THURSDAY, SEPTEMBER 4, 1890.

THE BRITISH ASSOCIATION.

LEEDS, *Tuesday Evening*.

IT is 32 years since the British Association met at Leeds, this being only its second visit, though it has frequently enough held its meetings in Yorkshire during that period. The President of 1858, Sir Richard Owen, happily still survives, though most of his eminent colleagues of the year have quitted the field—Sir John Herschel, Sir David Brewster, Sir Roderick Murchison Sir Benjamin Brodie, Robert Stephenson, Phillips, Darwin, Nasmyth. But the names of Huxley, Francis Galton, and others then coming into prominence, are found among the list of those who contributed to the proceedings of the meeting. Vast changes have taken place both in Leeds and in science during these 32 years—changes which we need not record here. Leeds during the interval has risen to its present prominence and prosperity mainly through the application of the discoveries of science, and therefore it seems appropriate that this year's President should be one who himself during 30 years has had so much to do with the application of these discoveries. As will be seen, Sir Frederick Abel's address deals largely with his own work in this direction.

So far as can be judged at present, the local authorities have done everything they could to render the meeting a success. All the best buildings in the town have been placed at the disposal of the Association. The Reception Room is spacious and handsome, and, so far as I have seen, the Sectional rooms are all that could be desired. The most thoughtful care has been taken for the comfort and convenience of the visitors. The Sectional Secretaries have seldom been so well housed. Their hotel is just opposite the Reception Room, and not only have well-furnished writing and dining rooms been placed at their disposal, but a handsome billiard room with three tables, on which the Secretaries of Section A hope to work out some abstruse problems. The Guide-book to Leeds, which has been prepared under the editorship of Prof. Miall, is well packed with useful information and guidance, and is handy enough to go into the pocket. A small pamphlet gives full details as to all the arrangements of the meeting, and another all the information about excursions.

As to the general work of the Sections, it is probable that it will be up to the average. So far as I can learn, there is no paper as yet of striking or sensational importance. There will, however, be several discussions that are likely to have useful results. In Section A, for example, there will be a discussion on electrical units, and possibly another on mechanical units and nomenclature. In Section D, again, there will be a discussion on the teaching of botany, in connection with which papers will be read by Dr. F. Oliver, Dr. Scott, and Prof. Marshall Ward, and in which Mr. F. Darwin, Prof. Bower, and others, will take part. A joint meeting will be held, on Monday, of Sections E and F, for the consideration of the important subject of the lands of the globe still available for settlement. One of the most striking papers in Section G will be one by Mr. Read Murphy (a native of Australia), on the Victorian torpedo. The Anthropological Laboratory will be at work this year again, though unfortunately it has been located at a distance from the meeting-room of Section H. Public and private hospitality, it need hardly be said, will be lavish.

INAUGURAL ADDRESS BY SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L. (OXON.), D.SC. (CANT.), F.R.S., P.P.C.S., HON.M.INST.C.E., PRESIDENT.

MANY who had the pleasure of listening last year, at Newcastle, to the interesting and instructive address of the President to whom I am a most unworthy successor, could not fail, both by the chief subject of his discourse, and by the circumstance of the official position which he occupies with so much benefit to science and the public, to have their thoughts directed to the illustrious naturalist whose philosophical address delighted the members of the Association and the people of Leeds thirty-two years ago.

More than one-half the period of existence of this Association has passed since Richard Owen presided over its meeting in this town. Alas! what gaps have been created in the ranks of those who then were prominent for activity in advancing its work: the then General Secretary, Sir Edward Sabine; the all-popular Assistant-General Secretary, John Phillips; the Treasurer, John Taylor, now live with us only through their works and the enduring esteem which they inspired. But very few of those who held other prominent positions at that meeting have survived to see the Association reassemble in this town. Whewell, Herschel, Hopkins, the elder Brodie, Murchison, William Fairbairn, all Presidents of Sections in 1858, have long since been removed from among us; and the then President of Section F, Edward Baines, a much-honoured and highly-talented son of the "Franklin of Leeds," whom we had hoped to count among those Vice-Presidents representing the city on this occasion, has recently passed away, in his ninetieth year, after a most honourable and useful career, during which he especially distinguished himself by his successful exertions in the advancement of the great educational movements of his time.

The illustrious President of our last meeting here, concerning whose health the gravest apprehensions were not long since entertained, is happily still preserved to us; still intellectually bright at the ripe age of eighty-six, and still, with the keen pleasure of his early life, following the progress of those branches of scientific research which have constituted the favourite occupations and the arena of many intellectual triumphs of a long career of ardent and successful devotion to the advancement of science.

To not a few of those who have flocked to Leeds to attend the annual gathering of this Association, our present meeting-place is doubtless known chiefly by its proud position as one of the most thriving manufacturing towns of the United Kingdom; of ancient renown, especially in connection with one of the chief industries identified with Great Britain in years past. But this good town of Leeds, whose cloth market was described by Daniel Defoe, one hundred and sixty odd years ago, as "a prodigy of its kind, and not to be equalled in the world," and whose present position in connection with divers of our great industries would have equally excited the enthusiasm of that graphic writer, is famous for other things than its prominent association with manufactures and commerce.

Not many of our great industrial centres can boast of so goodly an array, upon the scroll of their past history, of names of men eminent in the Sciences, the Arts and Manufactures, in Divinity and Letters, and in heroic achievements, such as are identified with Leeds and its immediate vicinity: Thomas, Lord Fairfax, one of the most prominent heroes of the Commonwealth; Smeaton, an intellectual giant among engineers; William Hirst and John Marshall, illustrious examples of the men who by their genius, energy, and perseverance placed Great Britain upon the pinnacle of industrial and commercial greatness which she so long occupied unassailed; Richard Bentley, the eminent classic and divine; John Nicholson, the Airedale poet; John Fowler and Peter Fairbairn, worthy followers in the footsteps of Smeaton; Isaac Milner, weaver and mathematician, afterwards Senior Wrangler, Smith's Prizeman, Jacksonian Professor, President of Queen's College, Vice-Chancellor of Cambridge University, Dean of Carlisle, and a most illustrious Fellow of the Royal Society; Thoresby, antiquarian and topographer; Benjamin Wilson, painter, and industrious contributor to the development of electrical science; William Hey, the eminent surgeon, and friend and counsellor of Priestley; Sadler, political economist and philanthropist; the brothers Sheepshanks—Richard, the astronomer, and John, the accomplished patron of the arts, and munificent contributor to our national art treasures; Edward Baines, whose conspicuous talents and energy developed a small provincial journal into one of the most powerful public organs of the country; his talented sons, of whom not the least conspicuous and highly respected was the late Sir Edward Baines. I might swell this voluminous list by reference to illustrious members of such families as that of Denison, of Beckett, of Lowther, but the men I have referred to fitly illustrate the remarkable array of worthies whose careers have shed lustre upon the town in or near which they were born. Yet that illustration would be altogether incomplete if I failed to speak of one whose career and works alone would suffice to place Leeds in the foremost rank of those English towns which can claim as their own men whose course of life and whose achievements have secured their pre-eminence among our illustrious countrymen. Needless to say that I refer to Joseph Priestley, born within six miles of Leeds, whose name holds rank among the foremost of successful workers in science; who, by brilliant powers of experimental investigation, rapidly achieved a series of discoveries which helped largely to dispel the shroud of mystery surrounding the art of alchemy, and to lay the foundation of true chemical science. An ardent student of the classics, of Eastern languages, and of divinity, a zealous exponent of theological doctrines which marred his career as divine and instructor, he early displayed conspicuous talents for the cultivation of experimental science, which he pursued with ardour under formidable difficulties. His acquaintance with Franklin probably developed the taste for the study of electric science which led him to labour successfully in this direction and the publication, in 1767, of his valuable work on "The History and Present State of Electricity, with Original Experiments," secured for him a prominent position among the working Fellows of the Royal Society. His connection with Mill Hill Chapel, in 1768, appears to have given rise accidentally to his first embracing the experimental pursuit of what formerly was termed pneumatic chemistry, the foundation of which had been laid by Cavendish's memorable contribution, in 1766, to the Philosophical Transactions, on carbonic acid and hydrogen. Priestley's first publication in pneumatic chemistry, on "Impregnating Water with Fixed Air" (carbonic acid), attracted great attention; it was at once translated into French, and the College of Physicians addressed the Lords of the Treasury thereon, pointing out the advantages which might result from the employment, by men at sea, of water impregnated with carbonic acid gas, as a protective against, or cure for, scurvy.

Six years later Priestley investigated the chemical effects produced on the air by the burning of candles and the respiration of animals, and, having demonstrated that it was thereby diminished in volume and deteriorated, he showed that living plants possessed the power of rendering air, which had been thus deteriorated, once more capable of supporting the combustion of a candle. At about this time Priestley received very advantageous proposals to accompany Captain Cook upon his second expedition to the South Seas; but when about to prepare for his departure he learned from Sir Joseph Banks that objections against his appointment, on account of the great latitude of his religious principles, had been successfully urged by some ecclesiastic member of the Board of Longitude. In 1773 the Royal Society awarded Priestley the Copley Medal for a remarkable paper entitled "Observations on Different Kinds of Air," and in that year he became librarian and literary companion to the Earl of Shelburne (afterwards Marquis of Lansdowne), and thereby secured special advantages in the pursuit of his scientific researches.

With respect to his departure from Leeds, he expressed himself as having been very happy there "with a liberal, friendly, and harmonious congregation, to whom my services (of which I was not sparing) were very acceptable. Here I had no unreasonable prejudices to contend with, so that I had full scope for every kind of exertion; and I can truly say that I always considered the office of a Christian minister as the most honourable of any upon earth, and in the studies proper to it I always took the greatest pleasure." During the next five years he published as many volumes describing the results of important experiments on air. After investigating the properties of nitric oxide, and applying it to the analysis of air, Priestley, in 1774, discovered and carefully studied oxygen, which he obtained by the action of heat upon the red oxide of mercury. He was the first to prepare and study sulphurous acid, carbonic oxide, nitrous oxide, hydrochloric acid (*marine acid air*), and the fluoride of silicon, and carried out important researches on the properties of hydrogen, and of other gases previously but little known. His great quickness of perception and power of experiment led him to the achievement of many novel and important results; but one cannot help contrasting his somewhat random search after new discoveries with the close logical reasoning and philosophic spirit which guided and pervaded the remarkable researches of him whose departure from amongst us since the last gathering of this Association is so universally deplored—of the great discoverer of the universal law of the conversion of energy, James Prescott Joule. I could not add to the judicious and graceful reference to his work which Sir Henry Roscoe was privileged to make, in the last year of that philosopher's valuable life, when presiding over the recent meeting of the Association in the town which gloried in numbering Joule among its citizens; but I may, perhaps, be permitted to express the sanguine hope that the desire of the scientific world to secure the establishment of an international memorial fitly commemorative of his great life-work may be realized in the most ample manner.

The wide scope of the admirable discourse delivered by Owen in this town thirty-two years ago affords an interesting illustration of the delight which men whose best energies are devoted to the cultivation of one particular branch of science take in the results of the labours of their fellow-workers in other departments, and in their achievements in contributing to the general advancement of our knowledge of Nature's laws and of their operations. It is to this bond of intimate union between all workers in pure science that we owe the instructive reviews of the progress made in different departments of science, with which we have often been presented at our annual gatherings. On the other hand, those men, from time to time selected to fill the distinguished office of President, whose lives have been mainly devoted to the practical utilization of the results of scientific research, and to the extension in particular directions of the consequent resources of civilization, seize with keen pleasure the opportunity afforded them of directing attention to the triumphs achieved in the application, to the purposes of daily life, of the great scientific truths established by such illustrious labourers in the fields of pure science as Newton, Dalton, Faraday, and Joule. The wide and constantly-extending domain of applied science presents, even to the superficial observer, a continually varied scene; not a year passes but some great prize falls to the lot of one or other of its explorers, and some apparently insignificant vein of treasure, struck upon but a few years back, is rapidly opened out by cunning explorers, until it leads to a mine of vast wealth, from which branch out in many directions new sources of power and might.

Among the branches of science in the practical applications of which the greatest strides have been made since the Association met at Leeds in 1858, is electricity. That year witnessed the accomplishment of the first great step towards the establishment of electrical communication between Europe and America, by the laying of a telegraph-cable connecting Newfoundland with Valencia. Through this cable a message of thirty-one words was shortly afterwards transmitted in thirty-five minutes; an achievement which, though exciting great enthusiasm at the time, scarcely afforded promise of the succession of triumphs of ocean-telegraphy which have since surpassed the wildest dreams of the pioneers in the realms of applied electricity.

The development of the electric telegraph constitutes a never-failing subject of the liveliest interest. The experiments made by Stephen Gray, in 1727, of transmitting electrical impulses through a wire 700 feet long; by Watson, twenty years afterwards, of transmitting frictional electricity through many thousand feet of wire, supported by a line of poles, on Shooter's Hill, in Kent; and by Franklin, who carried out a similar experiment at Philadelphia,—although they were followed by many other interesting and philosophical applications of frictional electricity to the transmission of signals—were not productive of really practical results. The work of Galvani and of Volta was more fruitful of an approach to practical telegraphy in the hands of Sömmering and of Coxe, while the researches of

Oersted, of Ampère, of Sturgeon, and of Ohm, and especially the discoveries of volta-electric induction and magneto-electricity by Faraday, paved the way for the development of the electric telegraph as a practical reality by Cooke and Wheatstone in 1837. How remarkable the strides have been in the resources and powers of the telegraphist since that time is demonstrated by a few such facts as these: the first needle-instrument of Cooke and Wheatstone transmitted messages at the rate of four words per minute, requiring five wires for that purpose; six messages are now conveyed by one wire, at ten times that speed, and news is despatched at the rate of 600 words per minute. Duplex working, which more than doubled the transmitting power of a submarine cable, was soon eclipsed by the application of Edison's quadruplex working, which has in its turn been surpassed by the multiplex system, whereby six messages may be sent independently, in either direction, on one wire. When last the British Association met in Leeds, submarine telegraphy had but just started into existence; thirty years later, the accomplished President of the Mechanical Section informed us, at our meeting at Bath, that 110,000 miles of cable had been laid by British ships, and that a fleet of nearly forty ships was occupied in various oceans in maintaining existing cables and laying new ones.

The important practical achievements by which most formidable difficulties have been surmounted, step by step, in the successive attainment of the marvellous results of our day, have exerted an influence upon the advancement, not merely of electrical science, but also of science generally and of its applications, fully equal to that which they have exercised upon the development of commerce and of the intercourse between the nations of the earth.

Thus, the laying of the earliest submarine cables, between 1851 and 1855, led Sir W. Thomson, in conference with Sir George Stokes, to work out the theory of signalling in such cables, by utilizing the mathematical results arrived at by Fourier in his investigation of the propagation of heat-waves. The failure of the first Atlantic cable led to the survey of the bottom of the Atlantic, which was the forerunner of deep-sea explorations, culminating in the work of the *Challenger* Expedition, and opening up new treasures of knowledge scarcely dreamt of when last the British Association met at Leeds. To the difficulties connected with the early attempts at submarine telegraphy, and the determination with which Thomson drove home the lessons learned, we owe the systematic investigations into the causes of the variations in resistance of copper-conductors, and the consequent improvements in the metallurgy of copper, which led to the realization of the high standard of purity of metal essential for the efficient working of telegraphic systems, and also to the extensive utilization of electricity in the production of pure copper. The rare combination of originality in powers of research and perspicuity in mathematical reasoning, with inventive and constructive genius, for which Thomson has so long been pre-eminent, has placed at the disposal of the investigator of electric science, and of the practical electrician, instruments of measurement and record which have been of incalculable value, and which owe their origin to the theoretical conclusions arrived at by him in his researches into the conditions to be fulfilled for the attainment of practical success in the construction and employment of submarine cables. The mirror galvanometer, the quadrant electrometer, the syphon-recorder, and the divided-ring electrometer, are illustrations of the valuable outcome of Thomson's labours; the combination of the last-named instrument with sliding resistance coils has rendered possible the accurate subdivision of a potential difference into 10,000 equal parts. The general use of condensers in connection with cable signalling, due to Varley's application of them for signalling through submerged cables with induced short waves, was instrumental in establishing the fact that all electro-static phenomena are simply the result of starting an electric current of known short duration round a closed circuit. The practical application of the Wheatstone Bridge led to numerous important mathematical investigations, and induced Clerk Maxwell to devise a new mode of applying determinants to the solution of the complicated electrical problems connected with networks of conductors. The necessity for the universal recognition of an electrical unit of resistance led to the establishment, in 1860, of the Electrical Standards Committee of the British Association, whose long succession of important annual reports was instrumental in most important developments of theoretical electricity, and, indeed, served to open up the whole science of electrical measurement. Matthiessen's important investigations of the electrical behaviour of metals and their alloys, and the preparation and properties of pure iron, were the outcome of the commercial demand for a practically useful standard of electrical resistance; while Latimer Clark's practical standard of electromotive force, the mercurous sulphate cell, became invaluable to the worker in pure electrical research. The unit of resistance established by the British Association Committee received, in 1866, most important scientific application at the hands of Joule, who, by measuring the rate of development of heat in a wire of known resistance by the passage of a known current, obtained a new value of the mechanical equivalent of heat. This value differed by about 1·3 per cent. from the most accurate results arrived at by his experiments on mechanical friction, a difference which eventually proved to be exactly the error in the British Association unit of resistance; so that the true value of the unit of resistance, or Ohm, was determined by Joule fifteen years before this result was achieved by electricians. Clerk Maxwell's remarkable electro-magnetic theory of light was put to the test, through the aid of the British Association unit of resistance, by Thomson, in determining the ratio of the electro-magnetic unit to the electro-static unit of quantity. Many other most interesting illustrations might be given of the invaluable aid afforded to purely scientific research by the practical results of the development of electrical science, and of the constant co-operation between the science student and the practical worker. No one could, more fitly than the late Sir William Siemens, have maintained, as he did in his admirable address at our meeting in Southampton in 1882, that we owe most of the rapid progress of recent times to the man of science who partly devotes his energies to the solution of practical problems, and to the practitioner who finds relaxation in the prosecution of purely scientific inquiries. Most assuredly both these classes of the world's benefactors may with equal right lay claim to rank the name of Siemens among those whom they count most illustrious!

In that highly interesting and valuable address delivered little more than a year before his sudden untimely removal from among us, the numerous important subjects discussed by him included not a few which he had made peculiarly his own in the wide range embraced by his enviable power of combining scientific research with practical work. Prominent among these were the applications of electric energy to lighting and heating purposes, and to the transmission of power, to the future development of which his personal labours very greatly contributed.

Siemens referred to the passing of the first Electric Lighting Bill, in the year of his presidency, as being designed to facilitate the establishment of electric installations in towns; but the anxiety of the Government of that day to protect the interests of the public through local authorities, led to the assignment of such power to these over the property of lighting companies, that the utilization of electric lighting was actually delayed for a time by those legislative measures. There can now be no doubt, however, that this delay has really been in the interests of intending suppliers and of users of the electric light, as having afforded time for the further development of practical details, connected with generation and distribution, which was vital to the attainment of a fair measure of initial success. The subsequent important modification of legislation on the subject of electric lighting, together with the practical realization of comparatively economical methods of distribution, the establishment of fairly equitable arrangements between the public and the lighting companies, and the apportionment, so far as the metropolis is concerned, of distinct areas of operation to different competing companies, have combined to place electric lighting in this country at length upon some approach to a really sound footing, and to give the required impetus to its extensive development. Nine companies either are now, or will very shortly be, actually at work supplying, from central stations, districts of London comprising almost the entire western and north-western portions of the metropolis. As regards other parts of England, there are already twenty-seven lighting stations actually at work in different towns, besides others in course of establishment, and many more projected. The town of Leeds has not failed to give serious attention to the subject of utilizing the electric light, and, although no general scheme has yet been adopted, the electricians who now visit this town will rejoice to see many of its public buildings provided with efficient electric illumination.

While the prediction made by Siemens, eight years ago, that electric lighting must take its place with us as a public illuminant, has thus been already, in a measure, fulfilled, important progress is being continuously made by the practical electrician in developing and perfecting the arrangements for the generation of the supply, its efficient distribution from centres, and its delivery to the consumer in a form in which it can be safely and conveniently dealt with and applied at an outlay which, even now, does not preclude a considerable section of the public from enjoying the decided advantages presented by electric lighting over illumination by coal-gas. Yet our recent progress in this direction, encouraging though it has been, is insignificant as compared with the strides made in the application of electric lighting in the United States, as may be gauged by the fact that, while in America the number of arc lamps in use, in April of this year, was 235,000, and of glow-lamps about three millions, there are at present only about one-tenth the number of the latter, and one hundredth the number of arc lamps, in operation in England.

In some important directions we may, however, lay claim to rank foremost in the application of the electric light; thus, our large passenger-ships and our war-ships are provided with efficient electrical illumination; to the active operations of our Navy the electric light has become an indispensable adjunct; and our system of coast defence, by artillery and submarine mines, is equally dependent, for its thorough efficiency, upon the applications of electricity in connection with range-finding, with the arrangement and explosion of mines, and with the important auxiliary in attack and defence, the electric light, which, while so arranged, at the operating stations, as to be protected against destruction by artillery-fire and difficult of detection by the enemy, is available at any moment for affording invaluable information and important assistance and protection.

Other important applications of the electric light, such as its use as a lighthouse-illuminant, for the lighting of main roads in coal-mines, where its value is being increasingly appreciated, and even for signalling purposes in mid-air, through the agency of captive balloons, are continually affording fresh demonstrations of the value of this particular branch of applied electric science.

At the Electrical Exhibition at Vienna in 1883, where, not long before the lamented death of Siemens, I had the honour of serving as one of his colleagues in the representation of British interests, the progress which had been made in the construction of electrical measuring instruments since the French Exhibition and the Electrical Congress, two years before, was very considerable. The advance in this direction has been enormous since that time; but although the practical result of Thomson's and of Carlew's important work has been to supply us with trustworthy electrical balances and voltmeters, while efficient instruments have also been made by other well-known practical electricians, we have still to attain results in all respects satisfactory in these indispensable adjuncts to the commercial supply and utilization of electric energy.

In connection with this important subject the recent completion of the Board of Trade standardizing laboratory, established for the purposes of arriving at and maintaining the true values of electrical units, and of securing accuracy and uniformity in the manufacture of instruments supplied by the trade for electrical measurements, may be referred to with much satisfaction as a practical illustration of official recognition of the firm root which the domestic and industrial utilization of electric energy has taken in this country.

The achievements of the telephone were referred to by Siemens in glowing terms eight years ago; but the results then attained were but indications of the direction in which telephonic intercommunication was destined speedily to become one of the most indispensable of present applications of electricity to the purposes of daily life. Preece, in speaking at Bath, two years ago, of the advances made in applied electricity, showed that the impediments to telephonic communication between great distances had been entirely overcome; and now, although considerably behind America and France in the use of the telephone, we are rapidly placing ourselves upon speaking terms with our friends throughout the United Kingdom. The operations of the National Telephone Company well illustrate our progress in telephonic intercommunication: that company has now 22,743 exchange lines, besides nearly 5000 private lines; its exchanges number 272, and its call-offices 526. The number of instruments under rental in England has now reached 99,000; but, important as this figure is compared to our use of the telephone a very few years ago, it sinks into insignificance by the side of the number of instruments under rental in America, which at the beginning of the present year had reached 222,430, being an increase of 16,675 over the number in 1889. Only thirteen years have elapsed since the telephone was first exhibited as a practically workable apparatus to members of the British Association at the Plymouth Meeting, and the number of instruments now at work throughout the world may be estimated as considerably exceeding a million.

The successful transmission of the electric current, and the power of control now exercised over the character which electrically-transmitted energy is made to assume, are not alone illustrated by the efficiency of the arrangements already developed for the supply of the electric light from central stations. Siemens dwelt upon this subject at Southampton with the ardent interest of one who had made its development one of the objects of his energetic labours in later years, and also with a prophet's prognostications of its future importance. In speaking of the electric current as having entered the lists in competition with compressed air, the hydraulic accumulator, and the quick-running rope driven by water-power, Siemens pointed out that no further loss of power was involved in the transformation of electrical into mechanical energy than is due to friction, and to the heating of the conducting wires by the resistance they oppose, and he showed that this loss, calculated upon data arrived at by Dr. John Hopkinson and by himself, amounted at the outside to 38 per cent. of the total energy. Subsequent careful researches by the Brothers Hopkinson have demonstrated that the actual loss is now much less than it was computed at in 1885; as much as 87 per cent. of the total energy transmitted being realizable at a distance, provided there be no loss in the connecting leads used.

The Paris Electric Exhibition of 1881 already afforded interesting illustrations of the performance of a variety of work by power electrically transmitted, including a short line of railway constructed by the firm of Siemens, which was a further development of the successful result already attained in Berlin by Werner Siemens in the same direction, and was, in its turn, surpassed by the considerably longer line worked by Messrs. Siemens at the Vienna Exhibition two years later. Various short lines which have since then been established by the firm of Siemens are well known, and one of the latest public acts in the valuable life of Siemens was to assist at the opening of the electric tramway at Portrush, in the installation of which he took an active part, and where the idea, so firmly rooted in his mind from the date of his visit to the Falls of Niagara, in 1876, of utilizing water-power for electrical transmission—a result first achieved on a small scale by Lord Armstrong—was more practically realized than had yet been the case. Since that time Ireland has witnessed a further application of electricity to traction purposes, and of water-power to the provision of the required energy, in the working of the Bessbrook and Newry tramway, while London at length possesses an electric railway, three miles in length, to be very shortly opened, which will connect the City with one of the southern suburbs through a tram subway, and, although including many sharp curves and steep gradients, will be capable of conveying one hundred passengers at a time, at speeds varying from thirteen to twenty-four miles per hour. During the past year a regular service of tramcars has been successfully worked, through the agency of secondary batteries, upon part of one of the large tramways of North London, with results which bid fair to lead to an extensive development of this system of working. The application of electricity to traction purposes has, however, received far more important development in the United States; at the commencement of this year there were in operation in different States 200 electrical tramroads, chiefly worked upon the Thomson-Houston and the Sprague systems, and having a collective length of 1641 miles, with 2346 motor-cars travelling thereon. Further extensions are being rapidly made; thus, one company alone has 39 additional roads, of a collective length of 385 miles, under construction, to be worked through the agency of storage-batteries.

The idea cherished by Siemens, and enlarged upon by him in more than one interesting address, of utilizing the power of Niagara, appears about to be realized, at any rate in part; as a large tract of land has been recently acquired, by a powerful American association, about a mile distant from the Falls, with a view to the erection of mills for utilizing the power, which it is also proposed to transmit to distant towns; and an International Commission, with Sir William Thomson at its head, and with Mascart, Turrettini, Coleman Sellers, and Unwin as members, will carefully consider the problems involved in the execution of this grand scheme.

The application of electric traction to water-traffic, first successfully demonstrated in 1883, is receiving gradual development, as illustrated by the considerable number of pleasure-boats which may now be seen on the Upper Thames during the boating season, and in connection with which Prof. George Forbes proposed, at our meeting last year, that stations for charging the requisite cells, through the agency of water-power, should be established at the many weirs along the river, so as to provide convenient electric coaling-stations for the river pleasure-fleet.

Electrically-transmitted energy was first applied in Germany to haulage work in mines by the firm of Siemens some years ago, and great progress has since been achieved herein on the Continent and in America. Comparatively little has been accomplished in this direction in England; but it is very interesting to note, on the present occasion, that the first successful practical application of electricity in this country to pumping and underground haulage-work was made in 1887, in this neighbourhood, at the St. John's Colliery, at Normanton, where an extensive installation, carried out by Mr. Immisch, so well known in connection with electric launches, is furnishing very satisfactory results in point of economy and efficiency. The gigantic installations existing for the same purposes in Nevada and California afford remarkable illustrations of the work to be accomplished in the future by electrically-transmitted energy.

Among the many subjects of importance studied by Joule with the originality and thoroughness characteristic of his work, was the application of voltaic electricity to the welding and fusion of metals. Thirty-four years ago he published a most suggestive paper on the subject, in which, after dealing with the difficulties attending the operation of welding, and of the interference of films of oxide, formed upon the highly heated iron surfaces, with the production of perfect welds either under the hammer or by the methods of pressure (of which he then predicted the application to large masses of forged iron), he refers to the possibility of applying the calorific agency of the electric current to the welding of metals, and describes an operation witnessed by him in the laboratory of his fellow-labourer, Thomson, of fusing together a bundle of iron wires by transmitting through them, when embedded in charcoal, a powerful voltaic current. Joule afterwards succeeded in fusing together a number of iron wires with the current of a Daniell battery, and in welding together wires of brass and steel, platinum and iron, &c. In discussing the question of the amount of zinc consumed in a battery for raising a given amount of iron to the temperature of fusion, he points out that the same object would probably be more economically attained by the use of a magneto-electric machine, which would allow the heat to be provided by the expenditure of mechanical force, developed in the first instance by the expenditure of heat; and he indicates the possibility of arranging machinery to produce electric currents which shall evolve one-tenth of the total heat due to the combustion of the coal used, so that 5000 grains of coal applied through that agency would suffice for the fusion of one pound of iron. The successful practical realization of Joule's predictions in regard to the application of electric currents, thus developed, to the welding of iron and steel, and to analogous operations, through the agency of the efficient machines devised by Prof. Elihu Thomson, was demonstrated to the members of the Association by Prof. Ayrton at Bath two years ago, and was shown upon a larger scale to visitors at the Paris Exhibition last year, and recently to highly interested audiences in London by our late President, Sir Frederick Bramwell. The latter demonstrated that the production of iron-welds by means of the Thomson machines was accomplished nearly twice as rapidly as by expert craftsmen; the perfection of the welds being proved by the fact that the strength of bars broken by tensile strains at the welds themselves was about 92 per cent. of the strength of the solid metal. At the Crewe Works Mr. Webb is successfully applying one of these machines to a variety of welding-work. The rapidity with which masses of metal of various dimensions are raised in those machines to welding heat is quite under control; the heat is applied without the advent of any impurities, as from fuel, and the speed of execution of the welding operation reduces to a minimum the time during which the heated surfaces are liable to oxidize. With such practical advantages as these, this system of electric welding bids fair to receive many useful applications.

Another very simple system of electric welding, especially applicable to thin iron and steel sheets, hoops, &c., has been cotemporaneously elaborated in Russia by Dr. Bernados, and is already being extensively used. The required heat at the surfaces to be welded is developed by connecting the metal with the negative pole of the dynamo-machine, or a battery of accumulators, the circuit being completed by applying a carbon electrode to the parts to be heated; the reducing power of the carbon is said to preserve the heated metal surfaces from oxidation during the very brief period of heating. This mode of operation appears to have been practised upon a small scale, some years ago, by Sir William Siemens, to whom we also owe the first attempt to practically apply electric energy to the smelting of metals.

In his address in 1882 he referred to some results attained with his small electrical furnace, and pointed out that, although electric energy could, obviously, not compete economically with the direct combustion of fuel for the production of ordinary degrees of heat, the electric furnace would probably receive advantageous application for the attainment of temperatures exceeding the limits (about 1800° C.) beyond which combustion was known to proceed very sluggishly. This prediction appears to have been already realized through the important labours of Messrs. Cowles, who some years ago attacked the subject of the application of electricity to the achievement of metallurgic operations with the characteristic vigour and fertility of resource of our Transatlantic brethren. After very promising preliminary experiments, they succeeded, in 1885, at Cleveland, Ohio, in maturing a method of operation for the production of aluminium-bronze, ferro-aluminium, and silicium-bronze, with results so satisfactory as to lead to the erection of extensive works at Lockport, N.Y., where three dynamo-machines, each supplying a current of about 3000 Amperes, are worked by water-power, through the agency of turbines, each of 500 horse-power, eighteen electric furnaces being now in operation for the production of aluminium alloys. These achievements have led to the establishment of similar works in North Stafford-hire, where a gigantic dynamo-machine has been erected, furnishing a current of 5000 Amperes, with an E.M.F. of 50 to 60 volts. The arrangements of the electrodes in the furnaces, the preparation of the furnace-charges (consisting of mixtures of aluminium-ore with charcoal and with the particular granulated metal with which the aluminium is to become alloyed at the moment of its elimination from the ore); the appliances for securing safety in dealing with the current from the huge dynamo-machine, and many other details connected with this new system of metallurgic work, possess great interest. Various valuable copper- and aluminium-alloys are now produced by alloying copper itself with definite proportions of the copper-alloy, very rich in aluminium, which is the product of the electric furnace. The rapid production in large quantities of ferro-aluminium—which presents the aluminium in a form suitable for addition in definite proportions to fluid cast-iron and steel—is another useful outcome of the practical development of the electric furnace by Messrs. Cowles.

The electric process of producing aluminium-alloys has, however, to compete commercially with their manufacture by adding to metals, or alloys, pure aluminium produced by processes based upon the method originally indicated by Oersted in 1824, successfully carried out by Wöhler three years later, and developed into a practical process by H. Ste. Claire Deville in 1854—namely, by eliminating aluminium from the double chloride of sodium and aluminium in the presence of a fluoride, through the agency of sodium. An analogous process, indicated in the first instance by H. Rose—namely, the corresponding action of sodium upon the mineral cryolite, a double fluoride of aluminium and sodium—has also been recently developed at Newcastle, where the first of these methods was applied, upon a somewhat considerable scale, in 1860, by Sir Lowthian Bell, but did not then become a commercial success, mainly owing to the costliness of the requisite sodium. As the cost of this metal chiefly determines the price of the aluminium, technical chemists have devoted their best energies to the perfection and simplification of methods for its production, and the success which has culminated in the admirable Castner process constitutes one of the most interesting of recent illustrations of the progress made in technical chemistry, consequent upon the happy blending of chemical with mechanical science, through the labours of the chemical engineer.

Those who, like myself, remember how, between forty and fifty years ago, a few grains of sodium and potassium were treasured up by the chemist, and used with parsimonious care in an occasional lecture-experiment, cannot tire of feasting their eyes on the stores of sodium-ingots to be seen at Oldbury as the results of a rapidly and dexterously executed series of chemical and mechanical operations.

The reduction which has been effected in the cost of production of aluminium through this and other processes, and which has certainly not yet reached its limit, can scarcely fail to lead to applications of the valuable chemical and physical properties of this metal so widespread as to render it as indispensable in industries and the purposes of daily life as those well-known metals which may be termed domestic, even although, and, indeed, for the very reason that, its association with many of these, in small proportion only, may suffice to enhance their valuable properties or to impart to them novel characteristics.

The Swedish metallurgist, Wittenström, appears to have been the first to observe that the addition of small quantities of aluminium to fused steel and malleable iron had the effect of rendering them more fluid, and, by thus facilitating the escape of entangled gases, of ensuring the production of sound castings without any prejudicial effect upon the quality of the metal. The excellence of the so-called Mitis castings, produced in this way, appears thoroughly established, and the results of recent important experiments seem to be opening up a field for the extensive employment of aluminium in this direction, provided its cost becomes sufficiently reduced. The valuable scientific and practical experiments of W. J. Keep, James Riley, R. Hadfield, Stead, and other talented workers in this country and the United States, are rapidly extending our knowledge in regard to the real effects of aluminium upon steel, and their causes. Thus it appears to be already established that the modifications in some of the physical properties of steel resulting from the addition of that metal, are not merely ascribable to its actual entrance into the composition of the steel, but are due, in part, to the de-oxidation by aluminium of some proportion of iron-oxide which exists distributed through the metal, and prejudicially affects its fluidity when melted. In the latter respect, therefore, the influence exerted by aluminium, when introduced in small proportions into malleable iron and steel, appears to be quite analogous to that of phosphorus, silicium, or lead when these are added in small proportions to copper and certain of its alloys, the de-oxidation of which, through the agency of those substances, results in the production of sound castings of increased strength and uniformity. It is only when present in small proportion in the finished steel that aluminium increases the breaking strain and elastic limit of the product.

The influence of aluminium, when used in small proportion, upon the properties of grey and white cast-iron, is also of considerable interest, especially its effect in promoting the production of sound castings, and of modifying the character of white iron in a similar manner to silicium, causing the carbon to be separated in the graphitic form; with this difference—that the carbon appears to be held in solution until the moment of setting of the liquid metal, when it is instantaneously liberated, with the result that the structure of the cast metal and distribution of the graphite are perfectly uniform throughout.

The probable beneficial connection of aluminium with the industries of iron and steel naturally directs attention to the great practical importance, in the same direction, which has already been acquired, and promises to be in increasing measure attained, by certain other metals which, for long periods succeeding their discovery, have either been only of purely scientific interest and importance, or have acquired practical value in regard to their positions in a few directions quite unconnected with metallurgy. Thus great interest attaches to the influence of the metals manganese, chromium, and tungsten upon the physical properties of steel and iron.

The name of Mushet is most prominently associated with the history of manganese in its relations to iron and steel. Half a century ago David Mushet carried out very instructive experiments on the influence exerted upon the properties of steel by the presence of manganese; and to Robert Mushet we owe the invaluable experiments leading to his suggestion to use manganese in the production of steel by the Bessemer process, which at once smoothed the path to the marvellously rapid and extensive development of the applications of steel produced by that classic method, and subsequently by the open-hearth or Siemens-Martin process—a development which has recently received its crowning illustration in the completion of one of the grandest of existing triumphs of engineering science and constructive skill—the Forth Bridge.

Robert Hadfield has recently contributed importantly to our knowledge of the relations of manganese to iron. His systematic study of the subject has revealed some very remarkable variations in the physical properties of so-called manganese-steel, according to the proportions of manganese which it contains. Thus, while the existence in steel of proportions ranging from 0·1 up to about 2·75 per cent. improves its strength and malleability, it becomes brittle if that limit is exceeded, the extreme of brittleness being obtained with between 4 and 5 per cent. of manganese; if, however, the percentage is increased to not less than 7, and up to 20, alloys of remarkable strength and toughness are obtained. Castings of high manganese steel, such as wheel-tyres, combine remarkable hardness with toughness. Even if the proportion of manganese is as high as 20 per cent. in a steel containing 2 per cent. of carbon, it can be forged; whereas it is very difficult to forge a steel of ordinary composition containing as much as 2·75 per cent. of carbon. Another remarkable peculiarity of the high manganese-steel is its behaviour when quenched in water. Instead of the heated metal being hardened and rendered brittle by the sudden cooling, like carbon-steel, its tensile strength and its toughness are increased; so that water-quenching is really a toughening process, as applied to the manganese-alloy; and an interesting feature connected with this is that, the colder the bath into which the highly-heated metal is plunged, the tougher is the product. The curious effect of manganese in reducing, and even destroying, the magnetic properties of iron was already noticed by Rinmann nearly 120 years ago; one result of Hadfield's important labours has been to place in the hands of such eminent physicists as Thomson, John Hopkinson, and Reinold, materials for the attainment of most interesting information respecting the electrical and other physical characteristics of manganese-steel. Hopkinson, from experiments with a sample of steel containing 12 per cent. of manganese, estimated that not more than 9 out of the 86 per cent. of the iron composing the mass was magnetic, and he considered that the manganese enters into that which must, for magnetic purposes, be regarded as the molecule of iron, completely changing its properties, a fact which must have great significance in any theory regarding the nature of magnetization. The great hardness of manganese-steel, and the consequent difficulty of dealing with it by means of cutting-tools, constitute at present the chief impediments to its technical applications in many directions; but where great accuracy of dimensions is not required, and where great strength is an essential, it is already put to valuable uses.

The importance of manganese in connection with the metallurgy of iron and steel is in a fair way of finding its rival in that of the metal chromium, the employment of which, as an alloy with steel, was first made the subject of experiment in 1821, by Berthier, who was led by the important experiments of Faraday and Stoddart, then just published, to endeavour to alloy chromium with steel, and obtained good results by fusing steel together with a rich alloy of chromium and iron, so as to introduce about 15 per cent. of the former into the metal. Further small experiments were made the year following, by Faraday and Stoddart, in the same direction; but chrome-steel appears to have been first produced commercially at Brooklyn, N.Y., sixteen years ago. Ten years later its manufacture had become developed in France, and the varieties of chrome-steel produced in the Loire district now receive important and continually-extending applications, on account of their combining comparative hardness with high tenacity, and only little loss in ductility, and of their acquiring great closeness of structure when tempered.

The influence of chromium upon the character of steel differs in several marked respects from that exercised by manganese; thus, chrome-steels weld badly, or not at all, whereas manganese-steels weld very readily, and work under the hammer better than ordinary carbon-steel. Again, the remarkable influence of manganese upon the magnetic properties of steel and iron is not shared by chromium. Chrome-steel has for some time been a formidable rival of the very highest qualities of carbon-steel produced for cutting-tools, and of the valuable tungsten-steel which we owe to Robert Mushet. The great hardness, high tenacity, and exceeding closeness of structure possessed by suitably-tempered steel containing not more than from 1 to 1·5 per cent. of chromium, and from 0·8 to 1 per cent. of carbon, renders this material invaluable for war purposes: cast projectiles, when suitably tempered, have penetrated compound steel and iron plates over nine inches in thickness, such as are used upon armoured ships of war, without even sustaining any important change of form. The proper tempering of these projectiles necessitates their being produced hollow; their cavities or chambers are only of small capacity, but the charge of violent explosive which they can contain, and which can be set into action without the intervention of fuze or detonating appliance, suffices to tear these formidable punching-tools into fragments as they force their way irresistibly through the armoured side of a ship, and to violently project those fragments in all directions, with fearfully destructive effects. The employment of chromium as a constituent of steel plates used for the protection of ships of war is already being entered upon, and the influence exerted by the presence of that metal in small quantities in steel employed in the construction of guns is also at present a subject of investigation. At Crewe, Mr. F. Webb has for some time past used chromium, with considerable advantage, in the production of high-quality steels for railway requirements.

The practical results attained by the introduction of copper and of nickel as components of steel have also recently attracted much attention. At the celebrated French steel works of M. Schneider, at Creuzot, the addition of a small percentage of copper to steel used for armour-plates and projectiles is practised, with the object of imparting hardness to the metal without prejudice to its toughness. James Riley has found that the presence of aluminium in very small quantities facilitates the union of steel with a small proportion of copper, and that the latter increases the strength but does not improve the working qualities of steel. With nickel, Riley has obtained products analogous in many important respects to manganese steel; the remarkable differences in the physical properties of the manganese alloys, according to their richness in that metal, are also shared by the nickel alloys, some of these being possessed of very valuable properties; thus, it has been shown by Riley that a particular variety of nickel-steel presents to the engineer the means of nearly doubling boiler-pressures, without increasing weight or dimensions. He has, moreover, found the co-existence of manganese in small quantity with nickel in the alloy to contribute importantly to the development of valuable physical properties.

The careful study of the alloys of aluminium, chromium, manganese, tungsten, copper, and nickel, with iron and with steel, so far as it has been carried, with especial reference to the influence which they respectively exercise upon the salient physical properties of those materials, even when present in them in only very small proportions, has demonstrated the importance of a more searching or complete application of chemical analysis, than hitherto practised, to the determination of the composition of the varieties of steel which practical experience has shown to be peculiarly adapted to particular uses. It appears, indeed, not improbable that certain properties of these, which have been ascribed to slight variations in the proportion or the condition of the constituent carbon, or in the amounts of silicium, phosphorus, and manganese which they contain, may sometimes have been due to the presence in minute quantities of one or other of such metals as those named, and to the effects which they produce, either directly, or indirectly by modifying or counteracting the effects of the normal constituents of steel. The important part now played by manganese in steel manufacture is an illustration of the comparatively recent results of research, and of practical work based on research, in these directions, and the effects of the presence in steel of only very small quantities of some of the other metals named are already, as I have pointed out, being similarly understood and utilized.

Such systematic researches as those upon which Osmond, Roberts-Austen, and many other workers have been for some time past engaged, may make us acquainted with the laws which govern the modifications effected in the physical characteristics of metals by alloying these with small proportions of other metals. The suggestion of Roberts-Austen, that such modifications may have direct connection with the periodic law of Mendeleeff, which may furnish explanations of the causes of specific variations in the properties of iron and steel, has been followed up energetically by Osmond, who has experimentally investigated the thermal influence upon iron of the elements phosphorus, sulphur, arsenic, boron, silicium, nickel, manganese, chromium, copper, and tungsten. He regards his results as being quite confirmatory of the soundness of Roberts-Austen's suggestion, as they demonstrate that foreign elements having atomic volumes lower than iron tend to make it assume or preserve the particular molecular form in which it has itself the lowest atomic volume, while the converse is the case for the foreign elements of high atomic volume. An analogous influence was found to be exerted by those two groups of elements upon the permanent magnetization of steel.

Captivating as such deductions are, those who have devoted much attention to the practical investigation of iron, steel, and other metals, cannot but feel that much caution has to be exercised in drawing broad conclusions from the results of such researches as these. Like the investigations recently made with the object of ascertaining the condition in which carbon exists in steel, and the part played by it in determining the modifications in the properties developed in that material by the influence of temperature and of work done upon it, they are surrounded by formidable difficulties, arising from the practical impossibility of altogether eliminating the disturbing influences of minute quantities of foreign elementary bodies, co-existing in the metal operated upon, with those whose effects we desire to study. Certain it is, however, that by acquiring an accurate acquaintance with the composition of varieties of iron and steel exhibiting characteristic properties; by persevering in the all-important work of systematic practical examination of the mechanical and physical peculiarities developed in iron and steel of known composition by their association with one or more of the rarer metals in varied proportions, and by the further prosecution of chemical and physical research in such directions as those which have already been fruitful of most instructive results, such talented labourers as Chernoff, Osmond, Roberts-Austen, Barus and Strouhal, Hadfield, Keep, James Riley, Stead, Turner, and others, cannot fail to contribute continually to the development of improvements equalling in importance those already attained in the production, treatment, and methods of applying cast-iron, malleable iron, and steel, or alloys equivalent to steel in their qualities.

The causes of the variations in the physical properties of steel produced by the so-called hardening, annealing, and tempering processes were for very many years a fruitful subject of experimental inquiry, as well as of theoretical speculation with regard to the condition in which the carbon is distributed in steel, according to whether the metal is hardened or annealed, or in an intermediate, tempered state. Recent researches have made our knowledge in the latter direction fairly precise; as yet, however, we are only on the track of definite information respecting the nature and extent of connection between the physical peculiarities of steel in those different conditions and the established differences in the form and manner in which the carbon is disseminated through it.

The careful systematic study of the modifications developed in certain physical properties of iron and steel by gradual changes of temperature between fusion of the metal and the normal temperature, has shown those modifications to be governed by a constant law, and that at certain critical temperatures special phenomena present themselves. This important subject, which was so clearly brought before the Association last year in the interesting lecture of Roberts-Austen, has been, and is still being pursued by accomplished workers, among whom the most prominent is F. Osmond. The phenomenon of recalescence, or the re-glowing of, or liberation of heat in, iron and steel at certain stages during the cooling process, first noticed by Gore, and examined into by Barrett, appears to be the result of actual chemical combination between the metal and its contained carbon at the particular temperature attained at the time; while the absorption of heat, demonstrated by the arrest in rise of temperature during its continuous application to the metal, is ascribed to the elimination, within the mass, of carbon as an iron-carbide perfectly stable at low temperatures. The pursuit of a well-devised system of experimental inquiry into this subject has led Osmond to propound theories of the hardening and tempering of steel, which are at present receiving the careful study of physicists and chemists, and cannot fail to lead to further important advancement of our knowledge of the true nature of the influence of carbon upon the properties of iron.

Another important subject connected with the treatment of masses of steel, and with the influence exercised upon their physical characteristics by the processes of hardening and tempering, and by submitting them to oft-repeated concussions or vibrations, or frequent or long-continued strains, is the development and maintenance, or gradual disappearance, of internal stresses in the masses—one of the many important subjects to which attention was directed by Dr. Anderson, the Director-General of Ordnance Factories, in his very suggestive address to the Mechanical Section last year. This question is one of especial interest to the constructor of steel guns, as the powers of endurance of these do not simply depend upon the quality of the material composing them, but are very largely influenced by the treatment which it receives at the hands of the gun-maker. Indeed, the highest importance attaches to the processes which are applied to the preliminary preparation of the individual parts of which the gun is constructed, and to the putting together of these so as to ensure their being and remaining in the physical condition best calculated to assist each other in securing for the structure the power of so successfully resisting the heavy strains to which it has to be subjected, as to suffer little alteration other than that due to the superficial action of the highly-heated products of explosion of the charges fired in the gun. The development of internal strains in objects of steel, especially by the hardening and tempering processes, or by their exposure to conditions favourable to unequal cooling of different parts of the mass, has long been a subject of much trouble and of experimental inquiry in connection with many applications of steel. Systematic experiments of the kind, commenced, about eighteen years ago, by the late Russian general Kalakoutsky, are now being pursued at Woolwich, with the objects of determining the nature and causes of internal stresses in steel gun-hoops and -tubes, and in shells, and of thereby establishing the proper course to be adopted for avoiding, lessening, or counteracting injurious stresses, on the one hand, and for setting up stresses beneficial to the powers of endurance of guns, on the other. One method of experiment pursued, with parts of guns, is to cut narrow hoops off the forgings, after a particular treatment, which are then cut right across at one place, it being observed whether, and to what extent, the resulting gaps open or close. This important subject has also been similarly investigated by my talented old friend and fellow-worker, the President this year of the Mechanical Section, Captain Andrew Noble, whose name in connection with the science and practice of artillery is familiar to us as household words.

The Crimean War taught nations many lessons of gravest import, to some of which Sir Richard Owen took occasion to call attention most impressively in the address delivered here, before the miseries of that war had become past history. The development of sanitary science, to which he especially referred, and which sprang from the bitter experience of that sad epoch, has had its parallel in the development of the science of artillery; but it would indeed be difficult to establish any parallelism between the benefits which even the soldier and the sailor have reaped from the great strides made by both these sciences. The acquisition of knowledge of the causes of the then hopelessness of gallant struggles which medical skill and self-sacrificing devotion made against the sufferings of the victims of battles and of fell diseases, as deadly as the cruellest implements of war; the application of that knowledge to the provision of the blessings of antiseptic treatment of wounds and to the intelligent utilization of disinfectants and of other valuable preventive measures, to the supply of wholesome water, of wholesome food in campaigning, of sensible clothing, and of wholesome air in hospitals, barracks, and ships—these are some few of the benefits which the soldier and the sailor have derived from the development of sanitary science, which was so powerfully stimulated by the terrible lessons learned during the long-drawn-out siege of Sebastopol: and it is indeed pleasant to reflect that there has been, for years past, most wholesome competition between nations in the enlargement of those benefits, and their dissemination among the men whose vocation it is to slay and be slain. The periodical International Congresses on Hygiene and Demography, of which we shall cordially welcome next year's assemblage in London, and whose members will deplore the absence from among them of the veteran Nestor in the science and practice of hygiene, Sir Edwin Chadwick, have afforded conclusive demonstration of the heartiness with which nations are now co-operating with a view to utilize the invaluable results attained by the successful labourers in sanitary science.

What, on the other hand, shall we say of the benefits which sailors and soldiers, in the pursuit of their calling, derive from the ceaseless costly competition amongst nations for supremacy in the possession of formidable artillery, violent explosives, quick-firing arms of deadly accuracy, and fearful engines which, unseen, can work wholesale destruction in a fleet? And what can we say of the benefits acquired by individual countries in return for their continuous, and sometimes ruinous, expenditure in endeavouring to maintain themselves upon an equality with their neighbours in man-killing power? The conditions under which engagements by sea or land will in the future be fought have certainly become greatly modified from those of thirty-five years ago, and the duration of warfare, even between nations in conflict who are on a fair equality of resources, must become reduced; but, as regards the results of a trial of strength between contending forces, similarly equipped, as they now will be, with the latest of modern appliances only varying in detail, these must, after all, depend, as of old, partly upon accident, favoured, perhaps, by a temporary superiority in equipment, partly upon the skill and military genius of individuals, and very much upon the characteristics of the men who fight the battles.

What really can be said in favour of the advances made in the appliances of war—and this is, perhaps, the view which in such a town as Leeds we should keep before our eyes to the exclusion of the dark side of the picture—is, that by continuous competition in the development of their magnitude, diversity, and perfection, the resources of the manufacturer, the chemist, the engineer, the electrician, are taxed to the uttermost; with the very important, although incidental, results, that industries are created or expanded and perfected, trades maintained and developed, and new achievements accomplished in applied science, which in time beneficially affect the advance of peaceful arts and manufactures. In these ways the expenditure of a large proportion of a country's resources upon material which is destroyed in creating destruction does substantially benefit communities, and tends to the accomplishment of such material progress by a country as goes far to compensate its people for the sacrifices which they are called upon to incur for the maintenance of their dignity among nations.

From this point of view, at any rate, it may interest members of the British Association for the Advancement of Science, and for the promotion of its applications to the welfare and happiness of mankind, to hear something of recent advances in one of the several branches of science in its applications to naval and military requirements with which, during a long and arduous official career, now approaching its close, I have become in some measure identified.

Since the meeting of the Association in this town in 1858, the progress which has been made in the regulation of the explosive force of gunpowder, so as to adapt it to the safe development of very high energy in guns presenting great differences in regard to size and to the work which they have to perform, has been most important. The different forms of gunpowder which were applied to war-purposes in this and other countries, until within the last few years, presented comparatively few differences in composition and methods of manufacture from each other, and from the gunpowder of our ancestors. The replacement of smooth-bore guns by rifled artillery, which followed the Crimean War, and the great increase in the size and power of guns, necessitated by the application of armour to ships and forts, soon called, however, for the pursuit of investigations having for their object the attainment of means for variously modifying the action of fired gunpowder, so as to render it suitable for artillery of different calibres whose power could not be effectively, or, in some instances, safely, developed by the use of the only kind of gunpowder then employed in English artillery of all calibres.

The means resorted to in the earlier of these investigations, and adhered to for many years, for controlling the violence of explosion of gunpowder, consisted exclusively in modifying the size and form of the individual masses composing a charge, and of their density and hardness, with the object of varying the rate of burning of those masses in a gun; it being considered that, as the proportions of ingredients generally employed very nearly correspond to those required for the development of the greatest chemical energy by the thoroughly-incorporated materials, the attainment of the desired results should be, if possible, effected rather by modifications of the physical and mechanical characters of gunpowder, than by variations of the proportions and chemical characters of its ingredients.

The varieties of powder from time to time introduced into artillery-service, as the outcome of investigations in this direction, were of two distinct types: the first of these consisted of further developments of the old granulated or corned powder, being produced by breaking up more or less highly-pressed slabs of the material into grains, pebbles, or boulders of approximately uniform size and shape. Gunpowders of this class, ranging in size from about 1000 pieces to the ounce to about 6 pieces to the pound, have performed efficient service, and certain of them are still employed. The character of the other type is based upon the theoretical view that uniformity in the action of a particular gunpowder, when employed under like conditions, demands not merely identity in regard to composition, but also identity in form, size, density, and structure of the individual masses of which a charge consists. To approach the practical realization of this view, equal quantities of one and the same mixture of ingredients, presented in the form of powder of uniform fineness and dryness, must be submitted to a particular pressure, for a fixed period, in moulds of uniform size, the surrounding conditions and subsequent manufacturing processes being as nearly as possible alike. Practical experience has however shown that uniformity in the ballistic properties of black powder can be even more readily secured by the thorough blending or mixing together of different products of manufacture, presenting some variations in regard to size, density, hardness, or other features, than by aiming at an approach to identity in the characters of the individual grains or masses.

When our attention was first actively directed to the modification of the ballistic properties of powder, the subject had already been to some extent dealt with, in the United States, by Rodman and Doremus, and the latter had proposed the employment, in heavy guns, of charges consisting of large pellets of prismatic form. While this prismatic powder, which was first used in Russia, was being perfected, and extensively applied there as well as in Germany and England, the production of powder-masses more suitable, by the comparatively gradual nature of their explosion, for the very large charges required for the heavy artillery of the present day, was actively pursued in Italy, and by our own Government Committee on Explosives; the outcome of exhaustive practical investigations being the very efficient Fossano powder, or *poudre progressif* of the Italians, and the boulder- and large cylindrical-powders produced at Waltham Abbey.

Researches carried out by Captain Noble and myself, some years ago, with a series of gunpowders, presenting considerable differences in composition, indicated that decided advantages might be secured, for heavy guns especially, by the employment of such a powder as would furnish a comparatively very large volume of gas, its explosion being at the same time attended by the development of much less heat than in the case of ordinary black powder. In the course of these researches much light was thrown upon the causes of the wearing or erosive action of powder-explosions upon the inner surface of the gun, an action which, especially in the larger calibres of artillery, produces so serious a deterioration of the arm that the velocity of projection and accuracy of shooting suffer considerably, the wear being especially great where the products of explosion, while under the maximum pressure, can escape between the projectile and the bore. The great velocity with which the very highly-heated gaseous and liquid (fused solid) products of explosion sweep over the heated surface of the metal gives rise to a displacement of the particles composing the surface of the bore, which increases in extent as the latter becomes roughened, and thus opposes greater resistance; at the same time, the high temperature to which the surface is raised reduces the rigidity of the metal, and its consequent power of resisting the force of the gaseous torrent; and, lastly, some amount of chemical action upon the metal, by certain of the highly-heated, non-gaseous products of explosion, contributes towards an increase in the erosive effects. Experiments made upon a large scale by Captain Noble with powders of different composition, and with other explosives, have afforded decisive evidence that the explosive agent which furnishes the largest proportion of gaseous products, and the explosion of which is attended by the development of the smallest amount of heat, exerts least erosive action.

Some eminent German gunpowder-manufacturers, who were at this time actively engaged upon the production of a suitable powder for heavy guns, directed their attention, not merely to an alteration of the proportions of the ingredients, but also to a modification in the character of charcoal employed; the eventual result was the production of a new prismatic powder, composed of saltpetre in somewhat higher proportion than in normal black powder, and of a very slightly-burned charcoal of reddish-brown colour, quite similar to the *charbon roux* which Violette produced about forty years ago for use in sporting-powder, by the action of superheated steam upon wood or other vegetable matter. This brown prismatic powder (or "cocoa powder") differs from black powder not merely in colour: it burns very slowly in the open air, and in guns its action is comparatively gradual and long-sustained. The products of its explosion are simple. As the powder contains saltpetre in large proportion relatively to the sulphur and charcoal, these become fully oxidized, and a relatively very large amount of water-vapour is produced, partly because of the comparatively high proportion of water in the finished powder, and partly from the large amount of hydrogen in the slightly-charred wood or straw used. The smoke from a charge of brown powder differs but little in volume from that of black powder, but it disperses much more rapidly, owing to the speedy absorption of the finely-divided potassium salts, forming the smoke, by the large proportion of water-vapour through which they are distributed.

This kind of powder has been substituted, with considerable advantage, for black powder in guns of comparatively large calibre, but it soon became desirable to attain even more gradual action in the case of the very large charges required for guns of the heaviest calibres, such as the 110-ton gun, from which shot of about 1800 lbs. weight are propelled by a powder-charge of 960 lbs. Brown powder has, therefore, been modified in composition to suit these conditions; while, on the other hand, a powder intermediate in rapidity of action between black powder and the brown prism powder has been found more suitable than the former for use in guns of moderately large calibre.

The importance which machine-guns and comparatively large, quick-firing guns have assumed in the armament of ships has made it very desirable to provide a powder for them which will produce comparatively little or no smoke, as their efficient employment becomes greatly limited when, after a very few rounds rapidly fired, with black powder, the objects against which it is desired to direct the fire, are more or less completely hidden by the interposed smoke. Hence much attention has of late been directed to the production of smokeless, or nearly smokeless, powders for naval use. At the same time, the views of many military authorities regarding the importance of dispensing with smoke in engagements on land have also created a demand for smokeless powders suitable for field-artillery and for small-arms.

The properties of ammonium-nitrate, of which the products of decomposition by heat are, in addition to water-vapour, entirely gaseous, have rendered it a tempting material to those who have striven to produce a smokeless powder; but its deliquescent character has been a formidable obstacle to its application as a component of a useful explosive agent. By incorporating charcoal and saltpetre in particular proportions with ammonium-nitrate, F. Gaus recently claimed to have produced an explosive material free from the hygroscopic character common to other ammonium-nitrate mixtures, and furnishing only permanently gaseous and volatile, or smokeless, products of explosion. These anticipations were not realized, but they led the talented German powder-maker, Mr. Heidemann, to produce an ammonium-nitrate powder possessing remarkable ballistic properties, and producing comparatively little smoke, which speedily disperses. It yields a very much larger volume of gas and water-vapour than either black or brown powder, and is considerably slower in action than the latter; the charge required to produce equal ballistic results is less, while the chamber-pressure developed is lower, and the pressures along the chase of the gun are higher, than with brown powder. No great tendency is exhibited by it to absorb moisture from an ordinarily dry, or even somewhat moist, atmosphere, but it rapidly absorbs water when the hygroscopic condition of the air approaches saturation, and this greatly restricts its use.

About five years ago reports began to reach us from France of the attainment of remarkable results with a smokeless powder employed with the repeating or magazine rifle then in course of adoption for military service, and of marvellous velocities obtained by the use of this powder, in specially constructed artillery of great length. As in the case of the explosive agent called *Mélinite*, the fabulously-destructive effects of which were much vaunted at about the same time, the secret of the nature of this smokeless powder was well preserved by the French authorities; it is now known, however, that more than one smokeless explosive has succeeded the original, and that the material at present in use with the Lebel repeating rifle belongs to a class of nitro-cellulose or nitro-cotton preparations, of which several have been made the subject of patents in England, and of which varieties are also being used in Germany and other countries.

A comparison between the chemical changes attending the burning or explosion of gunpowder, and of the class of nitro-compounds represented by gun-cotton, at once explains the cause of the production of smoke by the former, and of the smokelessness of the latter. Whilst the products of explosion of the nitro-compounds consist exclusively of gases and of water-vapour, gunpowder, being composed of a large proportion of saltpetre, or other metallic nitrate, mixed with charred vegetable matter and variable quantities of sulphur, furnishes products of which over 50 per cent. are not gaseous, even at high temperatures, and which are in part deposited as a fused solid—which constitutes the fouling in a firearm—and in part distributed in an extremely fine state of division through the gases and vapours developed by the explosion, thus giving to these the appearance of smoke as they escape into the air.

So far as smokelessness is concerned, no material can surpass *gun-cotton* (or other varieties of nitro-cellulose); but, even if the rate of combustion of the fibrous explosive in a firearm could be controlled with certainty and uniformity, its application as a safe propulsive agent is attended by so many difficulties that the non-success of the numerous early attempts to apply it to that purpose is not surprising. Those attempts, commencing soon after the discovery of gun-cotton, in 1846, and continued many years later in Austria, consisted entirely in varying the density and mechanical condition of employment of the gun-cotton fibre. No difficulty was experienced in thus exercising complete control over the rapidity of burning in the open air; but when the material was strongly confined, as in the bore of a gun, such methods of regulating its explosive force were quite unreliable, as some slight unforeseen variation in its compactness or in the amount and disposition of the air-spaces in the mass, would develop very violent action. Much more promising results were subsequently obtained by me by reducing the fibre to a pulp, as in the ordinary process of making paper, and converting this into highly-compressed, homogeneous masses of the desired form and size. Some favourable results were obtained at Woolwich, in 1867–68, in field-guns, with cartridges built up of compressed gun-cotton variously formed and arranged, with the object of regulating the rapidity of explosion of the charge. But although comparatively small charges often gave high velocities of projection, without any indications of injury to the gun, the uniform fulfilment of the conditions essential to safety proved to be beyond absolute control, even in guns of small calibre; and military authorities not being, in those days, alive to the advantages which might accrue from the employment of an entirely smokeless explosive in artillery, experiments in this direction were not persevered in. At the same time, considerable success attended the production of gun-cotton cartridges for sporting purposes, the rapidity of its explosion being controlled by various methods; very promising results were also attained with the Martini-Henry rifle and a lightly-compressed pulped gun-cotton charge, of pellet-form, the uniform action of which was secured by simple means.

A nearly smokeless sporting-powder had, in the meantime, been produced by Colonel Schultze, of the Prussian Artillery, from finely-divided wood, converted after purification into a mildly explosive form of nitro-cellulose, and impregnated with a small portion of an oxidizing agent. Subsequently this powder was produced in a granular form, and rendered considerably more uniform in character, and less hygroscopic; it then closely resembled the well-known E.C. sporting-powder, which consists of a nitro-cotton reduced to pulp, incorporated with the nitrates of potassium and barium, and converted into grains through the agency of a solvent and a binding material. Both these powders produce very little smoke compared with black powder, but do not compete with the latter in regard to accuracy of shooting, when used in military arms.

In past years both camphor and liquid solvents have been applied to the hardening of the surfaces of granulated or compressed masses of gun-cotton and of this class of its preparations, with a view to render them non-porous. In some smokeless powders of French, German, Belgian, and English manufacture, acetic ether and acetone have been also used, not merely to harden the granules or tablets of the explosive, but also to convert the nitro-cellulose, in the first instance, into a more or less gelatinous condition, so that it can readily be incorporated with other components and rolled, or spread into sheets, or pressed into moulds, or squirted into wires, rods, or tubes, while still in a plastic state. When the solvent has afterwards been removed, the hardened, horn-like, or somewhat plastic product is cut up into tablets, or into strips or pieces of suitable dimensions, for conversation into charges or cartridges.

Another class of smokeless powder, similar in physical characteristics to these nitro-cellulose powders, but containing nitro-glycerine as an important component, has been originated by Mr. Alfred Nobel, the well-known inventor of dynamite, and bears resemblance in its physical characteristics to another of his inventions, called blasting-gelatine, one of the most interesting of known violent explosive agents. When one of the lower products of nitration of cellulose is impregnated with the liquid explosive, nitro-glycerine, it gradually loses its fibrous nature, becoming gelatinized while assimilating the liquid; and the resulting product almost possesses the characters of a compound. This preparation, and certain modifications of it, have acquired high importance as blasting-agents more powerful than dynamite, and are possessed of the valuable property that their prolonged immersion in water does not separate from them any appreciable proportion of nitro-glycerine. The nitro-glycerine powder first produced by Mr. Nobel was almost perfectly smokeless and developed very high energy, accompanied by moderate pressures at the seat of the charge, but it possessed certain practical defects, which led to the development of several modifications of that explosive and various improvements in manufacture. The relative merits of this class of smokeless powder, and of various kinds of nitro-cellulose powder, are now under careful investigation in this and other countries, and several more or less formidable difficulties have been met with in their application, in small-arms especially; these arise in part from the comparatively great heat they develop, which increases the erosive effects of the products of explosion, and in part from the more or less complete absence of solid products. The surfaces of the barrel and of the projectile being left clean, after the firing, are in a condition favourable to their close adhesion while the bullet is propelled along the bore, with the consequent establishment of very greatly increased friction. The latter difficulty has been surmounted by more than one expedient, but always at the cost of absolute smokelessness.

Our knowledge of the results obtained in France and Germany with the use of smokeless powders in the new rifles and in artillery is somewhat limited; our own experiments have demonstrated that satisfactory results are attainable with more than one variety of them, not only in the new repeating-arm of our infantry, but also with our machine-guns, with field-artillery, and with the quick-firing guns of larger calibre which constitute an important feature in the armament of our Navy. The importance of ensuring that the powder shall not be liable to undergo chemical change detrimental to its efficiency or safety, when stored in different localities where it may be subject to considerable variations of temperature (a condition especially essential in connection with our own naval and military service in all parts of the world), necessitates qualities not very easily secured in an explosive agent consisting mainly of the comparatively sensitive nitro-compounds to which the chemist is limited in the production of a smokeless powder. It is possible, therefore, that the extent of use of such a material in our ships, or in our tropical possessions, may have to be limited by the practicability of fulfilling certain special conditions essential to its storage without danger or possible deterioration. If, however, great advantages are likely to attend the employment of a smokeless explosive, at any rate for certain Services, it will be well worth while to adopt such special arrangements as may be required for securing these without incurring special dangers; this may prove to be especially necessary in our ships of war, where temperatures so high as to be prejudicial even to ordinary black powder, sometimes prevail in the magazines, consequent mainly upon the positions assigned to them in the ships, but which may be guarded against by measures not difficult of application.

The Press accounts of the wonderful performances of the first smokeless powder adopted by the French—which, it should be added, were in some respects confirmed by official reports of officers who had witnessed experiments at a considerable distance—engendered a belief that a very great revolution in the conduct of campaigns must result from the introduction of such powders. It was even reported very positively that noiselessness was one of the important attributes of a smokeless powder, and highly-coloured comparisons have, in consequence, been drawn in Service-periodicals, and even by some military authorities, between the battles of the past and those of the future; the terrific din caused by the firing of the many guns and the roar of infantry-fire, in heavy engagements, being supposed to be reduced to noise so slight that distant troops would fail to know in what direction their comrades were engaged, and that sentries and outposts would no longer be able to warn their comrades of the approaching foe by the discharge of their rifles. Military journals of renown, misled by such legendary accounts, chiefly emanating from France, referred to the absence of noise and smoke in battles as greatly enhancing the demands for skill and courage, and as surrounding a fight with mystery. The absence of recoil when a rifle was fired with smokeless powder was another of the marvels reported to attend the use of these new agents of warfare. It need scarcely be said that a closer acquaintance with them has dispelled the credit given to such of the accounts of their supposed qualities as were mythical, and a belief in which could only be ascribable to a phenomenal combination of credulity with ignorance of the most elementary scientific knowledge.

The extensive use which has been made in Germany of smokeless or nearly smokeless powder in one or two special military displays has, however, afforded interesting indications of the actual change which is likely to be wrought in the conditions under which engagements on land will be fought in the future, provided these new explosives thoroughly establish and maintain their position as safe and reliable propelling agents. Although the powder adopted in Germany is not actually smokeless, the almost transparent film of smoke produced by independent rifle-firing with it is not visible at a distance of about 300 yards; at shorter distances it presents the appearance of a puff from a cigar. The most rapid salvo-firing by a large number of men does not have the effect of obscuring them from distant observers. When machine-guns and field-artillery are fired with the almost absolutely smokeless powder which we are employing, their position is not readily revealed to distant observers by the momentary vivid flash of flame and slight cloud of dust produced.

There now appears little doubt that in future warfare belligerents on both sides will alike be users of these new powders; the screening or obscuring effect of smoke will therefore be practically absent during engagements between contending forces, and while, on the one hand, the very important protection of smoke, and its sometimes equally important assistance in manœuvres, will thus be abolished, both combatants will, on the other hand, secure the advantages of accuracy of shooting and of the use of individual fire, through the medium of cover, with comparative immunity from detection. Such results as these cannot fail to affect, more or less radically, the principles and conditions under which battles have hitherto been fought. With respect to the naval service, it is especially for the quick-firing guns, so important for defensive purposes, that a smokeless powder has been anxiously looked for; by the adoption of such a powder as has during the past year been elaborated for our artillery, should experience establish its reliability under all Service conditions and its power to fulfil all reasonable requirements in regard to stability, these guns will not only be used by our ships under conditions most favourable to their efficiency, but their power will also be very importantly increased.

The ready and safe attainment of very high velocities of projection through the agency of these new varieties of explosive agents, employed in guns of suitable construction, would appear at first sight to promise a very important advance in the power of artillery; the practical difficulties attending the utilization of these results are, however, sufficiently formidable to place, at any rate at present, comparatively narrow limits upon our powers of availing ourselves of the advantages in ballistics which they may present. The strength of the gun-carriages and the character of the arrangements used for absorbing the force of recoil of the gun, need considerable modifications, not easy of application in some instances; greater strength and perfection of manufacture are imperative in the case of the hollow projectiles or shells to be used with charges of a propelling agent by the firing of which in the gun they may be submitted to comparatively very severe concussions; the increased friction to which portions of the explosive contents of the shell are exposed by the more violent setting back of the mass may increase the possibility of their accidental ignition before the shell has been projected from the gun; the increase of concussion to which the fuze in the shell is exposed may give rise to a similar risk consequent upon an increased liability to a failure of the mechanical devices which are applied to prevent the igniting arrangement, designed to come into operation only upon the impact or graze of the projected shells, from being set into action prematurely by the shock of the discharge; lastly, the circumstance that the rate of burning of the time-fuze which determines the efficiency of a projected shrapnel shell is materially altered by an increase in the velocity of flight of the shell, also presents a source of difficulty.

The fallibility of even the most simple forms of fuze, manufactured in very large numbers, although it may be remote, must always engender a feeling of insecurity, when shells are employed containing an explosive agent of the class which, in recent years, it has been sought, by every resource of ingenuity, combined with intimate knowledge of the properties of these explosives, to apply as substitutes for gunpowder in shells, on account of their comparatively great destructive power.

One of the first uses, for purposes of warfare, to which it was attempted to apply gun-cotton, was as a charge for shells. But even when this was highly-compressed, and accurately fitted the shell-chamber, with the intervention only of a soft packing between the surfaces of explosive and of metal, to guard against friction between the two upon the shock of the discharge, no security was attainable against the ignition of the comparatively sensitive explosive by friction established within its mass at the moment when the shell is first set in motion. By the premature explosion of a shell charged with gunpowder, no important injury is inflicted upon the gun, but a similar accidental ignition of a gun-cotton charge must almost inevitably burst the arm. The earlier attempts to apply gun-cotton as a bursting-charge for shells were several times attended by very disastrous accidents of this kind; but the fact, afterwards discovered, that wet compressed gun-cotton, even when containing sufficient water to render it quite uninflammable, can be detonated through the agency of a sufficiently powerful charge of fulminate of mercury, or of a small quantity of dry gun-cotton embedded within it, has led to the perfectly safe application of gun-cotton in shells, provided the fuze, through the agency of which the initiative detonating agent in the shell comes into operation, is secure against any liability to premature ignition when the gun is fired. Many successful experiments have been made with shells thus charged with wet gun-cotton, which is now recognized as a formidable destructive agent applicable in shells with much less risk of casualty than attends the use of many other of the violent explosive bodies which it has become fashionable, in professional parlance, to designate as "high explosives."

Many devices and arrangements, more or less ingenious and complicated, have been schemed, especially in the United States, for applying preparations of the very sensitive liquid, nitroglycerine, such as dynamite and blasting-gelatine, as charges for shells. Some of these consist in subdividing the charge by more or less elaborate methods; in others the shell is also lined with some soft elastic packing-material, and paddings of similar material are applied in the head and the base of the shell-chamber, with the object of reducing the friction and concussion to which the explosive is exposed when the projectile is first set in motion. Such arrangements obviously reduce the space available for the charge in the shell, and the best of them fail to render these explosives as safe to employ as wet gun-cotton. In order to avoid exposing shells loaded with such explosives to the concussion produced when propelling them by a powder-charge, compressed air has been applied as the propelling agent, and guns of special construction and very large dimensions, from which shells containing as much as 500 lbs. of gun-cotton or dynamite are projected through the agency of compressed air, have recently been elaborated in the United States, where great expectations are entertained of the value, for war-purposes, of these so-called pneumatic guns.

A highly ingenious device for utilizing a class of very powerful explosives in shells, without any risk of accident to the gun, was not long since brought forward by Mr. Grüsen, the well-known armour-plate and projectile manufacturer of Magdeburg. It consisted of a thoroughly efficient arrangement for applying the fact, first demonstrated by Dr. Sprengel, that mixtures of nitric acid of high specific gravity with solid or liquid hydrocarbons, or with the nitro-compounds of these, are susceptible of detonation, with development of very high energy. The two agents, of themselves non-explosive—nitric acid and the hydrocarbon, or its nitro-product—are separately confined in the shell; when it is first set in motion by the firing of the gun, the fracture of the receptacle containing the liquid nitric acid is determined by a very sinple device; the two substances are then free to come into contact, and their very rapid mixture is promoted by the rotation of the shell, so that, almost by the time that it is projected from the gun, its contents, at first quite harmless, have become converted into a powerfully explosive mixture, ready to come into operation through the action of the fuze. Although safety appears assured by this system, the comparatively complicated nature of the contrivance, and the loss of space in the shell thereby entailed, place it at a disadvantage, especially since some other very violent explosive agents have come to be applied with comparative safety in shells.

Between four and five years ago intelligence first reached us of marvellously destructive effects produced by shells charged with an explosive agent which the French Government was elaborating. The reported results surpassed any previously recorded in regard to violently destructive effects and great velocity of projection of the fragments of exploded shells, and it was asserted that the employment of this new material, Mélinite, was unattended by the usual dangers incident to this particular application of violent explosive agents, an assertion scarcely consistent with accounts which soon reached us of several terrible calamities due to the accidental explosion of shells loaded with Mélinite.

Although the secret of the precise nature of Mélinite has been extremely well preserved, it transpired ere long that extensive purchases were made in England, by or for the French authorities, of one of the many coal-tar derivatives which for some years past has been extensively manufactured for tinctorial purposes, but which, although not itself classed among explosive bodies until quite lately, had long before been known to furnish, with some metals, more or less highly explosive combinations, some of which have been applied to the production of preparations suggested as substitutes for gunpowder.

The product of destructive distillation of coal from which, by oxidation, this material is now manufactured, is the important and universally-known antiseptic and disinfectant, carbolic acid, or phenol. Originally designated carbazotic acid, the substance now known as picric acid was first obtained in small quantities as a chemical curiosity by the oxidation of silk, aloes, &c., and of the well-known blue dye indigo, which thus yielded another dye of a brilliant yellow colour. To the many who may regard this interesting phenol-derivative as a material concerning the stability and other properties of which we have little knowledge it will be interesting to learn that it has been known to chemists for more than a century. It was first manufactured in England for tinctorial purposes by the oxidation of a yellow resin (*Xanthorrhœa hastilis*), known as Botany Bay gum. Its production from carbolic acid was developed in Manchester in 1862, and its application as a dye gradually extended, until, in 1886, nearly 100 tons were produced in England and Wales.

Although picric acid compounds were long since experimented with as explosive agents, it was not until a very serious accident occurred, in 1887, at some works near Manchester where the dye had been for some time manufactured, that public attention was directed in England to the powerfully explosive nature of this substance itself. The French authorities appear, however, to have been at that time already engaged upon its application as an explosive for shells. It is now produced in very large quantities at several works in Great Britain, and it has been extensively exported during the last four years, evidently for other than the usual commercial purposes. Large supplies of phenol, or carbolic acid, have, at the same time, been purchased in England for France, and lately for Germany, doubtless for the manufacture of picric acid, very extensive works having been established for its production in both those countries. It has been made the subject of experiment by our military authorities, and its position has been well established as a thoroughly stable explosive agent, easily manufactured, comparatively safe to deal with, and very destructive when the conditions essential for its detonation are fulfilled.

The precise nature of Mélinite appears to be still only known to the French authorities: it is asserted to be a mixture of picric acid with some material imparting to it greater power; but accounts of accidents which have occurred even quite recently in the handling of shells charged with that material appear to show that, in point of safety or stability, it is decidedly inferior to simple picric acid. Reliable as the latter is in this respect, its employment is, however, not unattended with the difficulties and risks which have to be encountered in the use, in shells, of other especially violent explosives. Future experience in actual warfare can alone determine decisively the relative value of violent explosive agents, like picric acid or wet gun-cotton, and of the comparatively slow explosive, gunpowder, for use in shells; it is certain, however, that the latter still presents distinct advantages in some directions, and that there is no present prospect of its being more than partially superseded as an explosive for shells.

With regard to submarine mines and locomotive torpedoes, such as those marvels of ingenuity and constructive skill, the Whitehead and Brennan torpedoes, the important progress recently made in the practical development of explosive agents has not resulted in the provision of a material which equals wet compressed gun-cotton in combining with great destructive power the all-important essential of safety to those who have to deal with these formidable weapons, and to man the small vessels which have to perform the very hazardous service of attacking ships of war at short distances by means of locomotive torpedoes.

Although the subject of the development of explosive force for purposes of war has of late received from workers in applied science, from seekers of patentable inventions, and even from the public generally, a somewhat predominating share of attention, considering that we congratulate ourselves upon the enjoyment of a period of profound peace, yet the production of new explosive agents for mining and quarrying purposes, which present or lay claim to points of superiority over the well-established blasting-agents, has been by no means at a standstill. For many years the main object sought to be achieved in this direction was to surpass, in power or adaptability to particular classes of work, the well-known preparations of nitro-glycerine and gun-cotton, which, during the past twenty years, have been formidable competitors and, in many directions, absolutely successful rivals, of black powder. It is both interesting and satisfactory to note, however, that this object has of late, and especially since the publication of the results of labours of English and foreign Commissions on the causes of mine-accidents, been prominently associated with endeavours to solve the important problems of combining, in an explosive agent, efficiency in point of power with comparative non-sensitiveness to explosion by friction or percussion, and of securing its effective operation with little or no accompaniment of projected flame. Safety-dynamites, flameless explosives, water-cartridges, and other classes of materials and devices connected with the getting of coal, the quarrying of rock, or the blasting of minerals, have claimed the attention of those who guide the miner's work; in some of these directions the practical results obtained have been beyond question important, and, indeed, conclusive as regards the great diminution of risks to which men need be exposed in those coal-mines where the ordinary use of explosives, although not altogether inadmissible, may at times be attended with danger. It is to be feared that those results are still far from receiving the amount of application which might reasonably be hoped for; but, at any rate, there are, among the extensive mining districts where the employment of explosives in connection with the getting of coal cannot be dispensed with, several of importance where the use of gunpowder has almost entirely given place to the adoption of blasting-agents or methods of blasting, the employment of which is either not, or only very exceptionally, attended by the projection of flame or incandescent matter into the air where the shot is fired.

The mining public is especially indebted to German workers for much of the success which has been obtained in this direction, and also to the eminent French authorities, Mallard and Le Chatelier, for their thorough theoretical and practical investigations bearing upon the prevention of accidental ignition of fire-damp during blasting operations. Having arrived at the conclusion that fire-damp- and air-mixtures are not ignited by the firing of explosive preparations which develop by their detonation temperatures lower than 2220° C., they found that ammonium-nitrate, although in itself susceptible of detonation, does not develop a higher temperature than 1130° C., while the temperature of detonation of nitro-glycerine and gun-cotton are, respectively, 3170° and 2636°. The admixture of that salt with nitro-glycerine or gun-cotton in sufficient proportion to reduce the temperature of detonation to within safe limits allows, therefore, of the employment of those explosive agents in the presence of fire-damp mixtures without risk of accident, and this fact has led to the effective use of such mixtures as safe blasting-agents in coal.

Those who have been content to labour long and arduously with the objects steadily in view of advancing our knowledge of the causes of mine-accidents and of developing resources and measures for removing or combating those causes, can cherish the conviction that recent legislation in connection with coal-mines, based upon the results of those labours, has been already productive of decided benefits to the miner, even although it has fallen short of what might reasonably have been hoped for as an outcome of the very definite results and conclusions arrived at by the late Royal Commission on Accidents in Mines (in the recent much-lamented death of whose universally respected chairman, my late esteemed friend and colleague, Sir Warington Smyth, the scientific world has sustained the loss of an ardent worker, and the miner, of an invaluable friend).

The fearful dangers arising from the accumulation of inflammable dust in coal-mines, and the equality of mine-dust with fire-damp in its direful power of propagating explosions, which may sometimes even be, in the first instance, established chiefly or entirely through its agency, have now been long recognized as beyond dispute; and it is satisfactory to know that permission to fire shots in mine-workings which are dry and dusty has, by recent legislation, been made conditional upon the previous laying of the dust by effective watering. In some mining districts, moreover, the purely voluntary practice has been extensively adopted by mine-owners of periodically watering the main roads in dry and dusty mines, or of frequently discharging water-spray into the air in such roads, which must tend greatly to reduce the possible magnitude of the disastrous results of a fire-damp or dust explosion in any part of the mine-workings.

The encouragement given to the application of the combined resources of ingenuity, mechanical skill, and knowledge of scientific principles, through the elaborate, but thoroughly practical comparative trials to which almost every variety of safety-lamp has, during the last few years, been submitted by competent and conscientious experimenters, has resulted in the provision of lamps to the hand of the miner which combine the essential qualities of safety, under the most exceptionally severe conditions, with good illuminating power, simplicity of construction, lightness, and moderate cost. Very important progress has also been made, since the first appointment of the late Accidents in Mines Commission, towards the provision of thoroughly serviceable and safe portable electric lamps for use in mines. Of those which have already been in the hands of the miners, several have fairly fulfilled his requirements as regards size, weight, and illuminating power of sufficient duration; but much still remains to be accomplished with respect to durability, simplicity, thorough portability, and cost, before the self-contained electric lamp can be expected to compete successfully with the greatly improved miners' lamps which are now in use, or available.

The recent legislation in connection with mines is certainly deficient in any sufficiently decisive measure for excluding from mine-workings certain forms of lamps which, while fairly safe in the old days of sluggish ventilation, are unsafe in the rapid air-currents now frequently met with in mines; it is, however, very satisfactory to know that the strong representations on this subject made by the late Commission, combined with the force of example and with the conclusive demonstration of the superiority of other lamps, by exhaustive experiments, have led within the last two years to the very general abandonment of the unprotected Davy, Clanny, and Stephenson lamps in favour, either of simple, safe modifications of these, or of other safe and efficient lamps, and that one possible element of danger to the miner has thus been eliminated, at any rate in many districts. In one important respect recent improved legislation has failed to effect a most desirable change—namely, in the substitution of safety-lamps for naked lights in workings where small local accumulations of fire-damp are discovered from time to time. There appears little doubt that one of the three fearful explosions which have occurred within the last twelve months—the explosion at Llanerch Colliery, near Pontypool—was caused by the continued employment of naked lights in a mine where inspection constantly revealed the presence of fire-damp. This, and two other terrible disasters, at Mossfield Colliery, in Staffordshire, at Morfa Colliery, near Swansea, which have occurred since the last meeting of the Association, may have seemed to weaken the belief that the operation of the recent Mines Regulation Act, which was based upon some of the results of seven years' arduous labour of the late Mines Commission, must have resulted in very substantial improvement in the management of mines and in the conduct of work by the men. Happily, however, there is a consensus of opinion among those most competent to judge—*i.e.* the Government Mine Inspectors—that very decided benefits have already accrued from the operation of the new Act. Although far from embodying all that the experienced mine-owners, miners, and scientific workers upon that Commission, as well as practical authorities in Parliament, concurred in regarding as reasonably adaptable, from the results of observation and experiment, to the furtherance of the safer working of mines, this Act does include measures, precautionary and preventive, of undeniable utility, well-calculated to lessen the dangers which surround the miner, and to add to his personal comfort underground. We may hope, moreover, that the operation of the Act is paving the way to more comprehensive legislation in the near future; for it can scarcely be doubted, by the light of recent sad experience, that there are directions in which both masters and men still hesitate to adopt, of their own free will, measures or regulations, methods of working or appliances and precautions, which are calculated to be important additional safeguards against mine-accidents, and which are either left untouched, or only hesitatingly and imperfectly dealt with in the recent enactments.

My labours upon the late Mines Commission represent only one of several subjects in connection with which it has been my good fortune to have opportunities of rendering some slight public service in directions contrasting with one of the main functions of my career, by endeavouring to apply the results of scientific research to a diminution of the risks to which particular classes of the community, or the public at large, are exposed—of being sufferers by explosions, the results of accidents or other causes.

During the pursuit of bread-winning vocations, and even in ordinary domestic life, the conditions, as well as the materials, requisite for determining more or less disastrous explosions are often ready to hand, and their activity may be evoked at any moment through individual heedlessness or through pure accident. Steam, or gases confined under pressure, volatile inflammable liquids, combustible gases, or finely-divided inflammable solids, are now all well recognized as capable of assuming the character of formidable explosive agents; but with respect to the three last-named, it is only of late that material progress has been made towards a popular comprehension and appreciation of the conditions conducive to danger, and of those by the fulfilment of which danger may be avoided. Thus, the causes of explosions in coal-laden ships, together with the occurrence of spontaneous ignition in coal-cargoes, another fruitful source of disaster, were made the subject of careful inquiry some years ago by a Royal Commission, upon which I had the pleasure of working with the late Dr. Percy, whose invaluable labours for the advancement of metallurgic science will always be gratefully remembered. The light thrown by that inquiry upon the causes of those disasters, and upon the conditions to be fulfilled for guarding against the accumulations of fire-damp, gradually escaping from occlusion in coal, and of heat, developed by chemical changes occurring in coal-cargoes, has unquestionably led to an important reduction of the risks to which coal-laden ships are exposed. Subsequent official inquiries and experimental investigations, in which I took part with the late Sir Warington Smyth and some eminent naval officers, consequent upon the loss of H.M.S. *Doterel* through the accidental ignition of an explosive mixture of petroleum spirit-vapour and air (and other calamities in war-ships originating with the gradual emission of fire-damp from coal), have resulted in the adoption of efficient arrangements for ventilating all spaces occupied by, and contiguous to, the large supplies of fuel which these vessels have to carry.

The thorough investigation, by Rankine and others, of the causes of explosions in flour-mills, which in years past were so frequent and disastrous, has secured the adoption of efficient measures for diminishing the production, and the dissemination through channels and other spaces in the mills, of explosive mixtures of flour-dust and air, and for guarding against their accidental ignition. The numerous terrible accidents caused by the formation and accidental ignition of explosive mixtures of inflammable vapour and air in ships carrying cargoes of petroleum stored in barrels or in tanks, have, by the investigations to which they have given rise, led to the indication of effective precautionary measures for guarding against their recurrence. Again, the many distressing accidents, frequently fatal, which have attended the domestic use of those valuable illuminants, petroleum and mineral oils of kindred character, have been made the subject of exhaustive investigations, which have demonstrated that these disasters may readily be prevented by the employment of lamps of proper construction, and by the observance of very simple precautions by the users of them; and a recent official inquiry which I have conducted with Mr. Boverton Redwood has furnished most gratifying proof that very substantial progress has been made within the last few years by lamp-manufacturers in the voluntary adoption of such principles of construction as we had experimentally demonstrated to be essential for securing the safe use of mineral oils in lamps for lighting and heating purposes, the employment of which has, within a brief period, received enormous extension in this and other countries.

The creation and rapid development of the petroleum industry has, indeed, furnished one of the most remarkable illustrations which can be cited of industrial progress during the period which has elapsed since the British Association last met in Leeds. One year after that meeting, viz. on August 28, 1859, the first well, drilled in the United States with the object of obtaining petroleum, was successfully completed, and the rate of increase in production in the Pennsylvania oil-fields during the succeeding years is shown by the following figures:—

In 1859, 5000 barrels (of forty-two American gallons) were produced In the following year the production increased to 500,000 barrels; while in the next year (1861) it exceeded 2,000,000 barrels, at which figure it remained, with slight fluctuations, until 1865. The supply then continued to increase gradually, until, in 1870, it reached nearly 6,000,000 barrels; while in 1874 it amounted to nearly 11,000,000 barrels. In 1880 it amounted to over 26,000,000 barrels, and in 1882 it reached 31,000,000. Since then the supply furnished by the United States has fallen somewhat, and last year it amounted to 21,500,000 barrels. The production of crude petroleum in the Pennsylvanian fields, large as it has been, has not, however, kept pace with the consumption, for we find that the accumulated stocks, which on December 31, 1888, amounted to over 18,000,000 barrels, had become reduced to about 11,000,000 barrels at the close of last year. At this rate the surplus stock above ground will have vanished by the end of the current year. In addition to the petroleum raised in Pennsylvania, there is now a very large production in the State of Ohio; but this has not as yet been employed as a source of lamp-oil; it is, however, transported by pipe line in great quantities to Chicago, for use as liquid fuel in industrial operations.

A few years after the development of the United States petroleum-industry, the production of crude petroleum in Russia also began to extend very rapidly. For more than 2500 years, Baku, on the borders of the Caspian Sea, has been celebrated for its naphtha springs, and for the perpetual flames of the Fire Worshippers, fed by the marvellous subterranean supplies of natural gas. To a limited extent neighbouring nations appear to have availed themselves of the vast supplies of mineral oil at Baku during the past thousand years. By the thirteenth century the export of the crude oil had already become somewhat extensive, but the production of petroleum from it by distillation is of comparatively recent date. In 1863 the supplies of petroleum from the Baku district amounted to 5018 tons; they increased to somewhat more than double during the succeeding five years. In 1869 and following three years the production reached about 27,000 tons annually, and in 1873 it was about 64,000 tons; three years later, 153,000 tons were produced, and in the following five years there was a steady annual increase, until, in 1882, the production amounted to 677,269 tons; in 1884 it considerably exceeded 1,000,000 tons, and last year it had reached the figure of about 3,300,000 tons. The consumption of crude petroleum as fuel for locomotive purposes has, moreover, now assumed very large proportions in Russia, and many millions of gallons are annually consumed in working the vast system of railways on both sides of the Caspian Sea.

The imported refined petroleum used in this country in lamps for lighting, heating, and cooking, was exclusively American until within the last few years, but a very large proportion of present supplies comes from Russia. The imports of kerosene into London and the chief ports of the United Kingdom during 1889 amounted to 1,116,205 barrels of United States oil, and 771,227 barrels of Russian oil. During the same period the outturn of mineral oil for use in lamps by the Scottish shale oil companies probably amounted to about 500,000 barrels.

Another important feature connected with the development of the petroleum industry is the great extent to which the less volatile products of its distillation have replaced vegetable and animal oils and fats for lubricating purposes in this and other countries. The value of petroleum as a liquid fuel and as a source of gas for illuminating purposes has, moreover, been long since recognized, and it is probable that one outcome of the attention which is now being given to the hitherto unworked deposits of petroleum in the East and West Indies, South America, and elsewhere, will be a very large increase in its application to these purposes. In the East Indies there are vast tracts of oil-fields in Burmah, Baluchistan, Assam, and the Punjab. The native Rangoon oil industry is one of great antiquity, although the oil was only used in the crude condition until about thirty-five years ago, at which time Dr. Hugo Müller, with the late Warren De la Rue, whose many-sided labours and generous benefactions have so importantly contributed to the advancement of science, made valuable researches on the products furnished by crude oil imported from Rangoon. The resources of the oil-fields of Upper Burmah, especially of the district of Yenangyoung (or *creek of stinking water*), have since then been developed by British enterprise, and have attained to considerable importance since our annexation of Upper Burmah.

The great extension of the petroleum trade is gradually leading to very important improvements in the system of transport of the material over water and on land. Until recently this has been carried out entirely in barrels and tin cases; the consequent great loss from leakage and evaporation, accompanied by risk of accident, is now becoming much reduced by the rapidly-increasing employment of tank-steamers, which transport the oil in bulk. Tank railway-waggons have for some time past been in use in Russia, and there is a prospect of these and of tank-barges being adopted here for the distribution of the oil; while in London, the practice is already spreading gradually of distributing supplies to tradesmen from tank road-waggons. Some considerable doubt as to whether the risk of accident has not rather been altered in character than actually reduced by the new system of transport, has not unnaturally been engendered in the public mind by the occurrence within a comparatively short period of several serious disasters during the discharge of cargoes from tank-vessels. The memorable explosion which took place, in October 1888, on board the *Ville de Calais*, in Calais Harbour, with widespread destructive effects, was followed by a similarly serious explosion in the *Fergusons*, at Rouen, last December, and, more recently, by a fire of somewhat destructive character at Sunderland, resulting from the discharge into the river of petrolem-residues from a ship's tanks. In all these cases the petroleum was of a nature to allow inflammable vapour to escape readily from the liquid, so that an explosive mixture could be rapidly formed by its copious diffusion through the air. No similar casualty has been brought to notice as having happened to tank-ships carrying petroleum oil of which the volatility is in accordance with our legal requirements, and this points to the prudence of restricting the application of the tank system to the transport and distribution of such petroleum as complies with well-established conditions of safety.

Another most remarkable feature connected with the development of the petroleum industry is presented by the utilization, within the last few years, of the vast supplies of natural inflammable gas furnished by the oil-fields.

In America this remarkable gas-supply was for a long time only used locally, but, before the close of 1885 its conveyance to a distance by pipes, for illuminating and heating purposes, had assumed large proportions; one of the companies in Pittsburgh having alone laid 335 miles of pipes of various sizes, through which gas was supplied equivalent in heating value to 3,650,000 tons of coal per annum. Since then the consumption in and around Pittsburgh has probably been at least tripled. At the close of 1886 six different companies were conveying natural gas by pipes to Pittsburgh from 107 wells; 500 miles of pipe, ranging in diameter from 30 inches to 3 inches, were used by these companies, 232 miles of which were laid within Pittsburgh itself. The Philadelphia Company, the most important of these associations, then owned the gas supply from 54,000 acres of land situated on all the anticlinals around Pittsburgh, but drew its supplies only from Tarentum and the Murraysville field. It supplied, in 1886, 470 factories and about 5000 dwellings within the city, besides many factories and dwellings in Alleghany, and in numerous neighbouring villages. The average gas-pressure at the wells, when the escape is shut off, is about 500 lbs. per square inch, and in the case of new wells this pressure is very greatly exceeded. In order to minimize the danger from leakage the gas-pressure in the city is reduced to a maximum of 13 lbs., and is regulated by valves at a number of stations under the control of a central station. The usual pressure in the larger lines is from 6 to 8 lbs., while in the low-pressure lines it does not exceed 4 to 5 ounces.

The effect of the change from coal-gas to natural gas upon the atmosphere over Pittsburgh has been most marked: formerly the sky was constantly obscured by a canopy of dense smoke; now the atmosphere is clear, and even white paint may with impunity be employed for the house fronts.

The very rapid development of the employment of natural gas is not confined to the neighbourhood of Pittsburgh; it is used for heating purposes in the cities of Buffalo, Erie, Jamestown, Warren, Olean, Bradford, Oil City, Titusville, Meadville, Youngstown, and perhaps twenty more towns and villages in Pennsylvania and North-western New York. In North-western Ohio, the cities of Toledo and Sandusky, the towns of Findlay, Lima, Tiffin, Fostoria, and others in that section are also supplied with natural gas; a pipe line has moreover been recently laid to Detroit, Mich., and it is estimated that in these localities 36,131,669,000 cubic feet of the gas were consumed during last year, displacing 1,802,500 tons of coal. To the south-west of Pittsburgh there are many smaller places which consume natural gas; it also occurs in considerable quantity, and is being utilized, in Indiana (whence an account has recently reached us of a terrific subterranean explosion of the gas); and it is at the present time contemplated to carry a natural gas-supply to Chicago.

The utilization of the natural gas of the Russian oil-fields, although of very ancient date, has hitherto not been extensive, neither does the magnitude of the supply appear to bear comparison with that of the Pennsylvanian district.

A form of gaseous fuel which has long been known to technical chemists and metallurgists, but which has of late attracted considerable attention, especially in connection with the recent interesting work relating to its applications pursued by Mr. Samson Fox, of Leeds, has become, within the last four years, a competitor, in the United States, both of the natural gas of Pennsylvania and of coal-gas. Since Felix Fontana first produced so-called water-gas in 1780, by passing vapour of water over highly-heated fuel, many methods, differing chiefly in small details, have been proposed for carrying out the operation, with a view to the ready and cheap production of the resulting mixture of hydrogen and carbonic oxide, and numerous technical applications of water-gas have been suggested from time to time, with no very important results, excepting as regards its use for lighting-purposes. Being of itself non-luminous, its utilization in this direction is accomplished, either by mixing it with a highly luminous gas, or by causing a hydrocarbon vapour to be diffused through it; or the non-luminous flame, produced by burning it in the air, is made to raise to incandescence some suitably prepared solid substance, such as magnesia, lime, a zirconium salt, or platinum, whereby bright light is emitted. The objection to its employment as an illuminant for use in buildings, to which great weight is attached by us, and rightly, as sad experience has shown—viz. that, as it consists, to the extent of about one-half its volume, of the highly poisonous gas carbonic oxide, the atmosphere in a confined space may be rendered irrespirable by a small accidental contamination with water-gas, by leakage or otherwise, not detectable by any odour—appears to constitute no great impediment to its employment in the United States, as it is now manufactured for illuminating and heating purposes by a large proportion of their gas-works, being in some places employed in admixture with a highly luminous coal-gas, in others rendered luminous by the alternative methods mentioned. It is stated that about three-fourths of the illuminating gas now supplied to the cities of New York, Brooklyn, Philadelphia, Jersey, St. Paul, and Minneapolis, is carburetted water-gas; in Chicago the entire supply now consists of this gas, and Boston will also soon be supplied exclusively with it. The use of water-gas for metallurgic work does not appear to be contemplated in the United States, but it is especially to such applications of the gas that much attention has been devoted here in Leeds; and although some eminent experts are sceptical regarding the attainment of advantages, especially from an economical point of view, by the employment of this form of gaseous fuel, especially after practical experience in the same direction acquired in Germany, the technical world must feel grateful to Mr. Fox for his work in this direction, affording, as it does, an interesting illustration of the qualities of perseverance and energy which, when combined with sound knowledge, often achieve success in directions that have long appeared most unpromising—qualities which have been characteristic of many pioneers in industrial progress in this country.

Leeds has been especially fortunate in the possession of such pioneers, who, when competition brought about great changes in the particular trade through which, for many generations, this city chiefly enjoyed prosperity and high renown, developed its power and resources in new directions, from which success soon flowed in continually increasing measure. The rapid rise of Leeds to its present high position in industrial prosperity and national importance most probably dates from the period when its chief staple industry began to experience serious rivalry, in its own peculiar achievements, on the part of other districts of the kingdom and of other countries. From early days a flourishing centre of one of the provinces of Great Britain most richly endowed with some of Nature's best treasures, Leeds could scarcely have failed, through the energy, acute intelligence, and powerful self-reliance especially characteristic of the men of Yorkshire, to rapidly acquire fresh renown in connection with industries which either were new to the town and district, or had been pursued in comparatively modest fashion, and which have combined to place the Leeds of to-day upon a higher pinnacle of commercial prosperity, power, and influence than her patriotic citizens of old could ever have dreamt of.

An examination into the present educational resources of Leeds places beyond any doubt the fact that her present prosperity in commerce and industries is in no small degree ascribable to the paramount importance long since attached here to the liberal provision of facilities for the diffusion of knowledge among the artisan- and industrial-classes, and especially for the acquisition of a sound acquaintance with the principles of the sciences and their applications to technical purposes, with particular reference to the prominent local industries, by all grades of those who pursue or intend to pursue them. There is, probably, no town in the kingdom more amply provided with efficient elementary and advanced schools for both sexes, while the special requirements of the artisan are efficiently met by the prosperous School of Science and Technology. The resources of the Yorkshire College provide, in addition, a combination of thorough scientific education with really practical training in the more important local industries; indeed, during the sixteen years of its continually-progressive work, this institution has acquired so widespread a reputation that students come from abroad to reap the advantages afforded by the unrivalled textile and dyeing departments of the Leeds College. The keen competition now existing between these departments and the corresponding branches of the much younger but most vigorous sister College at Bradford, can only conduce to the further development of both, and to their thorough maintenance up to the requirements of the day.

The very important pecuniary aid afforded to these establishments, and to a number of other technical schools in Yorkshire, by one of the most important of the ancient Companies of the City of London, the Clothworkers, affords an interesting illustration of the good work in the cause of education performed by those Guilds, and, especially of late years, by means of their flourishing Institute for the advancement of technical education, which, through its two great instructional establishments in London, and through the operation of its system of examinations throughout the country, extending now even to the colonies, has afforded very important aid towards eradicating the one great blot upon our national educational organization. To have been first in the field in practically developing a far-reaching scheme for the advancement of technical education in this country must continue to be a source of pride to the City of London and its ancient Guilds in time to come, when the operation of efficient legislation, supported and extended by patriotic munificence and by the hearty co-operation of associations of earnest and competent workers in the cause, shall have placed the machinery and resources for the technical instruction of the people upon a footing commensurate with our position among nations.

The remarkable address delivered by Owen here in 1858, wherein the condition, at that time, of those branches of natural science which he had made particularly his own was most comprehensively reviewed, included some especially interesting observations on the importance to the cultivation and progress of the natural sciences, and to the advancement of education of the masses in this country, of providing adequate space and resources for the proper development of our national Museum of Natural History; and it cannot but be a source of great satisfaction and pride to him to have lived to witness the thoroughly successful realization of the objects of his own indefatigable strivings and powerful advocacy in that direction. Comprehensive as were the views adopted by Owen regarding the scope and possible extension of that Museum, it may, however, be doubted whether they ever embraced so extensive a field as was presented for our contemplation by his successor last year, when he told us that a natural history museum should, in its widest and truest sense, represent, so far as they can be illustrated by museum-specimens, all the sciences which deal with natural phenomena, and that the difficulties of fitly illustrating them have probably alone excluded such subjects as astronomy, physics, chemistry, and physiology, from occupying departments in our national Museum of Natural History.

The application, in its broadest signification, of the title, Natural History Museum, may doubtless be considered to include, not only illustrations and examples of the marvellous works of the Creator and of the results of man's labours in tracing their intimate history and their relations to each other, but also illustrations of the means employed, and of the results attained, by man in his strivings to fathom and unravel the laws by which the domains of Nature are governed. But the reason why representative collections, illustrative of the physical sciences, do not form part of our national Natural History Museum, has, I venture to think, scarcely been correctly ascribable to any difficulty of organizing fit illustrations of methods of investigation, of the attendant appliances, and of the results obtained by experimental research; it appears, rather, to exist in the fact that physical science has hitherto had no share in such a combination of circumstances as has been favourable to the good fortunes and advancement of the natural sciences, and as is analogous to those which, from time to time, give rise to the provision of increased accommodation for our national art treasures. Our present national Science Collection, which has, indeed, had a struggle for existence, does not owe the development it has hitherto experienced to any such moral pressure as has been several times exercised in the case of our art collections, by the munificence of individuals, with the result of securing substantial aid from national resources; its gradual increase in importance has been due to the untiring perseverance of men of science, and of a few prominent influential and public-spirited authorities, in keeping before the public the lessons taught by careful inquiries, such as those intrusted to the Royal Commission on Scientific Instruction, into the opportunities afforded for the cultivation of science and the development of its applications, in other countries, as compared with those provided here.

The success of the efforts made in 1875 by a committee thoroughly representative of every branch of experimental science, to bring together in London an international loan collection of scientific apparatus, and the widespread interest excited by that collection, led the President of the Royal Society, in union with many distinguished representatives of science, to lay before our Department of Education a proposal to establish a national museum of pure and applied science, including the Museum of Inventions, which had already existed since 1860 as a nucleus of a science museum, the establishment whereof had formed part of the original scheme of the Science and Art Department. The Loan Collection of 1876 did, in fact, and in consequence of the urgent representations then made, first put into practical shape the long-cherished desire of men of science to see an institution arise in England similar to the Conservatoire des Arts et Métiers of France, and it became the starting-point of the national collection, representative of the several branches of experimental science, which has been undergoing slow but steady development since that time, patiently awaiting the provision of a suitable home for its contents. This collection, which illustrates not only the means whereby the triumphs of research in experimental science have been and are achieved, but also the methods by which these departments of science are taught, yields, small as it is, to none of our national museum-treasures in interest and importance.

In yet another way did that Loan Collection become illustrious: one of the most interesting features connected with it was the organization of a series of important conferences and explanatory lectures, serving to illustrate, and also greatly to enhance, its value, and affording most invaluable demonstration of the way in which such collections must exercise direct influence upon the advancement of science and upon the diffusion of scientific knowledge. These lectures and conferences demonstrated the wisdom of the suggestion made by the illustrious representative of associated science in Leeds eighteen years previously, that public access to museums should be combined with the delivery of lectures emphasizing and amplifying the information afforded by their contents. The example there set of thoroughly utilizing for instructional purposes, and for the advancement of science, a collection illustrative of the physical sciences, has since been followed by the Science and Art Department; illustrative lectures connected with the existing nucleus of a national science collection, have been delivered from time to time, and the objects in the collection are constantly utilized in the courses of instruction of the adjoining Normal School of Science.

Although the national importance of thoroughly representative and continously-maintained science collections has long been manifest, not only to all workers in science, but also to all who have cared to inquire, even superficially, into the influence of the cultivation of science upon the industrial and commercial prosperity of the country, the labours of a Royal Commission, and of successive Committees, in demonstrating the necessity for the provision of adequate accommodation for such collections, and for their support upon the basis of that afforded to the natural history collections, have been very long in bearing fruit. However, lovers of science, and those who have the prosperity of the country near at heart, have at length cause for rejoicing at the acquisition by the nation of a site in all respects suitable and adequate for the accommodation of the science collections, which, as soon as appropriate buildings are provided for their reception, will not fail, in comprehensiveness and completeness, to become worthy of a country which has been the birthplace of many of the most important discoveries in science, and of a people who have led the van among all nations in making the achievements of science subservient to the advancement of industries and commerce.

The site selected as the permanent home of our national Science Collections is immediately in rear of the Natural History Museum, and faces the stately edifice, now rapidly progressing towards completion, for the erection of which, as an Imperial memorial of the Queen's Jubilee, funds were provided by voluntary contributions from every portion of the Empire and every class in the Empire's nations. The Imperial Institute, the conception of which we owe to His Royal Highness the Prince of Wales, occupies a central position among buildings devoted to the illustration and cultivation of pure and applied science and of the arts—*i.e.* the Normal School of Science, the Technical College of the City and Guilds of London, the National Schools of Art, the Science Museum, the South Kensington Museum, and the Royal College of Music; to which we may ere long see added a National Gallery of representative British Art. A more fitting location could scarcely be conceived for this pre-eminently national institution, which has for its main objects the comprehensive and continuously progressive illustration—of the practical applications of the vast resources presented by the animal, vegetable, and mineral kingdoms to industries and the arts; of the extent, and the progressive opening up, of those resources in all parts of the Empire; of the practical achievements emanating from the results of scientific research; and of the utilization of the arts for the purposes of daily life. With the attainment of these objects it will be the function of the Imperial Institute to combine the continuous elaboration of systematic measures tending to stimulate progress in trades and handicrafts, and to foster a spirit of emulation among the artisan and industrial classes. Another branch of the Institute's work, upon which it is already engaged, is the systematic collection of data relating to the natural history, commercial geography, and resources of every part of the Empire, for wide dissemination, together with all current information bearing upon the commerce and industries of the Empire and of other countries, which can be comprised under the head of Commercial Intelligence. The achievement of these objects should obviously tend to maintain intimate intercourse, relationship, and co-operation between the great home and colonial centres of commerce, industries, and education, and to enhance importantly our power of competing successfully in the great struggle, in which nations are continuously engaged, for supremacy in commercial and industrial enterprise and prosperity.

To the elaboration of the practical details of a system of operation calculated to secure the objects I have indicated, eminent public-spirited men are now devoting their best energies, with the sanguine expectation of realizing the hope cherished by the Royal Founder of the Imperial Institute, that this memorial of the completion, by our beloved Sovereign, of fifty years of a wise and prosperous reign, is destined to be one of the most important bulwarks of this country, its colonies and dependencies, by becoming a great centre of operations, ceaselessly active in fostering the unity, and developing the resources, and thus maintaining and increasing the power and prosperity, of our Empire.

SECTION B.

CHEMISTRY.

OPENING ADDRESS BY PROF. T. E. THORPE, B.SC., PH.D., F.R.S., TREAS.C.S., PRESIDENT OF THE SECTION.

LEEDS has one most notable association with chemistry of which she is justly proud. In the month of September 1767, Dr. Joseph Priestley took up his abode in this town. The son of a Yorkshire cloth-dresser, he was born, in 1733, at Fieldhead, a village about six miles hence. His relatives, who were strict Calvinists, on discovering his fondness for books, sent him to the academy at Daventry to be trained for the ministry. In spite of his poverty and of certain natural disadvantages of speech and manner, he gradually acquired, more especially by his controversial and theological writings, a considerable influence in Dissenting circles. A pressing invitation and the offer of one hundred guineas a year induced him to accept an invitation to take charge of the congregation of Mill Hill Chapel here. He was already known to science by his "History of Electricity," and the effort was made to attach him still more closely to its cause by the offer of an appointment as naturalist to Cook's second expedition to the South Seas. But, thanks to the intervention of some worthy ecclesiastics on the Board of Longitude who had the direction of the business, and who, as Prof. Huxley once put it, "possibly feared that a Socinian might undermine that piety which in the days of Commodore Trunnion so strikingly characterized sailors," he was allowed to remain in Leeds, where, as he tells us in his "Memoirs," he continued six years, "very happy with a liberal, friendly, and harmonious congregation," to whom his services (of which he was not sparing) were very acceptable. "In Leeds," he says, "I had no unreasonable prejudices to contend with, and I had full scope for every kind of exertion."[1]

We have every reason to feel grateful to the "worthy ecclesiastics," since their action indirectly occasioned Priestley to turn his attention to chemistry. The accident of living near a brewery led him to study the properties of "fixed air," or carbonic acid, which is abundantly formed in the process of fermentation, and which at that time was the only gas whose separate and independent existence had been definitely established. From this happy accident sprang that extraordinary succession of discoveries which earned for their author the title of the Father of Pneumatic Chemistry, and which were destined to completely change the aspect of chemical theory and to give it a new and unexpected development.

I have been led to make this allusion to Priestley, not so much on account of his connection with this place as for the reason that, as it seems to me, there has been a disposition to obscure his true relation to the marvellous development of chemical science which made the close of the last century memorable in the history of learning. Our distinguished fellow-worker, M. Berthelot, the Perpetual Secretary of the French Academy, has recently published, under the title of "La Révolution Chimique," a remarkable book, written with great skill, and with all the charm of style and perspicacity which invariably characterizes his work, in which he claims for Lavoisier a participation in discoveries which we count among the chief scientific glories of this country. From the eminence of M. Berthelot's position in the world of science, his book is certain to receive in his own country the attention which it merits, and as it is issued as one of the volumes of the Bibliothèque Scientifique Internationale, it will probably obtain through the medium of translations a still wider circulation. I trust that I shall not be accused of being unduly actuated by what Mr. Herbert Spencer terms "the bias of patriotism" in deeming the present a fitting occasion on which to bring these claims to your notice with a view of determining how far they can be substantiated.

All who are in the least degree familiar with the history of chemical science during the last hundred years will recognize, as I proceed, that the claims which M. Berthelot asserts on behalf of his illustrious predecessor are not put forward for the first time. Explicitly made, in fact, by Lavoisier himself, they were uniformly and consistently disallowed by his contemporaries. M. Berthelot now seeks to support them by additional evidence, and to strengthen them with new arguments, and asks us thereby to clear the memory of Lavoisier from certain grave charges which lie heavily on it. You have doubtless anticipated that these claims have reference to Lavoisier's position in relation to the discovery of oxygen gas and the determination of the non-elementary nature of water.

The substance we now call oxygen—a name we owe to Lavoisier—was discovered by Priestley on August 1, 1774; he obtained it, as every schoolboy knows, by the action of heat upon the red oxide of mercury. We all remember the characteristically ingenuous account which Priestley gives of the origin of his discovery. M. Berthelot sees in it merely the evidence of the essentially empirical character of his work. "Priestley," he says, "the enemy of all theory and of every hypothesis, draws no general conclusion from his beautiful discoveries, which he is pleased, moreover, not without affectation, to attribute to chance. He describes them in the current phraseology of the period with an admixture of peculiar and incoherent ideas, and he remained obstinately attached to the theory of phlogiston up to his death, which occurred in 1804" (p. 40). Such a statement is calculated to give an erroneous idea of Priestley's merit as a philosopher. That the implication it contains is wholly opposed to the real spirit of his work might be readily shown by numerous quotations from his writings. Perhaps this will suffice:—"It is always our endeavour, after making experiments, to generalize the conclusions we draw from them, and by this means to form a *theory* or system of principles to which all the *facts* may be reduced, and by means of which we may be able to foretell the result of future experiments." This quotation is taken from the concluding chapter of his "Experiments and Observations on Different Kinds of Air," in which he actually seeks to draw "general conclusions" concerning the constituent principles of the various gases which he himself made known to us, and to show the bearing of these conclusions on the doctrine of phlogiston. That he was content to rest in the faith of Stahl's great generalization, even to the end, is true, and the fact is the more remarkable when we recall the absolute sincerity of the man, his extraordinary receptivity, and, as he says of himself, his proneness "to embrace what is generally called the heterodox side of almost every question." If it is argued that this merely shows Priestley's inability to appreciate theory, it must be at least admitted that there is no proof that he was inimical to it. His position is clearly evident from the concluding words of the section of his work from which I have already quoted:—"This doctrine of the composition and decomposition of water has been made the basis of an entirely new system of chemistry, and a new set of terms has been invented and appropriated to it. It must be acknowledged that substances possessed of very different properties may, as I have said, be composed of the same elements in different proportions and different modes of combination. It cannot, therefore, be said to be absolutely *impossible* but that water may be composed of these two elements or any other. But then the supposition should not be admitted without *proof*; and if a former theory will sufficiently account for all the *facts* there is no occasion to have recourse to a new one, attended with no peculiar advantage (*loc. cit.*, p. 543). . . . I should not feel much reluctance to adopt the *new doctrine*, provided any new and stronger evidence be produced for it. But though I have given all the attention that I can to the experiments of M. Lavoisier, &c., I think that they admit of the easiest explanation on the *old system*" (*loc. cit.*, p. 563).

The fact that Priestley was the first to consciously isolate oxygen is not contested by M. Berthelot, although he is careful to point out, what is not denied, that the exact date of the discovery depends on Priestley's own statement, and that his first publication of it was made in a work published in London in 1775. It was known before Priestley's famous experiment that the red oxide of mercury, originally formed by heating the metal in contact with air, would again yield mercury by the simple action of heat and without the intervention of any reducing agent. Bayen, six months before the date of Priestley's discovery, had observed that a gas was thus disengaged, but he gave no description of its nature, contenting himself merely by pointing out the analogy which his experiments appeared to possess to those of Lavoisier on the existence of an elastic fluid in certain substances. Afterwards, when the facts were established, Bayen drew attention to

[1] Leeds still enjoys one of the fruits of Priestley's insatiable power of work in her admirable Proprietary Library. He seems to have suggested its formation, and was its first honorary secretary.

his earlier experiments, and claimed, not only the discovery of oxygen, but all that Lavoisier deduced from it. "But," says M. Berthelot, in reference to this circumstance, "his contemporaries paid little heed to his pretensions, nor will posterity pay more" ("La Révolution Chimique," p. 60).

M. Berthelot, however, does not dismiss Lavoisier's claims to a participation in the discovery in the same summary fashion. On the contrary, whilst not explicitly claiming for him the actual isolation, in the first instance, of oxygen, the whole tenor of his argument is to extenuate, and even to justify, his demand to be regarded as an independent discoverer of the gas. He begins by asserting that Lavoisier had already a presentiment of its existence in 1774, and he quotes, in support of this assumption, an abstract from Lavoisier's memoir, published in December 1774, in the *Journal de Physique* of the Abbé Rozier: "This air, deprived of its fixable portion (by metals during calcination), is in some fashion decomposed, and this experiment would seem to afford a method of analyzing the fluid which constitutes our atmosphere, and of examining the principles of which it is composed. . . . I believe I am in a position to affirm that the air, as pure as it is possible to suppose it, free from moisture and from every foreign substance, far from being a simple body, or element, as is commonly thought, should be placed, on the contrary, . . . in the group of the mixtures, and perhaps even in that of the compounds."

M. Berthelot further asserts that Lavoisier was at this time the first to recognize the true character of air, and he expresses his belief that it is probable that he would himself have succeeded in isolating its constituents if the path of inquiry had been left to him alone. It is no disparagement to Lavoisier's prescience to say that there is nothing in these lines, nor in the memoir of the repetition of Boyle's experiments on the calcination of tin to which they refer, to show that Lavoisier had made any advance beyond the position of Hooke and Mayow. It has been more than once pointed out that the chemists of the seventeenth century understood the true nature of combustion in air mnch better than their brethren of the last quarter of the eighteenth century. Hooke, in the "Micrographia," and Mayow, in his "Opera Omnia Medicophysica," indicated that combustion consists in the union of something with the body which is being burnt; and Mayow, both by experiment and inference, demonstrated in the clearest way the analogy between respiration and combustion, and showed that in both processes one constituent only of the air is concerned. He distinctly stated that, not only is there increase of weight attending the calcination of metals, but that this increase is due to the absorption of the same *spiritus* from the air that is necessary to respiration and combustion. Mayow's experiments are so precise, and his facts so incontestable, that, as Chevreul has said, it is surprising that the truth was not fully recognized until a century after his researches (*vide* Watts's "A Dictionary of Chemistry," by Morley and Muir, Art. "Combustion," p. 242).

It is now necessary to examine Lavoisier's claims rather more closely and in the light of M. Berthelot's book. A *résumé* of his work "On the Calcination of Tin" was given by Lavoisier to the Academy in November 1774, but the complete memoir was not deposited until May 1777. A careful comparison of an abstract of what was stated to the Academy in November 1774, contributed by Lavoisier himself, in December 1774, to the *Journal de Physique* of the Abbé Rozier, makes it evident that very substantial additions were made to the communication before it was finally printed in the *Mémoires de l'Académie des Sciences*. The possibility of this is allowed by M. Berthelot. He says:—"A summary communication, often given *vivâ voce* to a learned Society, such as the Academy of Sciences of Paris or the Royal Society of London, would immediately call forth verifications, ideas, and new experiments, which would develop the range and even the results of such communication. The original author, when printing his memoir, would in return—and for this he is hardly blamable—embody these additional results and later interpretations. It thus becomes most difficult to assign impartially to each his share in a rapid succession of discoveries" (*loc. cit.*, p. 58).

But although, as we shall see, Lavoisier was certainly aware of Priestley's great discovery, no allusion is made to the gas, nor to Priestley's previous work on the other constituent of air, which is printed in the Philosophical Transactions for 1772, and for which he was awarded the Copley Medal by the Royal Society. It is simply impossible to believe that Lavoisier could have been uninfluenced by this work. Indeed, we venture to assert that the full and clear recognition of the non-elementary nature of the air which he eventually made was based upon it. It is noteworthy that in the early part of his memoir he states his opinion that the addition, not only of powdered charcoal, but of any phlogistic substance to a metallic calx is attended with the formation of fixed air. It is certain that at this period he had not only not consciously obtained any gas resembling Priestley's dephlogisticated air from any calx with which he had experimented, but that none of his experiments had afforded him any idea that the gas absorbed during calcination was identical with it.

At Easter 1775, Lavoisier presented a memoir to the Academy "On the Nature of the Principle which Combines with Metals during Calcination." This was "*relu le* 8 *août*, 1778." To the memoir there is a note stating that the first experiments detailed in it were performed more than a year before; those on the red precipitate were made by means of *a burning-glass* in the month of November 1774, and were repeated in the spring of 1775 at Montigny in conjunction with M. Trudaine. In this paper Lavoisier first distinctly announces that the principle which unites with metals during their calcination, which increases their weight, and which transforms them into calces, is nothing else "than the purest and most salubrious part of the air; so that if that air which has been fixed in a metallic combination again becomes free, it reappears in a condition in which it is eminently respirable, and better adapted than the air of the atmosphere to support inflammation and the combustion of substances" ("Œuvres de Lavoisier," official edition, vol. ii. p. 123). He then describes the method of preparing oxygen by heating the red oxide of mercury, and compares its properties with those of fixed air. There is, however, no mention of Priestley, nor any reference to his experiments. It can hardly be doubted that in this memoir Lavoisier intended his readers to believe that he was "the true and first discoverer" of the gas which he afterwards named oxygen. This is borne out by certain passages in his subsequent memoir "On the Existence of Air in Nitrous Acid; *lu le* 20 *avril*, 1776, *remis en décembre* 1777." He had occasion incidentally to prepare the red oxide of mercury by calcining the nitrate, and says that he obtained from it a large quantity of an air "much purer than common air, in which candles burnt with a much larger, broader, and more brilliant flame, and which in no one of its properties differed from that which *I* had obtained from the calx of mercury, known as *mercurius præcipitatus per se*, and which Mr. Priestley had procured from a great number of substances by treating them with nitric acid."

In another part of this memoir he says that "perhaps, strictly speaking, there is nothing in it of which Mr. Priestley would not be able to claim the original idea; but as the same facts have conducted us to diametrically opposite results, I trust that, if I am reproached for having borrowed my proofs from the works of this celebrated philosopher, my right at least to the conclusions will not be contested." M. Berthelot remarks on the irony of this passage: we may infer from it that the friends of the English chemist had not been altogether idle. In his memoir "On the Respiration of Animals," read to the Academy in 1777, he again appears to admit the claim of Priestley to at least a share in the discovery: "It is known from Mr. Priestley's and my experiments that *mercurius præcipitatus per se* is nothing but a combination," &c. In several subsequent communications Priestley's name is mentioned in very much the same connection, until we come to the classical memoir "On the Nature of the Acids," when it is said: "I shall henceforth designate the dephlogisticated air, or the eminently respirable air, . . . by the name of the *acidifying principle*, or, if it is preferred to have the same signification under a Greek word, by that of the '*principe oxygine*.'"

In none of the memoirs after that of Easter 1775 is the claim for participation more than implied; it is made explicitly for the first time in the paper "On the Method of Increasing the Action of Fire," printed in the *Mémoires de l'Académie* for 1782, and in these words:—"It will be remembered that at the meeting of Easter 1775 I announced the discovery, which I had made some months before with M. Trudaine,[1] in the laboratory at Montigny, of a new kind of air, up to then absolutely unknown, and which we obtained by the reduction of *mercurius præcipitatus per se*. This air, which Mr. Priestley discovered at very nearly the same time as I, and I believe even before me, and which he had procured mainly from the combination of minium

[1] M. Trudaine de Montigny died in 1777.

and of several other substances with nitric acid, has been named by him *dephlogisticated air*."

In the "Traité Elémentaire de Chimie" the claim for participation is again asserted in these words: "This air, which Mr. Priestley, Mr. Scheele, and I discovered at about the same time . . ."

Now, there is no question that Lavoisier knew of the existence of oxygen some months before he made the experiments with the burning-glass of M. Trudaine at Montigny, *for the simple reason that Priestley had already told him of it*. Priestley left Leeds in 1773 to become the librarian and literary companion of Lord Shelburne, and in the autumn of 1774 he accompanied his lordship on to the Continent, and spent the month of October in Paris. Lavoisier was famous for his hospitality; his dinners were celebrated; and Priestley, in common with every foreign *savant* of note who visited Paris at that period, was a welcome guest. What followed is best told in Priestley's own words:—"Having made the discovery [of oxygen] some time before I was in Paris, in the year 1774, I mentioned it at the table of Mr. Lavoisier, when most of the philosophical people of the city were present, saying that it was a kind of air in which a candle burnt much better than in common air, but I had not then given it any name. At this all the company, and Mr. and Mrs. Lavoisier as much as any, expressed great surprise. I told them I had gotten it from *precipitate per se* and also from *red lead*. Speaking French very imperfectly, and being little acquainted with the terms of chemistry, I said *plombe rouge*, which was not understood till Mr. Macquer said I must mean *minium*."

In his account of his own work on dephlogisticated air, given in his "Observations," &c., 1790 edition, he further says, vol. ii. p. 108: "Being at Paris in the October following [the August of 1774], and knowing that there were several very eminent chemists in that place, I did not omit the opportunity, by means of my friend Mr. Magellan,[1] to get an ounce of *mercurius calcinatus* prepared by Mr. Cadet, of the genuineness of which there could not possibly be any suspicion; and, at the same time, I frequently mentioned my surprise at the kind of air which I had got from this preparation to Mr. Lavoisier, Mr. le Roy, and several other philosophers, who honoured me with their notice in that city, and who, I dare say, cannot fail to recollect the circumstance."

If any further evidence is required to prove that Lavoisier was not only not "the true and first discoverer" of oxygen, but that he has absolutely no claim to be regarded even as a later and independent discoverer, it is supplied by M. Berthelot himself. Not the least valuable portion of M. Berthelot's book, as an historical work, is that which he devotes to the analysis of the thirteen laboratory journals of Lavoisier, which have been deposited, by the pious care of M. de Chazelles, his heir, in the archives of the Institute. M. Berthelot has given us a synopsis of the contents of almost every page of these journals, with explanatory remarks and dates when these could be ascertained. As he well says, these journals "are of great interest because they inform us of Lavoisier's methods of work and of the direction of his mind—I mean the successive steps in the evolution of his private thought." On the fly-leaf of the third journal is written "*du* 23 *Mars*, 1774, *au* 13 *février*, 1776." From p. 30 we glean that Lavoisier visited his friend M. Trudaine at Montigny about ten days after his conversation with Priestley, and repeated the latter's experiments on the marine acid and alkaline airs (hydrochloric acid gas and ammonia). He is again at Montigny some time between February 28 and March 31, 1775, and repeats not only Priestley's experiments on the decomposition of mercuric oxide, presumably by means of M. Trudaine's famous burning-glass, but also his observations on the character of the gas. The fly-leaf of the fourth journal informs us that it extends from February 13, 1776, to March 3, 1778. On p. 1 is an account of experiments made February 13 on "précipité *per se* de chez M. Baumé," in which the disengaged gas is spoken of as "*l'air déphlogistique de M. Prisley*" (*sic*). Such a phrase in a private notebook is absolutely inconsistent with the idea that at this time Lavoisier considered himself as an independent discoverer of the gas. How he came to regard himself as such we need not inquire. Nor is it necessary to occupy your time by any examination of the arguments by which M. Berthelot, with the skill of a practised advocate, would seem to identify himself with the case of his client. We would do him the justice of recognizing the difficulty of his position. He seeks to discharge an obligation of which the acknowledgment has been too long delayed. The Académie des Sciences a year ago awoke to the sense of its debt of gratitude to the memory of the man who had laboured so zealously for its honour, and even for its existence, during the stormy period of which France has just celebrated the centenary, and out of the *éloge* on Lavoisier which M. Berthelot, as Perpetual Secretary, was commissioned to deliver, has grown "La Révolution Chimique." To write eulogy, however, is not necessarily to write history. We cannot but think that M. Berthelot has been hampered by his position, and that his opinion, or at least the free expression of it, has been fettered by the conditions under which he has written. We imagine we discern between the lines the consciousness that, to use Brougham's phrase, the brightness of the illustrious career which he eulogizes is dimmed with spots which a regard for historical truth will not permit him wholly to ignore.

Two cardinal facts made the downfall of phlogiston complete —the discovery of oxygen, and the determination of the compound nature of water. M. Berthelot's contention is that not only did Lavoisier effect the overthrow, but he also discovered the facts. In other words, he has not only a claim to a participation in the discovery of oxygen, but he is also "the true and first discoverer" of the non-elementary nature of water. This second claim is directly and explicitly stated. Although it is supported by a certain ingenuity of argument, we venture to think that we shall be able to show it has no greater foundation in reality than the first.

Members of the British Association, who are at all familiar with its history, will recall the fact that this is not the first occasion on which the attempt to transfer "those laurels which both time and truth have fixed upon the brow of Cavendish" has had to be resisted. At the Birmingham meeting of 1839 the Rev. W. Vernon Harcourt, who then presided, devoted a large portion of his address to an able and eloquent vindication of Cavendish's rights. The attack came then as now from the Perpetual Secretary of the French Academy, and the charges were also formulated then, as now, in an *éloge* read before that learned body. The assailant was M. Arago, who did battle, not for his countryman, Lavoisier, whose claims are dismissed as "pretensions," but on behalf of James Watt, the great engineer, who was one of the foreign members of the Institute.

It is not my wish to trouble you at any length with the details of what has come to be known in the history of scientific discovery as the Water Controversy—a controversy which has exercised the minds and pens of Harcourt, Whewell, Peacock, and Brougham in England; of Brewster, Jeffrey, Muirhead, and Wilson in Scotland; of Kopp in Germany; and of Arago and Dumas in France. This controversy, it has been said, takes its place in the history of science side by side with the discussion between Newton and Leibnitz concerning the invention of the Differential Calculus, and that between the friends of Adams and Leverrier in reference to the discovery of the planet Neptune. Up to now it has practically turned upon the relative merits of Cavendish and Watt. M. Berthelot is the first French *savant* of any note who has seriously put forward the claims of Lavoisier, his countryman and predecessor Dumas having deliberately rejected them.

At the risk of wearying you with detail, I am under the necessity of restating the facts in order to make the position clear. Some time before April 18, 1781, Priestley made what he called "a random experiment" for the entertainment of a few philosophical friends. It consisted in exploding a mixture of inflammable air (presumably hydrogen) and common air, contained in a closed glass vessel, by the electric spark, in the manner first practised by Volta in 1776. The experiment was witnessed by Mr. John Warltire, a lecturer on natural philosophy and a friend of Priestley, who had rendered him the signal service of giving him the sample of the mercuric oxide from which he had first obtained oxygen. Warltire drew Priestley's attention to the fact that after the explosion the sides of the glass vessel were bedewed with moisture. Neither of the experimenters attached any importance to the circumstance at the time, Priestley being of opinion that the moisture was pre-existent in the gases, as no special pains were taken to dry them. Warltire, however, conceived the notion that the experiment would afford the means of determining whether heat was ponderable or not, and hence he was led to repeat it, firing the mixture in a copper vessel for

[1] Prof. Grimaux ("Lavoisier," p. 51), says: "Un de ses [Lavoisier's] amis qui habitait Londres, Magalhaens ou Magellan, de la famille du célèbre navigateur, lui envoyait tous les mémoires sur les sciences qui paraissaient en Angleterre, et le tenait au courant des découvertes de Priestley."

greater safety. The results of these observations are contained in Priestley's "Experiments and Observations on Air," vol. v. 1781, App., p. 395.

At this period Cavendish was engaged on a series of experiments "made, as he says, principally with a view to find out the cause of the diminution which common air is well known to suffer by all the various ways in which it is phlogisticated, and to discover what becomes of the air thus lost or condensed" (Cavendish, Phil. Trans. 1784, p. 119). On the publication of Priestley's work he repeated Waltire's experiment, for, he says, as it "seemed likely to throw great light on the subject I had in view, I thought it well worth examining more closely." The series of experiments which Cavendish was thus induced to make, and which he made with all his wonted skill in quantitative work, led him some time in the summer of 1781 to the discovery that a mixture of two volumes of the inflammable air from metals (the gas we now call hydrogen) with one volume of the dephlogisticated air of Priestley combine together under the influence of the electric spark, or by burning, to form the same weight of water. If Cavendish had published the results of these observations at or near the time he obtained them, there would have been no Water Controversy. But in the course of the trials he found that the condensed water was sometimes acid, and the search for the cause of the acidity (which incidentally led to the discovery of the composition of nitric acid) occasioned the delay. The main result that a mixture of two volumes of inflammable air and one volume of dephlogisticated air could be converted into the same weight of water was, however, communicated to Priestley, as he relates in a paper in the Phil. Trans. for 1783. Priestley was at this time interested in an investigation on the seeming convertibility of water into air, and he was led to repeat Cavendish's experiments, some time in March 1783, on what was apparently the converse problem. Priestley, however, made a fatal blunder in the repetition. With the praiseworthy idea of obviating the possibility of any moisture in the gases, he prepared the dephlogisticated air from nitre, and the inflammable air by heating what he calls "perfectly made charcoal" in an earthenware retort. At this time, it must be remembered, there was no sharp distinction between the various kinds of inflammable air: hydrogen, sulphuretted hydrogen, marsh gas and olefiant gas, coal gas, the vapours of ether and turpentine, and the gas from heated charcoal, consisting of a mixture of carbonic oxide, marsh gas, and carbonic acid, were indifferently termed "inflammable air." Priestley attempted to verify Cavendish's conclusion on the identity of the weight of the gases used with that of the water formed; but his method in this respect, as in his choice of the inflammable air, was wholly defective, and could not possibly have given him accurate results. It consisted in wiping out the water from the explosion vessel by means of a weighed piece of blotting-paper and determining the increase of weight of the paper. He says, however:—"I always found as near as I could judge the weight of the decomposed air in the moisture acquired by the paper. . . . I wished, however, to have had a nicer balance for this purpose; the result was such as to afford a strong presumption that the air was reconverted into water, and therefore that the origin of it had been water." These results, together with those on the conversion of water into air, were communicated towards the end of March 1783 by Priestley to Watt, who began to theorize upon them, and then to put his thoughts together in the form of a letter to Priestley, dated April 26, 1783, and which he requested might be read to the Royal Society on the occasion of the presentation of Priestley's memoir. In this letter Watt says:—"Let us now consider what obviously happens in the case of the deflagration of the inflammable and dephlogisticated air. These two kinds of air unite with violence, they become red-hot, and upon cooling totally disappear. When the vessel is cooled, a quantity of water is found in it equal to the weight of the air employed. This water is then the only remaining product of the process, and *water, light*, and *heat* are all the products. *Are we not then authorized to conclude that water is composed of dephlogisticated air and phlogiston deprived of part of their latent or elementary heat; that dephlogisticated or pure air is composed of water deprived of its phlogiston and united to elementary heat and light, &c.?*"

This letter, although shown to several Fellows of the Society, was not publicly read at the time intended. Priestley, before its receipt, had detected the fallacy of his experiments on the seeming conversion of water into air, and as much of the letter was concerned with this matter Watt requested that it should be withdrawn. Watt, however, as he tells Black[1] in a letter dated June 23, 1783, had not given up his theory as to the nature of water, and on November 26, 1783, he restated his views more fully in a letter to De Luc. In the meantime, Cavendish, having completed one section of his investigation, sent in a memoir to the Royal Society, which was read on January 15, 1784, in which he gives an account of his experiments, and announces his conclusion "that dephlogisticated air is in reality nothing but dephlogisticated water, or water deprived of its phlogiston; or, in other words, that water consists of dephlogisticated air united to phlogiston; and that inflammable air is either pure phlogiston, as Dr. Priestley and Mr. Kirwan suppose, or else water united to phlogiston." Watt thereupon requested that his letter to De Luc should be published, and it was accordingly read to the Royal Society on April 29, 1784. Which of the two—Cavendish or Watt—is, under these circumstances, to be considered as "the true and first discoverer" of the compound nature of water is the question which has been hitherto the main subject of the Water Controversy.

Let us now consider the matter as it affects Lavoisier. In 1783, Lavoisier had publicly declared against the doctrine of phlogiston, or rather, as M. Dumas puts it, "against the crowd of entities of that name which had no quality in common except that of being intangible by every known method" ("Leçons sur la Philosophie Chimique," p. 161). How completely Lavoisier had dissociated himself from the theory may be gleaned from his memoir of that year. "Chemists," he says, "have made a vague principle of phlogiston which is not strictly defined, and which in consequence accommodates itself to every explanation into which it is pressed. Sometimes this principle is heavy and sometimes it is not; sometimes it is free fire and sometimes it is fire combined with the earthly element; sometimes it passes through the pores of vessels and sometimes they are impenetrable to it: it explains at once causticity and non-causticity, transparency and opacity, colours and the absence of colours. It is a veritable Proteus which changes its form every moment."

But Lavoisier had merely renounced one fetich for another. At the time that he penned these lines he was as much under the thraldom of *le principe oxygine* as the most devoted follower of Stahl was in the bondage of phlogiston. The idea that the calcination of metals was but a slow combustion had been fully recognized. M. Berthelot tells us that, as far back as the March of 1774, Lavoisier had written in his laboratory journal:—"I am persuaded that the inflammation of inflammable air is nothing but a fixation of a portion of the atmospheric air, a decomposition of air. . . . In that case in every inflammation of air there ought to be an increase of weight, and he tried to ascertain this by burning hydrogen at the mouth of a vessel from which it was being disengaged. In the following year he asks, What remains when inflammable air is burnt completely? According to the theory by which he is now swayed it should be an acid, and he made many attempts to capture this acid. In 1777 he and Bucquet burnt six pints of the inflammable air from metals in a bottle containing lime-water, in the expectation that fixed air would be the result. And in 1781 he repeated the experiment with Gengembre, with the modification that the oxygen was caused to burn in an atmosphere of hydrogen, but not a trace of any acid product could be detected. Of course there must have been considerable quantities of water formed in these experiments, but Lavoisier was preoccupied with the conviction that oxidation meant acidification, and its presence was unnoticed, or, if noticed, was unheeded. Macquer, in 1776, had drawn attention to the formation of water during the combustion of hydrogen in air, but Lavoisier has stated that he was ignorant of that observation. What was it then that put him on the right track? We venture to think that M. Berthelot has himself supplied the answer. He says (p. 114):—"Rumours of Cavendish's trials had spread throughout the scientific world during the spring of 1783. . . . Lavoisier, always on the alert as to the nature of the products of the combustion of hydrogen, was now in such position that the slightest hint would enable him to comprehend its true nature. He hastened to repeat his trials, as he had the right to do, never having ceased to occupy himself with a question which lay at the very heart of his doctrine."

"On the 24th of June, 1783," continues M. Berthelot, "he repeated the combustion of hydrogen in oxygen, and he obtained a notable quantity of water without any other product, and he

[1] Watt, "Correspondence," p. 31.

concluded from the conditions under which he had worked that the weight of the water formed could not be other than equal to that of the two gases which had formed it. The experiment was made in the presence of several men of science, among whom was Blagden, a member of the Royal Society of London, who on *this occasion* recalled the observations of Cavendish (*qui rappela à cette occasion les observations de Cavendish*)."

On the following day Lavoisier published his results. The following is the official minute of the communication taken from the register of the sittings of the Académie des Sciences :—

Meeting of Wednesday, June 25, 1783.

MM. Lavoisier and De Laplace announced that they had lately repeated the combustion of Combustible Air with Dephlogisticated Air; they worked with about 60 *pints of the airs, and the combustion was made in a closed vessel: the result was very pure water.*

The cautious scribe who penned that minute did not commit himself too far. M. Berthelot, however, regards it as the first certain date of publication, established by authentic documents, in the history of the discovery of the composition of water; "a discovery," he adds, "which, on account of its importance, has excited the keenest discussion."

You will search in vain through the laboratory journals, as given by M. Berthelot, for any indications either of experiments or reflections which would enable you to trace the course of thought by which Lavoisier was guided to the truth. There is absolutely nothing on the subject until in the eighth volume (25 *mars*, 1783, *au février* 1784), and on p. 63 we come to the experiment of June 24, and we read :—"In presence of Messieurs Blagden, of [name illegible], de Laplace, Vandermonde, de Fourcroy, Meusnier, and Legendre, we have combined in a bell-jar dephlogisticated air and inflammable air drawn from iron by means of sulphuric acid, &c. . . . The amount of water may be estimated at 3 drachms: the amount which should have been obtained was 1 ounce 1 drachm and 12 grains. Thus we must suppose that there was a loss of two-thirds of the amount of the air or that there has been a loss of weight."

And this is the experiment which, according to M. Berthelot, enabled Lavoisier to conclude that "the weight of the water formed could not be other than equal to that of the two gases which had formed it"! It is on this single experiment, hurriedly and imperfectly done, that Lavoisier's claim to the discovery of the compound nature of water is based! M. Berthelot objects to the assumption that it was hurriedly done. He says, on p. 114: "Lavoisier caused a new apparatus to be made, with a couple of tubes and two reservoirs for the gases, an arrangement which would require a certain amount of time to put together; this circumstance proves that it could not have been an improvised trial." To what extent it was improvised will be seen immediately.

Now although the laboratory journals do not in this case "inform us of Lavoisier's methods, and of the direction of his mind, . . . the successive steps in the evolution of his private thought," we have other means of ascertaining how he arrived at his knowledge. The method was simplicity itself: he *was told of the fact, and his informant was none other than Cavendish's assistant, Blagden.*

Cavendish's memoir was published in 1784. Before it was struck off its author caused the following addition to be made: "During the last summer also a friend of mine gave some account of them [the experiments] to M. Lavoisier, as well as of the conclusion drawn from them, that dephlogisticated air is only water deprived of phlogiston; but at that time so far was M. Lavoisier from thinking any such opinion warranted that, till he was prevailed upon to repeat the experiment himself, he found some difficulty in believing that nearly the whole of the two airs could be converted into water." This addition, as I have had the opportunity of verifying by an inspection of the original MSS. in the archives of the Royal Society, was made in the handwriting of Cavendish's assistant and amanuensis, Blagden.

When Lavoisier's memoir appeared, it was found to contain the following reference to this circumstance :—"It was on the 24th June that M. de Laplace and I made this experiment in presence of MM. le Roi, Vandermonde, and several other Academicians, and of Mr. Blagden, the present Secretary of the Royal Society of London. The latter informed us (*ce dernier nous apprit*) that Mr. Cavendish had already tried, in London, to burn inflammable air in closed vessels, and that he had obtained a very sensible quantity of water."

This reference was so partial, and its meaning so ambiguous, that Blagden addressed the following letter to Crell to be published in his *Chemische Annalen* (Crell's *Annalen*, 1786, vol. i. p. 58).

It is so direct and conclusive that I offer no apology for giving it almost entire :—[1]

"I can certainly give you the best account of the little dispute about the first discoverer of the artificial generation of water, as I was the principal instrument through which the first news of the discovery that had been already made was communicated to Mr. Lavoisier. The following is a short statement of the history :—

"In the spring of 1783, Mr. Cavendish communicated to me, and other members of the Royal Society, his particular friends, the result of some experiments with which he had for a long time been occupied. He showed us that out of them he must draw the conclusion that dephlogisticated air was nothing else than water deprived of its phlogiston; and, *vice versâ*, that water was dephlogisticated air united with phlogiston. About the same time the news was brought to London that Mr. Watt, of Birmingham, had been induced by some observations to form a similar opinion. Soon after this I went to Paris, and in the company of Mr. Lavoisier and of some other members of the Royal Academy of Sciences I gave some account of these new experiments and of the opinions founded upon them. They replied that they had already heard something of these experiments, and particularly that Dr. Priestley had repeated them. They did not doubt that in such manner a considerable quantity of water might be obtained, but they felt convinced that it did not come near to the weight of the two species of air employed, on which account it was not to be regarded as water formed or produced out of the two kinds of air, but was already contained in and united with the airs, and deposited in their combustion. This opinion was held by Mr. Lavoisier, as well as by the rest of the gentlemen who conferred on the subject; but, as the experiment itself appeared to them very remarkable in all points of view, they unanimously requested Mr. Lavoisier, who possessed all the necessary preparations, to repeat the experiment, on a somewhat larger scale, as early as possible. This desire he complied with on June 24, 1783 (as he relates in the latest volume of the Paris memoirs). From Mr. Lavoisier's own account of his experiment, it sufficiently appears that at that period he had not yet formed the opinion that water was composed of dephlogisticated and inflammable airs, for he expected that a sort of acid would be produced by their union. In general, Mr. Lavoisier cannot be convicted of having advanced anything contrary to truth; but it can still less be denied that he concealed a part of the truth; for he should have acknowledged that I had, some days before, apprised him of Mr. Cavendish's experiments, instead of which the expression 'il nous apprit' gives rise to the idea that I had not informed him earlier than that very day. In like manner Mr. Lavoisier has passed over a very remarkable circumstance—namely, that the experiment was made in consequence of what I had informed him of. He should likewise have stated in his publication not only that Mr. Cavendish had obtained 'une quantité d'eau très sensible,' but that the water was equal to the weight of the two airs added together. Moreover, he should have added that I had made him acquainted with Messrs. Cavendish and Watt's conclusions—namely, that water, and not an acid, or any other substance, arose from the combustion of the inflammable and dephlogisticated airs. But *those* conclusions opened the way to Mr. Lavoisier's present theory, which perfectly agrees with that of Mr. Cavendish, only that Mr. Lavoisier accommodates it to his old theory, which banishes phlogiston. . . . The course of all this history will clearly convince you that Mr. Lavoisier (instead of being led to the discovery by following up the experiments which he and Mr. Bucquet had commenced in 1777) was induced to institute again such experiments, solely by the account he received from me, and of our English experiments; and that he really discovered nothing but what had before been pointed out to him to have been previously made out and demonstrated in England."

[1] Mr. Muirhead's translation. *Vide* Watt, "Correspondence," "Composition of Water," p. 71.

To this letter, reflecting so gravely on his honour and integrity, Lavoisier made no reply. Nor did Laplace, Le Roi, Vandermonde, or any one of the Academicians concerned, vouchsafe any explanation. *De non apparentibus et de non existentibus eadem est ratio.* No explanation appeared, because none was possible. M. Berthelot ignores this letter, which is the more remarkable, since reference is made to it in more than one of the publications which he tells us he has consulted in the preparation of his account of the Water Controversy. If he knew of it he must regard it either as unworthy of an answer or as unanswerable.

It would be heaping Ossa on Pelion to adduce further evidence from letters of the time of what Lavoisier's contemporaries thought of his claims. *De mortuis nil nisi bonum.* I would much more willingly have dwelt upon the virtues of Lavoisier, and have let his faults lie gently on him; but I have felt it incumbent on me on this occasion to make some public answer to M. Berthelot's book, and in no place could that answer be more fittingly given than in this town, which saw the dawn of that work out of which these grand discoveries arose. It may be that much of what I have had to say is as a twice-told tale to many of you. I trust I need make no apology on that account. The honour of our ancestors is in our keeping, and we should be unworthy of our heritage and false to our trust if we were slow to resent or slack to repel any attempt to rob them of that glory which is their just right and our proud boast.

SECTION C.

GEOLOGY.

OPENING ADDRESS BY A. H. GREEN, M.A., F.R.S., PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF OXFORD, PRESIDENT OF THE SECTION.

THE truth must be told; and this obliges me to confess that my contributions to our stock of geological knowledge, never very numerous, have of late years been conspicuously few, and so I have nothing to bring before the Geological Section that can lay any claim to be the result of original research.

In fact, nearly all my time during the last fifteen years has been taken up in teaching. This had led me to think a good deal about the value of geology as an educational instrument, and how its study compares with that of other branches of learning in its capability of giving sinew and fibre to the mind, and I have to ask you to listen to an exposition of the notions that have for a long time been taking shape bit by bit in my mind on this subject.

I am not going to enter into the question, handled repeatedly and by this time pretty well threshed out, of the relative value of natural science, literature, and mathematics, as a means of educational discipline; for no one who is lucky enough to know a little of all three will deny that each has an importance of its own, and its own special place in a full and perfect curriculum. The question which is the most valuable of the three I decline to entertain, on the broad general ground that "comparisons are odorous," and for the special reason that the answer must depend on the constitution of the mind that is to be disciplined. I might quite as reasonably attempt to lay down that a certain diet which suits my constitution and mode of life must agree equally well with all that hear me.

I need scarcely say that nothing would induce me, if it could possibly be helped, to say one word that might tend to disparage the pursuit to which we are all so deeply attached. But I cannot shut my eyes to the fact that, when geology is to be used as a means of education, there are certain attendant risks that need to be carefully and watchfully guarded against.

Geologists, and I do not pretend myself to be any better than the rest of them, are in danger continually of becoming loose reasoners. I have often had occasion to feel this, and I recall a scene which brought it home to me most forcibly. At a gathering, where several of our best English geologists were present, the question of the cause of changes of climate was under discussion. The explanation which found most favour was a change of the position of the axis of rotation within the earth itself; and this, it was suggested, might have been brought about by the upheaval of great bodies of continental and mountainous land where none now exist, and an accompanying depression of the existing continents or parts of them. That such a redistribution of the heavier material of the earth would result in some shifting of the axis of rotation admits of no doubt. The important question is, How much? What degree of rearrangement of land and sea would be needed to produce a shift of the amount required? It is purely a question of figures, and the necessary calculations can be made only by a mathematician. I ventured to suggest that some one who could work out the sum should be consulted before a final decision was arrived at, for I knew perfectly well that not one of the company present could do it. But if I say that my advice met with scant approval, I should represent very inadequately the lack of support I met with. The bulk of those present seemed quite content with the vague feeling that the thing could be done in the way suggested, and there was a general air of indifference as to whether the hypothesis would stand the test of numerical verification or not.

I could bring many other similar instances which seem to me to justify the charge I have ventured to make; but it will be more useful to inquire what it is that has led to a failing, which, if it really exist, must be a source of regret to the whole brotherhood of hammerers.

The reason, I think, is not far to seek. The imperfection of the Geological Record is a phrase as true as it is hackneyed. No more striking instance of its correctness can be found than that furnished by the well-known mammalian jaws from the Stonesfield slate. The first of these was unearthed about 1764; others, to the number of some nine, between then and 1818. The rock in which these precious relics of the beginning of mammalian life occur has been quarried without intermission ever since; it has been ransacked by geologists and collectors without number; many of the quarrymen know a jaw when they see it, and are keenly alive to the market value of a specimen; but not one of these prized and eagerly-sought-after fossils has turned up during the last seventy years.

Then, again, how many of the geological facts which we gather from observation admit of diverse explanation. Take the case of *Eozoon Canadense.* Here we have structures which some of the highest authorities on the Foraminifera assure us are the remains of an organism belonging to that order; other naturalists, equally entitled to a hearing, will have it that these structures are purely mineral aggregates simulating organic forms. And hereby hangs the question whether the limestones in which the problematical fossil occurs are organic, or formed in some other and perhaps scarcely explicable way.

And this after all is only one of the countless uncertainties that crowd the whole subject of invertebrate palæontology. In what a feeble light have we constantly to grope our way when we attempt the naming of fossil Conchifers for instance. The two species *Gryphæa dilatata* and *G. bilobata* furnish an illustration. Marked forms are clearly separable, but it is easy to obtain a suite of specimens, even ftom the Callovian of which the second species is said to be specially characteristic, showing a gradual passage from one form into the other. And over and over again the distinctions relied upon for the discrimination of species must be pronounced far-fetched and shadowy, and are, it is to be feared, often based upon points which are of slender value for classificatory purposes. In the case of fossil plants the last statement is notoriously true, and yet we are continually supplied with long lists of species which every botanist knows to be words and nothing more, and zonal divisions are based upon these bogus species and conclusions drawn from them.

It is from data such as have been instanced, scrappy to the last degree, or from facts capable of being interpreted in more than one way, or from determinations shrouded in mist and obscurity, that we geologists have in a large number of cases to draw our conclusions. Inferences based on such incomplete and shaky foundations must necessarily be very largely hypothetical. That this is the character of a great portion of the conclusions of geology we are all ready enough to allow with our tongue—nay, even to lay stress upon the fact with penned or spoken emphasis. But it is open to question whether this homage at the shrine of logic is in many cases anything better than lip-service; whether we take sufficiently to heart the meaning of our protestations, and are always as alive as our words would imply to the real nature of our inferences.

A novice in trade, scrupulously honest, even morbidly conscientious to begin with, if he lives among those who habitually use false scales, runs imminent risk of having his sense of integrity unconsciously blunted and his moral standard insensibly lowered. A similar danger besets the man whose life is occupied in deducing tentative results from imperfectly ascertained facts. The living, day by day, face to face with approximation and conjecture must tend to breed an indifference to accuracy and certainty, and to abate that caution and that wholesome suspicion which make the wary reasoner look well to his foundations, and resolutely refuse to sanction any superstructures, however pleasing to the eye, unless they are firmly and securely based.

If I am right in thinking that the mental health of the geologist of matured experience and full-grown powers is liable to a disorder of the kind I have indicated, how much greater must the risk be in the case of a youth, in whom the reasoning faculty is only beginning to be developed, when he approaches the study of geology! And does it not seem at first sight that that study could scarcely be used with safety as a tool to shape his mind, and so train his bent that he shall never even have a wish to turn aside either to the right hand or to the left from the strait path that leads through the domain of sound logic?

That it is hazardous, and that evil may result from an incautious use of geology as an educational tool, I entertain no doubt. The same may, indeed, be said of many other subjects, but I feel that it is specially true in the case of geology. But I should be guilty of that very haste in drawing conclusions against which I am raising a warning word, if I therefore inferred that geology can find no place in the educational curriculum.

To be forewarned is a proverbial safeguard, and those who are alive to a danger will cast about for a means of guarding against it. And there are many ways of neuralizing whatever there may be potentially hurtful in the use of geology for educational ends. It has been said that the right way to make a geologist is not to teach him any geology at all to begin with. To send him first into a laboratory, give him a good long spell at observations and measurements requiring the minutest accuracy, and so saturate his mind with the conception of exactness that nothing shall ever afterwards drive it out. If a plan like this be adopted, it is easy to pick out such kinds of practical work as will not only breed the mental habits aimed at, but will also stand him in good stead when he goes on to his special subject. Goniometrical measurements and quantitative analysis will serve the double purpose of inspiring him with accurate habit of thought, and helping him to deal with some of the minor problems of geology. And I cannot hold that this practice of paying close attention to minute details will necessarily unfit a man for taking wider sweeps and more comprehensive views later on. That habit comes naturally to every man who has the making of a geologist in him directly he gets into the field. Put such a man where a broad and varied landscape lies before him, teach him how each physical feature is the counterpart of geological structure, and breadth of view springs up a native growth. I do not mean to say that the plan just suggested is the only way of guarding against the risk I have been dwelling upon. There are many others. This will serve as a sample to show what I think ought to be aimed at in designing the geological go-cart. And any such mind-moulding leads, be assured, not to hesitancy and doubt, but to conclusions, reached slowly it may be, but so securely based that they will seldom need reconstruction.

There is another aspect of the question. The uncertainties with which the road of the geologist are so thickly strewn have an immense educational value, if only we are on our guard against taking them for anything better than they really are. Of those stirring questions which are facing us day by day and hour by hour, none perhaps is of greater moment than the discussion of the value of the evidence on which we base the beliefs that rule our daily life. A man who is ever dealing with geological evidence and geological conclusions, and has learned to estimate these at their real value, will carry with him, when he comes to handle the complex problems of morals, politics, and religion, the wariness with which his geological experience has imbued him.

Now I trust the prospect is brightening. Means have been indicated of guarding against the danger which may attend the use of geology as an educational instrument. Need I say much to an audience of geologists about the immense advantages which our science may claim in this respect? In its power of cultivating keenness of eye it is unrivalled, for it demands both microscopic accuracy and comprehensive vision. Its calls upon the chastened imagination are no less urgent, for imagination alone is competent to devise a scheme which shall link together the mass of isolated observations which field work supplies; and if, as often happens, the fertile brain devises several possible schemes, it is only where the imaginative faculty has been kept in check by logic that the one scheme that best fits each case will be selected for final adoption. But, above all, geology has its home, not in the laboratory or study, but *sub Jove*, beneath the open sky; and its pursuit is inseparably bound up with a love of Nature, and the healthy tone which that love brings alike to body and mind.

And what does the great prophet of Nature tell us about this love?

> "The boy beholds the light and whence it flows;
> The man perceives it die away,
> And fade into the light of common day."

Will it not, then, be kind to encourage the boy to follow a pursuit which will keep alive in him a joy which years are too apt to deaden; and will not the teaching of geology in schools conduce to this end? Geology certainly should be taught in schools, and for more prosaic reasons, of which the two following are, perhaps, the most important. Geography is essentially a school subject, and the basis of all geographical teaching is physical geography. This cannot be understood without constant reference to certain branches of geology. Again, how many are the points of contact between the history of nations, the distribution and migrations of peoples, and the geological structures of the lands they have dwelt in or marched over.

But geology is not an easy subject to teach in schools. The geology of the ordinary text-book does not commend itself to the boy-mind. The most neatly-drawn sections, nay, even the most graphic representations of gigantic and uncouth extinct animals, come home to the boy but little, because they are pictures and not things. He wants something that he can handle and pull about; he does not refuse to use his head, but he likes to have also something that will employ his hands at the same time.

The kind of geology that boys would take to is outdoor work; and, of course, where it can be had, nothing better could be given them. A difficulty is that field work takes time and filches away a good deal of the intervals that are devoted to games. Still cross-country rambles and scrambling about quarries and cliffs are not so very different from a paper-chase; and if the teacher will only infuse into the work enough of the fun and heartiness which come so naturally in the open air, he need not despair of luring even the most high-spirited boy, every now and then, away from cricket and football.

But there are localities not a few—the Fen country, for instance—where it is scarcely possible to find within manageable distance of the school the kind of field-geology which is within the grasp of a beginner. But even here the teaching need not be wholly from books. The best that can be done in such cases is to make object-lessons indoors its basis. For instance, give a lad a lump of coarsish sandstone; let him pound it and separate by elutriation the sand grains from the clay; boil both in acid, and dissolve off the rusty coating that colours them; ascertain by the microscope that the sand grains are chips and not rounded pellets, and so on. All such points he will delight to worry out for himself; and, when he has done that, an explanation of the way in which the rock was formed will really come home to him. Or it is easy to rig up contrivances innumerable for illustrating the work of denudation. A heap of mixed sand and powdered clay does for the rock denuded; a watering-can supplies rain; a trough, deeper at one end than the other, stands for the basin that receives sediment. By such rough apparatus many of the results of denudation and deposition may be closely imitated, and the process is near enough to the making of mud-pies to command the admiration of every boy. It is by means like these that even indoor teaching of geology may be made life-like.

I need not dwell upon the great facts of physical geology which have so important a bearing on geography and history; but I would, in passing, just note that these too often admit of experimental illustration, such for instance as the well-known methods of imitating the rock-folding caused by earth-movements. I would add that wherever, in speaking of school teaching, I have used the word "boy," that word must of course be taken to include "girl" as well.

In conclusion I should like to give you an outline of the kind of course I endeavour to adopt in more advanced teaching in the case of students who are working at other subjects as well, and can give only a part of their time to geology. During the first year the lectures and book-work should deal with physical geology. In the laboratory the student should first make the acquaintance of the commoner rock-forming minerals, the means of recognizing them by physical characters, blowpipe tests, and the simpler methods of qualitative analysis, and may then go on to work at the commoner kinds of rocks and the elements of microscopic petrography. During the summer months I would take him into the field, but not do more than impress upon him some of the broader aspects of outdoor work, such as the connection between physical feature and geological structure.

During a second year stratigraphical geology should be lectured upon and studied from books, and so much of animal morphology as may be necessary for palæontological purposes should be mastered. The practical work would lie mainly among fossils, with a turn every now and again at mineralogy and petrology to keep these subjects going. Out of doors I would not yet let the student attempt geological mapping, but would put into his hands a geological map and descriptions of the geology of his neighbourhood, and he would be called upon to examine in minute detail all accessible sections, collect and determine fossils, and generally see how far he can verify by his own work the observations of those who have gone before him.

Indoor work during the third year would be devoted to strengthening and widening the knowledge already gained. Out of doors the student should attempt the mapping of a district by himself. It will be well, if there is any choice in the matter, to select one in which the physical features are strongly marked.

This sketchy outline must serve to indicate the notions that have grown up in my mind on the subject now before us, and the methods I have been led to adopt in the teaching of geology. I trust that they may be suggestive, and may call forth that kindly and genial criticism with which the brotherhood of the hammer are wont to welcome attempts, however feeble, to strengthen the corner-stones and widen the domain of the science we love so well, and to enlarge the number of its votaries.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

British Association Procedure.

I AM glad to see a letter from my colleague, Prof. Armstrong, on the subject of the procedure of the British Association. I am not disposed to take an exaggerated view of the harm that may arise from the mild excitement and dissipation which seem to be inseparable from gatherings of this kind; but I do not regard with satisfaction the prospect of annulling half the good effect of my much-needed rest and annual dose of fresh air, by spending a week in crowded rooms in the middle of a great town. The disinclination to run this risk increases, and the risk itself seems to increase, when the date fixed for the meeting is selected in such an unfortunate way as to cut in two the summer holiday of many members, and especially of those who are teachers, whether in school, college, or university.

Having been on two separate occasions concerned in making preparations for the reception of the Association, I know something of the circumstances which have to be considered. One of the most important points is the provision of suitable rooms for reception and Sectional business. These are very commonly obtained in colleges or schools, and cannot be placed at the disposal of the Association till the holidays begin. But all schools or colleges break up before the end of July, and the last days of July or the first days of August would be the most convenient time to the great majority of those who form the most numerous and active attendants at the meetings. The weather at that time is also more likely to be favourable to garden parties and excursions than at any time late in August or in September. That, at least, is my own opinion as to the time of meeting.

Then as to the work of the Sections. As a Sectional Secretary I have read papers (other people's) at 3 o'clock in the afternoon to an audience consisting of a Vice-President impatient to follow the President to lunch, two reporters who were not listening, and my wife making signals of distress from a back bench. As a Sectional President I have sat at the same hour, luncheonless and weary, while a paper which seemed as long and as discursive as the story of the Ancient Mariner, was droned forth by the author to an audience of about three persons fidgeting like the belated wedding guest. I wonder whether this sort of thing is supposed to be of any use to anybody.

The change which I proposed, and which was in part embodied in a recommendation from Section B to the Council, consisted in altering the hour for Committees from 10 to 9.30, and beginning general business at 10 instead of 11; the Section to close at 2.

The only objection I heard to 9.30 was that some members might be lodged at a distance, and find it difficult to attend so early. I never could see much except laziness at the bottom of this objection. The only other that occurred to me was that possibly sometimes the Committee business would occupy more than half an hour. But this difficulty, even if real, chiefly arises from the practice to which Prof. Armstrong has referred, of making the Committees so large.

This practice serves no obvious purpose except that of advertising a certain number of people who like to see their names in print. I believe the demand for election upon Sectional Committees would be considerably reduced if the names of the Sectional Committees *were no longer printed.* It would be quite sufficient for the purposes of business to give in the Journal only the names of the officers.

I think, further, that something should be done to reduce the cost of a meeting to the town visited by the Association. The gorgeousness of the entertainments given, and the demands made upon provincial pockets, have become so extravagant that none but wealthy or ambitious towns can face the luxury of a visit of the British Association. WILLIAM A. TILDEN.

Birmingham, September 1.

WHILST I entirely agree with Prof. Armstrong as to the desirability of reform in regard to most of the matters to which he has called attention, I would like to point out that in one respect the large Sectional Committees have perhaps served a useful purpose. Nowhere are the older and younger men of science brought so extensively into direct contact with each other as at the meetings of these Committees, and hence they have served perhaps more than anything else to introduce the younger provincial men to their older and younger brethren of the metropolis and to each other.

If it be admitted therefore that a chief object of the Association is that its members shall meet, I think, speaking as a provincial, that there is much to be said in favour of the retention of moderately large Sectional Committees; though no doubt the introduction of such reforms as would tend to discourage the presence on them of those who are out of place would add to their usefulness in every way. W. A. SHENSTONE.

Clifton, September 2.

Fine Group of Sun-spots.

THIS morning I saw a very large cluster of spots in the sun's northern hemisphere, and nearly at mid-transit across the disc. The group is elongated east and west, and there is a fine spot at each of the extremities. The length of the group is about 113,000 miles; it exhibits a very complicated structure, and I have made a drawing of it with some difficulty, owing to the rapid changes it is undergoing in detail. A 3-inch refractor, power 90, defines the object well, and reveals many peculiarities in its form. Though I have termed it a group of spots, it might with propriety be called a single spot, for it is connected with wisps of penumbra, and chains of small spots, which altogether represent an extensive area of disturbance.

On looking at the sun with the eye simply protected with tinted glass, I see the group of spots distinctly, and it would form quite a conspicuous appearance to the naked eye should the sun rise or set in a fog during the next day or two.

I ascertained by frequent scrutiny during the first half of the present year that the sun's spots were usually very small and fugitive, and the present fine display of *maculæ* is therefore all the more worthy of observation and record.

Bristol, August 31. W. F. DENNING.

Organic Colour.

IN considering the causes of bright colouring in animals and plants, I think the physical meaning of colour has not been sufficiently regarded.

All dull colours, such as browns, olives, plums, &c., mean that vibrations of every wave-length in the white sunlight are absorbed almost entirely, a very small proportion being reflected. A deep red colour means that there is a less proportion of the longest waves absorbed; a deep violet, that there is a less proportion of the shortest waves absorbed; and a full green, that the absorption is less in the intermediate wave-lengths. These are the primary hues; but in objects which reflect the brilliant secondary hues—scarlets, yellows, blues, and pinks—the chief absorption is confined to a small area in the spectrum, a large proportion of the light being reflected.

There are, then, three distinct stages of coloration, viz. (1) that in which all wave-lengths are absorbed; (2) that in which absorption ceases in respect to about one-third of the spectrum; (3) that in which absorption ceases in respect to about two-thirds of the spectrum.

These three stages are progressive, and in the direction of progress from chaos to unity; from a condition of the protoplasm in which molecular elements of very diverse vibrating capacity are mixed up together, to a condition in which the capacities of these elements have become greatly simplified.

When we speak of an organism arriving at maturity, we imply that it began its career in a state of immaturity, and that it gradually progresses to the condition of maturity. In what that condition consists, or what fundamental changes have taken place, it may not be easy to say; but it is surely true, as a rule, that organisms in an early and immature state are comparatively dull in colour, and do not put on their brightest hues until the period of maturity, indicating that one of the characteristics of maturity is the simplification of the vibrating capacity of the molecules. If this be really a law of Nature, it is a far-reaching one, and will account for much. F. T. MOTT.

Leicester.

On the Soaring of Birds.

I HAVE thought that this habit can be explained as follows; at least as regards rooks, which I have often noticed soaring in flocks, especially in the spring, and I think usually in warm cloudy weather.

An upward convection current of warm air is established over some area. The birds stretch out their wings, and if the upward velocity of the current should happen to be just equal to the velocity with which a bird with outstretched wings would sink through still air (the "terminal velocity"), the bird would be supported; but if it were somewhat greater, the bird would be raised upwards. In that case he inclines his wings so that the resolved part of the pressure on the under side of the wings carries him forward at a uniform level. But this movement, being rectilinear, would take him outside the warm column which he is enjoying. A centripetal force is therefore needed to maintain the circular movement, and this is obtained by tipping the wings, so that the wing which points outwards is raised, and that which points inwards towards the warm column is depressed, as noticed by your correspondent. If the upward velocity of the current is not sufficient to support the bird, an occasional flap with both wings, and the subsequent sinking, supplies the deficiency of upward pressure.

O. FISHER.

IN your issue of August 21 (p. 397) Mr. Magnus Blix gives a very ingenious explanation of the soaring of birds. It appears, however, to me that this explanation rests upon a false basis.

In his illustration, Mr. Blix supposes a bird to be moving in a direction, relative to the wind, at right angles to that of the wind, its absolute velocity, therefore, being greater than that of the wind. He then supposes the bird, by movement of wing-plane, to change its direction to one opposite to that of the wind, and assumes that its absolute velocity, in the new direction, will be equal to the absolute velocity in the old.

Now it is probably true that a bird can change its direction without sensible loss of *velocity relative to the air*, but any velocity it may have, in virtue of the motion of the air, must remain as a component of the new velocity in the same direction as before, however the bird may change the direction of its wing-plane.

Now the supposed bird, in changing its direction at *c*, would still have the component of velocity due to the wind acting in direction *ef* as before. Its velocity relative to the wind, therefore, from *c* to *d* would be the original velocity at *a* (diminished in its passage from *a* to *c*); its absolute velocity the difference of the two velocities.

If this objection hold good, Mr. Blix's theory seems to be no longer an explanation. C. O. BARTRUM.

19 Well Walk, Hampstead, August 26.

Occurrence of a Crocodile on Cocos Islands.

DURING a recent visit to Cocos Islands Mr. Ross showed me the skull of a crocodile of small size which had appeared about a year previously on the islands. It was first seen by a native Cocosian, who reported that he had seen something between a lizard and a log of wood in the sea. It then reappeared upon another island and destroyed a number of ducks, and was eventually shot by Mr. Ross. The distance from Java, the nearest land, is fully 700 miles. It is remarkable that this animal should have swum so far, and managed eventually to strike this small patch of land in the middle of the ocean. I do not know another record of a big reptile travelling so far. Mr. Ross tells me that bamboo-rafts sometimes drift to Cocos, and perhaps it managed to help itself along on one of these.

The whole seas here, but especially the Straits of Sunda and Malacca Straits, are full of drift-fruits, seeds, sticks, stems of Nipa and Pandanus; and between the Straits of Sunda and Cocos, large patches of pumice rolled lumps and dust can be seen, the relics of the destruction of Krakatão.

H. N. RIDLEY.

Botanic Gardens, Singapore, August 6.

Helix nemoralis and hortensis.

I SHOULD be very pleased if some of the various conchological readers of NATURE would kindly furnish me with their records of these two shells. The questions I specially want to ask concerning them are as follows:—What varieties (with band-formulæ) have they found? What number of each variety and band-variation have they taken? What is the environmental condition of the localities where they have found them, as regards plant-life and geological formation? And, in addition, I want the records (and this is a special point) from separate and distinct hedges or banks.

J. W. WILLIAMS.

57 Corinne Road, Tufnell Park, N.

Mr. Williams's "British Fossils."

IN my review of Mr. Williams's "British Fossils," published in NATURE of August 28 (p. 412), I notice a slip on my part in regard to eclogite. I should have said that whereas this rock is stated to consist of red garnets and hornblende, it is usually described as being composed of red garnets and one of the pyroxenes, such as omphacite or smaragdite, or both.

Since writing the review I have come to the conclusion that the twice repeated term "dermoid types" is intended for "demoid types"; a term used in the second edition of Phillips's "Manual of Geology." THE REVIEWER.

August 29.

A Remarkable Rainbow.

I HAVE just seen a very remarkable rainbow. It was plus 60° in height, and thin. The sunset was lurid, with a mock sun to the south of the real one. D. MACGILLIVRAY.

Oxford, August 25.

NOTES.

ON Sunday, August 17, M. Janssen ascended to the Grands Mulets, and next day he reached a hut called the Cabane des Bosses, which an Alpinist, M. Vallot, of Paris, has erected at a point about 400 metres below the summit of Mont Blanc. According to the Paris correspondent of the *Times*, the second day's journey was made in a sledge, drawn and pushed by twenty-two guides. Tuesday, Wednesday, and Thursday M. Janssen spent in a part of the hut which M. Vallot has fitted up as a scientific laboratory. On Friday, as the weather was very clear, M. Janssen had his sledge dragged up to the summit of the mountain to complete his observations. At the ridge of the

Bosses, which is almost vertical, and bordered on both sides by beds of snow ready to fall in avalanches at the slightest motion, the guides begged him to leave the sledge. He did so, but after taking five or six steps he fell exhausted on the snow and had to return to the sledge. He went back to the Grands Mulets the same day, and on the following Sunday he reached the Hôtel de Mont Blanc, and rejoined Mme. and Mdlle. Janssen, who had watched all his movements through a telescope. The results obtained by M. Janssen on this occasion confirm those to which he was led by his previous observations at the Grands Mulets.

THE medical profession loses much by the death of Dr. James Matthews Duncan, F.R.S. He died of heart disease at Baden-Baden, on Monday, September 1. He was born at Aberdeen in 1826.

WE regret to have to record the death of Prof. Carnelly. He died suddenly on August 27, at the age of 38. He had held the chair of chemistry at Firth College, and at the Dundee University College; and two years ago he was appointed Professor of Chemistry at Aberdeen.

ANOTHER death which we are sorry to have to record is that of Miss North, who died on Saturday, August 30, at her residence, Mount House, Alderley, Wotton-under-Edge, Gloucestershire, after a prolonged illness.

ORAZIO SILVESTRI, the distinguished chemist and vulcanologist, died at Catania on August 17. He was fifty-five years of age. In 1863 he was appointed to the professorship of chemistry at the University of Catania, whence he was transferred, in 1874, to a corresponding chair at the University of Turin. Afterwards he returned to Catania, where he became professor of mineralogy, geology, and vulcanology. Prof. Silvestri was an enthusiatic student of Mount Etna, and carried on many important investigations during the eruptions of 1865, 1869, 1879, 1883, and 1886. Through his efforts an astronomical and meteorological observatory has been constructed on Etna at a height of 3000 metres.

THE British Pharmaceutical Association held its twenty-seventh annual meeting in Leeds on Tuesday and Wednesday. The chair was occupied by Mr. Charles Umney. The attendance was unusually numerous.

THE Sanitary Institute had a most successful Congress at Brighton last week. Among the presidential addresses was one on "Geology in its relation to hygiene, as illustrated by the geology of Sussex," by Mr. W. Topley, F.R.S., President of the Section for Chemistry, Meteorology, and Geology. The discussions at the various meetings did much to foster the interest of the public in the laws of public health; and we should have been glad to devote more attention to the proceedings but for the pressure on our space due to the meeting of the British Association.

THIS week the International Congress of Agriculture and Forestry is holding a series of meetings at Vienna. There are delegates from Great Britain and many other countries. The proceedings began on Monday evening with a reception given by the organizing committee. On Tuesday the opening address was delivered by Count Christian Kinsky, President of the Diet of Lower Austria. The final sitting will be held on Saturday.

THE fourth annual series of vacation science courses at Edinburgh was brought to a close last Saturday with an excursion to Melrose and Abbotsford. These courses corresponded to the second part of the Oxford summer gathering, and were remarkably successful. A similar series is being organized for the winter months, and will be specially adapted to "the educational requirements of teachers."

ON August 27 and 28 earthquake shocks were felt along the Danube valley from Amstetten to Grein in Lower Austria. The seismic movement on August 28 lasted ten minutes, and was accompanied by a disturbance of the river, the water rising into long lines of waves similar to those caused by the paddle-wheel of a steamer.

THE Caucasus papers relate an interesting case of globular lightning which was witnessed by a party of geodesists on the summit of the Böhul Mountain, 12,000 feet above the sea. About 3 p.m., dense clouds of a dark violet colour began to rise from the gorges beneath. At 8 p.m., there was rain, which was soon followed by hail and lightning. An extremely bright violet ball, surrounded with rays which were, the party says, about two yards long, struck the top of the peak. A second and a third followed, and the whole summit of the peak was soon covered with an electric light which lasted no less than four hours. The party, with one exception, crawled down the slope of the peak to a better sheltered place, situated a few yards beneath. The one who remained was M. Tatosoff. He was considered dead, but proved to have been only injured by the first stroke of lightning, which had pierced his sheepskin coat and shirt, and burned the skin on his chest, sides, and back. At midnight the second camp was struck by globular lightning of the same character, and two persons slightly felt its effects.

A STUDY of five years' thunderstorms (1882–86) on the Hungarian plain has been recently made by M. Hegyfoky. We note the following points in his paper (communicated to the Hungarian Academy). The days of thunderstorm were those on which thunder was observed, and they formed 16·4 per cent. of all days from April to September. The air-pressure on those days sank about 2 mm. under the normal, morning and evening. The less the pressure, the greater the probability of thunderstorm. The temperature (estimated by the maximum thermometer) was higher than that of all days of the season indicated; and the moisture and cloudiness were similarly in excess. The wind blew about mid-day more softly, and in the evening more strongly than usual. It went round, as a rule, from the south-east by the south to the west and north-west. The clouds came oftener than usual from the south-east and south-west quadrants; so that the centre was generally north of the station. Nearly half of the season's rainfall was on days of thunderstorm. Hail fell on 11 days, on one of which there was no thunderstorm. There were most thunderstorms in June (59 out of 199). The June of 1886 had as many as 26. The commencement of a thunderstorm (first thunder) occurred most often from 2 to 5 p.m. Towards the end of the season the thunderstorms tend to come later in the day. When the pressure falls under the mean of the season (752·4 mm.), the thunderstorms last longer than when it is above the mean. The path was in most cases from south-west or west, and in most cases coincided with that of both lower and upper clouds, but in several cases only with that of the lower or upper. After the first thunder the meteorological elements are usually subject to great changes, most marked as the storm nears the zenith: rain falls, wind rises, and alters quickly in direction, temperature and vapour-pressure fall, relative humidity, cloud, and pressure increase. As the storm withdraws there is a return to the normal. Various other points are considered. The author accepts Sohncke's theory—that the electricity of thunderstorms is due to friction of water-drops on ice.

THE Meteorological Council have just published a series of observations made at Sanchez (Samaná Bay), St. Domingo, in the years 1886–88. They were made chiefly by the late Dr. W. Reid, Medical Officer of the Samaná and Santiago Railway Company. The Council, recognizing the value of the observations, which were taken with much care, and for a locality for which they are very scarce, determined to publish them in detail. The monthly means and summaries have been calculated in the Meteorological Office and added in a convenient form at the end of the volume. From these it is seen that the maximum shade temperature was $96°.5$ in September 1887, and the minimum $58°.5$ in March 1888. The rainfall varied considerably in the different years—as much as 26 inches. The greatest daily fall was 6 inches in April. The sunshine recorded in 1888 amounted to an average of 6·7 hours daily. Dr. Reid remarks, with regard to the wind, that in about 19 days out of 20 there is a light breeze in the west at 6h. a.m., which continues till about 8h. a.m., then a short calm, then a light breeze from about south, which veers round to east or east-south-east by 10 a.m., and there continues till about 4 p.m., when it remains calm till next morning. Only three gales are recorded during the three years, and these all occurred in 1886.

THE *Pall Mall Gazette* has issued in its "Extra" series a charming story of a dog. It is called "Teufel the Terrier: the Life and Adventures of an Artist's Dog," and is "told by J. Yates Carrington, and edited by Charing Cross." The tale is admirably illustrated, and will give much pleasure to all who study the ways of dogs, and appreciate their intelligence and sense of fun.

PART 23 of Cassell's "New Popular Educator" has been published. Besides the woodcuts in the text, there is a coloured plate illustrating electric discharges in rarefied gases.

MESSRS. GEORGE L. ENGLISH AND CO., of Philadelphia and New York, have published the fifteenth edition of their catalogue of the minerals which they have for sale. There has been in America, they say, a "very great increase in the demand for mineral specimens."

THE proposed creation of Universities in France will soon give rise to much animated discussion in the French Senate. Meanwhile, the Ministry of Public Instruction has prepared a return showing the number of students who at present attend the different French faculties. The total is 16,587, of whom 15,316 are Frenchman and 1271 foreigners, as against only 9863 fifteen years ago. Of this total 5843 students attend the faculty of medicine, 4570 that of law, 1834 that of literature, 1590 that of pharmacy, 1276 that of science, and 101 that of Protestant theology. Rather more than half of these (8653) are students of the different Paris faculties, and of the 1271 foreign students 1078 are in Paris. There are 989 Europeans (313 Russians, 159 Roumanians, and 121 Turks), 201 Americans (of whom 173 come from the United States), 68 Africans (of whom 51 are Egyptians), 12 Asiatics, and 1 Australian. The great majority of these foreigners are studying medicine; 907 belong to that faculty, while 240 are studying law, 58 science, 39 pharmacy, 24 literature, and 3 Protestant theology.

THE *Japan Weekly Mail* in a recent issue notices the publication of a kind of Japanese folk-lore journal, called the *Fuzoku Gwahōo*, the object of which is to collect and record important and curious Japanese national customs. Japanese customs, old and new, are classified by the new journal under seven heads—namely, customs that concern (1) human beings, (2) animals and plants, (3) dress and ornaments, (4) food and beverages, (5) buildings, (6) furniture and coins, (7) miscellaneous. For the illustrations resort is had to old pictures. Every number contains an essay on some interesting custom, with allusions to authorities on the subjects treated.

THE Government of India, it is reported, has decided to discontinue the annual grant hitherto devoted to search for, and purchase of, rare Sanskrit manuscripts, but the decision will not take effect until 1892. A regular staff of native searchers have been employed during the past ten years, and these have visited most of the large temples throughout India, examining and cataloguing the vast collections of works hoarded up there. The private libraries of several native gentlemen have been likewise carefully sifted, and their contents recorded. Of the manuscripts thus examined, no fewer than 2400 have been purchased by the Government, and rendered accessible to the public at Bombay and Calcutta. The most valuable "finds" have included numerous old Jain manuscripts, now being submitted to the scrutiny of competent scholars in Bombay. Although the search and purchase grants are to cease, the Indian Government has agreed to continue the allowance of Rs. 9000 per annum for the publication of texts and translations of the Sanskrit and Persian works discovered.

THE additions to the Zoological Society's Gardens during the past week include a Squirrel Monkey (*Chrysothrix sciurea* ♀) from Guiana, presented by Mrs. Osgood; two Chinese Alligators (*Alligator sinensis*) from China, presented by Mr. D. C. Jansen; a Great-billed Touracou (*Corythaix macrorhyncha*) from West Africa, a Wonga-wonga Pigeon (*Leucosarcia picta*) from Australia, a Madagascar Love Bird (*Agapornis cana*) from Madagascar, purchased.

OUR ASTRONOMICAL COLUMN.

OBJECTS FOR THE SPECTROSCOPE.

Sidereal Time at Greenwich at 10 p.m. on September 4 = 20h. 55m. 52s.

Name.	Mag.	Colour.	R.A. 1890.	Decl. 1890.
			h. m. s.	° ′
(1) G.C. 4627	—	—	20 57 10	+54 7
(2) G.C. 4628	—	Pale blue.	20 58 9	−11 48
(3) 3 Aquarii	5	Reddish-yellow.	20 41 56	− 5 21
(4) β Capricorni	3	Yellowish-white.	20 14 17	−15 10
(5) α Capricorni	4	White.	20 11 0	−12 53
(6) D.M. + 32° 3522 ...	8	Red.	19 36 44	+32 22
(7) V Cygni	Var.	Red.	20 37 46	+47 45

Remarks.

(1) The G.C. description of this nebula is: "Considerably bright; large; elongated in the direction 45° or thereabouts; barely resolvable." The spectrum appears to have been observed only by Dr. Huggins, who recorded:—"One bright line only was distinctly seen, of apparently the same refrangibility as the brightest of the nitrogen lines. This bright line appeared by glimpses to be double. Possibly this appearance was due to the presence near it of a second line. The faintness of the light did not permit the slit to be made sufficiently narrow for the determination of this point." This is an observation well worth repeating, as it may possibly throw some light on the origin of the chief nebula line. The magnesium fluting near λ 500 has been suggested, on various grounds, as the origin of the chief line, and this consists of a rhythmical series of flutings with well-defined edges towards the red end of the spectrum. It may be that the second faint line seen by Dr. Huggins was the second maximum of the compound fluting, but unfortunately he does not state whether it was more or less refrangible than the brighter line.

(2) It appears to be generally agreed that this is one of the finest specimens of planetary nebulæ in the heavens. Lassell saw it as an elliptic ring with a star in the centre. Dr. Huggins and Lieutenant Herschel each recorded three bright, sharp, and distinct lines in its spectrum, and Prof. Winlock suspected a fourth. The spectrum of this nebula might perhaps be advantageously observed in connection with that of the previous nebula. As the temperature of nebulæ indicating hydrogen is probably lower than that of nebulæ in which the hydrogen lines are absent, there is reasonable ground for supposing that the fluted appearance of the chief line (assuming it to be due to

magnesium) will be most obvious when the hydrogen lines are not seen. A comparison of the two spectra with the same instruments under similar conditions will therefore be valuable.

(3) This comparatively bright star of Group II. has not yet been observed in sufficient detail, Dunér simply stating that the bands 2–8 are wide and dark. For purposes of classification it is also necessary to know whether the bands in the blue or those in the red are most intense.

(4 and 5) These are stars of the solar type and of Group IV. respectively (Konkoly). The usual observations are required in each case.

(6) Dunér describes the spectrum of this star as one of Group VI., consisting of three zones, of which the blue is also pretty bright. The principal bands are very dark, and the secondary bands 4 and 5 (λ 589 and 576) were also occasionally seen. The brightness of the blue zone varies very considerably in stars of this group, and, moreover, does not depend upon the magnitude of the star. It probably therefore depends upon temperature. The associated phenomena are well worth investigation.

(4) This interesting variable will reach a maximum about September 6. The observations of the magnitude at maximum are a little discordant, but there can be no doubt that it changes considerably, the extremes being 6·8 and 9·5, whilst the minimum is a prolonged one of about magnitude 13. The spectrum is one of Group VI., showing very little blue light. Continuous spectroscopic observations will be very valuable in connection with Mr. Lockyer's theory of the cause of variability in stars of this group.

A. FOWLER.

VARIABLE STARS NEAR THE CLUSTER 5 M.—At the June meeting of the Royal Astronomical Society, Mr. A. A. Common, F.R.S., exhibited some photographs of the cluster 5 Messier, taken with his 5-foot telescope at Ealing. Four photographs had been taken on April 22, May 9, May 15, and June 9, with exposures of 25, 45, 66, and 45 minutes respectively. The plate taken on May 15—that is, the one with the longest exposure—contains five stars not shown on those taken before and after that date. The presence of these five stars was not due to longer exposures because they were all brighter than the 10th magnitude, whereas stars of at least the 12th magnitude were seen on all the plates. A great difference was also observed in the apparent magnitudes of many of the stars near the cluster.

Prof. E. C. Pickering notes (*Astronomische Nachrichten*, No. 2986) that an examination of the photographs of this region taken at Harvard College Observatory proves beyond doubt that the star about 9″ or 10″ south preceding the cluster varies between 9·76 and 11·6 magnitude, and that the south component of the wide pair just following the cluster varies between 9·3 and 12·2 magnitude.

NEW ASTEROIDS.—A new minor planet (295), of the 13th magnitude, was discovered by Dr. Palisa, at Vienna, on August 17; and another, (296), by Mr. Charlois, at Nice, on August 19. The latter was found near the position of Hera, (103), but because of the difference in magnitude it is thought to be new.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, August 25.—On a jawbone of a Greenland seal, found by M. Michel Hardy in the grotto of Raymonden.—Observations of the Denning (July 23, 1890) Comet, made at the Paris Observatory, by M. G. Bigourdan.—Observations of the new planet Palisa (Vienna, August 17, 1890), made at the Paris Observatory, by Mdlle. D. Klumpke.—Elements and ephemerides of the planet (294), discovered at the Nice Observatory, July 15, 1890, by M. Charlois.—On two forms of electrical gyroscopes, one serving to show the movement of the earth, and the other for the rectification of the marine compass, by M. G. Trouvé. The two instruments are similarly constructed, but the latter is heavier, and so hung as to be free from the various causes of disturbance always present on board. It is able to correct the compass with certainty, since its axis of rotation remains fixed in space, however long it is necessary to prolong the observation.—On the respiration of the grasshopper, by M. Ch. Contejean. The abdomen is chiefly concerned with the respiratory movements. Stimulation of the nervous system by applying induced electric currents causes an obvious acceleration in the breathing.—New researches on the production of light by animals and vegetables, by M. Raphael Dubois. The author concludes that the production of light in animal organisms is due to the transformation of the colloidal protoplasmic granulations into crystalloidal granulations, under the influence of a respiratory phenomenon.—On the presence of the carboniferous formation in Brittany, by M. P. Lebesconte. This paper contains a list of the fossils obtained from some newly-discovered fossil-bearing strata in the carboniferous limestones at L'Ille-et-Vilaine in Quenon.—On the storm of August 18, 1890, at Dreux, by M. Léon T. de Bort. In its local and destructive character this storm showed many analogies with the tornadoes of the United States.—Notes were also submitted by M. Chapel, on the coincidence of atmospheric disturbances with the meeting with the Perseids; by M. van Heyden, on the height of the atmosphere; and by M. E. Mathieu-Plessy, on a new base obtained by heating ammonium nitrate, possibly nitramide, $NO_2 . NH_2$.

BOOKS, PAMPHLETS, and SERIALS RECEIVED.

Principia; or, the Three Octaves of Creation: Rev. A. Kennion (E. Stock).—Transactions and Proceedings of the New Zealand Institute, 1889, vol. xxii.: Sir J. Hector (Trübner).—Paul Nugent, Materialist, 2 vols., 3rd edition: H. F. Hetherington and Rev. H. D. Burton (Griffith and Farran).—Annual Report of the Department of Mines, New South Wales, for the year 1889 (Sydney).—Inorganic Chemistry: Wm. Jago (Longmans).—Wild Flowers of North Wales Coast; R. Darlington (Roper and Drowley).—Wild Flowers of Vale of Llangollen, &c.: R. Darlington (Roper and Drowley).—The Ethical Problem: Dr. P. Carus (Chicago, Open Court Publishing Company).—Report of the French Commission on the Use of Explosives in the Presence of Fire-Damp in Mines (Newcastle-upon-Tyne).—Zur Geschichte der Ältesten Haustiere: Dr. Otto (Breslau).—Untersuchungen über die Physiologischen Wirkungen der Lupetidine und verwandter Körper und deren Beziehungen zu ihrer chemischen Constitution: A. Gürber (Zürich).—Timehri, No. xvii. (Stanford).—Journal of the Chemical Society, August (Gurney and Jackson).

CONTENTS.