THURSDAY, SEPTEMBER 6, 1888.

GEOLOGICAL NOMENCLATURE.

Les Dislocations de l'écorce terrestre: Essai de Définition et de Nomenclature. Texte en français et en allemand; Synonymie en français, allemand, et anglais. Par Emm. de Margerie et Dr. Albert Heim. Publié aux frais de la fondation de X. Schnyder de Wartensee. (Zurich: J. Wurster and Co., 1888.)

AT the meeting of the International Congress of Geologists which is to be held in London during the autumn of the present year, many praiseworthy attempts will doubtless be made to bring about some kind of uniformity in the nomenclature adopted by workers in different countries. It is doubtful, however, whether any conferences or discussions are more likely to contribute to this much-desired object than the work now before us. The writers of this essay are singularly well qualified for the important task they have undertaken. Prof. Heim, of Zurich, the author of the well-known "Mechanismus der Gebirgsbildung," and other works on orographic geology, is responsible, as we are informed in the preface, for the scientific discussions; while M. Margerie has taken charge of the literary portion of the work—a task for which a wide knowledge of geological literature in many languages so admirably fits him.

The book was prepared for press in 1885 and 1886, but considerable difficulties were found in the way of its publication; there fortunately exists, however, at the disposal of the Municipal Library of Zurich, a fund bequeathed by the late Xavier Schnyder von Wartensee, a musical composer, the yearly proceeds of which may be devoted to the publication of scientific works. The proceeds of this fund for the present year having been very judiciously applied to defray the cost of the book before us, the printing was undertaken by the well-known firm of Wurster and Co. M. Margerie has added a supplement bringing the work as nearly as possible down to the date of publication, but is compelled to state his regret in the preface that some valuable memoirs bearing upon the questions discussed (and notably Mr. Mellard Reade's "Origin of Mountain Ranges," which was some time ago noticed in NATURE) did not reach him in time to be utilized as he could have wished. In spite of these frankly acknowledged omissions, however, every-one who uses this work—and it is one which is almost indispensable to the student of the ever-accumulating mass of geological literature—will acknowledge the thoroughness with which the scientific literature of our own country and of the United States, as well as of France, Germany, Italy, and Scandinavia, has been ransacked by the indefatigable authors.

The work is divided into three principal sections, the first dealing with the dislocations resulting from vertical movements of the earth's crust, the second with those produced by horizontal thrusts, and the third with the internal results of the deformation of rock-masses. Exception may be taken to this distribution of the subject, and indeed no classification of the phenomena that could possibly be suggested would be likely to command universal assent, yet we think no better arrangement of the matter contained in this work could have been well devised. Although there are not wanting cases in which we find links between the comparatively simple vertical displacements of little-disturbed areas and the complicated over-folding and over-faulting of mountain ranges yet in the majority of cases the ordinary faults of the former and the grand and exaggerated reversed faults of the latter are as distinct in their distribution as they appear to have been in their mode of origin.

In the first section, the general characteristics of ordinary faults are discussed, as well as the classification of the different types of such faults and of simple flexures, and then the modes of grouping of such faults and their mode of origin are considered. As many of the English, French, and German terms employed in the definition of faults have originated with miners, and are of a provincial character, the exact sense in which they are used cannot be found explained even in the best dictionaries; hence a very great service is rendered to the geological reader by the care and thoroughness with which the authors of this essay have sought out and explained the synonymous words in the three languages.

It is when we come to the second section of the work, however, that we are impressed with the fullest sense of our indebtedness to MM. Heim and Margerie for removing obstacles to the mutual appreciation by the geologists of different countries of the labours of their fellow-workers.

More than forty years ago the brothers Rogers, in working out the geology of Pennsylvania, first showed what are the essential features in the structure of great mountain ranges. They described with great clearness the succession of great folds, "the axis-planes" of which had been pushed over into a nearly horizontal position; and others in which, by a still further movement, fracture had taken place along the axis-plane of the folds, leading to the upper limbs of the heeled-over and compressed arches being driven bodily for vast distances over the lower limbs. They described one of these exaggerated reversed faults or overthrusts in Pennsylvania as extending along a line twenty miles in length, with a displacement of five miles, while another similar rent was traced in Virginia for the distance of eighty miles. Henry Rogers saw clearly how these great dislocations enable us to explain the "fan-structure" and other remarkable appearances that had been described by De Saussure, Studer, and other pioneers in the study of Alpine geology; while James Hall, Dana, Vose, and other American geologists found in the structure of the Appalachians a key to the great problem of the origin of mountain chains. More recently the investigation of the Western Territories of the United States has supplied the able geologists of America with many beautiful and instructive illustrations of the same phenomena.

The light thrown upon the structure of mountain-chains by the study of the Appalachians soon began to influence the geologists of the Old World. Lory, Baltzer, Heim, and others, showed that in Dauphiny and in Switzerland "over-folding" and "over-faulting" are the great characteristics of Alpine structure, and they added much to our knowledge of the causes by which these structures are produced.

At the outset of these investigations upon the structure and origin of mountain chains, English geologists were conspicuous not only by the clearness of their views but by the skilful manner in which they applied the new principles to the explanation of our own mountain masses, especially those of the Scottish Highlands. Daniel Sharpe demonstrated the essential points of resemblance between the structure of the mountains of Scotland and those of Southern Europe; while Scrope and Darwin went still further in insisting that the intimate structure or foliation of the rock-masses of our own and other mountain chains must be attributed to the mechanical effects of the great movements to which they have been subjected. Unfortunately the great influence of Murchison, backed as it was by the authority of the officers of the Geological Survey, threw back the advance of English geology in this direction for nearly a quarter of a century. The doctrines that the rocks of the Highlands were in an essentially undisturbed condition, and that in them the planes of stratification and foliation were coincident, were backed by such a weight of authority, that for a time they overbore all opposition. To the labours of Prof. Lapworth we are indebted for initiating the great reaction against the mischievous teachings of this school; while Messrs. Peach and Horne have more than atoned for the evil done by their predecessors, by the energy and zeal with which they have sought to neutralize the effects of those teachings. It is a fortunate circumstance that these patient researches have been carried on in the very districts which had been appealed to as affording the strongest support to the erroneous interpretations.

In the second section of the work before us the various terms employed by Rogers and the American geologists, by Lory, Baltzer, Heim, Suess, Brögger, Reusch, and other Continental writers, as well as by Lapworth, Geikie, Peach, and Horne, are all brought into clear relation with one another. Where necessary the complicated effects of great mountain movements are illustrated by sketches, and the most invaluable aid is thus afforded to the student who seeks to make himself acquainted with and to compare the remarkable results attained by the workers in distant areas. Especially interesting are the observations upon the intricate phenomena displayed in cases where rocks that have been sheared and foliated during one period of mountain-making are subjected to a second process of the same kind at a long subsequent period. We regret that the space at our command forbids us from following the authors into some of these interesting questions.

The important problems connected with the changes in the internal structure of rocks resulting from the movements to which they have been subjected occupy the authors only so far as is necessary to fix the terms that shall be employed in describing the effects produced. The relative merits of such terms as "pressure metamorphism," proposed by Prof. Bonney; of "pressure-fluxion," by the late Prof. Carvill Lewis; of "dislocations-metamorphism," by Prof. Lossen; of "mechanical metamorphism," by Baltzer; of "metamorphism by friction," by Gosselet; and finally, of "dynamo-metamorphism," recently suggested by Prof. Rosenbusch, are all impartially considered. Whatever be the term eventually chosen to express the important effects produced by the internal movements—the "flowing"—of rock-masses, we can only rejoice that the ideas so ably advocated long ago by Scrope and Darwin are now beginning to meet with such wide and general recognition. Problems which in the days of these pioneers of geological thought were absolutely insoluble are now brought within the range of practical research. Lehmann, Lossen, and a host of other workers are showing us how by the application of microscopic methods the paramorphic changes and the mutual chemical reactions of minerals in a rock subjected to external stresses and internal movements may be clearly followed step by step; while the physical investigations of Daubrée, Tresca, and Spring afford to us the promise that the actual causes of the phenomena so carefully observed will not long remain hidden from our view.

The numerous workers in all the great centres of thought, whose attention and study are now concentrated upon these grand and fascinating problems, will welcome the work before us as supplying a want that has been widely and deeply felt. JOHN W. JUDD.

LETTERS TO THE EDITOR.

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Lamarckism *versus* Darwinism.

IN his first letter Dr. Romanes stated that I had accused him without evidence. In the second letter he repeats the statement in other words. The answer to both statements will be found in my last letter.

Dr. Romanes will not have replied to my first letter until he explains or expresses regret for his unfairness to Dr. Weismann.

Oxford, September 3. EDWARD B. POULTON.

The Zodiacal Light and Meteors.

I HAVE had the opportunity of looking at Mr. Maxwell Hall's letter (NATURE, vol. vii. p. 204), referred to by Mr. Mattieu Williams (May 31, p. 102), and find that it will not in the least bear out the suggestion made by the latter. Hall's observation was evidently not of any "spurious zodiacal light," but of the ordinary zodiacal light in the form called by some writers the "zodiacal band," though perhaps especially bright. Its position, also, as observed by Hall, was quite different from that which could be occupied by a stream of meteors from Biela's comet.

As regards Hall's theory, which he there propounds for the form of the zodiacal light, it has not met with acceptance, as writers in general consider the ordinary theory of the zodiacal light, viz. that it consists of a continuous disk, whether of meteors or any other substance, in which the sun is central, is sufficient to account for the appearances described by Maxwell Hall and other observers. T. W. BACKHOUSE.

Sunderland, August 31.

THE SERVICES OF CATHOLIC MISSIONARIES IN THE EAST TO NATURAL SCIENCE.

M. ARMAND DAVID, the well-known Lazarist missionary and man of science, has published a series of articles in the recent numbers of *Les Missions Catholiques* of Lyons on the services rendered to the natural sciences by the missionaries in the Far East. The following is a summary of these long and instructive articles.

It is a common mistake that Catholic missionaries are engaged in proselytizing, and in proselytizing only. Undoubtedly the original motive has been to convert pagan nations to Christianity; but, as will be shown, they have worked in other channels with very great success. Accounts of scientific work like that of the writer are not common, because the missionaries are so few that they have very little time to devote to anything outside their religious duties. The advantages of missionaries preceding the ordinary travellers are well known, and have been recognized by various learned Societies. It is, however, of Eastern Asia in particular of which M. David proposes to treat—that is, of China, which contains a third part of the population of the earth, and which is attracting more and more attention every day. The enemies of the Catholic clergy compare the present missionaries in China very unfavourably with the Jesuits who shone at Pekin in the seventeenth and eighteenth centuries. It is undoubted that the Jesuit fathers of Pekin bore an exceedingly high reputation in science and art, and that they produced very considerable results in almost every branch of human knowledge. They completed the most colossal geographical work that has ever yet been seen, by making a complete chart of the Chinese Empire. The "Lettres Édifiantes," the "Mémoires des Missionaires Jésuites de Pékin," the great works of Father Duhalde and of Father de Mailla show the immense mass of matter they have written upon almost every subject relating to the Chinese Empire. But, it is asked, why speak of the great achievements of the past? They only accentuate the total absence of any scientific labours at the present time in China. M. David has several answers to this question. (1) Formerly the Academies and learned Societies of Europe could communicate only with the missionaries on questions relating to China; no other travellers had then found their way into the Celestial Empire; and it was to aid this communication that the Catholic kings helped the missionaries with their protection and their money, as well as from religious motives. (2) The missionaries knew that they were compelled, in order to get permission to remain in China, to make their services indispensable to the emperor; and thus they put all their knowledge and skill at his service. (3) Whilst only a small number of missionaries thus resided at Pekin, and gained and kept the confidence of the emperor by their pursuit of astronomy, geography, and the arts, the rest, by the favour in which their brethren stood, got permission to preach throughout China.

St. Francis Xavier, the apostle of India, died without being able to enter China. Father Riccí, who entered it in 1580, led to Pekin quite a phalanx of eminent men, to occupy the posts of honour near the emperor. These high positions did not, however, prevent the missionaries from labouring in the cause of Christianity, and founding many Christian establishments. Amongst them were the Fathers Verbiest, Schall, de Premare, Gaubel, Amyot, and many others. The suppression of the Jesuit order stopped their work in China, and the Lazarists, who were sent to succeed them, and who had in their ranks men like MM. Raux, Ghislain, Hanna, and Lamiot, were themselves soon swept away by a revolution. The persecution soon became general in China, and some priests who were able to elude the edicts and remain in the country at the cost, very often, of their lives, were fully occupied without attending to scientific studies. The same was the case with their immediate successors, who were sent by various Societies to collect and strengthen the scattered congregations. Afterwards when the Anglo-French expedition procured freedom of conscience for the Christians and liberty for the missionaries to remain in China, things were very different from what they had been under the Emperors Kang-hi and Kien-lung. The thread of the scientific labours of the old fathers at Pekin could not be picked up. For, on the one hand, China was now in communication with the rest of the world, and had not the need nor the desire to have recourse to the missions for their learned and scientific men; and, on the other hand, the Christian missionaries and their flocks now enjoyed toleration, and the priests had nothing to gain by imitating their great predecessors in gaining the favour of the emperor. Besides, European diplomatists did not look with a favourable eye on the influence that would be acquired by priests over the emperor if they accepted official posts. The Jesuit fathers, however, who had returned to China when their suppression had been annulled, did not completely separate themselves from their former studies, but continued them as far as their changed condition would allow. For example, in their college of Zikawei, near Shanghai, they succeeded in establishing a very important meteorological observatory, whence Father Dechevrens regularly sends his observations to the men of science all over the world; natural history owes much to the persevering labours of Father Heude, who has published a work on the "Mollusques fluviatiles et terrestres" of Central China, and others on the stags and tortoises of China. The able draughtsman, Father Rhatouis, helped Father Heude by drawing the excellent illustrations of these books, some of which were printed in the Jesuit establishment in China. In other parts of the country, many of these missionaries give themselves up to forming and sending to our Museums collections of plants and animals. At Kwei-chow, Abbé Perny, of the Foreign Missions, put together a very interesting collection of plants, which, with other articles of value, he has presented to the Jardin des Plantes. He introduced into France the great silk-worm that bears his name (*Attacus pernyi*), and which already is reared in the open air on the oak-trees of the more temperate regions of France. On his return from China, Abbé Perny published a Chinese grammar and vocabulary, and many works on the productions of the Far East. From Tibet, Mgr. Chauveau and his successor, Mgr. Biet, and above all M. Desgodins, have sent to Europe many precious documents and several collections of animals, which give us an idea of the physical condition of that almost impenetrable region. M. Furet in Japan, M. Larnaudie in Siam, M. Pourthié in Corea, and M. Bon in Tonquin, and several others, have all in the respective countries of their adoption studied the geography and the natural history, and have sent their scientific collections to enrich our public and private establishments. At Yun-nan, M. Delavay, of the Foreign Missions, has given up for many years all his available time to the study of the plants of this unexplored province with the most remarkable zeal and success. The plants which he has already sent to the French Museum are the most important that have ever been sent from China to Europe, and botanists are surprised at the number of new species they contain. An account of these new species has been prepared by M. Frauchet, and will shortly be published in a big octavo volume. M. David prides himself on being the cause of M. Delavay following these botanical pursuits which have so enriched science. They met accidentally at Hong-Kong, and after some trouble M. David succeeded in inducing him to become a correspondent of the Jardin des Plantes. The Professors of that establishment have been so satisfied with the labours of M. Delavay that they have sent him one of their decorations with several money grants to help him to continue his fruitful researches. A few facts will show the value of the labours of this gentleman. Formerly only four or five Chinese representatives of the class *Rhododendron* were known, but the new species found by M. Delavay, added to those found by M. David at Moupinn, amount to forty-five. So, only one Chinese primrose was known, but now more than thirty new pecies have been classified by M. Delavay. Other missionaries besides those of China are actively engaged in the cause of science; for example, Father Montrouzier has studied the fauna of several of the islands of Oceania, and Fathers Duparquet, Augouard, and Le Roy, have sent from Africa many valuable collections. Our Museums and our naturalists have also received from the interior of America many objects more or less important, but chiefly many remarkable Coleoptera and Lepidoptera from MM. Sipolis, Gaujon, and Dorme, French Lazarists, who are quite at the head of the ardent collectors in the New World. To return to China, through the good offices of the Franciscan missionaries of Shen-si, M. Romanet du Cailland was able to obtain and introduce to France several new species of vine which have been cultivated under the names *Vitis Romaneti*, *Vitis Pagnuccii*, *Spinovitis Davidis*. This last species was found by M. David in a wild state in the central mountains of Tsin-lin, and is notable for having its stems covered with thorns. In spite of its somewhat aromatic flavour, it is well adapted for wine-making.

M. David then proceeds to particularize his own labours, and before doing so he gives a short history of his life, into which we shall not follow him. Shortly after the Anglo-French expedition to China he was ordered by his superiors to proceed to that country. Before setting out he was advised by several members of the Institute, amongst them being MM. Stanislas Julien, E. Milne-Edwards, Élie de Beaumont, and Decaisne, to make periodical reports. When he had settled down at Pekin in the year 1862, he began to explore the surroundings of Pekin to prepare materials for a natural history collection, and to send reports and specimens to the Jardin des Plantes. His first consignment of plants and animals was highly praised by the authorities of this institution, and grants of money were sent him to help him to proceed. The increasing importance of the results obtained in China made the Professors of the Museum believe that it was an Eldorado for naturalists, and accordingly they begged the Superior-General of the Lazarists to permit M. David to explore the lesser-known provinces of China. M. Etienne consented readily, chiefly because the request was made through the Government itself; and the Minister of Public Instruction officially styled M. David's proposed journey a scientific mission, and supplied the necessary funds. With regard to the collections sent home by him, he says that only zoologists can appreciate the great work of M. Milne-Edwards, entitled "Recherches sur les Mammifères," which, with the exception of a single species, treats of Chinese animals. The greater portion of these were sent by M. David, the new species alone amounting to sixty-five. One of the most remarkable of these is the *Semnopithecus roxellana*, a curious monkey with a nose very much turned up and a green face, with his back ornamented with long brown and white hair, whose haunts are in the cold forests of Tibet. It is a sort of counterpart of the long-nosed monkeys of Borneo. Besides this animal, China supplied two others, one of which was capable of bearing the severe winters of the north of Tchely, to which point its habitat extends. Another important discovery of the Tibetan region is the extraordinary *Ursus melanoleucus*, for which there was no generic name. The *Ailuropus melanoleucus* appears to be of great rarity in the very small region it inhabits. All the Museums of the world envy the Jardin des Plantes the possession of four specimens—the only ones M. David met. In Tibet also he saw the *Nectogale elegans*, a new kind of aquatic insectivorous animal, the hair of which assumes all the colours of the rainbow when the little creature is in the water. He also secured several varieties of this animal. In the lofty forests of Moupinn he found the *Budorcas*, a large ruminant of a grayish-white colour, with no tail and with immense horns. The hunters of the country regard this animal as the tiger is regarded in India. In spite of its heavy build it scrambles over the most rugged rocks as lightly as a chamois. In almost every district in China he came on some treasure. The deer with large hoofs and a long tail (*Elaphurus davidianus*) is now pretty well known; but the species is, unfortunately, threatened with extinction in China. In the genus *Mus* alone he got twenty-seven species. He noted down two hundred species of *Mammiferæ*, and in this number there are hardly five or six, omitting the domestic species, which appear identical with their species in Europe.

With regard to the birds of China, M. David has prepared, with the help of M. G. Masson, a book on them, in which he recognizes 807 species either living in China or coming there regularly. Amongst the greatest novelties he mentions the large *Lophophorus* of Tibet, which lives at a height of above 12,000 feet; the three known *Crossoptilon*, of which one is white, another blue, and the third black and white; the *Tragopan*, with a large many-coloured band around the throat, and its head ornamented with two very thin, blue, and fleshy horns; two *Eulophes*, crested pheasants, which are the most appreciated dish by gourmands; the sacred pheasant, with a tail over six feet long; the Amherst pheasant, now become, like the preceding, a common bird in the parks; and a new species of pheasant, dark-coloured, and always living under trees. All these birds, and hundreds of others from the same source, are exhibited in the French Museum. Some of them, according to the method common among naturalists, are named after the discoverer. Thus the *Cygnus davidi*, a very rare swan with red legs, and the *Pterorhinus davidi*, a kind of mocking-bird captured in the woods in the neighbourhood of Pekin; the *Sygrnium davidi*, a nocturnal rapacious bird of Tibet, described by Mr. Sharp, of the British Museum. M. H. Milne-Edwards, Professor at the Sorbonne, has also affixed M. David's name to two new species which he has described, *Carpodacus davidianus* and *Oreopneuste armandi*. China has not our sparrow, chaffinch, goldfinch, or linnet; our warbler, redbreast, and nightingale are unknown; their thrushes, blackbirds, tomtits, and crows, differ very much from ours. In fact, speaking generally, there is only about one-fifth of the Chinese birds found in Europe, and the greater part of these are very different in the two regions. The Eastern *Gallinæ*, *Insectivores*, and *Rapaces*, have scarcely any species like them in our continent. A very remarkable fact is that we find certain groups of birds within certain narrow limits where they are represented by numerous species, whilst they are totally absent from all other parts of the earth, even from those parts where it would be quite possible for them to live. Thus there are forty kinds of the beautiful pheasant class, all grouped around Tibet, while there is not a single member of the class in any other quarter of the globe. So the *Crateropodes*, of which there are thirty or forty species in China, do not appear to have any representatives in Europe. These and other facts furnish M. David with what he considers unanswerable objections to the theory that they were all created *ab origine*. Is it not more reasonable, he asks, to admit that the principal types of plants and animals having once appeared on earth, where and when it pleased Providence, have undergone slow variations which have divided them by degrees into species and varieties? America has upwards of four hundred species of humming-birds, while there is not a single other specimen in the rest of the tropical world, where those little creatures could live equally well. Every class of the animal kingdom, he says, furnishes similar examples and analogous facts.

The subject of reptiles, *Batrachia*, and fishes, which M. David only worked up slightly, has been carefully pursued by M. Duméril, Dr. Savage, and M. E. Blanchard. The last-named gentleman described before the Academy of Sciences, under the name of *Sieboldia davidiana*, an immense salamander which lives on fish and crabs in fresh water. A skeleton of a salamander, more or less resembling this one, has recently been found in Germany, where it was taken for a fossil man. It is the insect world which supplied M. David with the greatest novelties. Great though the collections sent to Europe are, they are but a small fraction of the riches in entomology that China supplies. The Coleoptera have been described by M. Fairmaire, formerly President of the French Entomological Society, and the Lepidoptera by M. Oberthur, of Rennes, who has the finest collection in France, and perhaps in the world. Amongst insects, more even than amongst animals and plants, there is a large number called by the names of the missionaries who sent specimens of them to Europe. For example, *Cicindela desgodinsii*, *Carabus delavayi*, *Cychrus davidi*, *Nebria chaslei*, *Enoplotrupes largeteani*, *Donacia provosti*, &c., in Coleoptera; and in butterflies, *Anthocharis bieti*, *Armandia thaïdina*, &c. With regard to the vegetable kingdom, the first important work we have on the Chinese flora has been finished this year, and styled "Plantæ Davidianæ." It has been printed at the expense of the State, and is in two quarto volumes, illustrated with forty-five very fine plates, and contains a description of all the new species of plants in M. David's collection, and an enumeration of all the plants collected by him. The collection contains a small proportion only of the plants of China. It should only be regarded as a mere skeleton of the magnificent vegetation of the east-central provinces, but it contains the greater portion of the plants to the north of the empire and in the Mongolian mountains. Collections made by English and Russian collectors do not include many of the specimens found by M. David. Perhaps the most remarkable find was the *Davidia involucrata*—a pretty tall tree with large leaves, for the introduction of which an English amateur has offered a big prize. Our European plants are not at all common in the East. No trefoils are found in China, nor heather, nor broom. There are also many plants there which have no representatives in Europe, but which have representatives in America, as, *Pavia*, *Bignonia*, *Aralia*, *Dielytra*. Northern China, with its dry climate, its cold winter, as cold as that of Upsala, and its summer as warm as that of Senegal, has a poor and little-varied vegetation when compared with the centre and west of the empire. The number of Phanerogams collected by M. David in the north of China did not exceed 1500 species, and he doubts if there are many more.

In geography and geology, besides several occasional reports, the "Archives du Muséum" have published full accounts of his first and second journeys of exploration. These voluminous writings are merely journals written for some friends, for whom he wrote day by day everything that seemed worthy of attention, whether botanical, geological, or geographical, in the extensive regions which for five years he travelled over. Itinerary charts, striking altitudes, up to 15,000 feet, the direction and importance of rivers and mountain chains, the position of the lesser known towns and countries, and of the coal and metal mines—all have been noted down by him. From the writings of M. David, M. Elisée Reclus took many of his observations on the Chinese Empire in vol. vii. of his "Géographie Universelle," and especially the natural history portion of that volume. Similarly Baron Richthofen has derived much of the information in his work on geology from M. David. In Mongolia M. David's guide was Sambdatchiemda, the famous ex-lama described by M. Huc, and this leads M. David to speak of the lamas, and tell some stories about them.

M. David describes a curious meteorological phenomenon observed by him when crossing the top of a mountain about 5500 feet high. A storm had just passed, and a little rain had fallen. The clouds were heavy, and lay on the numerous peaks below his feet like an immense sea of silvery white. Little by little the masses of clouds began to move and to split up here and there. They rose slowly and soon came to the right of M. David, who was journeying from south to north. The wind was blowing from the west, and when the clouds reached the summit of the mountain they could not pass over on account of the opposition of the wind, and there they rested, a huge mass of opaque clouds. The sun was setting on the horizon, and threw the image of M. David on the wall of white clouds, where it was surrounded by two rainbows, or rather two complete concentric circles. This phenomenon lasted nearly half an hour. M. David had been six months in Mongolia when the revolt of the Mussulmans broke out and prevented him from penetrating as far as Koukounoor, and even beyond it, as was his intention. These high Mongolian plateaux are of about three thousand feet above the level of the sea. The population is very sparse, and the fauna and flora but little varied. The remarkable animals most frequently seen in this region are the souslik, or yellow antelope, a kind of little marmot analogous to the prairie dog of America, a brownish weevil, and a curious lizard with round head (*Phrynocephalus*) which is seen everywhere rolling its tail in regular cadences. During the summer the open country is covered either with the blue-flowered iris, or with the liquorice (*Glycyrrhiza echinata*) or the yellow rose. M. David found in Mongolia in a wild state, but very rare, a pretty flowering tree, which the Pekinese cultivate as an ornamental plant (*Xanthoceras sorbifolia*), and which he introduced into France with much success. In his journey he satisfied himself of the existence of wild camels, some of which were afterwards captured by the Russian traveller Prjevalski. M. David spent twenty-five months in Western China. He had intended to spend three years, but his health broke down. In that time he travelled over 2500 leagues. He returned thence to Tien-tsin, fortunately for him after the massacres had taken place, his boat having been delayed on the way.

THE AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SYDNEY, *July* 1888.

THE formation of this Association, which already gives promise of being a great success, was first suggested by Prof. Liversidge, of the Sydney University, during the Exhibition in Sydney in 1879, but matters at that time not being considered quite ripe for it, the formation of the Association was again brought forward through the press in the year 1884. It was then suggested that, as it did not seem likely that the British Association would see their way to visit Australia during the Centennial year, an Australasian Association should be formed, on the same lines as the British Association, in order to bring about a federation or union of the members of the various scientific Societies throughout Australasia.

It was also suggested that the first general meeting should be held in Sydney on the one hundredth anniversary of the foundation of the colony, as it was at that time thought there would be an International Exhibition in Sydney to celebrate that event. In furtherance of this object a preliminary meeting of delegates was held in Sydney in November 1886, the project having met with the approbation and support of almost all the learned and scientific Societies of Australasia.

As this meeting the formation of the Australasian Association for the Advancement of Science was agreed to unanimously, the rules of the British Association being adopted until the first general meeting, which it was decided should be held in Sydney during the year 1888.

In accordance with another resolution passed at the meeting of delegates, the election of officers for the year took place in March of the present year, Mr. H. C. Russell, F.R.S., Government Astronomer, being elected President, Sir Edward Strickland, K.C.B., Hon. Treasurer, and Prof. Liversidge, F.R.S., and Dr. George Bennett, Hon. Secretaries.

The formation of the Council was afterwards proceeded with, each learned or scientific Society electing one representative for every hundred of its members; and the Chief Justice, Minister for Public Instruction, the Chancellor and Vice-Chancellor of the Sydney University, the Mayor of Sydney, and the Presidents of the Royal Societies in other colonies were elected Vice-Presidents for the year.

The Presidents of Sections were then elected, the gentlemen chosen being all resident in other colonies than New South Wales; whilst the Secretaries of Sections, as a matter of necessity, were elected from amongst residents in Sydney.

The Association is hence thoroughly Australasian in its character, and the succeeding general meetings are to take place in turn in the capitals of the other colonies, the executive officers being elected year by year by the colony in which the meeting is held.

The first general meeting is to be held at the Sydney University, the opening ceremony, at which His Excellency the Governor will be present, taking place on Tuesday evening, August 28, when the Presidential address will be delivered.

On the following day the Sectional meetings for the reading and discussion of papers will commence, and it is thought that the principal portion of the business will close with the end of the week.

Up to the present time the titles of about ninety papers have been sent in by gentlemen of distinction in science, literature and art, in the different colonies, and it seems probable that this number will be considerably increased before the meeting.

It may therefore be anticipated that the nature of the work done by the Association during the first year of its existence will be of a highly important and useful character.

The more solid work of the meeting is to be lightened by excursions to various places of interest to geologists, botanists, and others; and efforts are being made to provide for the entertainment and comfort of visiting members, as far as possible, so that they may spend their time to the best advantage.

The various steamship companies have arranged to carry members proceeding to Sydney to attend the meeting at a reduction of 20 per cent. on the ordinary rates, and it is anticipated that liberal concessions will also be granted in the railway fares.

The rules, as already mentioned, are practically the same as those of the British Association, and all who join the Association before the first general meeting in August next become original members, without entrance fee, the subscription of £1 entitling members to receive the publications of the Association gratis.

The number of members at the end of July exceeded 400.

PROFESSOR RUDOLF JULIUS EMANUEL CLAUSIUS.

BY the death of Prof. Clausius, which occurred on August 24 last, science has lost another member of the great triumvirate—Rankine, Clausius, and Thomson—who, upon the foundation laid by the experimental work of Davy and Rumford, the theoretical suggestions of Mohr, Séguin, Mayer, and Colding (which, though resting on imperfect data and defective reasoning, were the results of real scientific insight), and the splendid experimental investigations of Joule, founded and built up the great structure known as the science of thermodynamics.

Clausius was born at Cöslin, in Pomerania, on January 2, 1822. While yet at school in Berlin, he gave unmistakable evidence of the bent of his mind towards mathematics and physics, and on the completion of his University course he became Privatdocent in the University of Berlin and Instructor in Natural Philosophy at the School of Artillery. He very soon gave evidence of his power as an original worker, and some of his earliest papers—"On the Nature of those Constituents of the Atmosphere by which the Reflection of the Light within it is effected," and "On the Blue Colour of the Sky, and the Morning and the Evening Red"—contributed to *Poggendorff's Annalen*, were selected for translation in the first volume of Taylor's "Scientific Memoirs."

In 1857 he was appointed Professor of Natural Philosophy at the Polytechnic School of the Helvetic Confederacy at Zürich. Here he continued his researches in various branches of physics, and among these we may mention, to give some idea of the extent and variety ot his investigations, "The Influence of Pressure on the Freezing-point," "The Mechanical Equivalent of an Electric Discharge, and the Heating of the Conducting-wire which accompanies it," "Electrical Conduction in Electrolytes," and "The Effect of Temperature on Electric Conductivity." He also published some short papers on some purely mathematical questions, suggested, however, by physical problems, and some papers dealing with points of what is generally known as physical chemistry.

His attention was then directed towards the dynamical theory of gases, owing to the light which it appeared capable of throwing upon questions of thermodynamics. The dynamical or kinetic theory of gases, which has received such extensive developments at the hands of Clerk Maxwell, Boltzmann, and others, was originally suggested by J. Bernouilli about the middle of the last century; but it was Clausius who first placed it upon a secure scientific basis. In 1866 he published a most important paper "On the Determination of the Energy and Entropy of a Body" (translated in the *Philosophical Magazine*), in which the very valuable and suggestive conception of the entropy of a body was first set forth.

In 1869 he was appointed Professor of Natural Philosophy in the University of Bonn.

Among more recent papers of great importance we may mention the following, all of which have been translated in the *Philosophical Magazine*:—"On a New Fundamental Law of Electrodynamics"; "On the Behaviour of Carbonic Acid in relation to Pressure, Volume, and Temperature"; "On the Theoretic Determination of Vapour-pressure and the Volumes of Vapour and Liquid"; "On the Different Systems of Measures for Electric and Magnetic Quantities"; "On the Employment of the Electrodynamic Potential for the Determination of the Ponderomotive and Electromotive Forces"; "On the Theory of Dynamo-electrical Machines"; and "On the Theory of the Transmission of Power by Dynamo-electrical Machines."

When we consider the far-reaching and fundamental character of these and many other investigations, and the very wide field which they cover, we cannot but wonder at the marvellous energy of the great physicist who has passed from among us. The Royal Society catalogue contains a list of no less than seventy-seven papers published up to 1873, and those published subsequently bring the total number up to considerably over a hundred.

In addition to these there is his great treatise on "The Mechanical Theory of Heat," of which the first volume was published in 1864, and a smaller work, "On the Potential Function and the Potential."

It would be impossible to discuss in detail the portions of thermodynamics specially worked out by Clausius, as his work is throughout closely interwoven with that of Rankine and Thomson, but it will be of interest to quote the following from Prof. Rankine, who in his paper "On the Economy of Heat in Expansive Machines,"[1] says:—

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[1] "Rankine's Miscellaneous Scientific Papers," p. 309.

"Carnot was the first to assert the law *that the ratio of the maximum mechanical effect to the whole heat expended in an expansive machine is a function solely of the two temperatures at which the heat is respectively received and emitted, and is independent of the nature of the working substance.* But his investigations, not being based on the principle of the dynamical convertibility of heat, involve the fallacy that power can be produced out of nothing.

"The merit of combining Carnot's *law*, as it is termed, with that of the convertibility of heat and power belongs to Mr. Clausius and Prof. William Thomson; and in the shape into which they have brought it, it may be stated thus: *The maximum proportion of heat converted into expansive power by any machine is a function solely of the temperatures at which heat is received and emitted by the working substance, which function for each pair of temperatures is the same for all substances in Nature.*"

None will regret the loss of Prof. Clausius more keenly than the students of the University of Bonn, where he formed a centre of attraction not only as a great investigator, but as a teacher of almost unrivalled ability. The secret of his powers as a teacher may easily be guessed from the study of his published papers and treatises. Their great characteristic is the direct insight which they give into the very heart of the physical principles under discussion. The author, while showing himself a master of mathematical methods, ever keeps the physical meaning of the symbols before the eye of the reader, and never allows his analysis to carry him away into the regions of mere mathematical ingenuity. In this he was a worthy compeer of some of our own great mathematical physicists, like Thomson and Maxwell, and the greater part of his work has the additional advantage, for the majority of students, of being effected by the aid of comparatively simple analysis.

In 1868, Prof. Clausius was elected a Foreign Member of the Royal Society, and in 1879 he was presented with the Copley Medal, the highest distinction at the disposal of the Society. He was decorated with various civil Prussian and Bavarian orders; and after the Franco-German war, during which he had volunteered to serve as caretaker of the wounded, he received the German decoration of the Iron Cross, and the French decoration of the Legion of Honour.

G. W. DE TUNZELMANN.

THE BRITISH ASSOCIATION.

Wednesday Night.

THE meeting of the British Association which opens to-night, after twenty-four years' absence, in Bath, will be the fifty-eighth. At the meeting of 1864, the President was Sir Charles Lyell, and the occasion was rendered memorable by the presence at once of Dr. Livingstone and Bishop Colenso, both at the time filling a large space in the public eye. Though a vast majority of the members of the Association would prefer to visit Bath to either Birmingham or Manchester, the latter towns possess in Owens College and the Town Hall buildings which offer greater conveniences for the meeting of a scientific Congress. In Bath the Sections will be somewhat scattered. The Physical Science Section meets at the St. James's Hall; the Mechanical Section in the Masonic Hall; the Chemical Section in the Friends' Meeting-House; Geology and Biology are housed at the Mineral Water Hospital, with the Blue Coat School for the sub-sections; Geography at the Guildhall, and Anthropology at the Grammar School; while the President's address and some of the popular lectures, as well as the concluding general meeting, will be delivered at the Drill Hall. The Mayor gives a *conversazione* to-morrow in the Assembly Rooms, and the Chairman and Local Committee give another on Tuesday. A large number of foreign visitors, especially geologists for the International Geological Congress to be held in London on the 17th inst., are expected. Amongst those already arrived are Prince Roland Bonaparte; Profs. Dufont, Gilbert, Capellini, Stephenson, Lory, von Koenen, Frazer, Kalkowsky, and Waagen.

The retiring President, Sir Henry Roscoe, M.P., F.R.S., in introducing Sir Frederick Bramwell, the President-Elect, spoke as follows:—

"My Lords, Ladies, and Gentlemen,—Four-and-twenty eventful years in the history of science have passed away since the British Association last visited the city of Bath. Those of us who were present here in 1864 will not soon forget that memorable meeting. It was presided over, as you all will remember, by that veteran geologist, that great forerunner of a new science of life, Sir Charles Lyell, of beloved and venerated memory. Yes, ladies and gentlemen, it was he who prepared the way by his recognition of the true history of our globe for the even more illustrious Darwin. It was he who pointed out that the causes which have modified the earth's crust in the past are, for the most part, those which are now changing the face of Nature. Lyell was a typical example of the expositor of Nature's most secret processes. His work was that of an investigator of science pure and undefiled, and as such, his life and labours stand for ever as an example to all those who love Science for her own sake.

"But the far-seeing founders of this our British Association were as fully alive to the fact as we, in perhaps our more utilitarian age, can be, that, just as man does not live by bread alone, so it is not only by purely scientific discovery that the nations progress, or that science advances. They knew as well as we do that to benefit humanity the application of the results of scientific research to the great problems of every-day life is a necessity. Hence our founders, whilst acknowledging that the basis of our Association can only be securely laid upon the principles of pure science in its various branches, recognized the importance of the application of those principles in the establishment of a Section which should represent one of the most remarkable outcomes of the activity and force of the nation—a Section of Engineering. It is therefore meet and right that in due proportion this great department of our scientific edifice—a department which, perhaps, more than any other, has effected a revolution in our modern social system—should be represented in our Presidential chair.

"Twenty-four years ago it was pure science that we honoured in Sir Charles Lyell: to-day it is applied science to which we show our respect in the person of Sir Frederick Bramwell. It would ill become me, engaged as I have been in the study of subjects far removed from those which fill the life of an active and successful engineer, to venture on this occasion on a eulogium upon the work of my successor, still less is it in my mind to draw any comparison as to the relative importance to be attached to the work of the investigator, such as Lyell, and to that of him who applies the researches of others to the immediate wants of mankind. It is enough for me, as I am sure it will be for you, to remember that both classes of men are needed for the due advancement of science, and to rejoice that as in former years the names of Fairbairn, of Armstrong, and of Hawkshaw, have adorned our list of Presidents, so in the present instance, this branch of science, which represents lines of human activity rendered illustrious by the labours of many great Englishmen, is to-day represented by our eminent President.

"I have the honour of requesting Sir Frederick Bramwell to take the chair, and to favour us with the Presidential address."

INAUGURAL ADDRESS BY SIR FREDERICK BRAMWELL, D.C.L., F.R.S., M.INST.C.E., PRESIDENT.

THE late Lord Iddesleigh delighted an audience, for a whole evening, by an address on "Nothing." Would that I had his talents, and could discourse to you as charmingly as he did to his audience, but I dare not try to talk about "Nothing." I do, however, propose, as one of the two sections of my address, to discourse to you on the importance of the "Next-to-Nothing." The other section is far removed from this microscopic quantity, as it will embrace the "Eulogy of the Civil Engineer," and will point out the value to science of his works."

I do not intend to follow any system in dealing with these two sections. I shall not even do as Mr. Dick, in "David Copperfield," did—have two papers, to one of which it was suggested he should confine his memorial and his observations as to King Charles's head. The result is, you will find, that the importance of the next-to-nothing, and the laudation of the civil engineer, will be mixed up in the most illogical and haphazard way, throughout my address. I will leave to such of you as are of orderly minds, the task of rearranging the subjects as you see fit, but I trust—arrangement or no arrangement—that by the time I have brought my address to a conclusion I shall have convinced you that there is no man who more thoroughly appreciates the high importance of the "next-to-nothing" than the civil engineer of the present day, the object of my eulogy this evening.

If I may be allowed to express the scheme of this address in modern musical language, I will say that the "next-to-nothing" "motive" will commonly usher in the "praise-song" of the civil engineer; and it seems to me will do this very fitly, for in many cases it is by the patient and discriminating attention paid to the effect of the "next-to-nothing" that the civil engineer of the present day has achieved some of the labours of which I now wish to speak to you.

An Association for the Advancement of Science is necessarily one of such broad scope in its objects, and is so thoroughly catholic as regards science, that the only possible way in which it can carry out those objects at all is to segregate its members into various subsidiary bodies, or sections, engaged on particular branches of science. Even when this division is resorted to, it is a hardy thing to say that every conceivable scientific subject can be dealt with by the eight Sections of the British Association. Nevertheless, as we know, for fifty-seven years the Association has carried on its labours under Sections, and has earned the right to say that it has done good service to all branches of science.

Composed, as the Association is, of a union of separate Sections, it is only right and according to the fitness of things that, as time goes on, your Presidents should be selected, in some sort of rotation, from the various Sections. This year it was felt, by the Council and the members, that the time had once more arrived when Section G—the Mechanical Section—might put forward its claim to be represented in the Presidency; the last time on which a purely engineering member filled the chair having been at Bristol in 1875, when that position was occupied by Sir John Hawkshaw. It is true that at Southampton, in 1882, our lamented friend, Sir William Siemens, was President, and it is also true that he was a most thorough engineer and representative of Section G; but all who knew his great scientific attainments will probably agree that on that occasion it was rather the Physical Section A which was represented, than the Mechanical Section G.

I am aware it is said Section G does not contribute much to pure science by original research, but that it devotes itself more to the application of science. There may be some foundation for this assertion, but I cannot refrain from the observation that, when engineers such as Siemens, Rankine, Sir William Thomson, Fairbairn, or Armstrong, make a scientific discovery, Section A says it is made, not in the capacity of an engineer, and therefore does not appertain to Section G, but in the capacity of a physicist, and therefore appertains to Section A—an illustration of the danger of a man's filling two positions, of which the composite Prince-Bishop is the well-known type. But I am not careful to labour this point, or even to dispute that Section G does not do much for *original* research. I do not agree it is a fact, but, for the purposes of this evening, I will concede it to be so. But what then? This Association is for the "Advancement of Science"—the *advancement*, be it remembered; and I wish to point out to you, and I trust I shall succeed in establishing, that for the *advancement* of science it is absolutely necessary there should be the *application* of science, and that, therefore, the Section, which as much as any other (or, to state the fact more truly, which more than any other) in the Association *applies* science, is doing a very large share of the work of *advancing* science, and is fully entitled to be periodically represented in the Presidency of the whole Association.

I trust also I shall prove to you that applications of science, and discoveries in pure science, act and react the one upon the other. I hope in this to carry the bulk of my audience with me, although there are some, I know, whose feelings, from a false notion of respect for science, would probably find vent in the "toast" which one has heard in another place—this "toast" being attributed to the pure scientist—"Here's to the latest scientific discovery: may it never do any good to anybody!"

To give an early illustration of this action and reaction, which I contend occurs, take the well-worn story of Galileo, Torricelli, and the pump-maker. It is recorded that Galileo first, and his pupil Torricelli afterwards, were led to investigate the question of atmospheric pressure, by observing the failure of a pump to raise water by "suction," above a certain level. Perhaps you will say the pump-maker was not applying science, but was working without science. I answer, he was unknowingly applying it, and it was from that which arose in this unconscious application that the mind of the pure scientist was led to investigate the subject, and thereupon to discover the primary fact of the pressure of the atmosphere, and the subsidiary facts which attend thereon. It may appear to many of you that the question of the exercise of pressure by the atmosphere should have been so very obvious, that but little merit ought to have accrued to the discoverer; and that the statement, once made, must have been accepted almost as a mere truism. This was, however, by no means the case. Sir Kenelm Digby, in his "Treatise on the Nature of Bodies," printed in 1658, disputes the proposition altogether, and says, in effect, he is quite sure the failure of the pump to raise water was due to imperfect workmanship of some kind or description, and had nothing to do with the pressure of the air; and that there is no reason why a pump should not suck up water to any height. He cites the boy's sucker, which, when applied to a smooth stone, will lift it, and he says the reason why the stone follows the sucker is this. Each body must have some other body in contact with it. Now, the stone being in contact with the sucker, there is no reason why that contact should be broken up, for the mere purpose of substituting the contact of another body, such as the air. It seems pretty clear, therefore, that even to an acute and well-trained mind, such as that of Sir Kenelm Digby, it was by no means a truism, and to be forthwith accepted, when once stated, that the rise of water on the "suction side" of a pump was due to atmospheric pressure. I hardly need point out that the pump-maker should have been a member of "G." Galileo and Torricelli, led to reflect by what they saw, should have been members of "A" of the then "Association for the Advancement of Science."

But, passing away from the question of the value of the application of science of a date some two and a half centuries ago, let us come a little nearer to our own times.

Electricity (known in its simplest form to the Greeks by the results arising from the friction of amber, and named therefrom; afterwards produced from glass cylinder machines, or from plate machines; and produced a century ago by the "influence" machine) remained, as did the discoveries of Volta and Galvani, the pursuit of but a few, and even the brilliant experiments of Davy did not suffice to give very great impetus to this branch of physical science.

Ronalds, in 1823, constructed an electric telegraph. In 1837 the first commercial use was made of the telegraph, and from that time electrical science received an impulse such as it had never before experienced. Further scientific facts were discovered; fresh applications were made of these discoveries. These fresh applications led to renewed vigour in research, and there was the action and reaction of which I have spoken. In the year 1871 the Society of Telegraph-Engineers was established. In the year 1861 our own Association had appointed a Committee to settle the question of electrical standards of resistance, which Committee, with enlarged functions, continued its labours for twenty years, and of this Committee I had the honour of being a member. The results of the labours of that Committee endure (somewhat modified, it is true), and may be pointed to as one of the evidences of the value of the work done by the British Association. Since Ronalds's time, how vast are the advances which have been made in electrical communication of intelligence, by land lines, by submarine cables all over the world, and by the telephone! Few will be prepared to deny the statement, that pure electrical science has received an enormous impulse, and has been advanced by the commercial application of electricity to the foregoing, and to purposes of lighting. Since this latter application, scores, I may say hundreds, of acute minds have been devoted to electrical science, stimulated thereto by the possibilities and probabilities of this application.

In this country, no doubt, still more would have been done if the lighting of districts from a central source of electricity had not been, since 1882, practically forbidden by the Act passed in that year. This Act had in its title the facetious statement that it was "to facilitate electrical lighting"—although it is an Act which, even modified as it has been this year, is still a great discouragement of free enterprise, and a bar to progress. The other day a member of the House of Commons was saying to me: "I think it is very much to our discredit in England that we should have allowed ourselves to be outrun in the distribution of electric lighting to houses, by the inhabitants of the United States, and by those of other countries." Looking upon him as being one of the authors of the "facetious" Act, I thought it pertinent to quote the case of the French parricide, who, being asked what he has to say in mitigation of punishment, pleads, "Pity a poor orphan"—the parricide and the legislator being both of them authors of conditions of things which they affect to deplore. I will say no more on this subject, for I feel that it would not be right to take advantage of my position here to-night to urge political economy views, which should be reserved for Section F. I will merely, and as illustrative of my views of the value of the application of science to science itself, say there is no branch of physics pursued with more zeal and with more happy results than that of electricity, with its allies, and there is no branch of science towards which the public look with greater hope of practical benefits; a hope that, I doubt not, will be strengthened after we have had the advantage of hearing one of the ablest followers of that science, Prof. Ayrton, who, on Friday next, has been good enough to promise to discourse on "The Electrical Transmission of Power."

One of the subjects which, as much as (or probably more than) any other, occupies the attention of the engineer, and therefore of Section G, is that of (the so-called) prime movers, and I will say boldly that, since the introduction of printing by the use of movable type, nothing has done so much for civilization as the development of these machines. Let us consider these prime movers—and, first, in the comparatively humble function of replacing that labour which might be performed by the muscular exertion of human beings, a function which at one time was looked upon by many kindly but short-sighted men as taking the bread out of the mouth of the labourer (as it was called), and as being therefore undesirable. I remember revisiting my old schoolmaster, and his saying to me, shaking his head: "So you have gone the way I always feared you would, and are making things of iron and brass, to do the work of men's hands."

It must be agreed that all honest and useful labour is honourable, but when that labour can be carried out without the exercise of any intelligence, one cannot help feeling that the result is likely to be intellectually lowering. Thus it is a sorry thing to see unintelligent labour, even although that labour be useful. It is but one remove from unintelligent labour which is not useful; that kind of labour generally appointed (by means of the tread-wheel or the crank) as a punishment for crime. Consider even the honourable labour (for it is useful, and it is honest) of the man who earns his livelihood by turning the handle of a crane, and compare this with the labour of a smith, who, while probably developing more energy by the use of his muscles, than is developed by the man turning the crane-handle, exercises at the same time the powers of judgment, of eye, and of hand in a manner which I never see without my admiration being excited. I say that the introduction of prime movers as a mere substitute for unintelligent manual labour is in itself a great aid to civilization and to the raising of humanity, by rendering it very difficult, if not impossible, for a human being to obtain a livelihood by unintelligent work—the work of the horse in the mill, or of the turnspit.

But there are prime movers and prime movers—those of small dimensions, and employed for purposes where animal power or human power might be substituted, and those which attain ends that by no conceivable possibility could be attained at all by the exertion of muscular power.

Compare a galley, a vessel propelled by oars, with the modern Atlantic liner; and first let us assume that prime movers are non-existent, and that this vessel is to be propelled galley-fashion. Take her length as some 600 feet, and assume that place be found for as many as 400 oars on each side, each oar worked by three men, or 2400 men; and allow that six men under these conditions could develop work equal to one horse-power: we should have 400 horse-power. Double the number of men, and we should have 800 horse-power, with 4800 men at work, and at least the same number in reserve, if the journey is to be carried on continuously. Contrast the puny result thus obtained with the 19,500 horse-power given forth by a large prime mover of the present day, such a power requiring, on the above mode of calculation, 117,000 men at work, and 117,000 in reserve; and these to be carried in a vessel less than 600 feet in length. Even if it were possible to carry this number of men in such a vessel, by no conceivable means could their power be utilized so as to impart to it a speed of twenty knots an hour.

This illustrates how a prime mover may not only be a mere substitute for muscular work, but may afford the means of attaining an end that could not by any possibility be attained by muscular exertion, no matter what money was expended or what galley-slave suffering was inflicted.

Take again the case of a railway locomotive. From 400 to 600 horse-power developed in an implement which, even including its tender, does not occupy an area of more than fifty square yards, and that draws us at sixty miles an hour. Here again, the prime mover succeeds in doing that which no expenditure of money or of life could enable us to obtain from muscular effort.

To what, and to whom, are these meritorious prime movers due? I answer: To the application of science, and to the labours of the civil engineer, using that term in its full and proper sense, as embracing all engineering other than military. I am, as you know, a civil engineer, and I desire to laud my profession and to magnify mine office; and I know of no better means of doing this than by quoting to you the definition of "civil engineering," given in the Charter of the Institution of Civil Engineers—namely, that it is "the art of directing the great sources of power in Nature for the use and convenience of man." These words are taken from a definition or description of engineering given by one of our earliest scientific writers on the subject, Thomas Tredgold, who commences that description by the words above quoted, and who, having given various illustrations of the civil engineer's pursuits, introduces this pregnant sentence:—

"This is, however, only a brief sketch of the objects of civil engineering, the real extent to which it may be applied is limited only by the progress of science; its scope and utility will be increased with every discovery in philosophy, and its resources with every invention in mechanical or chemical art, since its bounds are unlimited, and equally so must be the researches of its professors."

"The art of directing the great sources of power in Nature for the use and convenience of man." Among all secular pursuits, can there be imagined one more vast in its scope, more beneficent, and therefore more honourable, than this? There are those, I know—hundreds, thousands—who say that such pursuits are not to be named as on a par with those of literature; that there is nothing ennobling in them; nothing elevating; that they are of the earth earthy; are mechanical, and are unintellectual, and that even the mere bookworm, who, content with storing his own mind, neither distributes those stores to others nor himself originates, is more worthily occupied than is the civil engineer.

I deny this altogether, and, while acknowledging, with gratitude, that, in literature, the masterpieces of master minds have afforded, and will afford, instruction, delight, and solace for all generations so long as civilization endures, I say that the pursuits of civil engineering are worthy of occupying the highest intelligence, and that they are elevating and ennobling in their character.

Remember the kindly words of Sir Thomas Browne, who said, when condemning the uncharitable conduct of the mere bookworm, "I make not, therefore, my head a grave, but a treasure of knowledge, and study not for mine own sake only, but for those who study not for themselves." The engineer of the present day finds that he must not make his "head a grave," but that, if he wishes to succeed, he must have, and must exercise, scientific knowledge; and he realizes daily the truth that those who are to come after him must be trained in science, so that they may readily appreciate the full value of each scientific discovery as it is made. Thus the application of science by the engineer not only stimulates those who pursue science, but adds him to their number.

Holding, as I have said I do, the view that he who displaces unintelligent labour is doing good to mankind, I claim for the unknown engineer who, in Pontus, established the first water-wheel of which we have a record, and for the equally unknown engineer who first made use of wind for a motor, the title of pioneers in the raising of the dignity of labour, by compelling the change from the non-intelligent to the intelligent.

With respect to these motors—wind and water—we have two proverbs which discredit them: "Fickle as the wind," "Unstable as water."

Something more trustworthy was needed—something that we were sure of having under our hands at all times. As a result, science was applied, and the "fire" engine, as it was first called, the "steam" engine, as it was re-named, a form of "heat" engine, as we now know it to be, was invented.

Think of the early days of the steam-engine—the pre-Watt days. The days of Papin, Savory, Newcomen, Smeaton! Great effects were produced, no doubt, as compared with no fire engine at all; effects so very marked as to extort from the French writer, Belidor, the tribute of admiration he paid to the "fire" engine erected at the Fresnes Colliery by English engineers. A similar engine worked the pumps in York Place (now the Adelphi) for the supply of water to portions of London. We have in his work one of the very clearest accounts, illustrated by the best engravings (absolute working drawings), of the engine which had excited his admiration. These drawings show the open-topped cylinder, with condensation taking place below the piston, but with the valves worked automatically.

It need hardly be said that, noteworthy as such a machine was, as compared with animal power, or with wind or water motors, it was of necessity a most wasteful instrument as regards fuel. It is difficult to conceive in these days how, for years, it could have been endured that at each stroke of the engine the chamber that was to receive the steam at the next stroke was carefully cooled down beforehand by a water injection.

Watt, as we know, was the first to perceive, or, at all events, to cure, this fundamental error which existed prior to his time in the "fire" engine. To him we owe condensation in a separate vessel, the doing away with the open-topped cylinder, and the making the engine double-acting; the parallel motion; the governor; and the engine-indicator, by which we have depicted for us the way in which the work is being performed within the cylinder. To Watt, also, we owe that great source of economic working—the knowledge of the expansive force of steam; and to his prescience we owe the steam-jacket, without which expansion, beyond certain limits, is practically worthless. I have said "prescience"—fore-knowledge—but I feel inclined to say that, in this case, prescience may be rendered "pre-Science," for I think that Watt *felt* the utility of the steam-jacket, without being able to say on what ground that utility was based.

I have already spoken in laudatory terms of Tredgold, as being one of the earliest of our scientific engineering writers, but, as regards the question of steam-jacketing, Watt's prescience was better than Tredgold's science, for the latter condemns the steam-jacket, as being a means whereby the cooling surfaces are enlarged, and whereby, therefore, the condensation is increased.

I think it is not too much to say that engineers who, since Watt's days, have produced machines of such marvellous power—and, compared with the engines of Watt's days, of so great economy—have, so far as principles are concerned, gone upon those laid down by Watt. Details of the most necessary character—necessary to enable those principles to be carried out—have, indeed, been devised since the days of Watt. Although it is still a very sad confession to have to make, that the very best of our steam-engines only utilizes about one-sixth of the work which resides (if the term may be used) in the fuel that is consumed, it is, nevertheless, a satisfaction to know that great economical progress has been made, and that the 6 or 7 pounds of fuel per horse-power per hour consumed by the very best engines of Watt's days, when working with the aid of condensation, is now brought down to about one-fourth of this consumption; and this in portable engines, for agricultural purposes, working without condensation—engines of small size, developing only 20 horse-power; in such engines the consumption has been reduced to as little as 1·85 pound per brake horse-power per hour, equal to 1·65 pound per indicated horse-power per hour, as was shown by the trials at the Royal Agricultural Society's meeting at Newcastle last year—trials in which I had the pleasure of participating.

In these trials Mr. William Anderson, one of the Vice-Presidents of Section G, and I were associated, and, in making our report of the results, we adopted the balance-sheet system, which I suggested and used so long ago as 1873 (see vol. lii., pp. 154 and 155, of the "Minutes of Proceedings of the Institution of Civil Engineers"), and to which I alluded in my address as President of Section G at Montreal.

I have told you that the engineer of the present day appreciates the value of the "next-to-nothings." There is an old housekeeping proverb that, if you take care of the farthings and the pence, the shillings and the pounds will take care of themselves. Without the balance-sheet one knows that for the combustion of 1 pound of coal, the turning into steam of a given quantity of water at a given pressure is obtained. It is seen, at once, that the result is much below that which should be had, but to account for the deficiency is the difficulty. The balance-sheet, dealing with the most minute sources of loss—the farthings and the pence of economic working—brings you face to face with these, and you find that improvement must be sought in paying attention to the "next-to-nothings."

Just one illustration. The balance-sheet will enable you at a glance to answer this among many important questions: Has the fuel been properly burnt—with neither too much air, nor too little?

At the Newcastle trials our knowledge as to whether we had the right amount of air for perfect combustion was got by an analysis of the waste gases, taken continuously throughout the whole number of hours' run of each engine, affording, therefore, a fair average. The analysis of any required portion of gases thus obtained was made in a quarter of an hour's time by the aid of the admirable apparatus invented by Mr. Stead, and, on the occasion to which I refer, manipulated by him. In one instance an excess of air had been supplied, causing a percentage of loss of 6·34. In the instance of another engine there was a deficiency of air, resulting in the production of carbonic oxide, involving a loss of 4 per cent. The various percentages of loss, of which each one seems somewhat unimportant, in the aggregate amounted to 28 per cent., and this with one of the best boilers. This is an admirable instance of the need of attention to apparently small things.

I have already said that we now know the steam-engine is really a heat engine. At the York meeting of our Association I ventured to predict that, unless some substantive improvement were made in the steam-engine (of which improvement, as yet, we have no notion), I believed its days, for small powers, were numbered, and that those who attended the centenary of the British Association in 1931 would see the present steam-engines in museums, treated as things to be respected, and of antiquarian interest to the engineers of those days, such as are the open-topped steam cylinders of Newcomen and of Smeaton to ourselves. I must say I see no reason, after the seven years which have elapsed since the York meeting, to regret having made that prophecy, or to desire to withdraw it.

The working of heat engines, without the intervention of the vapour of water, by the combustion of the gases arising from coal, or from coal and from water, is now not merely an established fact, but a recognized and undoubted, commercially economical, means of obtaining motive power. Such engines, developing from 1 to 40 horse-power, and worked by the ordinary gas supplied by the gas mains, are in most extensive use in printing-works, hotels, clubs, theatres, and even in large private houses, for the working of dynamos to supply electric light. Such engines are also in use in factories, being sometimes driven by the gas obtained from "culm" and steam, and are giving forth a horse-power for, it is stated, as small a consumption as 1 pound of fuel per hour.

It is hardly necessary to remind you—but let me do it—that, although the saving of half a pound of fuel per horse-power appears to be insignificant, when stated in that bald way, one realizes that it is of the highest importance when that half-pound turns out to be 33 per cent. of the whole previous consumption of one of those economical engines to which I have referred.

The gas-engine is no new thing. As long ago as 1807 a M. de Rivaz proposed its use for driving a carriage on ordinary roads. For anything I know, he may not have been the first proposer. It need hardly be said that in those days he had not illuminating gas to resort to, and he proposed to employ hydrogen. A few years later a writer in *Nicholson's Journal*, in an article on "Flying Machines," having given the correct statement that all that is needed to make a successful machine of this description is to find a sufficiently light motor, suggests that the direction in which this may be sought is the employment of illuminating gas, to operate by its explosion on the piston of an engine. The idea of the gas-engine was revived, and formed the subject of a patent by Barnett in the year 1838. It is true this gentleman did not know very much about the subject, and that he suggested many things which, if carried out, would have resulted in the production of an engine which could not have worked; but he had an alternative proposition which would have worked.

Again, in the year 1861, the matter was revived by Lenoir, and in the year 1865 by Hugon, both French inventors. Their engines obtained some considerable amount of success and notoriety, and many of them were made and used; but in the majority of cases they were discarded as wasteful and uncertain. The Institution of Civil Engineers, for example, erected a Lenoir in the year 1868, to work the ventilating fan, but after a short time they were compelled to abandon it and to substitute an hydraulic engine.

At the present time, as I have said, gas-engines are a great commercial success, and they have become so by the attention given to small things, in popular estimation—to important things, in fact, with which, however, I must not trouble you. Messrs. Crossley Brothers, who have done so much to make the gas-engine the commercial success that it is, inform me that they are prosecuting improvements in the direction of attention to detail, from which they are obtaining greatly improved results.

But, looking at the wonderful petroleum industry, and at the multifarious products which are obtained from the crude material, is it too much to say that there is a future for motor engines, worked by the vapour of some of the more highly volatile of these products—true vapour—not a gas, but a condensable body, capable of being worked over and over again? Numbers of such engines, some of as much as 4 horse-power, made by Mr. Yarrow, are now running, and are apparently giving good results; certainly excellent results as regards the compactness and lightness of the machinery. For boat purposes they possess the great advantage of being rapidly under way. I have seen one go to work within two minutes of the striking of the match to light the burner.

Again, as we know, the vapour of this material has been used as a gas in gas-engines, the motive power having been obtained by direct combustion.

Having regard to these considerations, was I wrong in predicting that the heat engine of the future will probably be one independent of the vapour of water? And, further, in these days of electrical advancement, is it too much to hope for the direct production of electricity from the combustion of fuel?

As the world has become familiar with prime movers, the desire for their employment has increased. Many a householder could find useful occupation for a prime mover of ¼ or ½ horse-power, working one or two hours a day; but the economical establishment of a steam-engine is not possible until houses of very large dimensions are reached, where space exists for the engine, and where, having regard to the amount of work to be done, the incidental expenses can be borne. Where this cannot be, either the prime mover, with the advantages of its use, must be given up as a thing to be wished for, but not to be procured, or recourse must be had to some other contrivance—say to the laying on of power, in some form or another, from a central source.

I have already incidentally touched upon one mode of doing this—namely, the employment of illuminating gas, as the working agent in the gas-engine; but there are various other modes, possessing their respective merits and demerits—all ingenious, all involving science in their application, and all more or less in practical use—such as the laying on of special high-pressure water, as is now being extensively practised in London, in Hull, and elsewhere. Water at 700 pounds pressure per inch is a most convenient mode of laying on a large amount of power, through comparatively small pipes. Like electricity, where, when a high electromotive force is used, a large amount of energy may be sent through a small conductor, so with water, under high pressure, the mains may be kept of reasonable diameters, without rendering them too small to transmit the power required through them

Power is also transmitted by means of compressed air, an agent which, on the score of its ability to ventilate, and of its cleanliness, has much to recommend it. On the other hand, it is an agent which, having regard to the probability of the deposition of moisture in the form of "snow," requires to be worked with judgment.

Again, there is an alternative mode for the conveyance of power by the exhaustion of air—a mode which has been in practical use for over sixty years.

We have also the curious system pursued at Schaffhausen, where quick-running ropes are driven by turbines, these being worked by the current of the River Rhine; and at New York, and in other cities of the United States, steam is laid on under the streets, so as to enable domestic steam-engines to be worked, without the necessity of a boiler, a stoker, or a chimney, the steam affording also means of heating the house when needed.

Lastly, there is the system of transmitting power by electricity, to which I have already adverted. I was glad to learn, only the other day, that there was every hope of this power being applied to the working of an important subterranean tramway.

These distributions from central sources need, as a rule, statutory powers to enable the pipes or wires to be placed under the roads; and, following the deplorable example of the Electrical Facilities Act, it is now the habit of the enlightened Corporation and the enterprising town clerk of most boroughs to say to capitalists who are willing to embark their capital in the plant for the distribution of power from a central source—for their own profit no doubt, but also, no doubt, for the good of the community—"We will oppose you in Parliament, unless you will consent that, at the end of twenty-one years, we may acquire compulsorily your property, and may do so, if it turns out to be remunerative, without other payment than that for the mere buildings and plant at that time existing." This is the way English enterprise is met, and then English engineers are taunted, by Englishmen—often by the very men who have had a share in making this "boa-constrictor" of a "Facilities Act"—that their energy is not to be compared with that which is to be found in the United States and other countries. Again, however, I must remember that I am not addressing Section F.

There is one application of science, by engineers, which is of extreme beauty and interest, and that cannot be regarded with indifference by the agriculturists of this country. I allude to the heat-withdrawing engines (I should like to say, "cold-producers," but I presume, if I did, I should be criticized), which are now so very extensively used for the importation of fresh meat, and for its storage when received here. It need hardly be said, that that which will keep cool and sweet the carcasses of sheep will equally well preserve milk, and many other perishable articles of food. We have in these machines daily instances that, if you wish to make a ship's hold cold, you can do it by burning a certain quantity of coals—a paradox, if ever there was one.

In this climate of ours, where the summer has been said to consist of "three hot days and a thunderstorm," there is hardly need to make a provision for cooling our houses, although there is an undoubted need for making a provision to heat them. Nevertheless, those of us who have hot-water heating arrangements for use in the winter would be very glad indeed if, without much trouble or expense, they could turn these about, so as to utilize them for cooling their houses in summer. Mr. Loftus Perkins, so well known for his labours in the use of very high-pressure steam (600 to 1000 pounds on the inch), and also so well known for those most useful high-pressure warming arrangements which, without disfiguring our houses by the passage of large pipes, keep them in a state of warmth and comfort throughout the winter, has lately taken up the mode of, I will say it, producing "cold" by the evaporation of ammonia, and, by improvements in detail, has succeeded in making an apparatus which, without engine or pumps, produces "cold" for some hours in succession, and requires, to put it in action, the preliminary combustion of only a few pounds of coke or a few feet of gas.

As I have said, our climate gives us but little need to provide or employ apparatus to cool our houses, but one can well imagine that the Anglo-Indian will be glad to give up his punkah for some more certain, and less draughty, mode of cooling.

I now desire to point out how, as the work of the engineer grows, his needs increase. New material, or better material of the old kind, has to be found to enable him to carry out these works of greater magnitude. At the beginning of this century, stone, brick, and timber were practically the only materials employed for that which I may call standing engineering work—*i.e.* buildings, bridges, aqueducts, and so on—while timber, cast iron, and wrought iron were for many years the only available materials for the framing and principal parts of moving machines and engines, with the occasional use of lead for the pipes and of copper for pipes and for boilers.

As regards the cast iron, little was known of the science involved (or that ought to be involved) in its manufacture. It was judged of by results. It was judged of largely by the eye. It was "white," it was "mottled," it was "gray." It was known to be "fit for refining," fit for "strong castings," or fit for castings in which great fluidity in the molten metal was judged to be of more importance than strength in the finished casting. With respect to wrought iron, it was judged of by its results also. It was judged of by the place of its manufacture—but when the works of the district were unknown, the iron, on being tested, was classed as "good fibrous," although some of the very best was "steel-like," or "bad," "hot-short," or "cold-short." A particular district would produce one kind of iron, another district another kind of iron. The ore, the flux, and the fuel were all known to have influence, but to what extent was but little realized; and if there came in a new ore, or a new flux, it might well be that for months the turn-out of the works into which these novelties had been introduced would be prejudiced. Steel again—that luxury of the days of my youth—was judged by the eye. The wrought bars, made into "blister" steel by "cementation," were broken, examined, and grouped accordingly. Steel was known, no doubt, to be a compound of iron and carbon, but the importance of exactness in the percentage was but little understood, nor was it at all understood how the presence of comparatively small quantities of foreign matter might necessitate the variation of the proportions of carbon. The consequence was that anomalous results every now and then arose to confound the person who had used the steel, and, falsifying the proverb "true as steel," steel became an object of distrust. Is it too much to say that Bessemer's great invention of steel made by the "converter," and that Siemens's invention of the open-hearth process, reacted on pure science, and set scientific men to investigate the laws which regulate the union of metals and of metalloids? and that the labours of these scientific men have improved the manufacture, so that steel is now thoroughly and entirely trusted? By its aid engineering works are accomplished which, without that aid, would have been simply impossible. The Forth Bridge, the big gun, the compound armour of the ironclad with its steel face, the projectile to pierce that steel face—all equally depend upon the "truth" of steel as much as does the barely visible hair-spring of the chronometer which enables the longitude of the ship in which it is carried to be ascertained. Now, what makes the difference between trustworthy and untrustworthy steel for each particular purpose? Something which, until our better sense comes to our aid, we are inclined to look upon as ridiculously insignificant—a "next-to-nothing." Setting extraneous ingredients aside, and considering only the union of iron and carbon, the question whether there shall be added or deducted one-tenth of 1 per cent. (pardon my clumsy way of using the decimal system) of carbon is a matter of great importance in the resulting quality of the steel. This is a striking practical instance of how apparently insignificant things may be of the highest importance. The variation of this fraction of a percentage may render your boiler steel untrustworthy, may make the difference between safety in a gun and danger in a gun, and may render your armour-piercing projectile unable to pierce even the thinnest wrought-iron armour.

While thus brought incidentally to the subject of guns, let me derive from it another instance of the value of small things. I have in my hand a piece of steel ribbon. It is probable that only those who are near to me can see it. Its dimensions are one-fourth by one-sixteenth of an English inch, equal to an area of one sixty-fourth of a square inch. This mode of stating the dimensions I use for the information of the ladies. To make it intelligible to my scientific friends, I must tell them that it is approximately ·00637 of a metre by approximately ·00159 of a metre, and that its sectional area is ·0000101283 (also approximately) of a square metre. This insignificant (and speaking in reference to the greater number of my audience), practically invisible piece of material—that I can bend with my hand, and even tie into knots—is, nevertheless, not to be despised. By it one reinforces the massive and important-looking A-tube of a 9·2-inch gun, so that from that tube can be projected with safety a projectile weighing 380 pounds at a velocity, when leaving the muzzle, of between one-third and one-half of a mile in a second, and competent to traverse nearly 12½ miles before it touches the ground. It may be said, "What is the use of being able to fire a projectile to a distance which commonly is invisible (from some obstacle or another) to the person directing the gun?" I will suggest to you a use. Imagine a gun of this kind placed by some enemy who, unfortunately, had invaded us, and had reached Richmond. He has the range-table for his gun; he, of course, is provided with our Ordnance maps, and he lays and elevates the gun at Richmond, with the object of striking, say, the Royal Exchange. Suppose he does not succeed in his exact aim. The projectile goes 100 yards to one side or to the other; or it falls 250 yards short, or passes 250 yards over; and it would be "bad shooting" indeed, in these days, if nearly every projectile which was fired did not fall somewhere within an area such as this. In this suggested parallelogram of 100,000 square yards, or some 20 acres, there is some rather valuable property; and the transactions which are carried on are not unimportant. It seems to me that business would not be conducted with that calmness and coolness which are necessary for success, if, say, every five minutes, a 380-pound shell fell within this area, vomiting fire, and scattering its walls in in hundreds of pieces, with terrific violence, in all directions. Do not suppose I am saying that similar effects cannot be obtained from a gun where wire is not employed. They can be. But my point is, that they can also be obtained by the aid of the insignificant thing which I am holding up at this moment—this piece of steel ribbon, which looks more suitable for the framework of an umbrella.

I have already spoken to you, when considering steel as a mere alloy of iron and carbon, as to the value of even a fraction of 1 per cent. of the latter; but we know that in actual practice steel almost always contains other ingredients. One of the most prominent of these is manganese. It had for years been used, in quantities varying from a fraction of 1 per cent. up to 2·5 per cent., with advantages as regards ductility, and as regards its ability to withstand forging. A further increase was found not to augment the advantage: a still further increase was found to diminish it; and here the manufacturer stopped, and, so far as I know, the pure scientist stopped, on the very reasonable ground that the point of increased benefit appeared to have been well ascertained, and that there could be no advantage in pursuing an investigation which appeared only to result in decadence. But this is another instance of how the application of science reacts in the interests of pure science itself. One of our steel manufacturers, Mr. Hadfield, determined to pursue this apparently barren subject, and in doing so discovered this fact—that, while with the addition of manganese in excess of the limit before stated, and up to as much as 7 per cent., deterioration continued, after this latter percentage was passed improvement again set in.

Again, the effects of the addition of even the very smallest percentages of aluminium upon the steel with which it may be alloyed are very striking and very peculiar, giving to the steel alloy thus produced a very much greater hardness, and enabling it to take a much brighter and more silver-like polish. Further, the one-twentieth part of 1 per cent. of aluminium, when added to molten wrought iron, will reduce the fusing-point of the whole mass some 500°, and will render it extremely fluid, and thus enable wrought iron (or what are commercially known as "mitis" castings of the most intricate character) to be produced.

No one has worked more assiduously at the question of the effect of the presence of minute quantities, even traces, of alloys with metals than Prof. Roberts-Austen, and he appears, by his experiments, to be discovering a general law, governing the effect produced by the mixture of particular metals, so that, in future, it is to be hoped, when an alloy is, for the first time, to be attempted, it will be possible to predict with reasonable certainty what the result will be, instead of that result remaining to be discovered by experiment.

I have just, incidentally, mentioned aluminium. May I say that we engineers look forward, with much interest, to all processes tending to bring this metal, or its alloys, within possible commercial use?

One more instance of the effect of impurities in metals. The engineer engaged in electrical matters is compelled, in the course of his daily work, frequently to realize the importance of the "next to-nothing." One striking instance of this is afforded by the influence which an extremely minute percentage of impurity has on the electrical conductivity of copper wire; this conductivity being in some cases reduced by as much as 50 per cent., in consequence of the admixture of that which, under other circumstances, would be looked upon as insignificant.

Reverting to the question of big guns. According to the present mode of manufacture, after we have rough-bored and turned the A-tube (and perhaps I ought to have mentioned that by the A-tube is meant the main piece of the gun, the innermost layer, if I may so call it, that portion which is the full length of the gun, and upon which the remainder of the gun is built up)—after, as I have said, we have rough-bored and turned this A-tube, we heat it to a temperature lying between certain specified limits, but actually determined by the behaviour of samples previously taken, and then suddenly immerse it perpendicularly into a well some 60 feet deep, full of oil, the oil in this well being kept in a state of change by the running into it, at the bottom, of cold oil conveyed by a pipe proceeding from an elevated oil tank. In this way the steel is oil-hardened, with the result of increasing its ultimate tensile strength, and also with the result of raising its so-called elastic limit. In performing this operation it is almost certain that injurious internal strains will be set up—strains tending to produce self-rupture of the material. Experiments have been carried out in England, by Captain Andrew Noble, and by General Maitland of the Royal Gun Factory, by General Kalakoutsky, in Russia, and also in the United States, to gauge what is the value, as represented by dimensions, of these strains, and we find that they have to be recorded in the most minute fractions of an inch, and yet, if the steel be of too "high" a quality (as it is technically called), or if there has been any want of uniformity in the oil-hardening process, these strains, unless got rid of or ameliorated by annealing, may, as I have said, result in the self-rupture of the steel.

I have spoken of the getting rid of these strains by annealing, a process requiring to be conducted with great care, so as not to prejudice the effects of the oil-hardening. But take the case of a hardened steel projectile, hardened so that it will penetrate the steel face of compound armour. In that case annealing cannot be resorted to, for the extreme hardness of the projectile must not be in the least impaired. The internal strains in these projectiles are so very grave that for months after they are made there is no security that they will not spontaneously fracture. I have here the point of an 8-inch projectile, which projectile weighs 210 pounds; this with others was received from the makers as long ago as March of this year, and remained an apparently perfect and sound projectile until about the middle of August—some five months after delivery, and, of course, a somewhat longer time since manufacture—and between August 6 and 8 this piece which I hold in my hand, measuring 3¾ inches by 3½ inches, spontaneously flew off from the rest of the projectile, and has done so upon a surface of separation which, whether having regard to its beautiful regularity, or to the conclusions to be drawn from it as to the nature of the strains existing, is of the very highest scientific interest. Many other cases of self-rupture of similar projectiles have been recorded.

Another instance of the effect of the "next-to-nothing" in the hardening and tempering or annealing of steel. As we know, the iron and the carbon (leaving other matters out of consideration) are there. The carbon is (even in tool-steel) a very small proportion of the whole. The steel may be bent, and will retain the form given to it. You heat it and plunge it in cold water; you attempt to bend it and it breaks; but if, after the plunging in cold water, you temper it by carefully reheating it, you may bring it to the condition fit either for the cutting-tool for metal, or for the cutting-tool for wood, or for the watch-spring; and these important variations of condition which are thus obtained depend upon the "next-to-nothing" in the temperature to which it is reheated, and therefore in the nature of the resulting combination of the ingredients of which the steel is composed.

Some admirable experiments were carried out on this subject by the Institution of Mechanical Engineers, with the assistance of one of our Vice-Presidents, Sir Frederick Abel, and the subject has also been dealt with by an eminent Russian writer.

There is, to my mind, another and very striking popular instance (if I may use the phrase) of the importance of attention to detail—that is, to the "next-to-nothing." Consider the bicycles and tricycles of the present day—machines which afford the means of healthful exercise to thousands, and which will, probably within a very short time, prove of the very greatest possible use for military purposes. The perfection to which these machines have been brought is almost entirely due to strict attention to detail; in the selection of the material of which the machines are made; in the application of pure science (in its strictest sense) to the form and to the proportioning of the parts, and also in the arrangement of these various parts in relation the one to the other. The result is that the greatest possible strength is afforded with only the least possible weight, and that friction in working has been reduced to a minimum. All of us who remember the hobby-horse of former years, and who contrast that machine with the bicycle or tricycle of the present day, realize how thoroughly satisfactory is the result of this attention to detail—this appreciation of the "next-to-nothing."

Let me give you another illustration of the importance of small things, drawn from gunnery practice.

At first sight one would be tempted to say that the density of the air on the under side of a shot must, notwithstanding its motion of descent, be so nearly the same as that of the air upon the upper side as to cause the difference to be unworthy of consideration, but we know that the projectiles from rifled guns tend to travel sideways as they pass through the air, and that the direction of their motion, whether to the right or to the left, depends on the 'hand' of the rifling. We know also, that the friction against liquid or against gaseous bodies varies with the densities of these bodies, and it is believed that, minute as is the difference in density to which I have referred, it is sufficient to determine the lateral movement of the projectile. This lateral tendency must be allowed for, in these days of long ranges, in the sighting and laying of guns, if we desire accuracy of aim, at those distances at which it is to be expected our naval engagements will have to be commenced, and perhaps concluded. We can no longer afford to treat the subject as Nelson is said to have treated it, in one of his letters to the Secretary of the Admiralty, who had requested that an invention for laying guns more accurately should be tried. Nelson said he would be glad to try the invention, but that, as his mode of fighting consisted in placing his ship close alongside that of the enemy, he did not think the invention, even if it were successful, would be of much use to him.

While upon the question of guns, I am tempted to remark upon that which is by no means a small thing (for it is no less than the rotation of the earth), which in long-distance firing may demand attention, and that to an extent little suspected by the civilian.

Place the gun north and south, say in the latitude of London, and fire a 12-mile round such as I have mentioned, and it will be found that, assuming the shot were passing through a vacuum, a lateral allowance of more than 200 feet must be made to compensate for the different velocity of the circumference of the earth at 12 miles north or south of the place where the gun was fired, as compared with the velocity of the circumference of the earth at that place itself—the time of flight being in round numbers one minute.

At the risk of exciting a smile, I am about to assert that engineering has even its poetical side. I will ask you to consider with me whether there may not be true poetry in the feelings of the engineer who solves a problem such as this:—Consider this rock, never visible above the surface of the tide, but making its presence known by the waves which rise around it: it has been the cause of destruction to many a noble vessel which had completed, in safety, its thousands of leagues of journey, and was, within a few score miles of port, then dashed to pieces upon it! Here is this rock. On it build a lighthouse. Lay your foundations through the water, in the midst of the turmoil of the sea; make your preparations; appear to be attaining success, and find the elements are against you, and that the whole of your preliminary works are ruined or destroyed in one night; but again commence, and then go on and go on until at last you conquer; your works rise above ordinary tide-level; then upon these sure foundations, obtained it may be after years of toil, erect a fair shaft, graceful as a palm and sturdy as an oak; surmount it with a light, itself the produce of the highest application of science; direct that light by the built-up lens, again involving the highest application of science; apply mechanism, so arranged that the lighthouse shall from minute to minute reveal to the anxious mariner its exact name and its position on the coast. When you have done all this, will you not be entitled to say to yourself, "It is I who have for ever rendered innocuous this rock which has been hitherto a dread source of peril"? Is there no feeling, do you think, of a poetical nature excited in the breast of the engineer who has successfully grappled with a problem such as this?

Another instance: the mouth of a broad river, or, more properly speaking, the inlet of the sea, has to be crossed at such a level as not to impede the passage of the largest ships. Except in one or two places the depth is profound, so that multiple foundations for supporting a bridge become commercially impossible, and the solution of the problem must be found by making, high in the air, a flight of span previously deemed unattainable. Is there no poetry here? Again, although the results do not strike the eye in the same manner, is there nothing of poetry in the work that has to be thought out and achieved when a wide river or an ocean channel has to be crossed by a subterranean passage? Works of great magnitude of this character have been performed with success, and to the benefit of those for whose use they were intended. One of the greatest and most noble of such works, encouraged, in years gone by, by the Governments of our own country and of France, has lately fallen into disfavour with an unreasoning public, who have not taken the pains to ascertain the true state of the case.

Surely it will be agreed that the promotion of ready intercourse and communication between nations constitutes the very best and most satisfactory guarantee for the preservation of peace: when the peoples of two countries come to know each other intimately, and when they, therefore, enter into closer business relations, they are less liable to be led away by panic or by anger, and they hesitate to go to war the one with the other. It is in the interests of both that questions of difference which may arise between them should be amicably settled, and having an intimate knowledge of each other, they are less liable to misunderstand, and the mode of determination of their differences is more readily arranged. Remember, the means of ready intercourse and of communication, and the means of easy travel, are all due to the application of science by the engineer. Is not therefore his profession a beneficent one?

Further, do you not think poetical feeling will be excited in the breast of that engineer who will in the near future solve the problem (and it certainly will be solved when a sufficiently light motor is obtained) of travelling in the air—whether this solution be effected by enabling the self-suspended balloon to be propelled and directed, or perhaps, better still, by enabling not only the propulsion to be effected and the direction to be controlled, but by enabling the suspension in the air itself to be attained by mechanical means?

Take other functions of the civil engineer—functions which, after all, are of the most important character, for they contribute directly to the prevention of disease, and thereby not only prolong life, but do that which is probably more important—afford to the population a healthier life while lived.

In one town, about which I have full means of knowing, the report has just been made that in the year following the completion of a comprehensive system of sewerage, the deaths from zymotic diseases had fallen from a total of 740 per annum to a total of 372—practically one-half. Has the engineer no inward satisfaction who knows such results as these have accrued from his work?

Again, consider the magnitude and completeness of the water-supply of a large town, especially a town that has to depend upon the storing up of rain water: the prevision which takes into account, not merely the variation of the different seasons of the year, but the variation of one year from another; that, having collated all the stored-up information, determines what must be the magnitude of the reservoirs to allow for at least three consecutive dry years, such as may happen; and that finds the sites where these huge reservoirs may be safely built.

All these—and many other illustrations which I could put before you if time allowed—appear to me to afford conclusive evidence that, whether it be in the erection of the lighthouse on the lonely rock at sea; whether it be in the crossing of rivers, or seas, or arms of seas, by bridges or by tunnels; whether it be the cleansing of our towns from that which is foul; whether it be the supply of pure water to every dwelling, or the distribution of light or of motive power; or whether it be in the production of the mighty ocean steamer, or in the spanning of valleys, the piercing of mountains, and affording the firm, secure road for the express train; or whether it be the encircling of the world with telegraphs—the work of the civil engineer is not of the earth earthy, is not mechanical to the exclusion of science, is not unintellectual; but is of a most beneficent nature, is consistent with true poetical feeling, and is worthy of the highest order of intellect.

SECTION A.

MATHEMATICAL AND PHYSICAL SCIENCE.

OPENING ADDRESS BY PROF. G. F. FITZGERALD, M.A., F.R.S., PRESIDENT OF THE SECTION.

THE British Association in Bath, and especially we here in Section A, have to deplore a very great loss. We confidently anticipated profit and pleasure from the presence in this chair of one of the leading spirits of English science, Dr. Schuster. We deplore the loss, and we deplore the cause of it. It is always sad when want of strength makes the independent dependent, and it is doubly sad when a life's work is thereby delayed; and to selfish humanity it is trebly sad when, as in this case, we ourselves are involved in the loss. And our loss is great. Dr. Schuster has been investigating some very important questions. He has been studying electric discharges in gases, and he has been investigating the probably allied question of the variations of terrestrial magnetism. We anticipated his matured pronouncements upon these subjects, and also the advantage of his very wide general information upon physical questions, and the benefit of his judicial mind while presiding here.

As to myself, his substitute, I cannot express how much gratified I feel at the distinguished honour done me in asking me to preside. It has been one of the ambitions of my life to be worthy of it, and I will do my best to deserve your confidence; man can do no more, and upon such a subject "the less said the soonest mended."

I suppose most former occupants of this chair have looked over the addresses of their predecessors to see what sort of a thing was expected from them. I find that very few had the courage to deliver no address. Most have devoted themselves to broad general questions, such as the relations of mathematics to physics, or more generally deductive to inductive science. On the other hand, several have dealt each with his own specialty. On looking back over these addresses my attention was specially arrested by the first two past Presidents of this Section whose bodily presence we cannot have here. They were Presidents of Section A in consecutive years. In 1874, Provost Jellett occupied this chair; and in 1875, Prof. Balfour Stewart occupied it. Both have gone from us since the last meeting of this Association. Each gave a characteristic address. The Provost, with the clearness and brilliancy that distinguished his great intellect, plunged through the deep and broad questions surrounding the mechanism of the universe, and with impassioned earnestness claimed on behalf of science the right to prosecute its investigations until it attains, if it ever does attain, to a mechanical explanation of all things. This intrepid honesty, to carry to their utmost the principles of whose truth he was convinced, the utter abhorrence of the shadow of double-dealing with truth, was eminently characteristic of one whom all, but especially we of Trinity College, Dublin, will long miss as a lofty example of the highest intellectual keenness and honesty, and mourn as the truest-hearted friend, full of sympathy and Christian charity. In 1875, Prof. Stewart gave us a striking example of the other class of address in a splendid exposition of the subject he did so much to advance—namely, solar physics. He brought together from the two great storehouses of his information and speculation a brilliant store, and displayed them here for the advancement of science. Him, too, all science mourns. Though, from want of personal acquaintance, I am unequal to the task of bringing before you his many abilities and great character, you can each compose a fitting epitaph for this well-known great one of British science. In this connection I am only expressing what we all feel when I say how well timed was the Royal bounty recently extended to his widow. At the same time, the niggardly recognition of science by the public is a disgrace to the enlightenment of the nineteenth century. What Chancellor or General with his tens of thousands has done that for his country and mankind that Faraday, Darwin, and Pasteur have done? The "public" now are but the children of those who murdered Socrates, tolerated the persecution of Galileo, and deserted Columbus.

In a Presidential address on the borderlands of the known delivered from this chair the great Clerk Maxwell spoke of it as an undecided question whether electro-magnetic phenomena are due to a direct action at a distance or are due to the action of an intevening medium. The year 1888 will be ever memorable as the year in which this great question has been experimentally decided by Hertz in Germany, and, I hope, by others in England.

It has been decided in favour of the hypothesis that these actions take place by means of an intervening medium. Although there is nothing new about the question, and although most workers at it have long been practically satisfied that electro-magnetic actions are due to an intervening medium, I have thought it worth while to try and explain to others who may not have considered the problem, what the problem is and how it has been solved. A Presidential address such as this is not for specialists—it is for the whole Section; and I would not have thought of dealing with this subject, only that its immediate consequences reach to all the bounds of physical science, and are of interest to all its students.

We are all familiar with this, that when we do not know all about something there are generally a variety of explanations of what we do know. Whether there is anything of which there are in reality a variety of explanations is a deep question, which some have connected with the freedom of the will, but which I am not concerned with here. A notable example of the possibility of a variety of explanations for us is recorded in connection with an incident said to have occurred in the neighbouring town of Clifton, where a remarkable meteorological phenomenon, as it appeared to an observing scientist, was explained by others as a bull's-eye lantern in the hands of Mr. Pickwick. Another kind of example is the old explanation of water rising in a pump, that "Nature abhors a vacuum," as compared with the modern one. Nowadays, when we know as little about anything, we say, "It is the property of electricity to attract." This is really little or no advance on the old form, and is merely a way of stating that we know a fact but not its explanation. There are plenty of cases still where a variety of explanations are possible. For example, we know of no *experimentum crucis* to decide whether the people I see around me are conscious or are only automata. There are other questions which have existed, but which have been experimentally decided. The most celebrated of these are the questions between the caloric and kinetic theories of heat, and between the emission and undulatory theories of light. The classical experiments by which the case has been decided in favour of the kinetic theory of heat and the undulatory theory of light are some of the most important experiments that have ever been performed. When it was shown that heat disappeared whenever work appeared, and *vice versâ*, and so the caloric hypothesis was disproved; when it was shown that light was propagated more slowly in a dense medium than in a rare, the sciences of light and heat were revolutionized. Not but that most who studied the subject had given their adhesion to the true theory before it was finally decided in general estimation. In fact, Rumford's and Davy's experiments on heat, and Young and Fresnel's experiments on light, had really decided these questions long before the erroneous views were finally abandoned. I hope that science will not be so slow in accepting the results of experiment in respect of electro-magnetism as it was in the case of light and heat, and that no Carnot will throw back science by giving plausible explanations on a wrong hypothesis. Rowland's experiment proving an electro-magnetic action between electric charges depending on their absolute and not relative velocities has already proved the existence of a medium relative to which the motion must take place, but the connection is rather metaphysical, and is too indirect to attract general attention. The importance of these striking experiments was that they put the language of the wrong hypothesis out of fashion. Elementary text-books that halted between two opinions, and, after the manner of text-books, leant towards that enunciated in preceding text-books, had all perforce to give prominence to the true theory, and the whole rising generation began their researches from a firm and true stand-point. I anticipate the same results to follow Hertz's experimental demonstration of a medium by which electro-magnetic actions are produced. Text-books which have gradually been invoking lines of force, in some respects to the aid of learners and in others to their bewilderment, will now fearlessly discourse of the stresses in the ether that cause electric and magnetic force. The younger generation will see clearly in electro-magnetic phenomena the working of the all-pervading ether, and this will give them a firm and true stand-point for further advances.

And now I want to spend a short time in explaining to you how the question has been decided. An illustrative example may make the question itself clearer, and so lead you to understand the answer better. In colloquial language we say that balloons, hot air, &c., rise because they are light. In old times this was stated more explicitly, and therefore much more clearly. It was said that they possessed a quality called "levity." "Levity" was opposed to "heaviness." Heaviness made things tend downwards, levity made things tend upwards. It was a sort of action at a distance. At least, it would have required such an hypothesis if it had survived until it was known that heaviness was due to the action of the earth. I expect levity would have been attributed to the direct action of heaven. It was comparatively recently in the history of mankind that the rising of hot air, flames, &c., was attributed to the air. Everybody knew that there was air, but it was not supposed that the upward motion of flames was due to it. We now know that this and the rising of balloons are due to the difference of pressure at different levels in the air. In a similar way we have long known that there is an ether, an all-pervading medium, occupying all known space. Its existence is a necessary consequence of the undulatory theory of light. People who think a little, but not much, sometimes ask me, "Why do you believe in the ether? What's the good of it?" I ask them, "What becomes of light for the eight minutes after it has left the sun and before it reaches the earth?" When they consider that, they observe how necessary the ether is. If light took no time to come from the sun, there would be no need of the ether. That it is a vibratory phenomenon, that it is affected by matter it acts through—these could be explained by action at a distance very well. The phenomena of interference would, however, require such complicated and curious laws of action at a distance as practically to put such an hypothesis out of court, or else be purely mathematical expressions for wave propagation. In fact, anything except propagation in time is explicable by action at a distance. It is the same in the case of electro-magnetic actions. There were two hypotheses as to the causes of electro-magnetic actions. One attributed electric attraction to a property of a thing called electricity to attract at a distance, the other attributed it to a pull exerted by means of the ether, somewhat in the way that air pushes balloons up. We do not know what the structure of the ether is by means of which it can pull, but neither do we know what the structure of a piece of india-rubber is by means of which it can pull; and we might as well ignore the india-rubber, though we know a lot about the laws of its action, because we do not know its structure, as to ignore the ether because we do not know its structure. Anyway, what was wanted was an experiment to decide between the hypothesis of direct action at a distance and of action by means of a medium. At the time that Clerk Maxwell delivered his address no experiment was known that could decide between the two hypotheses. Specific inductive capacity, the action of intervening matter, the delay in telegraphing, the time propagation of electro-magnetic actions by means of conducting material—these were known, but he knew that they could be explained by means of action at a distance, and had been so explained. Waves in a conductor do not necessarily postulate action through a medium such as the ether. When we are dealing with a conductor and a thing called electricity running over its surface, we are, of course, postulating a medium on or in the conductor, but not outside it, which is the special point at issue. Clerk Maxwell *believed* that just as the same air that transmits sound is able by differences of pressure—*i.e.* by means of its energy per unit volume—to move bodies immersed in it, so the same ether that transmits light causes electrified bodies to move by means of its energy per unit volume. He believed this, but there was no experiment known then to decide between this hypothesis and that of direct action at a distance. As I have endeavoured to impress upon you, no *experimentum crucis* between the hypotheses is possible except an experiment proving propagation in time, either directly, or indirectly by an experiment exhibiting phenomena like those of the interference of light. A theorist may speak of propagation of actions in time without talking of a medium. This is all very well in mathematical formulæ, but, as in the case of light we must consider what becomes of it after it has left the sun and before it reaches the earth, so every hypothesis assuming action in time really postulates a medium whether we talk about it or not. There are some difficulties surrounding the complete interpretation of some of Hertz's experiments. The conditions are complicated, but I confidently expect that they will lead to a decision on most of the outstanding questions on the theory of electro-magnetic action. However, there is no doubt that he has observed the interference of electro-magnetic waves quite analogous to those of light, and that he has proved that electro-magnetic actions are propagated in air with the velocity of light. By a beautiful device Hertz has produced rapidly alternating currents of such frequency that their wave-length is only about 2 metres. I may pause for a minute to call your attention to what that means. These waves are propagated three hundred thousand kilometres in a second. If they vibrated three hundred thousand times a second, the waves would be each a kilometre long. This rate of vibration is much higher than the highest audible note, and yet the waves are much too long to be manageable. We want a vibration about a thousand times as fast again with waves about a metre long. Hertz produced such vibrations, vibrating more than a hundred million times a second. That is, there are as many vibrations in one second as there are seconds—in a day? No, far more. In a week? No, more even than that. The pendulum of a clock ticking seconds would have to vibrate for four months before it would vibrate as often as one of Hertz's vibrators vibrates in one second. And how did he detect the vibrations and their interference? He could not see them; they are much too slow for that; they should go about a million times as fast again to be visible. He could not hear them; they are much too quick for that. If they went a million times more slowly they would be well heard. He made use of the principle of resonance. You all understand how by a succession of well-timed small impulses a large vibration may be set up. It explains many things, from speech to spectrum analysis. It is related that a former Marquess of Waterford used the principle to overturn lamp-posts—his ambition soared above knocker-wrenching. So that it is a principle known to others besides scientific men. Hertz constructed a circuit whose period of vibration for electric currents was the same as that of his generating vibrator, and he was able to see sparks, due to the induced vibration, leaping across a small air-space in this resonant circuit. The well-timed electrical impulses broke down the air-resistance just as those of my Lord of Waterford broke down the lamp-post. The combination of a vibrating generating circuit with a resonant receiving circuit is one that I spoke of at the meeting of the British Association at Southport as one by which this very question might be studied. At the time I did not see any feasible way of detecting the induced resonance: I did not anticipate that it could produce sparks. By its means, however, Hertz has been able to observe the interference between waves incident on a wall and the reflected waves. He placed his generating vibrator several wave-lengths away from a wall, and placed the receiving resonant circuit between the generator and the wall, and in this air-space he was able to observe that at some points there were hardly any induced sparks, but at other and greater distances from his generator they reappeared, to disappear again in regular succession at equal intervals between his generator and the wall. It is exactly the same phenomenon as what are known as Lloyd's bands in optics, which are due to the interference between a direct and a reflected wave. It follows hence that, just as Young's and Fresnel's researches on the interference of light prove the undulatory theory of optics, so Hertz's experiment proves the ethereal theory of electro-magnetism. It is a splendid result. Henceforth I hope no learner will fail to be impressed with the theory—hypothesis no longer—that electro-magnetic actions are due to a medium pervading all known space, and that it is the same medium as the one by which light is propagated, that non-conductors can, and probably always do, as Prof. Poynting has taught us, transmit electro-magnetic energy. By means of variable currents energy *is* propagated into space with the velocity of light. The rotation of the earth is being slowly stopped by the diurnal rotation of its magnetic poles. This seems a hopeful direction in which to look for an explanation of the secular precession of terrestrial magnetism. It is quite different from Edlund's curious hypothesis that free space is a perfect conductor. If this were true, there would be a pair of great antipoles outside the air, and terrestrial magnetism would not be much like what it is, and I think the earth would have stopped rotating long ago. With alternating currents we *do* propagate energy through non-conductors. It seems almost as if our future telegraph-cables would be pipes. Just as the long sound-waves in speaking-tubes go round corners, so these electro-magnetic waves go round corners if they are not too sharp. Prof. Lodge will probably have something to tell us on this point in connection with lightning-conductors. The silvered glass-bars used by surgeons to conduct light are exactly what I am describing. They are a glass, a non-conducting, and therefore transparent, bar surrounded by a conducting, and therefore opaque, silver sheath, and they transmit the rapidly alternating currents we call light. There would not be the same difficulty in utilizing the energy of these electro-magnetic waves as in utilizing radiant heat. Having all the vibrations of the same period we might utilize Hertz's resonating circuits, and in any case the second law of thermodynamics would not trouble us when we could practically attain to the absolute zero of these, as compared with heat, long-period vibrations.

We seem to be approaching a theory as to the structure of the ether. There are difficulties from diffusion in the simple theory that it is a fluid full of motion, a sort of vortex-sponge. There were similar difficulties in the wave theory of light owing to wave propagation round corners, and there is as great a difficulty in the jelly theory of the ether arising from the freedom of motion of matter through it. It may be found that there is diffusion, or it may be found that there are polarized distributions of fluid kinetic energy which are not unstable when the surfaces are fixed: more than one such is known. Osborne Reynolds has pointed out another, though in my opinion less hopeful, direction in which to look for a theory of the ether. Hard particles are abominations. Perhaps the impenetrability of a vortex would suffice. Oliver Lodge speaks confidently of a sort of chemical union of two opposite kinds of elements forming the ether. The opposite sides of a vortex-ring might perchance suit, or maybe the ether, after all, is but an atmosphere of some infra-hydrogen element: these two latter hypotheses may both come to the same thing. Anyway we are learning daily what sort of properties the ether must have. It must be the means of propagation of light; it must be the means by which electric and magnetic forces exist; it should explain chemical actions, and, if possible, gravity.

On the vortex-sponge theory of the ether there is no real difficulty by reason of complexity why it should not explain chemical actions. In fact, there is every reason to expect that very much more complex actions would take place at distances comparable with the size of the vortices than at the distances at which we study the simple phenomena of electro-magnetism. Indeed, if vortices can make a small piece of a strong elastic solid, we can make watches and build steam-engines and any amount of complex machinery, so that complexity can be no essential difficulty. Similarly the instantaneous propagation of gravity, if it exists, is not an essential difficulty, for vortices each occupy all space, and they act on one another simultaneously everywhere. The theory that material atoms are simple vortex-rings in a perfect liquid otherwise unmoving is insufficient, but with the innumerable possibilities of fluid motion it seems almost impossible but that an explanation of the properties of the universe will be found in this conception. Anything purporting to be an explanation founded on such ideas as "an inherent property of matter to attract," or building up big elastic solids out of little ones, is not of the nature of an ultimate explanation at all; it can only be a temporary stopping-place. There are metaphysical grounds, too, for reducing matter to motion and potential to kinetic energy.

These ideas are not new, but it is well to enunciate them from time to time, and a Presidential address in Section A is a fitting time. Besides all this, it has become the fashion to indulge in quaint cosmical theories and to dilate upon them before learned Societies and in learned journals. I would suggest, as one who has been bogged in this quagmire, that a successor in this chair might well devote himself to a review of the cosmical theories propounded within the last few years. The opportunities for piquant criticism would be splendid.

Returning to the sure ground of experimental research, let us for a moment contemplate what is betokened by this theory that in electro-magnetic engines we are using as our mechanism the ether, the medium that fills all known space. It was a great step in human progress when man learnt to make material machines, when he used the elasticity of his bow and the rigidity of his arrow to provide food and defeat his enemies. It was a great advance when he learnt to use the chemical action of fire; when he learnt to use water to float his boats and air to drive them; when he used artificial selection to provide himself with food and domestic animals. For two hundred years he has made heat his slave to drive his machinery. Fire, water, earth, and air have long been his slaves, but it is only within the last few years that man has won the battle lost by the giants of old, has snatched the thunderbolt from Jove himself, and enslaved the all-pervading ether.

SECTION C.

GEOLOGY.

OPENING ADDRESS BY W. BOYD DAWKINS, M.A., F.R.S., F.G.S., F.S.A., PROFESSOR OF GEOLOGY AND PALÆONTOLOGY IN OWENS COLLEGE, PRESIDENT OF THE SECTION.

IN taking the chair occupied twenty-four years ago in this place by my honoured master, Prof. Phillips, I have been much perplexed as to the most fitting lines on which to mould my address. It was open to me to deal with the contributions to our knowledge since our last meeting in Manchester in such a manner as to place before you an outline of our progress during the last twelve months. But this task, difficult in itself, is rendered still more so by the special circumstances of this meeting, attended, as it is, by so large a number of distinguished geologists, assembled from nearly every part of the world for the purposes of the Geological Congress. It would be presumptuous of me, in the presence of so many specialists, to attempt to summarize and co-ordinate their work. Indeed, we stand too near to it to be able to see the true proportions of the various parts. I will merely take this opportunity of offering to our visitors, in the name of this Section and of English geologists in general, a hearty welcome to our shores, feeling that not only will our science be benefited enormously by the simplification of geological nomenclature, but that we ourselves shall derive great advantage by a closer personal contact than we have enjoyed hitherto.

Our science has made great strides during the last twenty-four years, and she has profited much from the development of her sisters. The microscopic analysis of the rocks has opened out a new field of research, in which physics and chemistry are in friendly rivalry, and in which fascinating discoveries are being made almost day by day as to metamorphism, and the crushing and shearing forces brought to bear upon the cooling and contracting crust while the earth was young. The deep-sea explorations have revealed the structure and the deposits of the ocean abysses; and the depths supposed to be without life, like the fabled deserts in the interior of Africa, are now known to teem with varied forms glowing with the richest colours. From a comparison of these deposits with the stratified rocks we may conclude that the latter are marginal, and deposited in depths not greater than 1000 fathoms, or the shore end of the Globigerina ooze, and most of them at a very much less depth, and that consequently there is no proof in the geological record of the ocean depths having ever been in any other than their present places.

In North America the geological survey of the Western States has brought to light an almost unbroken series of animal remains, ranging from the Eocene down to the Pleistocene age. In these we find the missing links in the pedigree of the horse, and sufficient evidence of transitional forms to cause Prof. Flower to restore to its place in classification the order Ungulata of Cuvier. These may be expected to occupy the energies of our kinsmen on the other side of the Atlantic for many years, and to yield further proof of the truth of the doctrine of evolution. The use of this word reminds me how much we have grown since 1864, when evolution was under discussion, and when biological, physical, and geological laboratories could scarcely be said to have existed in this country. Truly may the scientific youth of to-day make the boast—

> ʽΗμεῖς μὲν πατέρων μέγ' ἀμείνονες εὐχόμεθ' εἶναι—

"We are much better off than our fathers were;" while we, the fathers, have the poor consolation of knowing that when they are fathers their children will say the same of them. There is reason to suppose that our science will advance more swiftly in the future than it has in the past, because it has more delicate and precise methods of research than it ever had before, and because its votaries are more numerous than they ever were.

In 1864 the attention of geologists was mainly given to the investigations of the later stages of the Tertiary period. The bent of my pursuits inclines me to revert to this portion of geological inquiry, and to discuss certain points which have arisen during the last few years in connection with the classificatory value of fossils, and the mode in which they may be best used for the co-ordination of strata in various parts of the world.

The principle of homotaxy, first clearly defined by Prof. Huxley, has been fully accepted as a guiding principle in place of synchronism or contemporaneity, and the fact of certain groups of plants and animals succeeding one another in a definite order, in countries remote from each other, is no longer taken to imply that each was living in the various regions at the same time, but rather, unless there be evidence to the contrary, that they were not. While, however, there is a universal agreement on this point among geologists, the classificatory value of the various divisions of the vegetable and animal kingdoms is still under discussion, and, as has been very well put by my predecessor in this chair at Montreal, sometimes the evidence of one class of organic remains points in one direction, while the evidence of another class points in another and wholly different direction, as to the geological horizon of the same rocks. The flora, put into the witness-box by the botanist, says one thing, while the Mollusca or the Vertebrata say another thing in the hands of their respective counsel. There seems to be a tacit assumption that the various divisions of the organic world present the same amount of variation in the rocks, and that consequently the evidence of every part of it is of equal value.

It will not be unprofitable to devote a few minutes to this question, premising that each case must be decided on its own merits, without prejudice, and that the whole of the evidence of the flora and fauna must be considered. We will take the flora first.

The Cryptogamic flora of the later Primary rocks shows but slight evidence of change. The forests of Britain and of Europe generally, and of North America, were composed practically of the same elements—Sigillaria, Calamites, and conifers allied to the Ginkho—throughout the whole of the Carboniferous (16,336 feet in thickness in Lancashire and Yorkshire) and Devonian rocks, and do not present greater differences than those which are to be seen in the existing forests of France and Germany. They evidently were continuous both in space and time, from their beginning in the Upper Silurian to their decay and ultimate disappearance in the Permian age. This disappearance was probably due to geographical and climatic changes, following the altered relations of land to sea at the close of the Carboniferous age, by which Secondary plants, such as *Voltzia* and *Walchia*, were able to find their way by migration from an area hitherto isolated. The Devonian formation is mapped off from the Carboniferous, and this from the Permian, but to a slight degree by the flora, and nearly altogether by the fauna. While the fauna exhibits great and important changes, the flora remained on the whole the same.

The forests of the Secondary period, consisting of various conifers and cycads, also present slight differences as they are traced upwards through the Triassic and Jurassic rocks, while remarkable and striking changes took place in the fauna, which mark the division of the formations into smaller groups. As the evidence stands at present, the cycads of the Lias do not differ in any important character from those of the Oolites or the Wealden, and the *Salisburia* in Yorkshire in the Liassic age is very similar to that of the Island of Mull in the Early Tertiary, and to that (*Salisburia adiantifolia*) now living in the open air in Kew Gardens.

Nor do we find evidence of greater variation in the Dicotyledonous forests, from their first appearance in the Cenomanian stage of the Cretaceous rocks of Europe and America, through the whole of the Tertiary period down to the present time. In North America, the flora of the Dakota series so closely resembles the Miocene of Switzerland, that Dr. Heer had no hesitation in assigning it in the first instance to the Miocene age. It consists of more than a hundred species, of which about one-half are closely allied to those now living in the forests of North America—sassafras, tulip, plane, willow, oak, poplar, maple, beech, together with *Sequoia*, the ancestor of the giant redwood of California. The first palms also appear in both continents at this place in the geological record.

In the Tertiary period there is an unbroken sequence in the floras, as Mr. Starkie Gardner has proved, when they are traced over many latitudes, and most of the types still survive at the present day, but slightly altered. If, however, Tertiary floras of different ages are met with in one area, considerable differences are to be seen, due to progressive alterations in the climate and altered distribution of the land. As the temperature of the northern hemisphere became lowered, the tropical forests were pushed nearer and nearer to the equator, and were replaced by plants of colder habit from the northern regions, until ultimately, in the Pleistocene age, the Arctic plants were pushed far to the south of their present habitat. In consequence of this, Mr. Gardner concludes that "it is useless to seek in the Arctic regions for Eocene floras as we know them in our latitudes, for during the Tertiary period the climatic conditions of the earth did not permit their growth there. Arctic fossil floras of temperate and therefore Miocene aspect are, in all probability, of Eocene age, and what has been recognized in them as a newer or Miocene facies is due to their having been first studied in Europe in latitudes which only became fitted for them in Miocene times. When stratigraphical evidence is absent or inconclusive, this unexpected persistence of plant types or species throughout the Tertiaries should be remembered, and the degrees of latitude in which they are found should be well considered before conclusions are published respecting their relative age."

This view is consistent with that held by the leaders in botany—Hooker, Dyer, Saporta, Dawson, and Asa Gray (whose recent loss we so deeply deplore)—that the North Polar region is the centre of dispersal, from which the Dicotyledons spread over the northern hemisphere. If it be true—and I, for one, am prepared to accept it—it will follow that for the co-ordination of the subdivisions of the Tertiary strata in various parts of the world the plants are uncertain guides, as they have been shown to be in the case of the Primary and Secondary rocks. In all cases where there is a clash of evidence, such as in the Laramie lignites, in which a Tertiary flora is associated with a Cretaceous fauna, the verdict, in my opinion, must go to the fauna. They are probably of the same geological age as the deposit at Aix-la-Chapelle.

I would remark, further, before we leave the floras behind us, that the migration of new forms of plants into Europe and America took place before the arrival of the higher types in the fauna, after the break-up of the land at the close of the Carboniferous period, and after the great change in geography at the close of the Neocomian. The Secondary plants preceded the Secondary vetebrates by the length of time necessary for the deposit of the Permian rocks, and the Tertiary plants preceded the Tertiary vertebrates by the whole period of the Upper Cretaceous.

Let us now turn to the fauna.

Prof. Huxley, in one of his many addresses which have left their mark upon our science, has called attention to the persistence of types revealed by the study of palæontology, or, to put it in other words, to the singularly little change which the ordinal groups of life have undergone since the appearance of life on the earth. The species, genera, and families present an almost endless series of changes, but the existing orders are for the most part sufficiently wide, and include the vast series of fossils without the necessity of framing new divisions for their reception. The number of these extinct orders is not equally distributed through the animal kingdom. Taking the total number of orders at 108, the number of extinct orders in the Invertebrata amounts only to 6 out of 88, or about 7 per cent., while in the Vertebrates it is not less than 12 out of 40, or 30 per cent. These figures imply that the amount of ordinal change in the fossil Vertebrates stands to that in the Invertebrata in the ratio of 30 to 7. This disproportion becomes still more marked when we take into account that the former had less time for variation than the latter, which had the start by the Cambrian and Ordovician periods. It follows also that as a whole they have changed faster.

The distribution of the extinct orders in the animal kingdom, taken along with their distribution in the rocks, proves further that some types have varied more than others, and at various places in the geological record. In the Protozoa, Porifera, and Vermes there are no extinct orders; among the Cœlenterates one—the Rugosa; in the Echinodermata three—Cystideans, Edriasterida, and Blastoidea; in the Arthropoda two—the Trilobita and Eurypterida. All these, with the solitary exception of the obscure order Rugosa, are found only in the Primary rocks. Among the Pisces there are none; in the Amphibia one; the Labyrinthodonts ranging from the Carboniferous to the Triassic age. Among the Reptilia there are at least six of Secondary age—Plesiosauria, Ichthyosauria, Dicynodontia, Pterosauria, Theriodontia, Deinosauria; in the Aves two—the Saururæ and Odontornithes, also Secondary. In the Mammalia the Amblypoda, Tillodontia, Condylarthra, and Toxodontia represent the extinct orders—the three first Early Tertiary, and the last Pleistocene. It is clear, therefore, that, while the maximum amount of ordinal variation is presented by the Secondary Reptilia and Aves, all the extinct orders in the Tertiary are Mammalian.

If we turn from the extinct orders to the extinct species, it will also be found that the maximum amount of variation is presented by the plants, and all the animals, excepting the Mammalia, in the Primary and Secondary periods.

The general impression left upon my mind by these facts is that, while all the rest of the animal kingdom had ceased to present important modifications at the close of the Secondary period, the Mammalia, which presented no great changes in the Secondary rocks, were, to quote a happy phrase of Prof. Gaudry, "en pleine évolution" in the Tertiary age. And when, further, the singular perfection of the record allows us to trace the successive and gradual modifications of the Mammalian types from the Eocene to the close of the Pleistocene age, it is obvious that they can be used to mark subdivisions of the Tertiary period, in the same way as the reigns of kings are used to mark periods in human history. In my opinion they mark the geological horizon with greater precision than the remains of the lower members of the animal kingdom, and in cases such as that of Pikermi, where typical Miocene forms, such as Deinotheria, are found in a stratum above an assemblage of marine shells of Pliocene age, it seems to me that the Mammalia are of greater value in classification than the Mollusca, some of the species of which have been living from the Eocene down to the present day.

Yet another important principle must be noted. The fossils are to be viewed in relation to those forms now living in their respective geographical regions. The depths of the ocean have been where they are now since the earliest geological times, although continual geographical changes have been going on at their margins. In other words, geographical provinces must have existed even in the earlier geological periods, although there is reason to believe that they did not differ so much from each other as at the present day. It follows from this that the only just standard for comparison in dealing with the fossils, and especially of the later rocks, is that which is offered by the fauna and flora of the geographical province in which they are found. The non-recognition of this principle has led to serious confusion. The fauna, for example, of the Upper Sivalik formation has been very generally viewed from the European stand-point and placed in the Miocene, while, judged by the stand-point of India, it is really Pliocene. A similar confusion has followed from taking the Miocene flora of Switzerland as a standard for the Tertiary flora of the whole of the northern hemisphere.

It now remains for us to see how these principles may be applied to the co-ordination of Tertiary strata in various parts of the world. In 1880 I proposed a classification of the European Tertiaries, in which, apart from the special characteristic fossils of each group, stress was laid on the gradual approximation of various groups to the living Mammalia. The definitions are the following:—

Divisions.	Characteristics.
1. Eocene, or that in which the higher Mammalia (Eutheria) now on the earth were represented by allied forms belonging to existing orders and families. Oligocene.	Extinct orders. Living orders and families. No living genera.
2. Miocene, in which the alliance between fossil and living Mammals is closer than before.	Living genera. No living species.
3. Pliocene, in which living species of Mammals appear.	Living species few. Extinct species predominant.
4. Plistocene, in which living species of Mammals preponderate.	Living species abundant. Extinct species present. Man present.
5. Prehistoric, or that period outside history in which Man has multiplied exceedingly on the earth and introduced the domestic animals.	Man abundant. Domestic animals present. Wild Mammals in retreat. One extinct Mammal.
6. Historic, in which the events are recorded in history.	Records.

These definitions are of more than European significance. The researches of Leidy, Marsh, and Cope prove that they apply equally to the Tertiary strata of North America. The

Wasatch Bridger and Uinta strata contain representatives of the orders Cheiroptera and Insectivora, the sub-orders Artio- and Perissodactyla, and the families Vespertilionidæ and Tapiridæ; but no living genera.[1] The Mammalia are obviously in the same stage of evolution as in the Eocenes of Europe, although there are but few genera, and no species common to the two.

The White River and Loup Fork groups present us with the living genera *Sciurus*, *Castor*, *Hystrix*, *Rhinoceros*, *Dicotyles*, and others; but no living species, as is the case with the Miocenes of Europe. In the Pliocenes of Oregon the first living species appear, such as the Beaver, the Prairie Wolf, and two Rodents (*Thomomys clusius* and *T. talpoides*), while in the Pleistocene river deposits and caves, from Eschscholtz Bay in the north to the Gulf of Mexico in the south, there is the same grouping of living with extinct species as in Europe, and the same evidence in the glaciated regions that the Mammalia occupied the land after the retreat of the ice.

If we analyze the rich and abundant fauna yielded by the caves and river deposits both of South America and of Australia, it will be seen that the Pleistocene group in each is marked by the presence of numerous living species in each, the first being remarkable for their gigantic extinct Edentata, and the second for their equally gigantic extinct Marsupials.

The admirable work of Mr. Lydekker allows us also to see how these definitions apply to the fossil Mammalia of India. The Miocene fauna of the Lower Sivaliks has yielded the living genera *Rhinoceros* and *Manis*, and no living species.

The fauna of the Upper Sivaliks, although it has only been shown, and that with some doubt, to contain one living Mammal, the Nilghai (*Boselaphus tragocamelus*), stands in the same relation to that of the Oriental Region as that of the Pliocenes of Europe to that of the Palæarctic Region, and is therefore Pliocene. And lastly, the Narbada formation presents us with the first traces of Palæolithic Man in India in association with the living one-horned Rhinoceros, the Nilghai, the Indian Buffalo, two extinct Hippopotami, Elephants, and others, and is Pleistocene.

It may be objected to the Prehistoric and Historic divisions of the Tertiary period that neither the one nor the other properly fall within the domain of geology. It will, however, be found that in tracing the fauna and flora from the Eocene downwards to the present day there is no break which renders it possible to stop short at the close of the Pleistocene. The living plants and animals were in existence in the Pleistocene age in every part of the world which has been investigated. The European Mollusca were in Europe in the Pliocene age. The only difference between the Pleistocene fauna, on the one hand, and the Prehistoric, on the other, consists in the extinction of certain of the Mammalia at the close of the Pleistocene age in the Old and New Worlds, and in Australia. The Prehistoric fauna in Europe is also characterized by the introduction of the ancestors of the present domestic animals, some of which, such as the Celtic shorthorn (*Bos longifrons*), sheep, goat, and domestic hog, reverted to a feral condition, and have left their remains in caves, alluvia, and peat-bogs over the whole of the British Isles and the Continent. These remains, along with those of Man in the Neolithic, Bronze, and Iron stages of culture, mark off the Prehistoric from the Pleistocene strata. There is surely no reason why a cave used by Palæolithic Man should be handed over to the geologist, while that used by men in the Prehistoric age should be taken out of his province, or why he should be asked to study the lower strata only in a given section, and leave the upper to be dealt with by the archæologist. In these cases the ground is common to geology and archæology, and the same things, if they are looked at from the stand-point of the history of the earth, belong to the first, and, if from the stand-point of the history of Man, to the second.

If, however, there be no break of continuity in the series of events from the Pleistocene to the Prehistoric ages, still less is there in those which connect the Prehistoric with the period embraced by history. The historic date of a cave or of a bed of alluvium is as clearly indicated by the occurrence of a coin as the geological position of a stratum is defined by an appeal to a characteristic fossil. The gradual unfolding of the present order of things from what went before compels me to recognize the fact that the Tertiary period extends down to the present day. The Historic period is being recorded in the strata now being formed, exactly in the same way as the other divisions of the Tertiary have left their mark in the crust of the earth, and history is incomplete without an appeal to the geological record. In the masterly outline of the destruction of Roman civilization in Britain the historian of the English Conquest was obliged to use the evidence, obtained from the upper strata, in caves which had been used by refugees from the cities and villas; and among the materials for the future history of this city there are, to my mind, none more striking than the proof, offered by the silt in the great Roman bath, that the resort of crowds had become so utterly desolate and lonely in the ages following the English Conquest as to allow of the nesting of the wild duck.

I turn now to the place of Man in the geological record, a question which has advanced but little since the year 1864. Then, as now, his relation to the glacial strata in Britain was in dispute. It must be confessed that the question is still without a satisfactory answer, and that it may well be put to "a suspense account." We may, however, console ourselves with the reflection that the River-drift Man appears in the Pleistocene strata of England, France, Spain, Italy, Greece, Algiers, Egypt, Palestine, and India along with Pleistocene animals, some of which were pre-glacial in Britain. He is also proved to have been post-glacial in Britain, and was probably living in happy, sunny, southern regions, where there was no ice, and therefore no Glacial period, throughout the Pleistocene age.

It may further be remarked that Man appears in the geological record where he might be expected to appear. In the Eocene the Primates were represented by various Lemuroids (*Adapis*, *Necrolemur*, and others) in the Old and New Worlds. In the Miocene the Simiadæ (*Dryopithecus*, *Pliopithecus*, *Oreopithecus*) appear in Europe, while Man himself appears, along with the living species of Mammalia, in the Pleistocene Age, both in Europe and in India.

The question of the antiquity of Man is inseparably connected with the further question: "Is it possible to measure the lapse of geological time in years?" Various attempts have been made, and all, as it seems to me, have ended in failure. Till we know the rate of causation in the past, and until we can be sure that it has been invariable and uninterrupted, I cannot see anything but failure in the future. Neither the rate of the erosion of the land by sub-aërial agencies, nor its destruction by oceanic currents, nor the rate of the deposit of stalagmite or of the movement of the glaciers, has as yet given us anything at all approaching a satisfactory date. We only have a sequence of events recorded in the rocks, with intervals the length of which we cannot measure. We do not know the exact duration of any one geological event. Till we know both, it is surely impossible to fix a date, in terms of years, either for the first appearance of Man or for any event outside the written record. We may draw cheques upon "the bank of force" as well as "on the bank of time."

Two of my predecessors in this chair, Dr. Woodward and Prof. Judd, have dealt with the position of our science in relation to biology and mineralogy. Prof. Phillips in 1864 pointed out that the later ages in geology and the earlier ages of mankind were fairly united together in one large field of inquiry. In these remarks I have set myself the task of examining that side of our science which looks towards history. My conception of the aim and results of geology is that it should present a universal history of the various phases through which the earth and its inhabitants have passed in the various periods, until ultimately the story of the earth, and how it came to be what it is, is merged in the story of Man and his works in the written records. Whatever the future of geology may be, it certainly does not seem likely to suffer in the struggle for existence in the scientific renascence of the nineteenth century.

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[1] The genus *Vesperugo* has not been satisfactorily determined.—Cope, "Report of Geol. Survey of the Territories: Tertiary Vertebrata," i., 1884

NOTES.

MAJOR-GENERAL PRJEVALSKY started on Thursday last on his fifth journey of exploration in Tibet, with the intention of penetrating, if possible, into Lhassa, the capital. The General, with his officers and Cossacks, will this time take advantage of the new Central Asian railway as far as Samarcand, whence they will proceed to Semiretchinsk, and so to the Tibetan table-lands. General Prjevalsky will, it is thought, on this occasion have the best chance ever afforded him of entering the forbidden residence of the Dalai Lama.

COLONEL HEAVISIDE, of the Indian Survey Department, has retired after more than twenty years' service in the Department, during which he had charge of several important geodetic and geographical operations, notably the completion and extension of the series of pendulum observations formerly carried on by Captain Basevi.

A SERIOUS earthquake, which was felt throughout both islands, occurred in New Zealand on the morning of the 1st instant. There were five distinct shocks, extending over the space of nearly half an hour. At Christchurch the spire of the Cathedral was destroyed, and other buildings were damaged. The inhabitants at first fled from their homes, but returned later when the danger appeared over. Another shock has since been reported from Westport, on the south-west coast of the Nelson district.

DURING the month of August at the Granton Marine Station, the use of which was kindly granted by Dr. Murray of the *Challenger*, Mr. Patrick Geddes and Mr. T. Arthur Thomson conducted a class of over thirty students of both sexes—teachers, medical students, and others from various parts of Scotland and England—through a course of lectures and laboratory work in botany and zoology. The work at Granton was supplemented by visits to the Botanical Gardens, Museum, &c., and by field and marine excursions, including a day's dredging in the Firth of Forth. This is the second year of the course, and it is meant to be continued in future years.

A CORRESPONDENT of the *Daily News* gives the following account of the recent eruption of Bandai-San in Northern Japan:—"The rumbling and trembling of the earth have now stopped, but the mountain still belches forth smoke, and there are evidences that mighty subterranean forces are still at work. The place where the disaster occurred has been and is greatly changing, mountains have risen where there were none before, and large lakes appearing where once there were only rice fields. This being so, it is with the greatest difficulty that guides can be procured, as none can tell where a road now leads and how far it is passable. Landmarks are obliterated, and villages which but a week ago nestled among the rich and plentiful vegetation of the mountain-side are now beneath twenty feet of ash and cinders. The wounded are receiving treatment in the school-house at Inawashiro, but their condition is terrible. Some have fractured skulls, the majority broken limbs, while others are fearfully burned. Five villages have been totally buried. The state of the bodies recovered resembles the appearance of victims of a huge boiler explosion. Many are cut to pieces, and others parboiled, so that it is difficult to distinguish sex. But the most ghastly sights which met the eye of the helpers were bodies dangling on the branches of blackened and charred trees. Thrown into the air by the awful violence of the eruption, their descent had in many cases been arrested by the trees, and there the victims hung, their bodies exposed to the cruel and well-nigh ceaseless rain of red-hot cinders and burning ashes. From appearances death speedily relieved them from their agony, yet, short as the time was, their sufferings must have been past belief. In other places flesh hangs from the branches of trees as paper from London telegraph wires. Bandai-San is composed of five separate peaks, of which the largest is called Great Bandai. The second is a perfectly smooth mountain. The third is called Kushigamine, and is the second in height. The fourth is called the Middle or Northern Bandai, and is the one which broke forth; while the fifth, which is called the Small Bandai, is close to the fourth. Great Bandai is only covered with white ashes, but No. 2 has been greatly shaken, while all the trees above the centre of the mountain have been destroyed. From No. 3 large stones and boulders have been hurled to the bottom, and from half-way down the mountain its sides are covered with bluish earth. No. 4, from which the eruption really occurred, has been entirely blown away, the lighter pieces ejected from it being swept away over the neighbouring mountains, whilst the heavier pieces were carried some five or seven miles, and have formed a table-land at its base, covered with stones and ashes. No report has been received as to any foreigners having been within the fatal region at the time of the occurrence."

M. CHEVREUL entered his 103rd year last week. On Tuesday he was able to walk through the Sanitary Exhibition at the Palace of Industry.

THE twenty-fifth annual meeting of the British Pharmaceutical Association is being held in Bath this week. On Monday evening the President, Mr. F. Baden Benger, and other officers of the Conference held a reception at the Grand Hotel, followed by a *conversazione*. The opening meeting took place on Tuesday morning. The Presidential address dealt largely with the progress of the Association since its establishment, and with the preliminary education of pharmacists.

THE thirty-seventh meeting of the American Association for the Advancement of Science was held at Cleveland, Ohio, on August 15 and following days. *Science* states that the meetings were not as well attended as in past years, but the whole gathering was nevertheless successful. The largest attendance of members appears to have been 303. The scientific departments at Washington were well represented, and the most prominent scientific men of the country were present. According to the secretary's report, the financial condition of the Association is excellent. The research fund, consisting of the contributions of life members, amounts to more than 4400 dollars. The subject of the address of Prof. Langley, the retiring President, was the history of the theory of radiant heat, which we hope to reprint *in extenso*, if space permits, on a future occasion. Prior to the meeting, advantage was taken of the presence of a number of American geologists to take the preliminary steps for the establishment of an American Geological Society. In its general report of the meeting, *Science* refers specially to a lecture delivered by Prof. Stanley Hall. "It was the first time that the new psychology had been given a place on the programme of the Association. . . . Prof. Hall gave a brief review of the scope of experimental psychology. He dwelt on the researches made in the study of psychologic physiology, and on the functions of brain and nerves; he mentioned the methods of psychophysic inquiries, and the important bearing of ethnological studies upon psychological questions. He concluded his sketch, which was listened to with the greatest attention, with a reference to the study of hypnotism, which is one of the most promising fields of psychic research." Major Powell is the President for the current year, and Prof. Mendenhall for next year.

MR. COOK, the President of the Section of Geology and Geography, took for the subject of his address the International Geological Congress, and the part of American geologists in it. He recalls the fact that in 1876 the Association originated the Congress of Geologists in Paris in 1878 for the settling of obscure points relating to geological classification and nomenclature; since that time similar Congresses have been held in Bologna and Berlin, and one is about to be held in London, but, says Mr. Cook, a meeting of the Congress must be held in the United States, and American geology must be fully represented, before any conclusion can be reached which will be accepted by the scientific world, and therefore an attempt will be made at the London Congress to have the meeting of 1891 held in the United States. The discussion on the important topics here mentioned should not be regarded as closed until after the American meeting, and he defines the business of American geologists, prior to the meeting, to be the preparation of a case which will fairly "present the claims of American geology to representation in a general system of geology."

THE Session of the Central Institution of the City and Guilds of London Institute will commence on October 2. The Clothworkers', Siemens's, Mitchell, and Institute's Scholarships will be competed for at an examination held on September 25 to 28. According to the Annual Report for the past year there has again been a large increase in the total number of candidates examined. In 1887, 5508 were examined, of whom 3090 passed; in 1888, 6166 were examined, of whom 3510 passed. The number of centres increased in the same period from 216 to 240, while another subject, viz. practical bread-making, was added to the list of subjects, which now number 49. This year, for the second time, examinations were held in New South Wales, candidates presenting themselves from Sydney, Bathurst, and Newcastle. The worked papers, as well as specimens of the hand-work of the candidates, were forwarded to this country in time for the inclusion of the results in the present Report. The number of colonial candidates has increased from 48 to 51, and the number of those who have passed from 31 to 34. 10,404 students were receiving instruction in the United Kingdom in 475 classes, in 183 different towns. Last year the corresponding numbers were 8613 students, 365 classes, and 121 towns; and these figures do not include the students at the Finsbury Technical College, the Yorkshire College, Leeds, and other Colleges the Professors of which do not receive grants on results, and the candidates from which are classed as "external." With the establishment of new Polytechnic Institutions in different parts of London, it is anticipated that there will be a large increase in the number of students in the technical classes registered by the Institute and in the number of candidates for examination. In most of the chemical subjects the number of candidates is diminishing, and the majority have received their instruction in institutions which obtain no help from the Institute by way of payment on results.

THE most interesting paper in the recent number of the Journal of the Anthropological Society of Bombay is Mr. Fawcett's account of the Saoros or Sowrahs of the Ganjam Hill Tracts. A good deal of Mr. Fawcett's paper is devoted to the investigation of the religious ideas, sacrifices, and funeral rites of the Saoros, and his account furnishes an interesting illustration of several well-known phenomena of early forms of religious belief. The objects of worship fall into two classes: malevolent deities, such as Jalia, Kanni, and Laukan, the sun, and ancestral spirits. Every human being possesses a *kulba*, or soul, which departs from the body at death, but which still retains the ordinary tastes of the Saoro—*e.g.* for tobacco and liquor—and which must be satisfied, or it will haunt the living. In the more primitive parts of the country, everything a man possesses—weapons, cloths, his reaping-hook, and some money—are burnt with him; but this is falling out of use. A hut is built for the *kulba* to dwell in, and food is placed there; but the more important ceremony is the *guar*, which occurs later, the great feature of which is the erection of a stone to the memory of the deceased. Near each village, clusters of such stones, standing upright in the ground, may be seen. The *guar* gives the *kulba* considerable satisfaction; but it is not quite satisfied till the *karja* is celebrated: this being a great biennial feast to the dead, when, after the sacrifice of many buffaloes and the consumption of much liquor, every house in which there has been a death is burnt; the *kulba* is finally driven away to the jungle or the hill-side. Sacrifices are made to appease deities or *kulbas* who have done harm, and in every paddy-field, when the paddy is sprouting, as well as at harvest, an offering of a goat must be made. It does not appear, however, that human sacrifice, once so common among the Khonds, was ever practised by the Saoros. Like all other savages, the Saoros have their priests, or diviners, called *kudangs*, whose occupation seems to be partly hereditary. The *kudang*, like the modern medium, is able to interview the spirit of the deceased and to ascertain his wishes. The method of divination usually practised is that of dropping from a leaf-cup grains of rice, uttering the name of a deity as each falls, and so ascertaining which divinity is the cause of the disease or other calamity. A similar practice has long been known to be in force among the Khonds, though Mr. Fawcett does not mention the fact. An account is given of an exorcism witnessed by the author, in the case of a boy who had suffered much from fever, which was supposed to be caused by the sun. The *kudang* told Mr. Fawcett afterwards that he had given the deity a good talking to and turned him out. "No fear of that deity returning to the boy after what he had said to him!" The *kudangs*, however, it must be added, generally work like ordinary mortals, and even when they are called in to officiate as priests they do not seem, from the account given of their fasting and exertions, to get their rewards for nothing.

EUROPE cannot compete with the United States in the loftiness of its stations for taking meteorological observations. There are only two stations on the European continent which reach any very great height, being about 10,000 feet and 11,000 feet respectively. Among the stations in America is Pike's Peak, which has an altitude of 14,100 feet—or only about 1600 feet lower than the summit of Mont Blanc—and exceeding by more than 3000 feet any meteorological station in Europe. These great heights are much more accessible in the United States than in Europe, there being five stations in America where a height of 11,000 feet or more is reached by railroads built fo facilitating mining work. The highest of those in North America Mount Lincoln, in Colorado, the mining works on which are 14,297 feet above the sea-level, and it has a meteorological station conducted by Harvard College. Another station is placed part way up the mountain, at a height of 13,500 feet. In the Andes Range, in Peru, continuous meteorological observations are also carried on, the loftiest point for this purpose being 14,300 feet above the level of the sea.

A CORRESPONDENT of the *Daily News* in Lucerne sends to that paper an account of an electric mountain railway—the first of its kind—which has recently been opened to the public at the Burgenstock, near Lucerne. Hitherto it has been considered impossible to construct a funicular mountain railway with a curve; but the new line up the Burgenstock has achieved that feat under the superintendence of Mr. Abt, the Swiss electrical engineer. The rails describe one grand curve formed upon an angle of 112°, and the journey is made as steadily and smoothly as upon any of the straight funiculars previously constructed. A bed has been cut, for the most part out of the solid rock, in the mountain-side from the shore of the Lake of Lucerne to the height of the Burgenstock—1330 feet above its level, and 2860 feet above the level of the sea. The total length of the line is 938 metres, and it commences with a gradient of 32 per cent., which is increased to 58 per cent. after the first 400 metres, and this is maintained for the rest of the journey. A single pair of rails is used throughout, with the exception of a few yards at half distance to permit the two cars to pass. Through the opposition of the Swiss Government, each car is at the present time only allowed to run the half distance, and they insist upon the passengers changing, in order, as they say, to avoid collision or accident. A number of journeys were made up and down the mountain in company with an engineer, and the experience is sufficient to prove that the prohibition is altogether unnecessary. The motive power, electricity, is generated by two dynamos, each of 25 horse-power, which are worked by a water-wheel of 125 horse-power, erected upon the River Aar at its mouth at Buochs three miles away. Only one man is required to manage the train, and the movement of the cars is completely under his control. One dynamo is sufficient to perform the work of hauling up and letting down the cars containing fifty or sixty persons. At the end of the journey, completed in about fifteen minutes, at an ordinary walking speed, the car moves gently against a spring buffer, and is locked by a lever, without noise and without jolting the passengers. This interesting undertaking has been carried out at a cost of £25,000.

MR. E. T. DUMPLE, writing in the *Geological Bulletin* of Texas, brings out a very interesting fact, and one which may shed some light upon the question of who were the builders of the shell-mounds of the coast regions of Texas. During the great storm of 1886, which so nearly destroyed Sabine Pass, one of these shell-mounds, which was near a certain house on the river-bank, and the locality of which was exactly known, was destroyed or carried away by the violence of the waves, and rebuilt nearly half a mile farther up stream than it formerly stood. It is therefore possible that these so-called Indian shell-mounds, which are composed almost entirely of shells, with fragments of pottery, and sometimes a crumbling bone or two, were not built, as has been supposed, by Indian tribes who lived on shell-fish, but are entirely due to the action of the water; and the presence of the Indian relics may be easily accounted for by remembering that these mounds are usually found in low ground, and, being high and dry, would naturally be selected as camping-places by the Indians in their hunting and fishing expeditions.

THE Vienna Correspondent of the *Times* records a curious relic of mediæval superstition in Austria. The Burgomaster of Zuraki, in Galicia, has just instituted a prosecution before the Criminal Court of Solotwina against a man named Jean Kowalesink for having, "by his malicious sorceries and incantations, caused a hailstorm to devastate the fields of Zuraki on July 28." The damages occasioned by Kowalesink's uncanny power over the elements are laid at 6000 florins.

WE are glad to report that the Central Meteorological Observatory of Mexico has recommenced the publication of its *Boletin Mensual*, and in a more convenient form than before. This publication had been discontinued since December 1885. It contains only a summary of the observations made at twenty or thirty stations, but the hope is expressed that the publication of the observations made at certain hours will be soon undertaken, and that the arrears will also be taken up, as the observations have been regularly made. The Bulletins for the first five months of this year have been received.

THE Report of the Meteorological Commission of the Cape of Good Hope, for the year 1887, states that "the whole service has assumed a satisfactory character." Monthly and yearly summaries are given for twenty-nine stations, and for a large number of rainfall stations. As an inducement to observers, they are presented with the instruments with which they have made a series of satisfactory observations for a continuous period of five years. Summarized reports are sent daily to each coast port, and are there entered on a sketch-map for the benefit of the seafaring community. We observe, however, that in counting the number of wet days, a rainy day is taken as one upon which 0·03 inch is recorded, whereas a quantity of 0·01 inch is the standard generally adopted in this country. The Commission express the hope that in time they may be able to issue storm warnings.

IN June last an interesting archæological discovery was made at Sönderby, on the west coast of Jutland. It consisted of about thirty urns of clay found in a moss at a depth of 3 feet. They occupied an area 4 feet wide and 10 feet long. Formerly there was a shallow lake here. Most of the vessels rested upon rough stones, but there was no trace of stone walls or roof; they varied from 2 to 8 inches in height. In most of them lay ashes and remnants of calcined bones, whilst the bottom was lined with some reed-like kind of grass. Some of the urns had lids, but others appear to have been placed in the earth open. Most of them were very simple in form, with smooth sides, but on some of the larger there were three knobs at the sides, and attempts at rough ornamentation. No metal or stone implement was found. In the same moss some huge oak trunks were also dug out.

A KIEL schoolmaster, Herr Spiedt, has excavated a so-called "Viking mound" in the south of Jutland, close to the old frontier between Denmark and Prussia. In the eastern edge remains of a skeleton were found, and in the centre an oaken coffin, nailed with iron nails, containing the skeleton of a tall powerful man was found; but no ornaments, weapons, or objects of any kind. The head pointed to the north-west. It was close to this mound that a Runic stone was found some years ago with the following inscription in runes: "King Svein set (raised) stone after (on the death of) Skarde, his homestead companion (probably meaning boy companion), who travelled west, and died in Hedeby." King Svein is the famous King Svein with the Double Beard, who ascended the thrones of England and Denmark on the death of his brother, King Canute, and his friend was one Skarde, who fought for him in this country. Hedeby was the ancient name for the town of Schleswig. It is believed that the skeleton is that of Skarde.

THE "Class-book of Elementary Chemistry," which Mr. W. W. Fisher, Aldrichian Demonstrator of Chemistry at Oxford, is preparing for the Clarendon Press Series, is nearly ready, and will be published in a few days.

THE additions to the Zoological Society's Gardens during the past week include a Small Hill Mynah (*Gracula religiosa*) from India, presented by Mr. Alexander Robertson; a Common Sheldrake (*Tadorna vulpanser*), British, presented by the Rev. H. H. Slater; an Avocet (*Recurvirostra avocetta*) from Holland, presented by Mr. J. Hoogerduyn; two Common Chameleons (*Chamæleon vulgaris*) from North Africa, presented by Mr. J. Alfred Lockwood; a Sea Anemone (*Bolvara eques*), a British Coral (*Caryophyllaca*, sp. inc.) from British Seas, presented by the Marine Biological Station, Plymouth, per Mr. G. C. Bourne; a Brown Bear (*Ursus arctos* ♂), European, a White-backed Piping Crow (*Gymnorhina leuconota*) from Australia, twelve Mandarin Ducks (*Æx galericulata*, 6 ♂, 6 ♀) from China, deposited; two White-headed Parrots (*Pionus senilis*) from Mexico, four Oyster-catchers (*Himantopus ostralegus*) from Holland, purchased.

ASTRONOMICAL PHENOMENA FOR THE WEEK 1888 SEPTEMBER 9-15.

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on September 9

Sun rises, 5h. 28m.; souths, 11h. 57m. 1·8s.; sets, 18h. 26m.: right asc. on meridian, 11h. 12·9m.; decl. 5° 4′ N. Sidereal Time at Sunset, 17h. 43m.

Moon (at First Quarter September 12, 22h.) rises, 9h. 19m.; souths, 14h. 55m.; sets, 20h. 19m.: right asc. on meridian, 14h. 11·1m.; decl. 7° 48′ S.

Planet.	Rises.	Souths.	Sets.	Right asc. and declination on meridian.	
	h. m.	h. m.	h. m.	h. m.	° ′
Mercury..	6 45 ...	12 49 ...	18 53 ...	12 4·7 ...	0 2 N.
Venus ...	6 57 ...	12 59 ...	19 1 ...	12 14·9 ...	0 23 S.
Mars ...	12 25 ...	16 30 ...	20 35 ...	15 46·7 ...	21 30 S.
Jupiter ...	12 16 ...	16 34 ...	20 52 ...	15 51·0 ...	19 31 S.
Saturn ...	2 21 ...	9 55 ...	17 29 ...	9 10·2 ...	17 5 N.
Uranus...	8 8 ...	13 43 ...	19 18 ...	12 58·9 ...	5 38 S.
Neptune..	21 1*...	4 48 ...	12 35 ...	4 2·4 ...	18 59 N.

* Indicates that the rising is that of the preceding evening.

Occultation of Star by the Moon (visible at Greenwich).

Sept.	Star.	Mag.	Disap. h. m.	Reap. h. m.	Corresponding angles from vertex to right for inverted image. ° °
14	50 Sagittarii	6	22 58	0 4†	134 308

† Occurs on the following morning.

Sept.	h.	
11	10	Mars in conjunction with and 6° 7′ south of the Moon.
11	10	Jupiter in conjunction with and 3° 55′ south of the Moon.
11	14	Mars in conjunction with and 2° 12′ south of Jupiter.

Variable Stars.

Star.	R.A. h. m.	Decl. ° ′		h. m.	
Algol	3 0·9	40 31 N.	Sept. 12,	2 37	*m*
			,, 14,	23 26	*m*
ζ Geminorum	6 57·5	20 44 N.	,, 13,	21 0	*M*
U Monocerotis	7 25·5	9 33 S.	,, 15,		*M*
Z Virginis	14 4·3	12 46 S.	,, 9,		*M*
δ Libræ	14 55·0	8 4 S.	,, 13,	21 16	*m*
U Coronæ	15 13·6	32 3 N.	,, 9,	3 23	*m*
U Ophiuchi	17 10·9	1 20 N.	,, 9,	2 0	*m*
			and at intervals of	20 8	
W Sagittarii	17 57·9	29 35 S.	Sept. 15,	15 0	*M*
T Herculis	18 4·9	31 0 N.	,, 13,		*m*
β Lyræ	18 46·0	33 14 N.	,, 14,	4 0	*M*
η Aquilæ	19 46·8	0 43 N.	,, 14,	4 0	*M*
S Sagittæ	19 50·9	16 20 N.	,, 11,	3 0	*m*
			,, 14,	3 0	*M*
X Cygni	20 39·0	35 11 N.	,, 15,	4 0	*m*
T Vulpeculæ	20 46·7	27 50 N.	,, 11,	0 0	*M*
			,, 12,	2 0	*m*
S Cephei	21 36·6	78 7 N.	,, 9,		*m*
δ Cephei	22 25·0	57 51 N.	,, 11,	0 0	*M*

M signifies maximum ; *m* minimum.

Meteor-Showers.

	R.A.	Decl.	
Near ε Persei	60°	37° N.	Swift ; streaks.
,, α Tauri	72	15 N.	Swift ; streaks.
	354	38 N.	Very swift.

GEOGRAPHICAL NOTES.

THE elaborate Report of Mr. Bourne on his journey in South-Western China, which has recently been laid before Parliament, and to which we referred recently in connection with the ethnology of the non-Chinese races of this region, is of much geographical interest. Part of Mr. Bourne's journey was already traversed in the reverse direction by Mr. A. R. Colquhoun, and described by him in his well-known work, "Across Chrysê." This observation applies to the route from Yunnan Fu, the capital of the province of that name, to Ssu-mao, and thence along the Tonquin frontier to Nanning on the West or Canton River. But Mr. Bourne traversed the region between Chung-king and Yunnan Fu, which, however, as it lies on one of the high roads across China into Burma, is not unfamiliar to Western readers, and he also crossed diagonally the province of Kweichow—one of the least known provinces in the Chinese Empire—from Nanning in Kwangsi to Chung-king in Szechuen. Here he travelled along unbeaten tracks for many weeks; but even where travellers had been before—and at best European travellers in Southern and South-Western China are extremely few and far between—his intimate knowledge of China and the Chinese, and the advantages which his official mission gave him, make his observations of exceptional value. He has also established the connection between the rivers of Northern Tonquin and the river system of Southern China. In regard to the seven route-sketches, which accompany the Report, of the different sections of the journey, Mr. Bourne explains that although the rate of travel (about 20 miles a day) precluded the idea of a running survey, it was easy to take notes of the prominent features of the country, as he walked nearly the whole way. These notes, which took the form of route-sketches, would, with an occasional position determined astronomically, have made it possible to give a much better idea of the country than the maps convey; but his record of astronomical observations, "which had cost him many a night's vigil," and portions of his route-sketches, were lost on the occasion of some riots in Chung-king, during which his house was attacked and looted. But the route-sketches of the last part of the journey were fortunately saved, and supply materials for a better map. There is likewise a vast number of careful meteorological observations. It is to be feared that the instinctive repulsion of the natural man to Blue-books, regardless of their contents, will prevent Mr. Bourne's Report from receiving the attention which it deserves. On a moderate computation, it would furnish materials for half a dozen works of travel such as those with which the public is made acquainted every year, which have their little day and cease to be. We have to go back to the Reports of Mr. Bourne's predecessors, Messrs. Baber and Hosie, to find any record of travel in China of equal interest and value.

Science reports that two important Expeditions left Rio de Janeiro in June for exploration and work in two of the least-known parts of the Brazilian territory. The first, sent out by the Ministry of War, under the command of Captain Bellarmino Mendonça, is to open a road from the town of Guarapuaba, on the frontier of the settled portion of the province of Parana, to the confluence of the Rivers Parana and Iguassu, and to found a military colony at the latter point. A road is also to be opened along the Parana River from the mouth of the Iguassu to the navigable portion of the river above the Sete Quedas Fall, and from this point to Guarapuaba, *viâ* the valley of the Piquiri. The founding of a colony at the mouth of the Iguassu, where the Argentines are already establishing themselves, will, aside from its military importance, prove of great value in peopling the valley of the Upper Parana, which has been deserted since the time of the expulsion of the Jesuits. By means of the Lower Parana the colony will have free water communication with Buenos Ayres and other markets of the Argentine Republic, where two of its natural products, lumber and matte, will find a ready sale. This will give at once to the proposed colony a commercial importance far beyond that of a purely military station, and will doubtless lead to the rapid spread of population along the Upper Parana and its tributaries, with their hundreds of miles of navigable waters. The second Expedition, consisting of three military engineers, Capt. Lourenço Telles, and Lieuts. Miranda and Villeray, is sent out under the auspices of the Sociedade de Geographia de Rio de Janeiro, the expenses being borne by the Ministry of Agriculture. It is to proceed to Cuiaba in the province of Mato Grosso, pass by land to the head-waters of the Paranapinga, and descend that river and the Sao Manoel or Tres Barras to the Tapajos, returning to Rio de Janeiro *viâ* Para by the Tapajos and Amazonas. This exploration will thus be a valuable complement to that of the Tapajos by Chandless, as the Sao Manoel and Paranapinga are almost absolutely unknown.

THE current number of the Proceedings of the Royal Geographical Society opens with a paper by Commodore Markham on Hudson's Strait as a navigable channel, which is a condensed narrative of former voyages from the time of Sebastian Cabot, coupled with an account of the author's own observations. Commodore Markham comes to the conclusion that the Strait is perfectly navigable and free from ice in August and later in the season. Mr. Portman has a most interesting paper on the Little Andamans, while General Walker discusses the well-worn theme of the hydrography of South-Eastern Tibet. The Persian *farsakh* cannot be of much value as a precise measure of length, for in a very learned paper, which concludes the number, General Houtum-Schindler, of the Persian Telegraph Service, concludes that it is 3·915 miles, while in a footnote he gives the estimates of eight other authorities all differing from his own and from each other.

THE first number of vol. ix. of the *Bulletin* of the Paris Geographical Society is occupied with M. Maunoir's annual summary of the progress of geography and exploration during 1887. The work is as full and careful as these annual reviews by the same author usually are. The second number is wholly devoted to a record of the commemoration of the centenary of the death of Laperouse. The grand-nephew of the great navigator writes on his private life, and reproduces a number of his private and official letters. Lieutenant Courcel describes his voyage, and Vice-Admiral Paris recounts the history of the discovery of the remains of the expedition. The appendixes contain numerous papers relating to Laperouse and his companions, including a bibliography of works relating to the hero himself.

NOTES ON METEORITES.[1]

II.

CHEMICAL ANALYSIS.

We have seen that the main difference between the specimens of these bodies which have been collected is that some of them are mainly iron, some of them are mainly stone, and that there is a passage between these two conditions represented by falls in which we have a paste of iron including stony fragments.

We have now to enter into some points connected with their chemical constitution somewhat more in detail.

Of the chemical elements which are at present recognized as such, about one-fourth are found by chemical analysis to exist in meteorites. These, according to the tables given by Maskelyne,[2] Fletcher,[3] Smith, and others are as follows:—

Those that occur most constantly are:—

Hydrogen
Iron
Nickel
Magnesium
Cobalt[4]
Copper[4]
Manganese
Calcium
Aluminium
Carbon
Oxygen
Silicon
Phosphorus
Sulphur;

while the following occur less frequently or in smaller quantities:—

Lithium
Sodium
Potassium
Strontium
Titanium
Chromium
Tin
Arsenic
Antimony
Chlorine
Nitrogen.

Of these elementary bodies only hydrogen, nitrogen, and carbon occur in an elementary condition.

Hydrogen and nitrogen are asserted to be occluded as gases by the stones. Carbon exists both in the form of graphite and diamond.

From the above lists it will be seen that among the elements most common in meteorites are recognized many which have a very wide distribution and exist in great quantities in the surface and envelopes of our planet. But this is true only of the elements.

Many mineral compounds terrestrially common are absent; perhaps the most striking case of all is the absolute absence of free quartz, whether crystallized or not, from meteorites, while terrestrially it is the most prevalent compound known, and enters into the composition of such common rocks as trachyte, felsite, syenite, gneiss, and granite.

Again, many of the chemical combinations met with are unknown to terrestrial mineralogy. The chemical compounds found in meteorites which are new to our mineralogy may be briefly referred to. Some are combinations with sulphur, as follows:—

Sulphur + Iron = Troilite
+ Calcium = Oldhamite
$+\left\{\begin{array}{l}\text{Calcium}\\ \text{Titanium}\end{array}\right\} = \text{Osbornite}$
$+\left\{\begin{array}{l}\text{Iron}\\ \text{Chromium}\end{array}\right\} = \text{Daubréelite.}$

Phosphides of iron and nickel, forming varieties of so-called schreibersite, are met with.

It has already been stated that carbon in some form or other exists in most meteorites. Some of them are partly composed of this element compounded with hydrogen and oxygen.

This exists as a white or a yellowish crystallizable matter, soluble in ether and partly so in alcohol, and exhibiting the characters and the composition of one or more hydrocarbonaceous bodies with high melting-points.

The meteorites of Alais and Cold Bokkeweld are instances of this group. The former is of a black colour both internally and externally, is combustible, and contains sulphates of magnesium, calcium, sodium, and potassium, which are all soluble in water. The latter, after being experimented upon, left a residue which gave out a very bituminous smell; this substance was yellow, and it was found that it was only another form of carbon in a state of intimate mixture, amounting to about 1·67 per cent.

Some carbonaceous stones are dark gray in colour, have little lustre, and are soft; they contain no visible meteoric iron, but an abundance of light gray rounded bodies, among which are occasionally some with a dull metallic lustre and of a greenish-yellow colour, and others of a dark gray compact substance and of earthy character.[1]

Various *alloys* of nickel and iron also occur.

The different alloys which play the most important part have, according to Meunier, the following composition:—

	Density.	Formula.
Tænite	7·380 ...	Fe_6Ni
Plessite	7·850 ...	$Fe_{10}Ni$
Kamacite	7·652 ...	$Fe_{14}Ni$
Braunine	(?) ...	$Fe_{16}Ni$

Among other minerals we may name—
Lawrencite, protochloride of iron;
Maskelynite, with the composition of labradorite;
Silica (as asmanite).

We now come to the common ground.

The following compounds are identical in composition and crystallographic character with minerals found on our globe:—

Magnetic pyrites ... ... Fe_7S_8.
Magnetite ... ... Fe_3O_4.
Chromite ... ... $(Fe,Cr)_3O_4$.
Silicates, viz.—
  Olivine varieties.
  Enstatite and bronzite.
  Diopside and augite.
  Anorthite and labradorite.
  Breunnerite.

Among gaseous compounds, the oxides of carbon have been detected in many meteorites, and it is asserted that these gases have been occluded by them in the same manner as the elementary gases hydrogen and nitrogen.

In the "irons" we deal chiefly with nickel-iron, magnesium, manganese, and copper, as metals.

In the "stones" we deal with combinations of magnesium, iron, oxygen, and silicon. One of the most usual substances is called olivine, and sometimes the olivine is in a slightly changed form, in which the quantity of iron is increased, and we get bronzite. Nickel-iron, manganese, and other substances are also found in the stones.

Chemical analysis of the irons has established in them, taken as a whole, the existence of the following mineral species.

(1) The general metallic mass, which consists of certain alloys, in which iron and nickel predominate to such an extent that the term nickel-iron is by common consent applied to it.

The nickel-iron is an alloy or compound special to meteorites, and the irons are chiefly composed of it. The tracery to which I have referred, observed on the metallic surface heated with acids, was discovered by Widmanstätten. The figures are caused by the crystallization of the mass: with the iron and nickel magnesium is always associated, *so that we get magnesium in all meteoric irons* as well as in the stones.

(2) Compounds of iron and carbon, principally campbelline and chalypite (Fe_2C).

(3) Troilite $(FeNi)_7S_8$, generally appearing as kidney-shaped masses.

(4) Schreibersite (Fe_4Ni_2P).

(5) Graphite.

(6) Stony grains, generally magnesium and iron silicates.

(7) Occluded gases.

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[1] Continued from p. 428.

[2] NATURE, vol. xii. p. 505.

[3] "Introduction to Study of Meteorites," p. 30.

[4] With regard to the presence of cobalt and copper, Dr. L. Smith says ("Mineralogy and Chemistry," p. 352):—"In every analysis that I have made of meteoric irons (over one hundred different specimens) cobalt has been invariably found, along with a minute quantity of copper."—Flight, "History of Meteorites," p. 164.

[1] Flight, *op. cit.* p. 211.

(8) The crust or varnish. This has been found to be due entirely to the oxidation of the metal. The formula of the crust of the Toluca meteorite is $Fe_2O_3(FeNi)O$, according to Meunier.

The quantities of occluded gases vary considerably. Hydrogen is the first to come out when a vacuum is produced, and in the cold—that is, when the tube containing the meteorite is not heated.

Thus, Graham found in the Lenarto meteorite, and in a comparative experiment with clean horse-shoe nails made of iron :—[1]

	Meteorite.	Nails.
Hydrogen	85·68	35·0
Carbonic oxide... ...	4·46	50·3
Carbonic acid	—	7·7
Nitrogen	9·86	7·0
	100·00	100·0

Mallet subsequently found in the meteorite picked up in Augusta County—[2]

Hydrogen	85·68
Carbonic oxide	4·46
Nitrogen	9·86

Dr. A. Wright subsequently determined the composition of the gases given off at different temperatures, using the Iowa meteorite. The results were as follows :—

	Hydrogen.	Carbonic oxide.	Carbonic acid.	Nitrogen
Cold	49	14	35	—
At 100° C. ...	4·54	0 (?)	95·46	—
At 200° C. ...	5·86	1·82	92·32	—
Red heat ...	87·53	0	5·56	6

As regards the so-called occluded gases, iron and stony meteorites, according to Wright, show a marked distinction. While the gases of the Lenarto iron contained 85·68 per cent. of hydrogen, those obtained from cosmical masses of the stony kind, such as the Iowa meteorite, are characterized by the presence of carbonic acid, which constitutes nine-tenths of the gas evolved at the temperature of boiling water, and about one-half of that given off at a low red heat.

This view of Wright's has been called in question by Mallet, who refers to his examination of the gases of the iron of Augusta Co., Virginia, where the ratio of the oxides of carbon to hydrogen is 4·3, and to his having pointed out in 1872 that hydrogen could no longer be regarded as the characteristic gaseous ingredient of meteoric iron.[3]

In the siderites, the iron varies from 80 to 98 per cent., and the nickel from 6 to 10 per cent. Sometimes the nickel is found in larger quantities, as in the iron of d'Octibbeha Co., Mississipi, found in the year 1854, which contained as much as 59 per cent., while the iron was only 37 per cent.

There is a singular circumstance connected with the varnish of stony meteorites which was observed by Reinsch in the meteorite of Krähenberg. The grains of metallic iron and troilite contained in the varnish show no signs of oxidation. In the meteorite of Morbihan, also, grains of nickel-iron project not only through the smooth inner but also the rough outer crust. It has been suggested that the surface of these meteorites was vitrified before it entered our air, or at all events those lower strata of it in which oxygen is abundant.[4]

In many cases minute chemical analysis has been most useful in showing that meteorites which have been found in different localities really belong to the same fall.

Prof. Nordenskjöld, on examining the Ställdalen meteorites (Sweden, June 28, 1876), found that they resembled some eight or nine others which he had before examined, although they were entirely unconnected as regards their date of appearance; and that together they would form a well-marked group, but which, he observes, will probably be found to be only one among many similar groups of aërolites which will hereafter be detected.

The following short table brings together in a compact form the chief substances met with in meteorites. It will indicate the cause of the continued reference to the spectra of magnesium iron, and manganese in what follows.

Siderites.

Nickel-iron, manganese, copper.
Troilite = FeS.
Graphite.
Schreibersite = iron and nickel phosphide, with which magnesium is always associated.
Daubréelite = iron and chromium sulphide.

Siderolites.

Chondritic—	
(α) Non-carbonaceous ...	Olivine = chrysolite = peridot = $(MgFe)_2O_4Si$ = SiO_2 41·3, MgO 50·9, FeO 7·7. Enstatite MgO_3Si = SiO_2 60, MgO 40. Bronzite = enstatite, in which some magnesium is replaced by iron. Nickel-iron, manganese. Troilite. Chromite = iron protoxide 32, chromium sesquioxide 68, + aluminium and magnesium. Augite = pyroxene, SiO_2 55, CaO 23, MgO 16, MnO 0·5, FeO 4. Silicate of calcium, sodium, and aluminium.
(β) Carbonaceous ...	Carbon in combination with H and O. Sulphates of Mg, Ca, Na, and K.
Non-chondritic—	Troilite. Olivine. Enstatite. Bronzite. Augite. Anorthite

SPECTRAL ANALYSIS.

It is imperative that we should know what spectroscopic phenomena are presented by meteorites when they are exposed to temperatures either high or low, such that luminous effects are produced, however the heat which is associated with luminosity is caused.

To this end a great many investigations have been made, and one method of investigation has been the following.

A small portion of any particular meteorite, or still better some dust or filings is inserted in an end-on tube, which is placed in front of a spectroscope, so that a spectroscopic record of the luminosity may be obtained. The tube is at the same time attached to a Sprengel pump, so that in this way a vacuum can be obtained, and is supplied with poles, so that an electric current can be sent through it. Supposing that such bodies as meteorites exist in free space, we must understand that they exist practically in a vacuum, so that it is a fair thing to begin the laboratory work by getting as nearly a vacuum as possible. The next thing to do is to try the effect of the lowest temperature, and for that purpose the central part of the tube containing the little fragments is heated by a Bunsen burner.

If any effect is produced by this application of heat it will after some little time be evidenced by the commencement of a spectrum or by some change in the pre-existing one. What has been found is that there is scarcely any meteorite which can be examined in this way which does not give off a sufficient quantity of hydrogen to allow the hydrogen spectrum, when a feeble electric current is made to travel along the tube, to be very beautifully visible.

If the temperature of the meteoric particles is kept sufficiently low, we see practically the spectrum of hydrogen alone. That is a demonstration of the very well known fact that with those bodies generally acknowledged to enter into the composition of meteorites, hydrogen is always associated.

If under these same conditions the temperature is increased, the spectrum of carbon begins to be visible, indicating that associated with the hydrogen there is some compound or com-

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[1] Graham, "Chemical and Physical Researches," p. 283.
[2] *Chemical News*, June 21, 1872.
[3] Flight, *op. cit* p. 80.
[4] Flight, *Geol. Mag.*, January 1875.

pounds of carbon in the meteorite which require a higher temperature to bring them out, but which come out when that higher temperature is employed. The carbonaceous structure of some meteorites has already been determined on other grounds.

If we carry the heating a little further still, and instead of leaving the particles relatively cold and dark while the current is passing we apply a higher temperature outside the tube by means of the Bunsen burner, then we get the luminous vapours of some constituents of the meteorite added to the spectra of hydrogen and carbon.

What luminous vapours do we get first, and which last? The experiment is a very interesting one, and may certainly be carried on in a tube such as that described until a pretty considerable development of the spectrum is obtained. The first substance which makes itself visible obviously after the hydrogen and carbon when particles of a meteorite are treated in this way is magnesium derived from the olivine, that substance which exists in the greatest quantity in the stones, and in the schreibersite, which exists in the irons.

From such a method of research as this we can pass to one in which, by means of the oxy-coal-gas flame, we can determine the spectrum of any vapour given off, provided any vapour is given off, at a still higher temperature. That work has been done, and the main result is that in the case of an "iron," the first substance to make its appearance is manganese, and the next substance to make itself obvious is iron.

Here a very important remark must be made. The substance which will give us the predominant spectrum at lowest temperature must be that substance the volatility of which at that temperature is greatest. If, however complicated the chemical constitution of one of these meteorites may be, there is one substance which volatilizes out of it more readily than another at a low temperature, that substance will be the first to give us its characteristic spectrum at that temperature—and in fact we may get the spectrum of that substance alone, although its percentage in the meteorite may be extremely small. It is therefore an important result to find that in meteorites in which the quantity of iron is very considerable it is always the manganese that makes itself visible first, because its volatility is greater than that of iron. The point to bear in mind is that when we pass to the temperature of the oxy-coal-gas flame we get predominant evidence of the existence of manganese, and afterwards of iron.

Many diagrams of observations made in this way have been constructed of the oxy-coal-gas flame of meteorites and of olivine, and not only the flame but the "glow,"—glow being the name given to the luminosity produced in the tube under the conditions stated. There are some points of similarity, and other points of difference. One of the results which is most constant is a line at 500 on the wave-length scale which appears to run through all the observations until we come to deal with such meteorites as the Limerick and Nejed. On the other hand some lines and flutings do not make their appearance generally.

If we wish to extend our inquiry into the function of a still higher temperature we can use the electric arc; that also has been done. For this purpose specimens of iron meteorites have been cut into poles, the spectra of which have been observed and photographed, so that the vapours produced have been the vapours of the pure iron meteorites; that is to say, a small portion of a meteorite has *not* been placed in an impure carbon pole, so that the impurities of the carbon would be observed and photographed with the pure vapours of the meteorites. In addition to this method—in the case of the stony meteorites—the lower pole after its spectrum has been well studied has been utilized in this way: the upper pole remaining constant as an iron pole, pretty big particles of various stony meteorites have been inserted into the lower pole, and the added result has been recorded. Further, composite photographs of the spectra of many meteorites have been obtained. Half a dozen different stony meteorites have been rendered incandescent by their insertion into the lower pole during the exposure of a single photographic plate.

It is pretty obvious that if we can get detailed information on such points as these, and provided there are meteorites in space at the temperatures at which we are able to determine their spectra in the laboratory, such data should be of extreme value, for at present we know of no reason why the spectra should differ according to locality.

J. NORMAN LOCKYER.

(*To be continued.*)

MOLECULAR PHYSICS: AN ATTEMPT AT A COMPREHENSIVE DYNAMICAL TREATMENT OF PHYSICAL AND CHEMICAL FORCES.[1]

II.

§ 6. *Double Refraction.*

ACCORDING to the theories both of Fresnel and of Neumann, double refraction is explained on the assumption that the elasticity of the ether in crystals which exhibit this phenomenon is different in different directions. The elasticity is proportional to the square of the velocity of propagation, and if a, b, c are the ratios of the elasticities, parallel to the principal axes of the crystal, of the ether within it to its density, the velocity in any direction α, β, γ will be given by the equation—

$$v^2 = a^2 \cos^2 \alpha + b^2 \cos^2 \beta + c^2 \cos^2 \gamma \quad . \quad . \quad . \quad . \quad (18)$$

According to the author's theory, the elasticity of the ether is the same in every direction, so that any difference in the velocities of propagation in different directions must be due to the mutual action between the ether and the molecules of the crystal being a function of the direction, and therefore the values of the quantities c_i for the molecules of the crystal, and hence also the value of μ, must depend on the direction.

Assuming, for simplicity, that the molecules have a single shell only, it follows from (8) and (9) that—

$$\mu^2 = \frac{1}{v^2} = \frac{\rho}{l} - \frac{c_1 T^2}{l}\left\{1 + \frac{c_1}{\dfrac{m_1}{T^2} - c_1 - c_2}\right\}$$

$$= \frac{1}{l}\left\{\rho - c_1 T^2\left[1 + c_1 \frac{T^2}{m_1} \frac{\kappa_1^2 R_1}{\kappa_1^2 - T^2}\right]\right\} \quad . \quad . \quad . \quad (19)$$

where $\kappa_1^2 = m_1/(c_1 + c_2)$ and $R_1 = m_1/\kappa_1^2(c_1 + c_2)$.

Let the values of c_i and μ for a second direction be c_i^1 and μ^1, then

$${\mu^1}^2 = \frac{\rho}{l} - \frac{c_1^1 T^2}{l} - \frac{{c_1^1}^2 T^4}{(c_1^1 + c_2^1)\left(\dfrac{m_1}{c_1^1 + c_2^1} - T^2\right)} \quad . \quad . \quad (20)$$

Now, as Thomson has pointed out, the dispersion accompanying double refraction is of very small amount, so that the difference $\mu^2 - {\mu^1}^2$ must be sensibly independent of T.

If T were less than κ, $\mu^2 - {\mu^1}^2$ would, from (12), be proportional to T^2. It must therefore be assumed that the critical period is at the extreme blue end of the spectrum, which will give T greater than κ_1 for all the rays. Then from (12*a*)—

$$\mu^2 - {\mu^1}^2 = \frac{c_1^2 m_1}{l(c_1 + c_2)^2} - \frac{{c_1^1}^2 m_1}{l(c_1^1 + c_2^1)^2}$$

$$- \left(c_1 - c_1^1 - \frac{c_1^2}{c_1 + c_2} + \frac{{c_1^1}^2}{c_1^1 + c_2^1}\right)\frac{T^2}{l}$$

$$+ \frac{c_1^2}{(c_1 + c_2)^3} - \frac{{c_1^1}^2}{(c_1^1 + c_2^1)^3} \frac{m_1^2}{l T^2} + \quad . \quad . \quad . \quad . \quad . \quad (21)$$

In order that the coefficient of T^2 may be small, c_1 and c_1^1 must be small and nearly equal. The other terms of the series will then be also very small, especially if T is large in comparison with m_1, and the series may, to a first approximation, be replaced by its constant term.

Now let it be assumed that the manner in which c_1 and c_2 depend on the direction α, β, γ, is determined by an equation of the form—

$$\left(\frac{c_1}{c_1 + c_2}\right)^2 = C_1 \cos^2 \alpha + C_2 \cos^2 \beta + C_3 \cos^2 \gamma \quad . \quad . \quad (22)$$

Then from (19) and (12*a*)—

$$v^2 = \frac{1}{\mu^2} = \left(\frac{l}{\rho} - \frac{m_1}{\rho} C_1\right)\cos^2 \alpha + \left(\frac{l}{\rho} - \frac{m_1}{\rho} C_2\right)\cos^2 \beta$$

$$+ \left(\frac{l}{\rho} - \frac{m_1}{\rho} C_3\right)\cos^2 \gamma,$$

an equation of the same form as (18), and which therefore gives a wave-surface identical with Fresnel's. It must, of course, be

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[1] A Paper read before the Physico-Economic Society of Königsberg, by Prof. F. Lindemann, on April 5, 1838. Continued from p. 407.

assumed that the axes of the molecules in the crystal are all parallel.

Thomson arrived at a different result, which the author attributes to his having assumed the product of the denominators $c_1 + c_2 - m_1/\mathrm{T}^2$ and $c_1{}^1 + c_2{}^1 - \dfrac{m_1}{\mathrm{T}^2}$ to be sensibly a constant, and therefore considered only the manner in which T enters into the numerators.

It is easy to see that similar results will be obtained for molecules consisting of any number of shells.

§ 7. *Spectra of Chemical Compounds.*

In considering chemical compounds it is necessary to make a clear distinction between atoms and molecules, and henceforward the author uses the term atom to denote a system of shells such as is described in § 1, and employs the term molecule only for a combination of two or more atoms having their external shells close together. The author restricts his investigations to diatomic molecules.

A molecule will then be capable of executing stationary vibrations without disturbing the ether, similar to those of an atom, and will therefore also have its critical periods; but their values, in the case of the molecule, will depend on the direction of the disturbance. A diatomic molecule may be considered approximately as consisting of a series of concentric prolate spheroidal shells having their longer axes coincident with the lines joining the centres of the spheres.

There will be two principal series of critical periods, corresponding respectively to disturbances propagated in the direction of the longest axis or of any of the shortest axes. If the direction of propagation of a disturbance differs slightly from one of these axes, the corresponding lines of the spectrum will only be slightly displaced, and in this way well-defined bright lines will be replaced by bright bands sharply defined on one side and indistinctly on the other. If two of these bands overlap on their indistinct sides, a band may be produced of equal brightness throughout, and having both its sides sharply defined.

This gives an explanation of the well-known experimental fact that the spectra of chemical compounds usually consist of bright fluted bands, sometimes accompanied by distinct bright lines, and not of bright lines only. Conversely, if the spectrum of a gas contains bright bands, it will be natural to infer that it is a chemical compound. This would lead us to suppose that oxygen, sulphur, nitrogen, phosphorus, carbon, and silicon are really compound bodies—a conclusion which receives independent confirmation from other points of view.

The theory does not lead to any simple law, such as has often been sought after, for determining the spectrum of a compound from the spectra of its constituents, but it throws a good deal of light on the subject generally.

The differential equations to determine the motions of the shells within an atom differ from equations (1) only in virtue of the core itself being supposed to be in motion, so that the last of these equations will become—

$$\frac{m_j}{4\pi^2}\frac{d^2x_j}{dt^2} = c_j(x_{j-1} - x_j) - c_{j+1}(x_j - x_{j+1}) \quad . \quad . \quad (23)$$

the difference consisting only in the presence of x_{j+1}, which was supposed equal to zero in equations (1).

If we discard the assumption that the mass of the core is so great relatively to that of the shells in an atom that the centre of gravity of the system may be identified with that of the core, the condition $x_{j+1} = 0$ will be replaced by the more general one—

$$m_1x_1 + m_2x_2 + \ . \ . \ . + m_{j+1}x_{j+1} = 0 \quad . \quad . \quad . \quad (24)$$

which determines the value of d^2x_{j+1}/dt^2, which is wanting in the system (23).

From (2), (3), and (23) we obtain the system—

$$\begin{aligned} -c_1\xi &= a_1x_1 + c_2x_2 \\ -c_2x_1 &= a_2x_2 + c_3x_3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25) \\ &. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \\ c_jx_{j-1} &= a_jx_j + c_{j+1}x_{j+1}\,; \end{aligned}$$

where, as before, $a_i = m_i/\mathrm{T}^2 - c_i - c_{i+1}$.

These, together with (24), form a set of $j + 1$ linear equations, which are sufficient to determine the $j + 1$ unknown quantities $x_1, x_2, \ . \ . \ . \ x_{j+1}$ in terms of the given quantities ξ and T^2.

Replacing ξ, m, x, c, j by η, n, y, e, κ respectively, we obtain a similar set of equations to determine the vibrations of the second atom. If the outer shells of these two atoms are in contact, x_1 must be equal to y_1, unless the disturbance is such as to effect a separation, x_i and y_i being corresponding displacements from the common centre of gravity. Writing x for the common displacement of the shells in contact, equations (25) assume the form—

$$\begin{aligned} -e_1\eta &= b_1x + e_2y_2 \\ -e_2x &= b_2y_2 + e_3y_3 \\ &. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \\ -e_\kappa y_{\kappa-1} &= b_\kappa y_\kappa + e_{\kappa+1}y_{\kappa+1}. \end{aligned}$$

The condition that the common centre of gravity of the two atoms may remain at rest will therefore be—

$$\begin{aligned} (m_1 + n_1)x + m_2x_2 + m_3x_3 + \ . \ . \ . + m_{j+1}x_{j+1} \\ + n_2y_2 + \ . \ . \ . + n_{\kappa+1}y_{\kappa+1} = 0 \quad . \quad . \quad . \quad . \quad (27) \end{aligned}$$

(25), (26), and (27) form a system of $j + \kappa + 1$ equations to determine the same number of unknowns, x, x_2, . . . x_{j+1}, η_2 . . . $\eta_{\kappa+1}$, in terms of the known quantities ξ, η, and T^2. ξ is determined as before by equation (2), and gives the vibration of the ether at the point where the ray impinges on the first atom. The axis of a molecule may be at any angle with the impinging ray, and η will give the ether vibration at the point where a ray parallel to the first strikes the second atom. For a given period and wave-length, ξ and η will therefore in general be in different phases.

In the case of vibrations parallel to the axis of the molecule we shall have $\xi = \eta$, supposing all the parallel rays impinging on the molecule to be in the same phase. The ratio x/ξ, required for the determination of μ^2 will then be the quotient of the second and first minors (viz. the coefficients of u_1 and u) of the determinant of order $j + \kappa + 2$ given below, in which the first row is completed by arbitrary quantities.

$$\begin{array}{cccccccccccc}
u & u_1 & u_2 & u_3 & u_4 & \ldots & u_{j+1} & v_2 & v_3 & v_4 & \ldots & v_{\kappa+1} \\
0 & m_1 + n_1 & m_2 & m_3 & m_4 & \ldots & m_{j+1} & n_2 & n_3 & n_4 & \ldots & n_{\kappa+1} \\
c_1 & a_1 & c_2 & 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 \\
0 & c_2 & a_2 & c_3 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 \\
0 & 0 & c_3 & a_3 & c_4 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & \ldots & c_{j+1} & 0 & 0 & 0 & \ldots & 0 \\
e_1 & b_1 & 0 & 0 & 0 & \ldots & 0 & e_2 & 0 & 0 & \ldots & 0 \\
0 & e_2 & 0 & 0 & 0 & \ldots & 0 & b_2 & e_3 & 0 & \ldots & 0 \\
0 & 0 & 0 & 0 & 0 & \ldots & 0 & e_3 & b_3 & e_4 & \ldots & 0 \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
0 & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & e_{\kappa+1}
\end{array}$$

This will always be the case applicable to the determination of the light emitted by a molecule.

The equation $\xi = 0$, which determines the critical periods of the molecule, will then be obtained by equating the coefficient of u to zero, and as a_i and b_i are linear functions of T^{-2}, the resulting equation will be of the order $j + \kappa$. Therefore, for vibrations parallel to the axis, the number of critical periods of a diatomic molecule is equal to the sum of the numbers of critical periods of its constituent atoms. This number may be diminished if $x = 0$ while x/ξ and u_2 remain finite.

If a single ray only is considered, as at the limits of illumination, η may be taken equal to zero for any given value of ξ; it is only necessary to put $e_1 = 0$ in the first column of the determinant. This will, however, not affect the equation $\xi = 0$.

If the impinging ray is parallel to the axis of the molecule, in which case the vibrations will be perpendicular to it, the two atoms will be differently affected by the vibrations of the ether, for, in the case of the first atom, ξ is again determined by (2), or more generally by the equation—

$$\xi = a\cos\left(\frac{2\pi t}{\mathrm{T}} - \frac{\mathrm{X}}{\lambda}\right),$$

where X is the abscissa of the atom; and if r and s are the radii of the two atoms we shall have for the second atom—

$$\eta = a\cos\left(\frac{2\pi t}{\mathrm{T}} - \frac{\mathrm{X} + r + s}{\lambda}\right).$$

Now the radii of the atoms are supposed to be very small in comparison with the wave-length λ, so that ξ and η will be nearly equal, and therefore we may write—

$$\eta = \xi \left\{ 1 + \frac{r + s}{\lambda} \tan\left(\frac{2\pi t}{T} - \frac{X}{\lambda}\right) \right\}.$$

As a first approximation we may take $\xi = \eta$, and then the vibrations will be the same as those parallel to the axis. Since, however, the centre of gravity remains fixed, the vibration must be a pendulous one about this centre, which introduces a fresh set of considerations. The proper vibrations of the molecule would still be given by $\xi = 0$ and $\eta = 0$, but, owing to the pendulous vibration, these would not completely determine the motion. The difference in the action of light in different directions, and the corresponding fluted nature of the spectrum, would appear to depend essentially on considerations of this kind.[1]

In the case of a triatomic molecule, we obtain three sets of linear equations of the same form as (25) and (26), together with one of the form (27); it is, however, unnecessary to pursue this further.

§ 8. *Production of Chemical Compounds by the Effect of Light and Heat.*

When an atom of any gas strikes in its course against an atom of some other gas, the question which presents itself is whether the two will unite to form a single molecule or not. The internal equilibrium of each atom will be disturbed by the impact, so that the resultant of the internal forces of the system formed by the two atoms will in general have a value different from zero. Let this resultant be transferred parallel to itself until it passes through the centre of gravity, as is allowable from a theorem of dynamics, then it will increase its velocity of translation. The total energy of the system must, however, remain constant, so that the energy of the internal atomic vibrations must be diminished by exactly the same amount as that by which the energy of the motion of the centre of gravity is increased. After the impact the internal vibrations will at first be of a very irregular character; but under the action of the light rays they will ultimately attain a condition of stationary equilibrium, supposing such to be possible with the diminished energy. When it is possible its stability will be greater, the greater the diminution in the internal energy.

Consider, for example, the formation of hydric chloride gas by the action of light on a mixture of chlorine and hydrogen, accompanied as it is by a measurable development of heat. Both these gases exhibit strong bright lines in the blue portion of the spectrum, and, in the case of hydrogen, also in the ultra-violet. Vibrations of corresponding critical periods will therefore easily be excited, which will greatly increase the internal energy of the atoms. When an atom of chlorine now impinges upon one of hydrogen, they will remain in contact for a finite, though exceedingly short interval. During this interval the mechanical theorem relative to the motion about the centre of gravity is applicable, since there will be no external forces acting on the pair of atoms during their common rectilinear motion. Let it be assumed further that the energy of the molecule formed by the union of the two atoms is, under the existing conditions, less than the sum of their separate energies, viz. that the critical vibrations of the molecule are less sensitive to the action of light than those of the separate atoms, then the spherical atomic shells will tend to execute resultant vibrations proper to the molecule according to § 7, so that the chlorine and hydrogen will unite to form hydric chloride. No energy can of course be lost, so that the difference between the internal energy of the molecules and that of the separate atoms will be added to that of the translatory motion, and will therefore become sensible in the form of heat.

It will be noted that no special chemical affinity between chlorine and hydrogen has to be assumed, but two elements may be said to have a chemical affinity whenever the energy of the resultant molecular vibration is, under the given conditions, less than that of the separate atomic vibrations.[2]

The given conditions may depend on light, heat, or electromotive force, though the consideration of the last-named may be eliminated (see § 16). An example of the action of heat is given by the formation of water from hydrogen and oxygen. The hydrogen burns with a blue flame. Both the elements give bright lines in the red portion of the spectrum, hydrogen at 6562, and oxygen at 6171,[1] so that their internal energy can easily be increased by the action of heat, so that combination will take place, and this is accompanied by a considerable development of heat. Water being a very stable compound with respect to the action of heat, we should expect it to give chiefly blue lines. This has not hitherto been proved by direct experiment, but it appears to be indicated by the blue colour and intense heat of the hydrogen flame.

Since the heat of combustion which is usually developed during the formation of oxides arises from a diminution in the internal energy of the atoms, we should infer that (1) the stability of an oxide will be greater the greater its heat of combustion; (2) the spectrum of the oxide will not extend so far towards the red end of the spectrum as the spectra of the constituents.

The former inference is confirmed by the researches of Favre and Silbermann; the latter is found to be justified for the oxides of aluminium, lead, carbon, copper, and strontium (the ultra-red portion of the spectrum in the case of strontium should be specially noted), but it cannot be expected to hold good so universally as the former.

§ 9 *Molecular Theory of Chemistry.*

In modern chemistry the term molecule is used to denote the smallest mass of a substance which can exist separately. This conception of a molecule is essentially different from that set forth in § 7 of this paper. The chemical molecule may be simply an atom, as in the cases of mercury and cadmium, but this is not the case for the molecules considered by the author. On the author's theory, each atom is supposed capable of separate existence, which agrees with chemical phenomena when the atoms are considered in the isolated, or so-called nascent condition, but appears to be in conflict with them in that Mariotte's (Boyle's) law, and the comparison of the weights of equal volumes of various elements in the gaseous state, appear to point to the conclusion that their chemical molecules consist of two or more atoms.

This only applies to elements in the gaseous state and under the ordinary conditions of pressure and temperature, and it is quite conceivable that in high vacua and at a high temperature, as for example in a Geissler tube, the atoms of diatomic molecules may exist separately, a dissociation taking place similar to that which is invariably found to occur in the case of chemical compounds under similar circumstances (see § 10). The ordinary hypothesis must therefore be regarded as simply expressing that under ordinary circumstances the atoms of diatomic molecules tend to unite in pairs to form chemical molecules.

According to § 8, it must therefore be assumed that the diatomic molecules of certain elements are less sensitive to the external influences of light and heat than the separate atoms, and that the internal energy of such a molecule is less than the sum of the internal energies of its two constituent atoms. Suppose that ξ is again determined by (2) and that $x_i = \alpha_i \cos 2\pi t/T$, then the quantities α_i must be determined from the equations (25) and (24). The internal energy of an atom will therefore be

$$E = \tfrac{1}{2}(m_1\alpha_1^2 + m_2\alpha_2^2 + \ . \ . \ . + m_{j+1}\alpha_{j+1}^2).$$

The energy of a second atom of the same substance under identical external conditions will have the same value. If the two atoms are placed in contact, the new values of x_i must be determined from (25), (26), and (27). In this case, however, we have $y_i = x_i$, $a_i = b_i$, $c_i = e_i$, $m_i = n_i$, so that (26) and (27) become identical, and (27) reduces to (24), with the distinction, however, that the quantities x_i now represent the displacements relatively to the common centre of gravity, instead of relatively to the centre of gravity of the single atom. It therefore follows that, approximately, the critical vibration periods of a molecule consisting of two similar atoms will be identical with those of the separate atoms.

Now the energy of the molecule is just double that of either of the constituent atoms, so that the union of the atoms cannot be due to a decrease in the internal energy. It is easy to understand, however, that when two atoms have once combined they

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[1] Bunsen's observations (*Poggendorff's Annalen*, vol. cxxviii.) on crystals of certain didymium salts show that there is actually a difference in the absorption of light in different directions.

[2] A chemical compound may therefore be regarded as produced in a manner similar to the variation of a species on the Darwinian theories of adaptation and natural selection. A species undergoes variation such as to increase its suitability to its environment. In exactly the same way two atoms will unite to form a molecule, when they thereby become less sensitive to the influence of their surroundings than they would be separately. Accidental conditions are of no more importance in determining the formation of chemical compounds, than the voluntary actions of individuals in determining the variation of a species.

[1] See B. A. Reports, 1884, 1885, and 1886.

will not separate again, except under special circumstances; but so far the fact that different gases behave differently in this respect remains unexplained. If two spherical bodies collide, they will remain in contact only if perfectly inelastic, otherwise they will fly off in opposite directions.

In the latter case the elastic forces are due to the displacement of the molecules of the spheres from their positions of equilibrium. If the colliding bodies are two of Thomson's atoms, similar elastic forces will be called into play by a displacement of their outer shells. If the mass m_1 of each of the outer shells is very large compared with that of the inner ones, the outer shells will remain nearly at rest after the collision, while the inner ones will be thrown into violent vibration; indeed it follows from (24) that x_1 will be very small. The atoms will therefore behave very nearly as if they were inelastic, and may remain long enough in contact to assume a new condition of equilibrium by uniting to form a single molecule. Exactly the reverse will happen if m_1 is small compared with the mass of the inner shells.

We must therefore assume that in diatomic chemical molecules the masses of the outer shells are very large compared to the sums of the masses of the interior shells, while in the monatomic molecules the masses of the outer shells are comparatively small.

We might now inquire why it is that in general more than two atoms do not unite in this manner. To which the answer is that the more complicated the structure of a molecule, the more easily will it be broken up by the impacts of other molecules. We must therefore assume that in the case of diatomic molecules the violence and frequency of the impacts, even under ordinary circumstances, are sufficient to break up any molecules which may be formed containing more than two atoms; while in the case of other elements, such as arsenic and phosphorus, the impacts are unable to break up the tetratomic molecules, even at the high temperature of vaporization.

In virtue of these considerations it appears that the formation of a chemical compound, such as hydric chloride, is not such a simple process as it was supposed to be in § 7. The impacts will frequently produce diatomic molecules of hydrogen and of chlorine respectively. The final condition of equilibrium will, however, be arrived at on the same principle as before—namely, that the molecules of hydric chloride are the least sensitive to the action of light. Tetratomic molecules of hydric chloride, will not be permanently formed, as the impacts, increased in violence and frequency by the heat developed, will break them up. Similar considerations apply to the formation of water.

The formation of these simple compounds is, therefore, accompanied by, and due to the simultaneous breaking up of the original diatomic molecules of the elements present.

Double decompositions will take place in an exactly similar manner, and considerations of the same kind apply to solid and liquid bodies, in which, however, the impacts will be very much less frequent.

We also see that the broadening of the bands in the spectrum of a gas, especially when due to a lowering of temperature, does not necessarily show that the gas is a compound, as it may be due to the union of previously dissociated similar atoms into molecules.

§ 10. *Dissociative Action of Light and Heat.*

The fact that the same compounds which are formed by the action of heat are again broken up when the temperature is further increased, and, indeed, the dissociation of every chemical compound at a sufficiently high temperature, is in apparent contradiction to the conclusions of § 8. In the case of compounds formed by the action of light it is quite possible that the internal energy due to the action of heat may be greater than that of the atoms at the same temperature. In general, it may be that when the two constants c_i (§ 1) combine to form one, the corresponding critical vibrations are only produced at a much higher temperature, and may then give rise to dissociation. Since, however, all compounds are dissociated at sufficiently high temperatures, there must be some other causes at work. We may suppose that in gases at very high temperatures the molecules are broken up simply by the violence of the impacts, and this process would be facilitated by the molecules not being spherical in form.

The dissociative action of light observed in certain cases cannot of course have a similar general explanation, and must not be attributed to special chemical properties of light of certain wave-lengths, but to the values of the internal constants of the molecules being of a kind specially favourable to such action. Thus, as the author points out, we are led to the point of view expressed by Lockyer,[1] as follows:—

"The causes which are given in the text-books, showing us the maxima of heat, light, and chemical action, are, I fancy, merely causes showing us, as it were, the absorption spectra of those substances by which the maxima have been determined—whether they be lamp-black, the coating of the retina, or salts of silver, and are really altogether independent of the nature of light."

§ 11. *Fluorescence.*

It has been pointed out in § 4 how critical vibrations may be excited in a molecule by external disturbances, causing the molecule to emit light of a certain wave-length. The disturbance was supposed to be due to the action of heat, but from what has gone before it is clear that they may be produced by ether vibrations if only the molecule or atom is very sensitive to light vibrations. For as soon as the impact of light waves of a certain (critical) vibration period has raised the internal energy of the molecule to its maximum value, the molecule itself—that is to say, its centre of gravity—will begin to execute vibrations; the different molecules will strike against one another, and the result of these encounters will be to produce vibrations of the other critical periods of the molecule, which will be different from the vibration period of the impinging light.

The substance will therefore emit rays different from those which have fallen upon it. As a matter of fact some substances having such special sensitiveness have been observed,[2] and are known as fluorescent substances. The phenomena of fluorescence must therefore be attributed to the absorption of light, as was pointed out by Stokes.

A fluorescent body is to be regarded as one in which the molecular constants c_i have such values that the corresponding light vibrations can be easily excited by external impulses. Fluorescent substances must, in agreement with Stokes's conclusions, be regarded as being exceptionally sensitive.

The theory does not lead to the law which has usually been asserted, that the emitted light must necessarily be of longer wave-length than the impinging light, and therefore the theory is not inconsistent with Lömmel's observations on naphthalin red.

Fluor-spar exhibits the phenomena of fluorescence to an exceptional degree. It may be that fluorine itself is exceptionally sensitive to the action of light, and that the formation of the mineral has not altogether destroyed this sensitiveness. If this be so, it would explain the impossibility of preventing fluorine from entering into combination with any substance with which it is in contact. G. W. DE TUNZELMANN.

(*To be continued.*)

THE FORESTRY SCHOOL IN SPAIN.

IN a Report to the Foreign Office which has just been published the British Ambassador at Madrid states that Mr. Gosling, First Secretary to the Embassy, has had the opportunity of studying the excellent School of Forestry established at the Escurial, and as great interest is now taken in forestal science in England, and as efforts are being made to establish a British National School of Forestry, he sends the information collected by Mr. Gosling at an institution which, he thinks, is well adapted as a type for a similar institution in England.

Forestal legislation in Spain dates as far back as the close of the fifteenth century—that is, in the reign of Ferdinand and Isabella—and there is reason to believe that reckless destruction of the rich forests was checked from time to time by Royal ordinances. At the close of the sixteenth century Madrid was surrounded by dense forests; in fact, the city arms—a bear climbing up a green tree—bear out the old chroniclers when they speak of the forests which lay around the city, which must have existed in the time of Charles V. So far is this from being the case at present that for the most part the districts around Madrid are treeless and unproductive, and as a consequence exposed to the furious mountain storms, and unsheltered in the scorching summer, whence comes the extreme unhealthi-

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[1] "Studies in Spectrum Analysis," p. 110.

[2] Thomson mentioned, "Lectures on Molecular Dynamics," p. 280, that his theory of absorption would account for the phenomena of fluorescence, but he did not follow up the subject.

ness for any person with a delicate constitution. While Spanish rule in South America carefully protected the forests from destruction, it permitted this to go on almost unchecked at home. Towards the end of the last century the great agrarian lawyer and reformer, Jovellanos, who was the first to call the attention of Spain to the disastrous effects which were being produced by the want of supervision of the forests, wrote a pamphlet entitled "Informe de la Sociedad economica de Madrid, al real y supremo Consejo de Castilla, en el expediente de ley agraria extendido por su individuo de numero Don Melchor Gaspar de Jovellanos à nombre de la Santa encargada de su formacion, y con arreglo à sus opiniones." This pamphlet paved the way for the present excellent system of forestry. Special ordinances were passed in the year 1835 for the foundation of a school of forest engineers, but at the time no practical steps were taken; but ten years later, when domestic troubles had to some extent passed away, the "Escuela especial de Ingenieros de Montes" (School of Forestry) was firmly established and was followed by the formation of a corps of forest engineers. The first School of Forestry was situated at Villaviciosa, not far from Madrid, and was under the control of Señor Bernardo de la Torre Rojas, who is still styled "el padre de la Escuela Española de Montes." In 1869 the school was transferred from Villaviciosa to the Escurial, part of which had been granted by the Government in the preceding year for that purpose. This institution is now under the direction of Señor Bragat y Viñals, and there are nine professors and three assistants under him, all of whom must have served five years on the staff of forest engineers. The annual salaries of these officers amount to £1400, and appear in the annual Budget of the Minister of "Fomento," which Department includes public works, industry and commerce, agriculture, public instruction. The total yearly cost of the school is £1700. The following are the subjects taught by the professors, each group having a professor: (1) forestal legislation; (2) political economy, forestal meteorology; (3) applied mechanics and forestal construction; (4) topography and geodesy; (5) chemistry, mineralogy, and geology (applied); (6) botany; (7) sylviculture, (8) zoology and forestal industries; (9) classification of forests and their valuation. The instruction is free, but the books and instruments are charged for. The vacation depends on circumstances. If the practical work is completed, the months of August and September are given; four days in December and three during the Carnival are given—that is, in all about nine weeks. The number of students is practically unlimited. The school is open to all who pass the preliminary examination—that is, to all who show proficiency in Spanish and Latin grammar, geography, and Spanish history, elements of natural history, of theoretical mechanics, geometry, and its relations to projections and perspective, physics, chemistry, lineal, topographical, and landscape drawing, and an elementary knowledge of French and German. Immediately on entrance to the school, particular attention is paid to topography, chemistry (practical), and mathematics (applied). The topography course includes the object of topography, and the difference between it and geodesy; the rules of triangulation and methods of demonstrating the physical characteristics of the ground under survey; chart and plan drawing; and an intimate knowledge of the use of the instruments used in forestal topography. The course in chemistry is very wide, including every detail of the applied science appertaining to botany, mineralogy, and sylviculture. In the school is a very fine collection of chemical apparatus and instruments, including those of Bunsen, Dupasquier, Gay-Lussac, Donovan, &c. Every kind of instrument required in applied mechanics is also here. There is a very good library of books attached to the school, comprising about 3000 volumes on mathematics and the physical sciences, natural history, language, literature, and history, arts and manufactures, &c. During the first year the studies are topography, differential and integral calculus, descriptive geometry, applied mathematics, and chemistry. In the second year the subjects are mechanics, geodesy, meteorology, climatology, construction, and drawing; in the third year, mineralogy and applied zoology, applied geology, botany, and sylviculture; in the fourth year, kilometry, scientific classification of forests, forest industries, law, and political economy. On the completion of this four years' course, the successful candidates are appointed to the staff of forest engineers. This corps consists of 3 general inspectors, 15 district inspectors, 40 chief engineers of the first class, 50 chief engineers of the second class, 60 second engineers of the first class, and 70 of the second class. There are also 25 assistants of the first class, 350 of the second class, and 420 foremen planters. The salaries of the six grades of engineers are respectively £500, £400, £300, £260, £200, £160, besides an active service allowance of £1 a day to inspectors, 16*s.* a day to chief engineers, and 12*s.* a day to the others. The country is divided into 46 forestal departments, the forest in each case being under the care of a chief engineer, but the inspecting officers reside in Madrid.

SCIENTIFIC SERIALS.

American Journal of Science, August.—History of the changes in the Mount Loa craters; Part 2, on Mokuaweoweo, or the summit crater (continued), by James D. Dana. The subjects here considered are (1) the times and time-intervals of eruptions and of summit illuminations or activity, with reference to periodicity, relations to seasons, variations in activity since 1843, and lastly the changes in the depth of the crater; (2) the ordinary activity within the summit crater; (3) causes of the ordinary movements within the crater. Among the general conclusions are the rejection of any law of periodicity, and the apparently established fact that the inland waters supplied by precipitation are the chief source of the vapours concerned in Hawaiian volcanic action. Then follows Part 3, dealing with the characteristics and causes of eruptions; metamorphism under volcanic action; the form of Mount Loa as a result of its eruptions; the relations of Kilauea to Mount Loa; lastly, general volcanic phenomena.—The Fayette County (Texas) meteorite, by J. E. Whitfield and G. P. Merrill. The specimen was found about ten years ago on the Colorado River near La Grange, Fayette County. It weighs about 146 kilogrammes, and analysis shows that the rocky portion consists essentially of olivine and enstatite with some pyrrhotite. It belongs to the class to which G. Rose has given the name of "chondrites," and its most striking feature is its fine and compact texture, exceeding that of any similar meteorite known to the authors.—Evidence of the fossil plants as to the age of the Potomac formation, by Lester F. Ward. From these researches it appears that no Jurassic species, but many strongly Jurassic types, occur. The Wealden furnishes the largest number of identical species, after which follow the Cenomanian and Urgonian. All these formations also yield many allied species, which, however, are most abundant in the Oolitic. Altogether the flora would appear to be decidedly Cretaceous, but probably not higher than the Wealden and Neocomian.—E. H. Hall describes some experiments carried on for over three years at Harvard College on the effect of magnetic force on the equipotential lines of an electric current; and Thomas M. Chathard gives the analyses of the waters of some Californian and other North American alkali lakes.

Mémoires de la Société d'Anthropologie, tome troisième (Paris, 1888).—This volume contains an exhaustive treatise by Dr. Nicolas on automatism in voluntary acts and movements. The author, who is an ardent opponent of the materialistic and atheistic views common to many of his scientific brethren, is especially anxious to call attention to questions such as those of which he here treats, and which have hitherto been little considered in France. The main conclusion that he draws from the accumulated mass of facts, which he has borrowed principally from the labours of British and German biologists, is that the superiority of an animal in the scale of being is determined by the degree of liberty which it enjoys in controlling reflex actions, and directing automatic reactions.—Contribution to the study of anomalies of the muscles, by M. Ledouble. The principal subjects here treated of are the variations in the iliac, costal, and spinal processes of the latissimus dorsi muscle.—Philosophy, considered from an anthropological point of view, by Dr. Fauvelle. Although the writer passes in review the various schools of philosophy which have sprung up in various periods of time, his purpose is rather to follow the gradual evolution of philosophic thought from the first appearance of man, than to recount its history. Pointing out that comparative anatomy and physiology teach us that intelligence depends directly on the number and degree of differentiation of the cerebral cellules, he asks whether we must assume that these have reached their utmost limits of development, or whether new manifestations of cerebral perfection may not be reserved for man? According to his views, religions of all forms, and speculative philosophy, have equally had the effect of impeding every kind of independent intellectual labour, and have thus in different parts of the universe and in different ages applied successive checks to cerebral evolution, which Dr. Fauvelle regards as identical with human progress.—On the hand and figure of native East Indians, by Dr. Mugnier. In this exhaustive article the author gives elaborate measurements based on his own observations of the maxima and minima and the means of every part of the hand specially, and of the body generally, in the six principal Asiatic races, with tables of comparative measurements of Europeans. From these it is seen that the absolute size of the hand among Asiatics is less than in Europeans, the Japanese approximating most closely to the estimates given for the latter, while the Malays exhibit the lowest maximum. In regard to stature, and relative proportions of figure, all Asiatics are inferior to Europeans, the Japanese presenting the greatest divergence, while the Arabs of Yemen approximate most nearly to the general means of European races.—An anthropological and ethnographic study of the kingdom of Cambodia, by Dr. E. Maurel. Shaded maps of the territorial divisions of Indo-China from the seventh century to the present time curiously illustrate the varying supremacy of Siamese, Laos, and Cambodian tribes in that portion of the Far East which lies between the China Sea and the Indian Ocean. The rapidity with which alluvial deposits are formed would seem to justify the author's assertion that the territories now known as Cochin-China and South Cambodia are of recent geological origin, and were possibly submerged till near the dawn of actual historical ages. Interesting information is supplied as to the effect on the land, and the habits and pursuits of the people, of the regular inundations to which the country is exposed by the overflow of the Mekong, the great river which, rising in East Tibet, flows southward till it divides into three branches in the heart of Cambodia, and ultimately forms the important inland sea of Toulé Sap, whose area exceeds 3000 kilometres before the return of the current temporarily diminishes its volume. The orography and the climatology of the district are carefully treated, but the materials seem still wanting for supplying us with any exact data as to the numbers and ethnic character of the population.—Platycnemia in man and the Anthropoda, by M. Manouvrier. After describing the actual anatomical characters of this peculiar lateral flattening of the tibial bone, the writer considers the grounds on which this condition has been regarded as a character of inferiority by which certain prehistoric and other ancient races would seem to show their affinity to the anthropomorpha. This opinion he absolutely rejects, and finally asserts, as the result of his comparative anatomical investigations of fossil and recent tibiæ, that platycnemia has existed and still exists among the most different human races, although it is of very rare occurrence among certain savage peoples, as the Negroes of Africa, and the Indians of California. He denies that it is a special simian characteristic, since, notwithstanding its frequent occurrence in the chimpanzee and gorilla, it does not present the same features in them as in man, and finally he believes that, even if it were originally transmitted from some arboreal anthropoid, it has been maintained simply by the activity of an essentially human function, its survival being most frequent among nations and tribes addicted to hunting and fishing, or compelled by sudden and great differences of elevation, or extreme inequalities of the surface, to make exertions in ascending and descending steep heights, by which the tibial bones are continuously and often violently exercised. Finally, platycnemia manifests itself only in the human and anthropoid adult, the young being free from it.

SOCIETIES AND ACADEMIES.

SYDNEY.

Royal Society of New South Wales, May 2.—Annual Meeting.—C. S. Wilkinson, Government Geologist, President, in the chair.—The report stated that twenty-four new members had been elected during the year, and the total number on the roll on April 30 was 482.—Dr. Michael Foster, F.R.S., Professor of Physiology, University of Cambridge, had been elected an honorary member.—During the year the Society held nine meetings, at which the following papers were read:—Presidential Address, by Christopher Rolleston, C.M.G.—Recent work on flying machines, by L. Hargrave.—Some N.S.W. tan-substances, Parts 1, 2, 3, and 4, by J. H. Maiden.—Notes on the experience of other countries in the administration of their water supply, by H. G. McKinney.—Notes on some inclusions observed in a specimen of the Queensland opal, by D. A. Porter.—The influence of bush fires in the distribution of species, by Rev. R. Collie.—Origin and mode of occurrence of gold-bearing veins and of the associated minerals, by Jonathan Seaver.—Results of observations of comets vi. and vii., 1886, at Windsor, N.S.W., by John Tebbutt.—Port Jackson silt beds, by F. B. Gipps.—On the presence of fusel oil in beer, by W. M. Hamlet.—Autographic instruments used in the development of flying machines, by Lawrence Hargrave.—The Medical Section held seven meetings, fourteen papers being read; the Sanitary Section four meetings, five papers read; and the Microscopical Section held eight meetings.—The Clarke Medal for the year 1888 had been awarded to the Rev. J. E. Tenison-Woods; the Society's bronze medal and money prize of £25 had been awarded to Mr. Jonathan Seaver for his paper on the origin and mode of occurrence of gold-bearing veins and of the associated minerals; and the Council has since issued the following list of subjects, with the offer of the medal and a prize of £25, for each of the best researches, if of sufficient merit; (to be sent in not later than May 1, 1888) anatomy and life-history of the Echidna and Platypus; anatomy and life-history of Mollusca peculiar to Australia; the chemical composition of the products from the so-called kerosene shale of New South Wales; (to be sent in not later than May 1, 1889) on the chemistry of the Australian gums and resins; on the aborigines of Australia; on the iron ore deposits of New South Wales; list of the marine fauna of Port Jackson, with descriptive notes as to habits, distribution, &c.; (to be sent in not later than May 1, 1890) influence of the Australian climate, general and local, in the development and modification of disease; on the silver ore deposits of New South Wales; on the occurrence of precious stones in New South Wales, with a description of the deposits in which they are found.—The Chairman read the Presidential Address, and the officers and Council were elected for the ensuing year.—A compressed air-engine for driving a flying machine was exhibited by Mr. L. Hargrave. The engine weighed only 2 lbs. 7 oz.; cylinder, $1\frac{5}{8}$ inch diameter; stroke, 2 inches. The receiver for the compressed air was 0·21 cubic feet capacity, made of $\frac{1}{16}$-inch steel, single riveted and brazed. The bursting pressure was 900 lbs., working pressure 500 lbs., and reduced pressure 900 lbs., per square inch. There would be 9200 foot-pounds available for work; this power would have to be expended in from half to three-quarters of a minute. The charged receiver weighed 6 lbs. 12 oz., wood and paper work about 2 lbs. A small Richards's indicator had been made for adjusting the piston-valve. The machine was intended for a flight of 200 yards.

June 6.—Sir Alfred Roberts, President, in the chair.—The Chairman announced that the Council had awarded the Society's medal and prize of £25 to the Rev. J. E. Tenison-Woods for his paper upon the anatomy and life-history of Mollusca peculiar to Australia.—The following papers were read:—Notes on some minerals and mineral localities in the northern districts of New South Wales, by D. A. Porter.—Forest destruction in New South Wales, and its effect on the flow of water in watercourses, and on the rainfall, by W. E. Abbott.—The increasing magnitude of η Argûs, by H. C. Russell, F.R.S.—On a simple plan of easing railway curves, by W. Shellshear.—Indigenous Australian forage plants (exclusive of grasses), including plants injurious to stock, by J. H. Maiden.

July 4.—Sir Alfred Roberts, President, in the chair.—A discussion took place upon Mr. W. E. Abbott's paper on forest destruction in New South Wales, and its effect on the flow of water in watercourses and on the rainfall, read at the preceding meeting. The general result of the discussion was to the effect that the destruction of forests had no appreciable effect on the rainfall.—The following papers were read:—On an improvement in anemometers, by H. C. Russell, F.R.S.—On the anatomy and life-history of Mollusca peculiar to Australia, by the Rev. J. E. Tenison-Woods, in which the author gave evidence as to the existence of eyes in the skulls of many Australian Mollusca.

PARIS.

Academy of Sciences, August 27.—M. Janssen, President, in the chair.—Observations relative to a previous communication on a general property of elastic solid bodies, by M. Maurice Lévy. The author's attention has been called by M. Boussinesq to the fact that the final formula of his note inserted in the *Comptes rendus* of August 13 is found in Prof. Betti's lectures on the theory of electricity. He consequently points out that the theorem, which forms the chief object of that note, must also be accredited to the same illustrious geometrician.—Observations of

Brooks's comet made at the Observatory of Algiers with the 0·50 m. telescope, by MM. Trépied, Sy, and Renaux. The observations are for the period from August 11 to August 15 inclusive. On the former date the brilliancy of the nucleus was about equal to that of a star of the tenth magnitude; diameter of nebulosity about 1′, with faint tail in the direction of the diurnal movement.—Observations of Faye's comet made at the Observatory of Nice, by M. Perrotin. These observations were made on August 11, 14, and 17.—On some experiments with the marine telephone, by M. A. Banaré. These experiments were carried out by order of the Minister of Marine, at Brest, by means of the apparatus to which the author has given the name of "hydrophone." Sounds emitted by various sonorous instruments, such as bells, whistles, and trumpets, were distinctly heard, that of a bell weighing 150 kilogrammes at a distance of 5200 metres. The experiment, with a ship under way also gave favourable results, and here also the ringing of a bell was clearly detected at a distance of 1400 metres simultaneously with the noise of the engine and screw of the tug.—On the remains and zoological affinities of *Testudo perpiniana*, a gigantic fossil turtle of the Perpignan Pliocene epoch, by M. P. Fischer. This magnificent specimen, discovered by M. A. Donnezan, and described by M. Ch. Depéret, has recently been acquired by the Palæontological Department of the Paris Museum. A comparative study of the remains (various parts of the carapace) leads to the conclusion that it must have been a gigantic species of a living African group (*Testudo pardalis*, *sulcata*). Its affinities with the gigantic turtles at present confined to the Aldabra Islands in the Indian Ocean, and the Galapagos in the Pacific, do not appear to have been established. Its relations with the Chersites of South Europe are also doubtful, so that it may be considered as a Pliocene survival in the south of France of an older land fauna of an African type. Its ancestors may perhaps be found amongst the large turtles discovered by M. Gaudry in the Mount Léberon beds, but which are known only by some fragments of the carapace.—The Secretary announced the death of Herr Rudolf Clausius, Corresponding Member of the Section for Mathematics, who died at Bonn on August 24.

BERLIN.

Physiological Society, August 3.—Prof. du Bois Reymond, President, in the chair.—Dr. A. König gave an account of researches which he had carried out, in conjunction with Dr. Brodhun, for the experimental testing of Fechner's psychophysical law in its relationship to the sense of sight. In the case of lights whose brightness varied between the limits $\frac{1}{200}$ and 200000 of the unit used, it was necessary to measure at six different points of the spectrum—that is to say, for six different kinds of monochromatic light—the minimum change of intensity which could be appreciated as a change at all. The experiments were carried out on the trichromatic eye of the speaker and the dichromatic eye of Dr. Brodhun. The observer sat in a dark chamber, into which the eye end of the observing telescope projected, and was able, by the rotation of a handle, to vary the relative brightness of the upper and lower half of the field of vision until the difference was just perceptible. The field of vision was illuminated by a double slit, through which the pure spectral red, orange, yellow, green, blue, or violet light could be admitted. The upper half of the slit was fixed, while the lower half could be widened or narrowed by the observer, and the amount of the alteration in width of the slit observed and recorded by an assistant. The source of light used was a gas-burner with zirconium light. Several thousand separate observations were made, from which it was found that the several colour-systems have no influence on the sensitiveness to differences in brightness of lights; the values obtained in the case of Dr. König's eye were identical with those obtained for Dr. Brodhun's. The shape of the curve which expressed the percentage relationship of the least possible perceptible change in intensity (expressed as an ordinate) to the intensity of the light itself (expressed as an abscissa) was the same for all the above six colours, differing only in the case of lights of minimal intensity. The curve was not a straight line for all intensities of light which were investigated, as it should be according to Fechner's law. In the case of the greatest and least intensities of light it was found that the smallest increase of intensity which was just perceptible was greater than in the case of medium intensities of light. With weak illumination the curve for lights of greater wave-length, such as red, orange, and yellow, was steeper than for lights of shorter wave-length. From this the speaker pointed out that the divergence in the curves of sensitiveness to varying intensities commences with that intensity at which, according to Purkinje, the subjective sensitiveness to lights of different kinds changes as their intensity is diminished, and in the same way as does the sensitiveness to varying intensities. The speaker concluded with some interesting considerations respecting the zero-point of the curve and the negative parts of the abscissæ.—Dr. Uhthoff gave an account of experiments made with a view to determining the amount of change in wave-length of spectral lights which are necessary to produce the least perceptible difference in their colour. The object of the experiments was to subject the results obtained by Drs. König and Dieterici to a renewed testing, in answer to objections which had been raised against them. Using the same apparatus, but a different method, he had confirmed their results. He also found, as Pearce had done in 1883, that the sensitiveness to change of colours is greatest for yellow and blue, and least for red and green.

BOOKS, PAMPHLETS, and SERIALS RECEIVED.

Beginner's Guide to Photography. 2nd edition (Perken).—A Bibliography of the Foraminifera from 1565 to 1888: C. D. Sherborn (Dulau).—Handbuch der Palæontologie, i. Abtheilung, Palæozoologie, iii. Band, 2 Liefg. (München).—Dr. H. G. Bronn's Klassen und Ordnungen des Thier-Reichs, Erster Band. Protozoa, 47, 48, u. 49, Liefg.: Dr. O. Bütschli (Leipzig).—A Text-book of Euclid's Elements. Parts 1 and 2, containing Books i.-vi.: H. S. Hall and F. H. Stevens (Macmillan).—Catalogue of the Fossil Reptilia and Amphibia in the British Museum (Natural History), Part 1: R. Lydekker (London).—Forschungsreise S.M.S *Gazelle*, iv. Theil, Botanik *Algen*: Prof. Dr. E. Askenasy (Berlin).—Journal of the Chemical Society, September (Gurney and Jackson.

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