidden in papers hastily, not to say negligently, written. But no one ever found fault with Dumas in this respect. Few chemists, perhaps, published their researches in a more attractive and lucid form. And the same graceful elegance and perspicuity of style are found in whatever proceeded from his pen. One might fancy that he took the same pains whether it was a friendly letter or an elaborate report, a festal oration or a philosophic essay that he was writing; or, perhaps, we should rather say, they seem all to have been written with the same facility.

The works of Dumas present considerable variety, both as to the

subjects discussed and to the form of treatment adopted. There are several elaborate treatises and a great many minor pamphlets. His academical notices, his official documents, his municipal reports, his festal speeches, his opening discourses, his commemoration addresses, his funeral orations, are countless. We may be allowed briefly to allude to his more important writings.

Among these, his "Traité de Chimie appliquée aux Arts" deserves to be noticed first. This important work, which is dedicated to Baron Thénard, consists of eight volumes, the first of which, as has been already stated, appeared as far back as 1828; the last one was published twenty years later. It is accompanied by a fine Atlas of Plates. The treatise has been translated into several languages, the German edition being by Gottlieb Alexander and Friedrich Engelhart. In the preface the author informs us that the book is founded upon the notes collected for a course of chemical technology extending over three years, which he had to deliver at the Royal Athenæum. And nothing could give a better idea of the time and energy devoted to the preparation of these lectures. The labour of accumulating such a mass of facts must certainly have been enormous, nor could the effort made in disposing them in such luminous order have been less.

At a later period, about ten years after the first volume of the "Traité de Chimie appliquée aux Arts" had appeared, Dumas' celebrated "Leçons sur la Philosophie Chimique" were published. In these eleven lectures, which, during the summer of 1836, were delivered in the College of France, he traces the development of chemical doctrines from remotest antiquity up to the time at which the course was given. Indeed, the last lecture is devoted to the generation of electricity by chemical action, to the chemical effects of the battery, to the ever-memorable experiments of Sir Humphry Davy, and to thee lectro-chemical theory he founded thereon, as well as to the electro-chemical theories of Ampère and Berzelius; while it concludes with a survey of Faraday's electrolytical researches.

Among the numerous writings of Dumas none, perhaps, has found a more cordial reception in wide-spread circles than the lecture with which on August 23, 1841, he concluded his course of chemistry in the Medical School of Paris. This lecture is published under the title "Essai de Statique Chimique des Êtres Organisés," par MM. Dumas et Boussingault, and gives in a simple form the principal features of the life of plants and animals considered from a chemical point of view, presenting a most eloquent *résumé* of the chemical and physiological researches in which the two friends, either individually or jointly, had been engaged for many years.

The publication of this lecture gave rise to a dispute between Dumas and Liebig regarding the priority of the ideas propounded

therein. The great German chemist having but a year previously, in 1840, published his celebrated work, "Organic Chemistry in its Application to Agriculture and Physiology," had been naturally led to investigations of a similar order concerning the chemical phenomena of animal life, and was then actually preparing his "Chemistry applied to Animal Physiology." Liebig, no doubt, had freely stated the results of his researches in lectures delivered long before the publication of Dumas and Boussingault's pamphlet; but there is not a shadow of proof that Dumas was influenced by inquiries which at the time were not published. The accusations, it cannot be denied, rather hastily hazarded by Liebig, could not but cause a temporary estrangement between the two great chemists. Fortunately it was of only short duration, and left, as we already have had occasion to learn from their own mouths, no bitterness in their minds. Nor was there any cause for such estrangement. Indeed, the unbiassed reader of to-day no longer doubts that the conceptions which formed the subject of dispute were independently arrived at by both inquirers. And we are all the more confirmed in this view when we learn that documents have since been found which unmistakably prove that as far back as 1792 Lavoisier was acquainted with the mutual relation presented by the phenomena of vegetal and animal life.

We have still to allude to the important series of commemoration addresses which Dumas delivered on many of his departed friends and colleagues. Each one of these addresses, which collected would fill an imposing volume, is a work of art we are never tired of contemplating; each one attains its end by giving a life-like portrait of the person commemorated, a portrait which remains indelibly stamped on our memory. We know not which to admire most, the conciseness which excludes all that is non-essential from the sketch, or the poetic inspiration which fires the monumental style and throws upon the form it pictures the light of an ideal conception. Nor are these addresses wanting in numerous interesting particulars which, drawn from the author's own personal intercourse with his heroes, give a life-like colouring to his portraits. Such commemoration addresses Dumas has delivered on Auguste Béroet, Jules Pelouze, Geoffroy Saint-Hilaire, Auguste de la Rive, Alexandre and Adolphe Brongniart, Guizot, Antoine Balard, Count Rumford, Victor Regnault, Charles and Henri Sainte Claire-Deville.

Nor should, when Dumas's commemoration addresses are enumerated, his beautiful Faraday lecture be left unnoticed. It is well known that soon after Faraday's death in 1867 the Council of the Chemical Society of London organised a periodical celebration of his life and labours by instituting a triennial prize to be conferred upon scientific men of all countries whom they proposed from time to time to invite for the purpose of rendering homage to the memory of the

great experimental inquirer of our century. It was Dumas who, on June 17, 1869, opened this cycle of commemoration addresses by delivering a most eloquent lecture in the theatre of the Royal Institution, where the voice of Faraday himself had been so often heard.

Essentially different from these commemoration addresses, but not less masterly of their kind, are the numerous orations he delivered —sometimes in the name of the Academy, sometimes in his capacity as Vice-President of the Educational Council—at the funeral obsequies of distinguished men, amongst which those on Elie de Beaumont (1874), on Le Verrier (1877), and on Claude Bernard (1878), may be specially mentioned.

But there were other duties than the delivery of commemoration addresses in store for the academician. Any task imposed upon the Institute in the accomplishment of which chemistry was directly or indirectly concerned, invariably devolved upon Dumas.

The "Comptes Rendus" of the last fifty years contain an endless series of reports addressed to the Academy, which, on a great variety of subjects, either alone or in conjunction with some of his colleagues, he drew up. Were we to attempt to do full justice to this part of Dumas' work, we should have to ask the reader to accompany us into the most different departments of inquiry.

Some of these reports are elaborate essays, the interest in which will not die with the ephemeral conditions of their origin. Among them, those on Nicolas Leblanc and the early history of the soda-process, on the diseases of the silkworm, on the devastations of the phylloxera, may be quoted as illustrations.

We have still to allude to some literary achievements of another character. It has been already stated that in 1824 Dumas founded, in conjunction with his friends Audouin and Adolphe Brongniart, the "Annales des Sciences Naturelles." At a later period, in 1840, he became one of the editors of the "Annales de Chimie et de Physique," an office which he held up to his death. He has thus been an editor of that journal for upwards of forty years, but his contributions to it extend over more than half a century.

The lectures at the Athenæum, together with the literary engagements which they had occasioned, his duties as Répétiteur at the École Polytechnique, and the experimental researches continued without interruption, would have left but little leisure to any man of ordinary energy. Dumas, however, found time for additional work. Well aware of the imperfection of scientific instruction for technical purposes in the then existing institutions of France, he conceived the idea of establishing, in conjunction with his friends Théodore Olivier and Eugène Péclet, a school intended to supply the defect. The new school, which assumed the title of "École Centrale des Arts et Manufactures," was opened in 1829.

At first Dumas lectured at this school on general, analytical, and industrial chemistry. At a later period, when its financial position permitted the appointment of additional chemical teachers, he confined himself to either one or other of these branches. The lectures on general chemistry he continued up to 1852, when he resigned in favour of Cahours.

The number and variety of lectures which Dumas had to deliver at the École Centrale immediately after its opening, in addition to his duties at the Polytechnic School, rendered it an absolute necessity for him to diminish his engagements elsewhere, so as to enable him to find time for the various researches he had then in hand. Nor did he hesitate (in 1829) to retire from the Professorship at the Royal Athenæum, to which Bussy was then appointed. The alleviation thus obtained was not of long duration. In 1832 Guy-Lussac resigned his chair at the Sorbonne, which, like a natural inheritance, fell to Dumas; and to this position, which he held up to 1868, when Henri Ste. Claire-Deville, after having acted as his substitute since 1853, became his successor, was soon added another important appointment. For when (in 1835) Thénard withdrew from his Professorship at the École Polytechnique, the duties of the office devolved upon Dumas, who for twelve years had been a Répétiteur at the School. Dumas was, in fact, appointed, and remained in connexion with the Institution up to 1840, when he resigned in favour of Pelouze. The list of his Professorial appointments, however, is not yet exhausted. After the death of Deyeux (in 1839) he was induced, chiefly by Orfila, to undertake the duties of the Chair of Chemistry in the École de Médecine.

In these several positions Dumas had to lecture on very different subjects: he had, moreover, to shape his courses according to the traditions of the places in which he lectured, and to adjust them to the different ages, acquirements, and wants of the students he addressed. His unprecedented success as a lecturer is unequivocally proved by the lively and lasting recollections which his lectures, addressed to such a diversity of audiences, have left in the minds of his hearers. Even those who have had the good fortune of attending but a single one of his lectures will ever remember the clearness and precision of his reasoning and the attractive grace of his delivery.

But it was by no means only in lectures that Dumas has sown broadcast the seeds of chemical science. He was, in fact, the first in France to adopt that efficient system of laboratory teaching so happily inaugurated by Liebig, which has ever since been a prominent feature of the German Universities. The laboratory which he had established in the École Polytechnique, though well adapted for an experimental inquirer working along with his assistant, was altogether unfit for the reception of a number of pupils. That he might be able to associate

with experimental students, he founded, as early as 1832, a laboratory of research at his own expense.

Almost immediately after the Revolution of February new labours of the most diverse kind began to encroach upon Dumas' scientific work. The political and social upheaval of 1848, shaking, as it did, the stability of all French institutions, turned into political and administrative courses many men of mark whose energies had been hitherto exclusively devoted to the service of science. It would have been strange, indeed, had not the want been felt of securing Dumas' well-tried powers for the public affairs of the country. Election to the National Legislative Assembly, appointment as Minister of Agriculture and Commerce, admission to the Senate, President of the Municipal Council of Paris, and nomination as Master of the Mint of France, are the steps by which he rapidly rose in his new career.

With the fall of the second Empire the political and administrative career of Dumas came to an abrupt termination. The Senate had ceased to exist, and in the stormy days which followed, the Municipal Council had naturally changed its composition; and even in the Mint, where his rich experience and his rare talent of organisation might have been still of such use in the public service, the man who played so conspicuous a part under the Imperial Government had to vacate his place.

Having thus withdrawn from his official positions, Dumas found himself at the age of seventy in the possession of *otium cum dignitate;* but he never allowed himself to enjoy it in any other than the Ciceronian acceptation of the words. After his retirement from political and municipal life Dumas once more exclusively belonged to science. There was no chemical aspiration which he was not anxious to assist, no problem in the domain of chemistry, physics, or physiology to the solution of which he was not happy and proud to contribute, no scientific movement of any kind to the furtherance of which he was not willing to open the treasury of his matured experience or to lend at least the prestige of his name. But he was never more happy than when, in furthering science, he was at the same time able to serve the material wants and to promote the well-being of his fellow-citizens.

That to scientific services continued for upwards of half a century science should have accorded with unstinted hand a rich share even of her external marks of honour was but to be expected; no Academy, no learned Society but has deemed it an honour to inscribe the name of Dumas on its register. A member of the French Institute at the early age of thirty-two, he has in due time reaped the full harvest of distinctions in store for successful cultivators of science. He became a correspondent of the Berlin Academy of Science in 1834, and a Foreign Associate of that body in 1880; he was elected a Foreign Member of the Royal Society of London in 1840. He was an hono-

rary member of the English, French, and German Chemical Societies. These associations, the second of which originated in Dumas' laboratory, elected him as a matter of course immediately after their institution. In 1843 the Royal Society awarded to him the much-coveted Copley Medal. That he was the first to obtain the Faraday Medal in the gift of the Chemical Society of London, has been already mentioned. Dumas was a Knight of the Prussian Order *pour le Mérite*, the highest scientific honour Germany can bestow, and it may further be added that he received the Grand Cross of the Legion of Honour, and was a Knight of a goodly number of other Orders in Christendom.

In the autumn of 1883 Dumas' health, which up to that time had been unimpaired, began to fail. By the advice of his physicians he passed the winter in the south of France. He died at Cannes on 11th of April, 1884. A. W. H.

[For further information the reader is referred to a sketch of Dumas' life and labours, by Professor A. W. Hofmann, of which the above notice is an abstract. See series of Scientific Worthies ("Nature," 1880, Feb. 6).]

A short account of the life of Dr. TODHUNTER, founded on personal knowledge, and information derived from papers and letters and notes communicated by his relations, has recently been published by his intimate friend, Professor Mayor. From this pamphlet we learn that Dr. Todhunter was born in 1820, and that he was the second of four sons of a Congregationalist Minister at Rye. We are also told that as a child he was unusually backward, and gave no promise of his future eminence. If this be correct, it is a fact from which many boys may draw some encouragement. Passing over his boyhood we find him an assistant-master in a school at Peckham, and at the same time attending the evening classes at University College, and among others the lectures of De Morgan. Here he seems to have come under the fascination which so many of the pupils of that great teacher experienced. We are told that his admiration for that mathematician was unbounded. Need we wonder that the influence of that teaching is seen in so many of the books he afterwards wrote? In 1839 he matriculated in the University of London, obtaining the exhibition for mathematics, and in 1842 he carried off the scholarship at B.A. Finally in 1847 he gained the gold medal at M.A., which was then the highest honour to be obtained in that University. Having thus acquired the means of coming to Cambridge he entered at St. John's College, and took his degree in 1848. That he would be Senior Wrangler and take the first Smith's Prize was never doubtful. Coming up rather older than men usually do, and having brilliant talents, he found himself so much in advance of his year that he was

able to devote a great part of his attention to other than the usual studies. He once told the writer of this notice how as an undergraduate he read Electricity to fill up his time, though the subject did not then enter into the Tripos Examination List.

In the same year in which he took his degree he gained the Burney Prize. According to the regulations, this prize is to be awarded to a graduate of the University who is not of more than three years' standing from admission to his first degree, and who shall produce the best English Essay "on some Moral or Metaphysical subject, on the Existence, Nature, and Attributes of God, or on the Truth and Evidence of the Christian Religion." His essay was printed in 1849 under the title "The Doctrine of a Divine Providence is inseparable from the belief in the existence of an absolutely perfect Creator." These headings are mentioned here to show how widely he was accustomed to spread his studies.

Soon after his degree he established himself in his college as a mathematical tutor, and then acquired a great reputation for his skill as a teacher. Afterwards when new arrangements were made at St. John's College he was appointed Principal Lecturer, and was expected to devote his teaching powers chiefly to the service of his college. Soon after this he vacated his fellowship by marriage, and following the rules of the college he retired from his position at the head of the staff of lecturers. He continued, however, to lecture for some years, but gradually he turned his attention more and more to the work of writing books. Finally he gave up all share in the tuition of his college, and devoted himself to those labours by the results of which he is best known.

Dr. Todhunter also spent much of his time as an Examiner. He was Examiner for the University of London for the five years ending 1869. He examined for the Indian Civil Service Commissioners more than once. He was Senior Moderator in 1865 and Senior Examiner in the following year, but though asked several times to examine again he always declined, declaring that the work was so onerous that it took up too much of his time. This is an opinion held by many other distinguished mathematicians who have examined once. At the same time this circumstance illustrates the care and patience usually given to the preparation of examination papers. He also examined for the Smith's Prize. But the Mathematical Tripos did not alone obtain his attention, he also examined for the Moral Sciences Tripos in the three years 1863, 1864, and 1865.

He was a member of many learned Societies. He became a Fellow of the Royal Society in 1862, and served on the Council during the years 1871–1873. He was elected a member of the Mathematical Society of London in 1865, the first year of its existence. He was also a member of the Royal Astronomical Society.

Some time after his marriage he was elected to be an Honorary Fellow of his college. This was a distinction which he evidently prized so much that he sometimes placed this title by itself after his name, joined solely to the letters M.A. or F.R.S. Later on in his life he was chosen as an Elector to three University Professorships, viz., the Knightbridge Professorship of Moral Philosophy, the Plumian Professorship of Astronomy and Experimental Philosophy, and the Professorship of Mental Philosophy and Logic. Lastly, when the University of Cambridge established its new degree of Doctor of Science, restricted to those who have made original contributions to the advancement of science or learning, he was one of those whose application was granted within the first few months.

The great work of Dr. Todhunter's life lies in the part he has taken in the education of this generation. There are few of us who have not studied some of his books. Many have made their first acquaintance with mathematics through his aid; and not their first acquaintance only, for his books conduct the student through a vast range of mathematical learning. Writing to his wife in 1878, when he was Examiner for the Indian Civil Service, he says: "There is a library of mathematical books provided by the Civil Service Commissioners for the use of the Examiners. It consists of fourteen volumes, ten of which are by myself. Thus you see I am able to do much of that labour which Matthew Arnold thinks distasteful, namely, that of perusing your own books."

A detailed account of the numerous educational books he has written would be too long for so slight a sketch of his life as the present. A simple list of these books is a history of the labours of his life, as the dates run on we see his time filled up with correcting one edition after another.

In writing, his first care was to be accurate. He once told the writer of this notice that, with the assistance of two of his pupils in correcting the press, the first misprint in his "Integral Calculus" did not occur till past the seventieth page. It might have been thought that he would have stereotyped his elementary books, but this was not done until many editions had been issued. Though at pecuniary loss, and with great labour, he yet preferred to correct edition after edition in hopes of eliminating all errors.

In constructing his books, he seems to have discovered that, for the teaching of boys, novelties would be out of place. What was wanted in any subject was a short and accurate account of the things then known. The object was to put the reader as quickly as possible in possession of all the knowledge which was most likely to be useful to him afterwards. Accordingly he gives in his books a clear statement of the well-known principles of each subject, arranged in a logical order. Each step in the argument is explained at length in clear

English. Nothing is assumed but what a reader should know. Every page makes it evident how thoroughly he was keeping in mind that he was writing for beginners.

Whatever his own ideas were, his books were certainly a great success. His "Euclid" and his "Elementary Algebra" have in twenty years run through fifteen or sixteen editions. They were appreciated by the schoolmasters, and by those who had to teach these subjects. With their recommendations, the sale has grown into something enormous. His more advanced text-books being addressed to a more limited circle of readers could not be expected to run through so many editions; yet we find his "Differential Calculus" reaching its ninth and his "Integral Calculus" a seventh edition.

His reputation in future time will undoubtedly rest on his histories, for the fashion of elementary books will pass away, and a new generation will like a new arrangement of old things. The most important of these are (1) "A History of the progress of the Calculus of Variations during the nineteenth century:" 1861; (2) "A History of the Mathematical Theory of Probability from the time of Pascal to that of Laplace:" 1865; (3) "A History of the Mathematical Theories of Attraction and the Figure of the Earth from the time of Newton to that of Laplace:" 1873. The first of these is a continuation of Woodhouse's history of the Calculus of Variations from its origin until the close of the eighteenth century; and it has been stated that it was his admiration for this work that led him to write this history.

These books appear to the writer of this notice to be of great importance. It is a great boon to the student to have a short and clear account of what has been already done, and what remains to be accomplished in any subject. Though the third of these histories extends over two volumes of nearly five hundred pages each, yet these are not too much for so great a subject.

It is unnecessary to give a particular account of these histories, as they have now been some time before the public. But we would call the attention of those who have not yet read them to their extreme interest. As we read one of them, it seems as if a new light were thrown on the subject. The difficulties of each investigator are put before us; we see how the subject advances, each discoverer adding a little, until step by step we arrive at our present state of knowledge. We see here sketched out before us the gradual growth of those modern methods which we now find so ready to our hands. Thus, in one place, Dr. Todhunter points out the first appearance of those confocal shells which play so important a part in modern works of attraction. These appear in a memoir of Maclaurin's, who introduces them in a remarkable manner without appearing to realise their

importance. In another place, we find a sketch in eight pages of a memoir of Legendre's which Dr. Todhunter considers to be the foundation of all that Laplace added in the theories of attraction and the figure of the earth to the works of Maclaurin and Clairaut. As we read the sketch, we see the first beginning of Laplace's coefficients and a recognition of the importance of the potential. This was the commencement of a new era in mathematical physics. In a third place, the history shows us how D'Alembert, trying to find the attraction of an ellipsoid, makes it depend on a single definite integral. This result, Dr. Todhunter reminds us, is the point at which modern investigations have finally arrived. But D'Alembert, after effecting this, strangely rejects his result as inadmissible. "In his process," says Dr. Todhunter, "there is nothing wrong in principle, but he has omitted a bracket which renders his result slightly inaccurate. He gives some invalid argument against his method. Thus D'Alembert deliberately rejects one of the most important formulæ of the subject, which in fact quite supersedes a large part of his memoir. This is perhaps the strangest of all his strange mistakes." A little further on in the history, we read how Laplace values and appropriates the treasure which D'Alembert deliberately threw away.

In 1869, the subject prescribed for the Adams' Prize was "A determination of the circumstances under which Discontinuity of any kind presents itself in the solution of a problem of Maximum or Minimum in the Calculus of Variations." The proposal of this subject seems to have arisen from a controversy which had been carried on in the "Philosophical Magazine" a few years previously. In this controversy Dr. Todhunter had taken part, and when the subject was proposed for the essay he was anxious that his own view should prevail. This view is given in the opening sentences of his essay:—"We shall find that, speaking generally, discontinuity is introduced by virtue of some restriction which we impose, either explicitly or implicitly, in the statement of the problems which we propose to solve." This thesis he supports by considering in turn the usual applications of the calculus, and pointing out where he considers the discontinuities which occur to have been introduced into the conditions of the problem. This he successfully proves in many instances. In some cases, the want of a distinct test of what discontinuity is, somewhat obscures the argument. His essay was rewarded with the prize. It is published under the title "Researches in the Calculus of Variations."

In the midst of so busy a life, Dr. Todhunter could yet find time to write for others. The second edition of Boole's "Differential Equations" was published under his care; and, what is more, he undertook the labour of arranging and editing the supplementary

volume. This task was undertaken from friendship to the late Professor Boole. The difficulty of preparing unfinished papers for the press is obvious; and it is not surprising that, as he once mentioned to the writer, it should have cost him some months of hard work.

Dr. Todhunter has left a treatise on Elasticity, which was very nearly finished. The time and labour he spent over this work injured his eyesight, and probably led to his final illness. These MSS. had been sent to Professor Cayley to report on; and we learn from Professor Mayor's pamphlet that the investigation shows that they are of the same class as the history of the Theory of Attraction, and seem fairly complete.

Another result of the labours of his latter years is a treatise on Arithmetic. Such a work when perfected would have smoothed the way for the young beginner over many difficulties. It is greatly to be regretted that he did not undertake it sooner.

In the summer of 1880 Dr. Todhunter first began to suffer from his eyesight, and from that date he gradually and slowly became weaker. But it was not until September, 1883, when he was at Hunstanton, that the worst symptoms came on. He then partially lost by paralysis the use of the right arm, and, though he afterwards recovered from this, he was left much weaker. In January of the next year he had another attack, and on the 1st of March, 1884, he died at his own residence in Cambridge, surrounded by his dearest relatives. It was a fit ending to an honourable and respected life spent in the advancement of that science which he loved so well.

E. J. R.

April, 1884.