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Creative Science and Industry.

WHILE it would be difficult to find a more brilliant example of the value of creative science to industry than the experimental investigations of Michael Faraday, there is a tendency to regard such contributions of science as exceptional. Even on this point it is pertinent to recall the verdict of Huxley in 1877 in urging the value of technical education: "If the nation could purchase a potential Watt, or Davy, or Faraday at the cost of a hundred thousand pounds down, he would be dirt-cheap at the money. . . . What these men did has produced untold millions of wealth in the narrowest economical sense of the word." In scientific research, quality counts supremely, but industry owes an incalculable debt to innumerable investigators engaged in scientific research directed by no other motive than the pursuit of knowledge.

At the moment, our interest is centred chiefly on the discovery of electromagnetic induction by Faraday and its consequences—electrical industry and its ramifications of the present day. The dyestuffs industry is, of course, the classical example of the relation of scientific research to industry, and it is worth recalling that this industry owes much to Faraday's discovery of benzene. Chemical industry abounds in similar examples. The manufacture of synthetic drugs may be traced back to such purely scientific work as Kolbe's synthesis of salicylic acid, and its expansion has invariably been connected with external scientific work like Knorr's discovery of antipyrine, Ehrlich's salvarsan, Fourneau's 309, Kraut's aspirin, Molle and Kleist's veronal, the isolation and synthesis of adrenaline, Banting and Best's isolation of insulin, Kendall's preparation of thryoxin and its brilliant synthesis by Harington. Pasteur's scientific investigations on yeast prompted by a brewing difficulty led him to the discovery of the whole theory of fermentation, the existence and action of bacteria, thence to the pasteurisation process, and finally to the discovery of the antitoxin of hydrophobia. These discoveries have not merely transformed the brewing, yeast, dairy, and cheese industries, but have also led to the rise of important new branches in the production of solvents such as acetone and butyl alcohol by fermentation. It would be difficult to measure the debt of either the fermentation industries or, indeed, of humanity to the scientific work of Pasteur, whose chance discoveries were so momentous because he was prepared.

When we turn, however, to such men as Ludwig Mond and Sir William Siemens, whose names are pre-eminently associated with industry, we find once more that the technical processes associated with them equally had their origins in scientific research. Long and patient investigations led to the discovery of nickel carbonyl, and the Siemens process was similarly the outcome of the scientific study of heat economy. The remarkable progress during the last two decades in the metallurgical industries is also based on purely scientific investigations—metals such as tungsten, molybdenum, vanadium being little more than curiosities for years after they were discovered.

Even in our older industries, scientific research has been responsible for revolutionary changes and developments. The art of soap-making has been transformed into a science. Sabatier's observation of the hydrogenating properties of finely divided nickel is the germ from which has developed the industrial hydrogenation or hardening of oils and fats and innumerable processes in almost every section of organic chemistry, including the Berginisation process for obtaining liquid fuels from coal. Scientific investigations on nitrocellulose and cellulose acetate and their solvents have led to the discovery of lacquers which have not only revolutionised the paint and varnish industry but have also made possible the enormous expansion of the automobile industry. The leather-substitute used extensively in upholstering motor cars has itself been produced by industry as an outcome of the scientific investigation of nitrated cellulose. Equally important is the development of the whole rayon industry from scientific investigations and observations in the same field of cellulose—Chardonnet's discovery of nitrocellulose silk and Cross and Bevan's viscose. The technical possibilities of any one of these discoveries were scarcely dreamed of by industry when the first investigation was commenced. Finally, the great fertiliser industry, including the fixation of atmospheric nitrogen, is essentially based on Liebig's discovery of the superphosphate process and Lawes and Gilbert's patient investigations on the effect of fertilisers on plant growth, and from Sir William Abney's measurements of the absorption of light by silver halide emulsions have came the advances of modern photography leading ultimately to the cinematograph industry.

We might continue the story by referring to other industries, and particularly to the electrical industries, which have been developed from Faraday's discoveries in electricity and magnetism and from Maxwell's and Hertz's investigations on electromagnetic waves, but limitations of space forbid. We have only discussed one aspect, however, of the contribution of science to industry. Equally important is the contribution which science makes in technique—the provision of new technical methods. The importance of this aspect of the service of science to industry was enforced on British industry in the early days of the War, when our dependence on continental firms for all classes of scientific instruments and glassware imposed a considerable handicap on the expansion of the munitions and other industries to meet the wartime demand. Without the instruments of precision for measurement and control of temperature, pressure, refractivity, and other properties, which have been evolved by purely scientific work, industrial development would have been much more laborious. Essentially modern advances in the measurement of high temperatures paved the way for the developments in the metallurgical industries. The development of the newer industries such as the radio industry, the manufacture of synthetic resins and rayon, is indeed a record of advance closely related to the utilisation not merely of scientific discoveries but also of scientific methods and scientific instruments for purposes of control.

The significance of such methods of X-ray analysis, ultra-violet light, hydrogen ion determination, thermionic valves for control purposes, including automatic control, in industry is only now being appreciated. In high-pressure reactions as well as low-pressure reactions and distillation in very high vacuum, science has provided industry with a whole range of new technique. Scientific work on the two forms of hydrogen has recently simplified the evaluation of industrial catalysts, while almost simultaneously the discovery of the selective properties of a copper chromite catalyst has enormously increased the possibilities of development in the industrial hydrogenation processes.

X-ray methods themselves provide a striking example of the reaction on industry of scientific technique. The recent application of X-ray methods to textile research has led to discoveries relating to the structure of cellulose, wool, and hair which throw new light on just those typical properties of wool which are of fundamental importance in manufacturing operations. As a result, a correct interpretation of the conditioning, dyeing, and other absorptive processes has been facilitated and a method elaborated for measuring the surface scale structure of the wool fibre which represents the first step towards placing the important technical operations of milling on a scientific foundation. In addition, the discoveries *suggest* an interpretation of the structure of cellulose which has a direct bearing on the mercerisation process.

While science has thus provided industry with instruments of precision and methods of attack on technical problems, an important contribution has also been made in the field of industrial health and safety. Until science had revealed the cause of yellow fever and the methods of its prevention and control, the resources of the engineer were inadequate to construct the Panama canal. Merely to walk through a modern dry battery or accumulator factory is to realise how medical science, by examining the causes of industrial poisoning, dusts, and their prevention, has revolutionised conditions of work. Hundreds of industrial processes operate smoothly every day because the scientific study of the properties of materials has enabled working conditions to be devised which satisfy stringent requirements of safety and efficiency.

In the past hundred years, industry has come to adopt not only the results of scientific discoveries but also scientific methods both for the development of new processes and for the control and improvement of existing processes or products. Individually or collectively, progressive industrial firms are now invariably associated with research departments or institutions in which the investigation of technical problems is systematically undertaken. Such technical research work will, however, usually be restricted either in the subject or the object of the work, and occasionally in both, leaving the investigator only freedom to select his methods. Without detracting from the merits of such work, which frequently compares in brilliancy with the ablest research conducted at the universities, the importance of fundamental scientific investigation, with its full freedom of aim, method, and materials, must not be overlooked. Great as has been the service of science to industry in improving or elaborating technique, it is from the fundamental discoveries of creative science that industry has derived its greatest benefits. While recent *rapprochements* between the universities and chemical industry indicate that this is fully realised, at any rate by chemical industry, economic reasons limit the possibilities of fundamental research being organised in industry. Authorities like Sir Harry McGowan and Dr. Levinstein have recently stressed the relations between industrial research and profits which influence the research policy of any sound industrial organisation, and Major F. A. Freeth has pointed out that the drift of modern life is against discovery. The vertical organisation of industry and of science restricts the exchange of technique, upon which probably the technique of discovery largely depends.

We are, however, as far to-day from a technique of discovery as when Francis Bacon wrote his "Novum Organum". A century of industrial progress testifies to the interdependence of science and industry. The great names on science's roll of honour are again and again to be found on the roll of the greatest benefactors of industry and of humanity. There is no truer touchstone of the sincerity of the tributes paid by industry and the State to the memory of Michael Faraday than the volume of support accorded to scientific research in Great Britain and elsewhere, and although we live in times of unprecedented depression, we must maintain the facilities, the institutions, and the technical and monetary equipment which will make it possible for others, though like Faraday of humble birth, to devote their splendid gifts unhindered to the service of mankind. The dynamo, broadcasting, the aeroplane, the cinematograph were not further beyond the imagination of Faraday's listeners in the Royal Institution than future developments from our own, if creative science continues to exert its fertilising influence on industry and the ties between discovery and service are knitted closer through the whole fabric of modern life.

Nansen's Last Journey.

Through the Caucasus to the Volga. By Fridtjof Nansen. Translated by G. C. Wheeler. Pp. 255+23 plates. (London: George Allen and Unwin, Ltd., 1931.) 12*s.* 6*d.* net.

IN 1925 Nansen visited Armenia on behalf of the League of Nations as one of a commission of five appointed to investigate the possibility of settling refugees from Turkish Armenia on the land. An earlier book, "Armenia and the Near East", was a record of the mission up to the end of its labours in Erivan. Nansen now reopens the story in the train as he leaves Armenia on July 2, 1925; but he does not get into the swing of his narrative until he reaches Tiflis. Here he opened negotiations with the Transcaucasian Federation of the three republics, Armenia, Georgia, and Azerbaidjan, with the view of raising a loan in order to carry out the proposals of the Commission—a project which, he tells us, later failed to mature.

Nansen made a short stay in Tiflis, of which he gives a brief description. He speaks of the manifold different races to be seen in its streets and of the varied and cosmopolitan origin of its merchandise. He notes the fact that coats of mail, swords, iron-bound shields, and helmets, " such as might well be relics from crusading days ", are still offered for sale and, what is more, are worn by the mountain tribes of the remote Caucasian valleys. What he found most striking, however, was the " great seriousness which wraps all these people and the little show there is of any kind of joy in life ". The War brought many changes. What was left undone towards the ruin of the country was completed by the suicidal economic policy of the early days of the independent republic ; and on top of that came the Bolshevik invasion. In two respects, however, Georgia appears to have suffered little change. Nansen records that someone who was to meet him on Wednesday at one o'clock turned up at twelve on the following day, apologising for coming a little late. Nor have the Georgians lost their gift for, and appreciation of, opera, drama, and the ballet. It is here stated that when the Soviet government wished to suppress the ballet on the ground of expense, the whole working-class population petitioned against this action. As a matter of fact, before the War the opera in Tiflis was the centre of social life and the opera house the second largest in the whole Russian Empire.

It is a pity that Nansen's stay in Tiflis was not prolonged. It would have been instructive to have had the reflections of his more extended observation of a people of such an individual and distinctive character in their present changed and economically strenuous conditions.

Nansen left Tiflis by car, motoring through the Caucasus range to Daghestan, where he was to stay with Samursky, the president of the Daghestan Republic, whom he had met in Moscow. The Vladihavkas road, by which he travelled through the only pass over the range, is the great military road laid down by the Russians for their final conquest of the Georgians at the beginning of the nineteenth century, and along which the Bolsheviks advanced when they overthrew the independent republics after the War. Apart from its natural difficulties, this journey offered Nansen possibilities of excitement in another form. In the previous year a passenger in the post-car had been stripped and robbed while the mail-carrier at his side had been shot dead, and only a few months before Nansen's trip another passenger had had a bullet through both his knees. As it fared, however, the assurance that the road was now safe from these little attentions from the mountain tribes was justified and the party arrived at Vladikavkas in safety.

The danger was very real, for in these remote valleys isolation has preserved the fierce and indomitable character of tribes who held off the Russian arms for so long. As Nansen loosely but graphically says, there are more people of different race and speaking different languages in this small area than in any other spot in the world.

Of the magnificent scenery which once made the Caucasus one of the holiday grounds of the Russian Empire and of the resources of the country the author has given a vivid word picture which he has supplemented with some striking photographs. He notes the remarkable proclivity of the Georgians for building magnificent churches on inaccessible heights, inclining to the explanation that it is an expression of the Persian doctrine that on the lofty holy mountains we are nearer to heaven and to God. He does not incline to the view of that delightful old seventeenth-century traveller, Chardin (whose account of the Georgians has much that is still true to-day), that they chose this situation for their churches " to get out of decorating them or keeping them up, as it was seldom that anyone went there " —a reason which he, at least, considered in full accord with the rest of their actions. He does not appear on the whole to have cared very much for the Georgians.

Nansen was much impressed by the number of different tribes he saw near the military road, and he describes their character and culture at some length. He was also much attracted by their folklore, from which he quotes freely, and institutes a comparison between Scandinavian and Ossete mythology and the paganism beneath the orthodoxy of the latter with its holy groves in which now stand the altar and church. Prometheus still lies chained to Kasbek, the highest peak of the Caucasus, still expiating his sin of stealing fire from heaven for the use of man. Now, the people of the mountains say, he is old, his hair is white, like his beard, which reaches his feet, and his whole body is covered with hair. He is glad to see anyone who comes to him, but anyone who tries to visit him more than once never returns. The old man asks after the present state of the land, whether the young people are taught in the school, and whether the wild fruit trees bear much fruit, and when he is told " no ", he is sorely afflicted.

Nansen was keenly interested in social, political, and economic conditions in Daghestan and discusses them at some length. Daghestan is now one of the Soviet Socialist Republics ; but in religion it is Moslem. The Soviet Government has shown itself unusually tender to this religion ; but, owing to the preponderance of Moslem schools and the administration of justice among Moslems by their own religious officials, apprehension is beginning to be felt lest Moslem influence should become too great. For this there is probably good ground. It makes the situation as interesting to outsiders as it is difficult for the authorities. For the people of Daghestan before the War were said by some, who professed to be competent to judge, to be the most fanatical of all Islam. This is probably an exaggeration; but a country in which thirty-two different languages are spoken by as many and more separate races, and where blood-feud and blood-revenge are widespread, is likely to afford any government a sufficiency of problems without the addition of religious intolerance. The amazing career of Schamyl, a Rob Roy of the Caucasus on a heroic scale, who held back the Russians in a guerrilla war for more than thirty years and only surrendered in 1856, had a fit setting. His career conveys a warning which the Soviet Government is scarcely likely to ignore.

It says much for Nansen's powers of observation and narrative that, after the incidents of the Caucasus, Astrakhan and the Volga with its sturgeon fisheries, though on a lower key, are no anticlimax. The author would surely never have allowed his book to appear without a map. There are few regions for which a map is more necessary.

All who read this book, which is a striking example of the author's powers of observation and quickness in seizing the essentials of a situation, will feel the inevitable pang of regret that this acute and sympathetic intellect will travel no more.

Chemistry through the Ages.

Makers of Chemistry. By Eric John Holmyard. Pp. xvi + 314. (Oxford: Clarendon Press; London: Oxford University Press, 1931.) 7*s*. 6*d*. net.

MANY efforts have been made to assign an origin to alchemy. In less critical and sophisticated ages than ours, individual founders were sought: for example, in Thoth or Hermes; in Muhammad or the Caliph Ali; in Aristotle, Plato, Pythagoras, or Democritus; and in the patriarchs. Thus, Moses, from his convincing manipulation of the golden calf, was elected a member of "this strange chemical society"; Miriam, his sister, was added on account of her supposed invention of the water-bath; Tubal-Cain was welcomed as the metallurgical expert; Cleopatra, a second and rather disturbing woman member, was elected in recognition of her early work on calcium acetate; Jason was admitted as the first gold-maker; Hermes evidently troubled the publication committee with his 36,000 original contributions to chemical literature; "finally", as Dr. Holmyard remarks, "the *Song of Solomon* is an alchemical treatise, and chemistry is so called because it was invented by Noah's son Shem or Chem"! According to this intriguing conceit, Shem may have fitted up the first chemical laboratory in the Ark!

In recent years it has been suggested that alchemy arose in China from the philosophy of Taoism. Dr. Holmyard, however, quotes with approval the belief of von Lippmann, "the greatest living historian of chemistry", that alchemy proper reached China from the west in the eighth century: "in A.D. 714 the first Arab ships dropped anchor at Kanton, and thereafter trade developed with amazing rapidity". Dr. Holmyard casts his vote for "the probable truth of the tradition that chemistry first saw the light in the laboratories of Egyptian priests". Later, at Alexandria, Egyptian practice made effective contact with Greek scientific thought; Greek knowledge and theories were transmitted in turn to Islam; fresh material came in from surrounding countries, including perhaps even India and China; and eventually the accumulated knowledge of the Muslim chemists was disseminated throughout western Europe.

The tenor of these comments will perhaps suggest that Dr. Holmyard's "Makers of Chemistry" is something more than a series of biographical sketches of eminent chemists, such as he presented in his earlier work on "The Great Chemists". The book under notice is, indeed, a history of 'the noble science'; further, it is decidedly the best and brightest of the short histories of chemistry with which the present reviewer is acquainted. A novel point, which strikes the reader at the outset, is that the author has abandoned the customary division into chapters for a more fluid arrangement in a series of 58 sections, of which the following succession (Nos. 12 to 17) is illustrative: neo-Platonism, the fusion of practice with speculation, Zosimos the Panopolitan, a retrospect, the rise of Islam, the origins of alchemy in Islam. This device, blended with a skilful selection of the material, has resulted in a smoothly flowing narrative, seasoned with spirit and colour, which holds the attention from beginning to end. Indeed, it occurs to us that the professional teacher of chemistry (and even the professional student, if the term be admissible) may object that the treatment is too delicate, and that a subject which has so often been handled with a ponderosity proportionate to its importance should not be turned into a light and graceful similitude of a historical novel.

It must not be imagined, however, that Dr. Holmyard has reached so pleasing a result by shirking the primary duties of the historian. On the contrary, the weighing of evidence, the appraising of achievement, the portrayal of personality, the isolation of the salient features of an age, have all been undertaken in a manner worthy of the high reputation of the author. If he relaxes at all from his attitude of rigid and impersonal impartiality, it is when he deals with those former Cinderellas of historical chemistry—the Muslim chemists and the phlogiston theory. Thus, our author says of Razi that he " must be accepted as one of the most remarkable seekers after knowledge that the world has ever seen . . . with the possible exception of his acknowledged master, Jabir, Razi was the most noteworthy intellectual follower of the Greek philosophers that mankind produced for 1900 years after the death of Aristotle ". And here is his eloquent farewell to phlogiston :

" As Priestley's splendid but lonely figure disappears over the horizon, the old theory vanishes for ever. It was a great and brilliant theory, and served chemistry well : the reader will therefore feel a peculiar pleasure in learning that the victors always spoke of it with respect. One of them truly remarked that ' it made chemistry a new science by the precision of its luminous ideas ', and that its simple and easy principles had long been a compass to guide the path of each and every chemist."

Many chemists, however, will continue to hold that although the phlogiston theory—that ' veritable Proteus ' of Lavoisier, which changed its form at every instant—to some extent co-ordinated facts which might otherwise have remained in isolation, yet in the main the notable chemical discoveries of the phlogiston period were made in spite of the theory rather than as a consequence of it.

Roger Bacon is characterised as the epitome of his age rather than as a thinker in advance of it. Paracelsus's chief merit " lies in his emphatic opinion as to the aim of chemistry. . . . The honourable task of the age of iatrochemistry . . . that he inaugurated was to make the way clear for a reasonable medicine ; but it did more—it made the way clear also for a reasonable chemistry." Later, we read of Joseph Black that he " is correctly regarded as one of the greatest chemists of one of the most fruitful periods of chemistry, and his fame rests upon impregnable foundations ".

In discussing the Greek atomists, Dr. Holmyard wisely remarks that " it is fatally easy to read into the views of bygone scientists ideas of a later period ". Thus the superficial resemblance between the classical and modern theories of atomism " very largely vanishes in the light of close inspection ". In other words, each age has its own point of view, which the successful historian must learn to assimilate and understand. " Although Mayow appreciated the necessity of air for combustion, and the similarity between combustion in air and deflagration in nitre, he had no real conception of the true nature of burning or of the composition of the air."

The presentation of the chemical story is enhanced by the author's knack of providing it at intervals with a thumb-nail suggestion of its general historical setting. There is a wealth of illustrations, admirably selected and reproduced. The text, moreover, abounds in quotations from original sources ; these are so illuminating that the chemical reader will possibly regret the omission of the exact references which would allow him to identify them in the originals. Of errors in detail we notice surprisingly few in a work of this amplitude, but it may be remarked that van 't Hoff's space theory (p. 238) dates from 1874, and that it would be preferable to include oxygen in referring to the elementary composition of organic dyes (p. 274).

In concluding, one cannot do better than quote the following reflections upon the position of chemistry a hundred years ago and now :

" The ' makers of chemistry ' — those who fashioned it into the science as we know it—had accomplished their work, and a chemist of 1831 would feel more at home with the chemistry of 1931 than with that of 1781. True, he would be at first bewildered by the multitudes of new compounds, new elements, new reactions, new applications, but he would find the oxygen theory still reigning, the name of Dalton in present reverence, and Avogadro's hypothesis in universal currency. After the first amazement had evaporated he would realise that the basic theories of modern chemistry were the basic theories of his own day ; he would find expansion, extension, modification, but no such revolution as that which was witnessed by the closing years of the eighteenth century. The world has produced chemists of scintillating genius in the nineteenth and twentieth centuries, but their work, marvellous though it be, is but a working out of the principles laid down by Lavoisier, Dalton, and Avogadro."

JOHN READ.

Short Reviews.

Textbook of Quantitative Analysis. By Prof. William Thomas Hall. Pp. vii + 279. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1930.) 12*s.* 6*d.* net.

THIS book sets out in detail a course in analytical chemistry for the more advanced grades of intermediate students, who are likely to proceed to a final course in some branch of chemistry. It is based largely on Treadwell and Hall's well-known work, and is complete for the purpose in view so far as inorganic analysis is desired. An introductory course of organic analysis might, we think, have been included with advantage, even at a sacrifice of some of the more specialised portions such as the chapter on steel analysis and tungsten and titanium in ores. Prof. Hall takes the line that it is more advantageous for the student to begin analytical chemistry with volumetric analysis, on the ground that the student is likely to obtain a better view of the subject. This may well be the result in practice, for a volumetric process may be a far more searching test than a gravimetric. A feature of this work is the attention devoted to potentiometric methods. The chapter assigned to this is necessarily a short one in the circumstances, but is nevertheless a desirable addition to a book of more or less elementary character. The volume is free from printing errors, is well got up, and may be commended for its general utility as an intermediate textbook of analytical chemistry.

J. J. F.

La mesure des rayons de courbure des surfaces sphériques employées en optique. Par Albert Arnulf. Pp. 179. (Paris: Éditions de la *Revue d'Optique théorique et instrumentale*, 1930.)

THIS monograph by the director of practical work in the Institute of Optics at Paris gives an excellent account of the theory and practice of the measurement of the radii of spherical surfaces used in optics. The first part deals briefly with the ordinary and dihedral spherometers, their use and errors. The second part, about two-thirds of the book, gives a full account of the method of the dihedron of G. Burch as developed by Fabry, both for workshop and laboratory use, of the method of tangent spheres invented by Fabry, and of interference methods as practised in the laboratory of the Institute of Optics. The remainder of the book deals fully with the autocollimation methods, due originally to Guild, improved by Prytz, and perfected in the Institute, and also gives an account of the various pieces of apparatus built for carrying out these methods.

The book is well illustrated by diagrams and drawings of the apparatus described, and freely supplied with tables giving the results of laboratory experiments and the errors incurred in the various methods. It is extraordinarily complete for its size, and will no doubt prove of the greatest use to those engaged in the measurements indicated and in the construction of the optical apparatus needed.

Faraday. By E. W. Ashcroft. Pp. 134. (London: The British Electrical and Allied Manufacturers Association, 1931.) 7*s.* 6*d.* net.

WITH the forthcoming celebrations of the centenary of the discovery, on Aug. 29, 1831, by Michael Faraday of electromagnetic induction, the interest of scientific workers and of the general public will turn towards the life-story of this remarkable man. His friend and contemporary, Dr. Bence Jones, published a biography, but the time has now come when we can appreciate better the permanent value of Faraday's life and work. Early this year, Mr. Rollo Appleyard issued a brief 'life', and Mr. E. W. Ashcroft has now produced an equally brief survey but of a different type; whereas Mr. Appleyard gave us an intimate view of Faraday, Mr. Ashcroft deals rather with broad aspects of his work and philosophy. He takes successive periods in Faraday's career and endeavours to trace from his writings and from those of his contemporaries, both British and foreign, the growth of his character and work.

As a book, we may criticise the lack of headings to the twenty short chapters and the absence of an index, but we prefer to regard it as an inspiring little souvenir of a great but very human man, whose work marks the inception of an important stage in the progress of civilisation.

Epidemiological Essays. By Dr. F. G. Crookshank. Pp. ix + 136. (London: Kegan Paul and Co., Ltd., 1930.) 7*s.* 6*d.* net.

THIS little book, by a well-known consultant physician interested in epidemiology, consists of ten papers which, with the exception of the essay entitled "Why Times Flies", contributed to *Psyche*, have all been previously published in various medical journals. It may be doubted if some of the papers included were worth saving from the well-merited oblivion which enshrouds most contributions to the medical press; but those interested in the history of medicine and epidemiology are advised to read the essay on the "Trousse-Galants" of 1528–29 and 1545–46, a mysterious disease which seems to have been a severe form of influenza, and that entitled "Some Problems of Influenza", in which the author discusses the periodicity of the disease and the correlation between influenzal prevalences and cosmic and telluric influences.

Introduction to Human Parasitology. By Prof. Asa C. Chandler. Fourth edition, rewritten and enlarged, superseding "Animal Parasites and Human Diseases". Pp. xiv + 655. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1930.) 25*s.* net.

THIS volume is an extended form of an earlier book which was intended for students and the lay public. This larger edition should be more useful to students of biological and medical sciences where an intensive study is not indicated. Its presentation is clear and readable. A short, incomplete account of filterable viruses is included with protozoa, helminths, and arthropods. Only animal parasites are dealt with.

Modern Diving Devices.

By Capt. G. C. C. Damant, C.B.E.

The rubber diving dress evolved by Siebe a hundred years ago extended the useful range of human activities to rather more than a hundred feet below the surface of the sea, and for several years engineers and physiologists have been striving in their respective spheres to double or treble this working depth. Much progress has been made, and as an example of the most advanced methods now in use we reproduce, by courtesy of Messrs. Siebe, Gorman and Co., Ltd., two illustrations (Fig. 1) of the Davis submersible decompression chamber already described in these columns (Nature, March 15, p. 415; 1930) and to the British Association at its Bristol meeting last year. The diver on finishing his work ascends not to the salvage ship but to this chamber, and, clambering in, finds an attendant waiting to divest him of the helmet and lead weights; the two men close the bottom door, and the chamber, retaining air at any desired pressure, is hoisted on board the salvage ship, which is then free to manœuvre or explode blasting charges while the diver is being slowly decompressed. Within his range the rubber-suited diver will always be supreme, but for objectives still beyond his reach another system is being developed.

Beebe and Barton (*Bulletin New York Zoological Society*, Nov.-Dec. 1930; see also Nature, **126**, p. 220, Aug. 9, 1930), wishing to investigate life in the ocean at far greater depths than man had ever attained, adopted a method of admirable simplicity which H. G. Wells had foreseen in one of his early short stories. They constructed a spherical observation chamber (Fig. 2) capable of withstanding the external hydrostatic pressure of 2000 feet of water, furnished it with quartz windows, a telephone, simple apparatus (including two palm leaf fans) for renewing the air vitiated by respiration, and in it they were eventually lowered to a depth of 1400 feet in the sea off Bermuda, where many interesting observations were made. Their 'bathysphere' was a single steel casting 4 ft. 9 in. in diameter and $1\frac{1}{2}$ in. thick; it weighed $2\frac{1}{5}$ tons in air and $\frac{7}{8}$ of a ton when submerged. Beebe, who with his companion spent $1\frac{1}{2}$ hours in it on his principal descent, seems to have been quite comfortable, and writes, "I never realised how much room there was in a sphere four and a half feet in diameter". He found that blackening the interior made it easier to distinguish objects in the dimly lit waters outside, and that something warm and dry to sit on should by no means be forgotten. Since the adventurers were breathing air at atmospheric pressure, no question of compressed air illness arose.

To combine the flexibility of Siebe's dress with the protecting rigidity of Beebe's sphere has been a dream of enthusiasts for at least fifty years, and in 1923 Neufeldt and Kuhnke in Germany produced what at last seemed to be its practical realisation. Their steel dress, nicknamed 'The Iron Man', weighs about 800 lb. in air and has exquisitely constructed joints, watertight yet capable of movement at a depth of 500 feet under an external hydrostatic pressure of 220 lb. per square inch. The diver breathes air at atmospheric pressure, the necessities of respiration being provided for as in the bathysphere. The mechanical tongs in which the arms terminate are well seen in Fig. 3, as well as the telephone cable and steel wire by which the apparatus is raised and lowered.

The inventors soon gave ample demonstration at sea that their apparatus enabled men to descend 400 feet deep in safety, but technical opinion in Great Britain remained unsatisfied that the limbs could be moved with sufficient freedom and the tongs manipulated with sufficient accuracy to do much useful work. However, the Italian salvage company, 'Sorima', of Genoa, took up the invention and exploited it with extraordinary skill and energy in salving the cargoes of ships sunk at great depths during the War. Their remarkable successes, culminating in the location of the famous wreck of the *Egypt* off Ushant, are worthily described in a recent book,[1] the writer of which combines the shrewdest observation with vivid and witty descriptive powers, so that it will be read with lively pleasure by salvage engineers as well as the general public. The former will find it significant that in the hands of the Italian experts the original iron man has undergone a process of involution. At first there were twelve joints, three to each limb; next, the total number of joints was reduced to six; and finally the jointed appendages were cast off altogether, leaving the diver enclosed in a limbless rigid steel shell, where he becomes, as Scott says, "merely the directing brain of the salvage ship, which does its work by machinery under his control".

A limbed suit is still held in reserve, but one infers that, after years of experience, those best qualified to judge have found that the amount of work that can be done by this sort of apparatus does not justify its cost and complication. The observation chamber on which the Sorima now relies differs externally from the bathysphere in being of tapered cylindrical form, and, as a protection in the hurly-burly of salvage work, possessing a buoyancy chamber by which the occupant can cause it to float to the surface in case of breakage of the supporting cable.

It is odd that such a simple method, and one requiring so little strength or skill in the diver, has not been used before; often it is desirable for engineers to inspect submerged structures, and many of them, from a sense of duty, have acquired enough of the technique of the rubber suit to be able to go under water, but it is very difficult for anyone not thoroughly practised in diving to make a critical inspection: tides sway the tyro about,

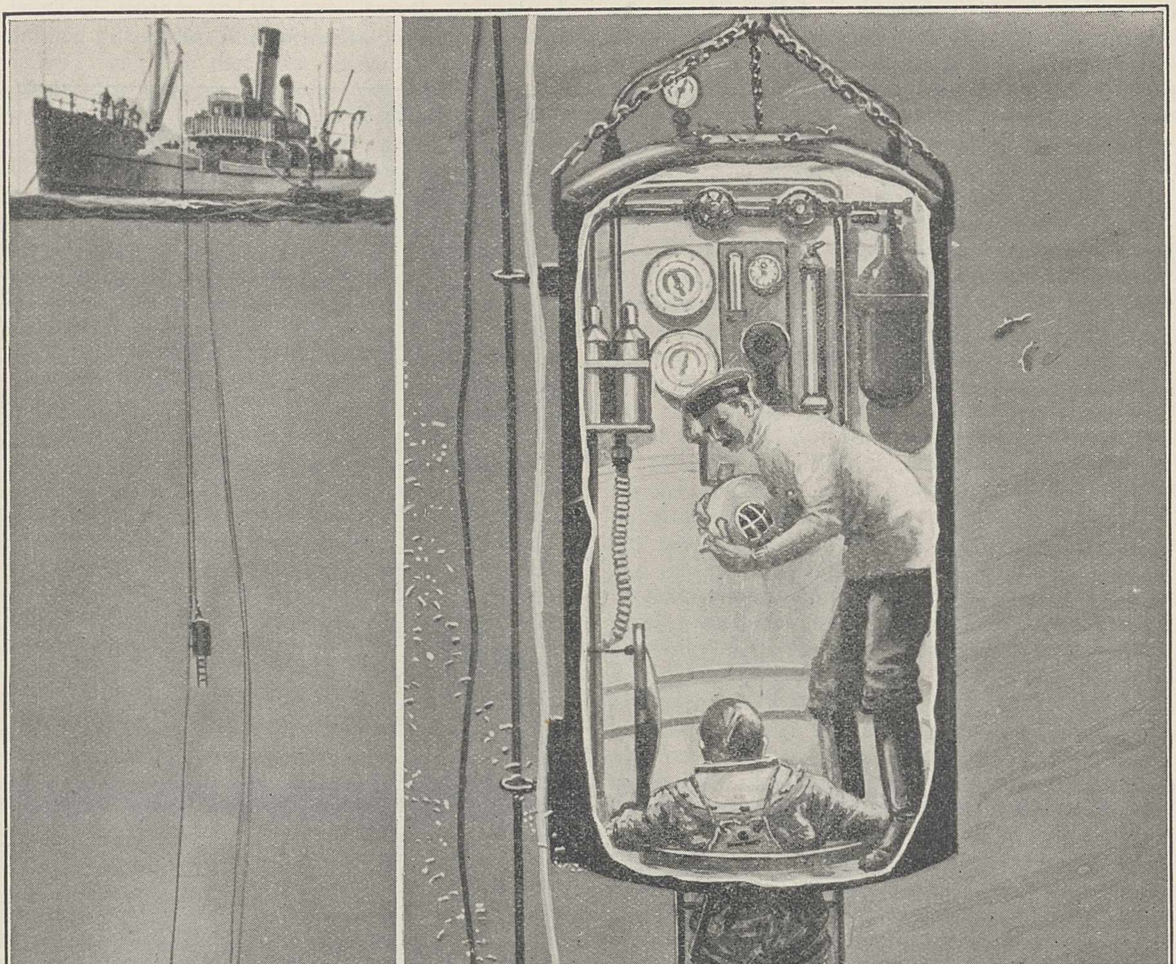


FIG. 1.—The Davis submersible decompression chamber. On the left, the chamber is slung in mid-water ready for the diver's ascent. On the right, the diver is entering the decompression chamber, which, until the lower door is closed, acts like a diving bell. The attendant has removed the diver's helmet and disconnected his air-pipe and breast rope.

he flounders and, stirring up the mud, obscures his own vision, his breathing is laboured and the discomfort so great that judgment is apt to be hasty; moreover, for elderly men the thing is impossible. The same man in a suitable observation chamber could be travelled by overhead tackle from one end of the work to the other without the least exertion. Beebe was surprised to find what misleading information his nets had been giving about the distribution of the bathypelagic creatures, and it seems certain that under-water observation will sooner or later be used in solving practical fishery problems; it is to be hoped that Great Britain, which used to lead the world in diving, will not be the last to divert some of her marine biologists from determining salinities and measuring herrings to going under water and watching the reactions of fish to the baits on a long line, or even to being towed along in the mouth of a trawl to see what proportion of fish dodge it and how they may be circumvented.

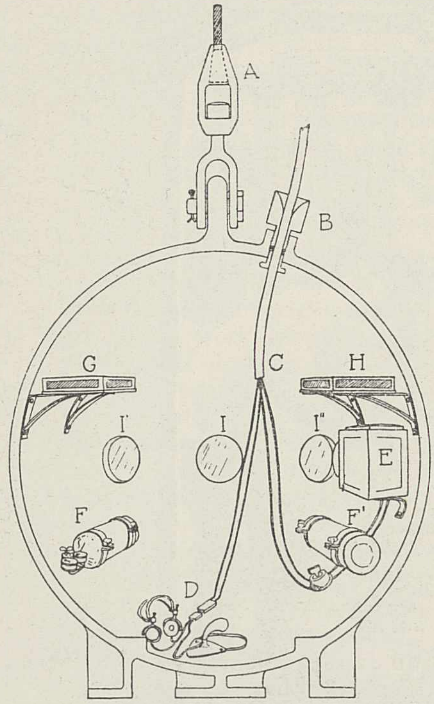


FIG. 2.—Section of the bathysphere. A, swivel for attaching cable to sphere. B, stuffing box through which electric cable enters sphere. C, electric cable, containing two wires for the telephone circuit and two for the electric lights. D, telephone. E, searchlight with beam focused through window I″. F, oxygen tank ready for use with valve attached—one dial showed the amount of oxygen remaining in the tank, the other the rate of discharge. F′, reserve oxygen tank. G, tray containing soda lime for absorbing carbon dioxide. H, tray containing calcium chloride for absorbing moisture. I, main observation window, 6 in. in diameter. I′ and I″, windows for searchlights. The windows were discs of fused quartz 3 in. thick and 8 in. in diameter.—From *Bull. New York Zoo. Soc.*, vol. 33, No. 6. By courtesy of Mr. William Beebe.

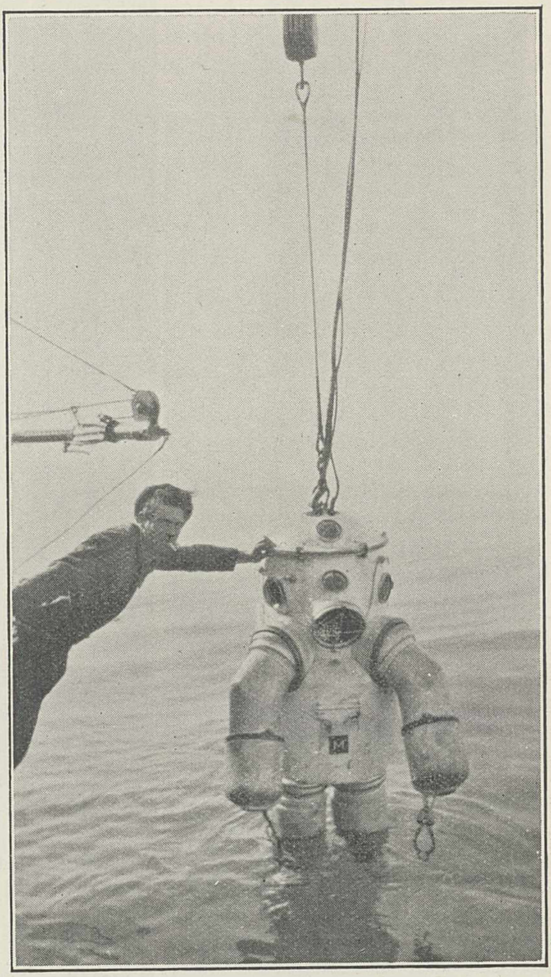


FIG. 3.—Neufeldt and Kuhnke's 'iron man' articulated shell.

[1] Seventy Fathoms Deep: with the Divers of the Salvage Ship *Artiglio*. By David Scott. Pp. 288+32 plates. (London: Faber and Faber, Ltd., 1931.) 12*s*. 6*d*. net.

Diet and Disease.

REFERENCE has already been made in these columns to certain recent dietary surveys[1, 2]. From such researches it is possible to enlarge our knowledge of the types of diet which different peoples or individuals may find adequate, to point out in what respects diets in common use may fail to satisfy accepted standards, in certain cases to correlate prevalent diseases with a particular type of diet and, by means of additions to the food supply, to confirm the results of the survey and indicate how the diet may most simply be improved. A recent report by Orr and Gilks is of great interest, since the investigators find a marked correlation between diet and physique and general health.[3]

The survey was carried out on two tribes living in Kenya, the A-Kikuyu, who are agriculturists, and the Masai, who are pastoralists. The Kikuyu diet consists chiefly of cereals (maize or millet), tubers, plantains, legumes, and green leaves. Only the women eat green leaves in any quantity; moreover, the consumption of edible earths (salt) is almost confined to them and children up to five years of age. Analysis of the dishes in common use showed that the diet was probably adequate in calories, protein and phosphorus, but low in fat for both sexes. The intake of calcium by the men was definitely subnormal, and probably that of sodium also; the women obtained more of these elements from the green leaves and salt consumed, and their intake of them was probably adequate: some of the edible earths eaten also supplied additional iron.

In contrast to the Akikuyu, the Masai live chiefly on meat, milk, and blood, with small amounts of cereals or fruit. The milk is richer in protein, fat and sugar, than English milk, but poorer in all inorganic constituents except calcium. The diet supplies a large excess of protein and fat, and a liberal supply of mineral elements, but is low in carbohydrate, cellulose, and other indigestible residues. The diet of the women was less extreme than that of the men and approached in composition that of the Kikuyu women.

Physical measurements showed that the Masai men were 5 in. taller and 23 lb. heavier on the average than the Kikuyu men, and the women 3 in. taller and 27 lb. heavier than the Kikuyu women. The Masai are typically larger in the chest and smaller in the abdomen than the Kikuyu. Dynamometer readings showed that the Masai men can exert a hand pressure 30 lb. greater than the Kikuyu; the latter, in fact, are only as strong as the Masai women, but their maximum pressure is about 10 lb. greater than that of their own women.

The incidence of disease was found to be very different in the two tribes. Among the Kikuyu children bone deformities, especially those of late rickets, dental defects, and anæmia were common, but relatively uncommon among the Masai. The incidence of enlarged tonsils and cervical adenitis was the same in both tribes, occurring in about half of the children examined. In the case of the adults, respiratory infections and ulcers were common among the Kikuyu, intestinal stasis and arthritis among the Masai. The Kikuyu women appeared to be less susceptible to disease than the men and were generally in better physical condition.

Some experiments were carried out on native prisoners, on hospital and prison diets, with the object of confirming the inadequacy of the native dietaries, by making additions to the diets and noting any improvements in the retention of different elements or in the composition of the blood. The diets were considered to be inadequate in calcium, and possibly some other inorganic constituents, and in vitamins A and D. The salt supplement was given as a mixture made up to supply in the daily dose approximately the amount of minerals present in 1 pint of milk; the vitamins were supplied in cod liver oil. In adult Kikuyu, it was found that the minerals, especially when given with cod liver oil, increased the calcium retention and also raised the level of the blood calcium, which is lower than that of Europeans at home or in Kenya. With growing Masai boys, it was found that a milk supplement was the most effective in increasing the weight and the calcium retention. The mineral mixture, calcium carbonate and bone flour, also increased the retention of calcium, but cod liver oil had little effect: it appears, therefore, that the chief deficiency in the diets is that of calcium. Bone flour also increased the retention of phosphorus. It was also found that a reformatory diet of maize, potatoes, and beans with ghee and salt did not permit of maximum growth; milk, maize and bone flour and maize supplements increased the growth rate of the boys, milk being the most effective. The diet appeared to be low in energy value as well as in calcium.

Tropical ulcer is common among the Kikuyu but comparatively rare among the Masai. Its incidence could not be correlated with the presence of malaria, syphilis, or intestinal parasites. Although slight injuries appear to precipitate its development, it is difficult to believe that they are the sole cause. The number of cases increases at the end of the dry season. Examination of the blood disclosed the fact that the inorganic phosphorus was very definitely raised in cases of ulcer as compared with other natives or Europeans in Kenya; the serum calcium was about the same in all natives and below the European level. A similar change in the direction of high phosphorus and low calcium occurs in animals on diets containing an excess of the former but deficient in the latter, suggesting that the abnormal ratio between these elements in the native diet is responsible for the change in the composition of the blood; the very high level of the blood phosphorus in ulcer cases, however, is not explained. The evidence certainly suggests that diet plays a large part in the ætiology of ulcer, presumably by decreasing the patient's resistance to trauma. No dramatic healing of ulcers was however produced when additions were made to the diet, although it appeared that they healed more quickly as the patient's general condition improved.

The observers conclude their survey with suggestions for the improvement of the diet of the tribes; both should consume more green vegetables, and the Kikuyu should also drink milk. The preliminary step would be a general improvement in agriculture and animal husbandry, especially among the Kikuyu.

The study is a striking illustration of the fact that man does not invariably select for himself a suitable dietary: it discloses that the incidence of disease among natives may be higher than among more civilised nations, which nevertheless consume 'artificial' rather than 'natural' foodstuffs. Finally, from the varying incidence of different diseases among the two tribes, it suggests that similar diseases among civilised peoples may also have a fundamental dietetic basis.

[1] Nature, Vol. 126, p. 963; 1930.
[2] Nature, Vol. 127, p. 897; 1931.
[3] "Studies of Nutrition: The Physique and Health of Two African Tribes". By J. B. Orr and J. L. Gilks (for the Dietetics Committee of the Economic Advisory Council). Medical Research Council. Special Report Series, No. 155. (London: H.M. Stationery Office, 1931.) 2s. net.

The Faraday and British Association Centenaries.

THE Royal Institution, the Institution of Electrical Engineers, and the British Association have recently issued programmes of the various events arranged in connexion with the Faraday centenary celebrations and the British Association centenary meetings, being held in London in September. From these, it will be seen that the Faraday centenary celebrations will begin with a reception of the delegates in the Royal Institution on Sept. 21 and conclude with the closing of the Faraday Exhibition on Oct. 3, while the meetings of the British Association will extend over the period Sept. 23–30.

The principal events of the Faraday celebrations will take place, with certain exceptions, on Sept. 21–23. At 11.30 A.M., Sept. 21, an informal meeting will be held in the lecture theatre of the Royal Institution, when an explanation of the programme will be given in English, French, and German, and at 3 P.M. the delegates to the celebrations will be received in the lecture theatre by the president and managers of the Institution. The Faraday commemorative meeting will be held that evening at 8 P.M., in Queen's Hall, Langham Place. W.1. Short speeches will be made by distinguished representatives of institutions in various parts of the world. Music will be given by the Symphony Orchestra of the British Broadcasting Corporation, under the direction of Sir Henry Wood, and the proceedings will be broadcast.

The proceedings of Sept. 22 will begin at 10.30 with a conference of the Institution of Electrical Engineers, to be held at Kingsway Hall, Kingsway, W.C.2. Speakers will include Mr. C. C. Paterson, (president), Mr. Ll. B. Atkinson, Miss C. Haslett, Mr. J. S. Highfield, Sir Oliver Lodge, and Sir Josiah Stamp, the subject for the conference being " The Place of Electricity in the Production and Utilization of Power, and in Transport, Communications, and the Household ". On that evening, at 8.30, conversaziones will be held by both the Royal Institution and the Institution of Electrical Engineers, the conversazione of the latter taking place at the Albert Hall, thus enabling the guests to have a private view of the Faraday Exhibition.

The Faraday Exhibition has been organised by the Institution of Electrical Engineers, assisted by the Royal Institution, in regard to Faraday's original experiments, and by the Federal Council for Chemistry, in relation to chemical discoveries. It will be formally opened to the public at 4.30 on Sept. 23, and will remain open until the evening of Saturday, Oct. 3, the charge for admission being 1*s*. for adults and 6*d*. for children under fourteen. The exhibition is being planned to illustrate the developments of electrical and chemical science and industry in all branches which have followed Faraday's work. Around a statue of Faraday, in the centre of the hall, will be an exhibition of historic apparatus, and from this the exhibits will spread out radially, so that at the outer circumference of the hall will be found the latest examples of electrical apparatus and machinery. There will be nine sections in all, relating to such things as the generation, transmission, and distribution of electric power, electric transport, domestic uses of electricity, and the many branches of electric communication.

In the Albert Hall also, on Sept. 23, at 3 P.M., Lieut.-Gen. the Right Hon. J. C. Smuts will assume the presidency of the British Association, and will receive the invited delegates to the centenary meetings of the Association. At 4.30 P.M., at the invitation of the Institution of Electrical Engineers, he will open the Faraday Exhibition. These will be the inaugural proceedings of the British Association, and in the evening at 9 P.M., in the Central Hall, Westminster, General Smuts will deliver his presidential address.

In addition to these events, the Royal Institution has arranged for a garden party on Sept. 24, at the National Physical Laboratory, by the invitation of the director, Sir Joseph Petavel; and on the evening of Sept. 25, His Majesty's Government will entertain representative delegates and guests to dinner at the Dorchester Hotel, Park Lane. The Prime Minister, Mr. Ramsay Macdonald, hopes to preside. Various visits and excursions are being arranged, and the rooms of the Royal Institution will be at the disposal of delegates and guests from Sept. 12 until Sept. 26.

In connexion with the British Association meetings, a volume is being issued to members, entitled " London and the Advancement of Science ", containing a historical survey of the advancement of science in London through the principal scientific, educational, and State institutions, etc., by various authors; together with another on " The British Association: a Retrospect, 1831–1931 ", by Mr. O. J. R. Howarth. This is a revised edition of the volume issued in 1922 through the generosity of the late Sir Charles Parsons. It was in 1831, at York, that the Association held its first meeting, and York has been chosen for the meeting in 1932. But an invited party from the Association will pay a visit to its birthplace on Saturday and Sunday, Sept. 26-27, in the middle of the present meeting.

The publications from which these particulars have been taken contain much further information regarding the general arrangements, railway fares, hotel accommodation, passport visas, etc.

Attention may also be directed to a small pamphlet issued by the Metropolitan Borough of Southwark about the Faraday Memorial Library, which was opened in Southwark in 1927. Faraday was born at a house in Newington Butts in the borough, in 1791, and the library, which was established to commemorate his work, now contains some 1800 books devoted to the life and work of Faraday, with text-books and periodical publications of scientific societies. It is maintained by a small endowment fund in the hands of four trustees.

News and Views.

Although it has been exhibited there before, the walrus is sufficiently rare in captivity to make the recent acquisition of two young specimens by the Zoological Gardens at Regent's Park, London, a noteworthy event. Walruses are delicate animals in captivity, perhaps because those that come to land are young, tuskless individuals. It is said that the walrus-cub is suckled by its dam until the tusks appear, so that it may be that the change from the maternal milk diet is at the root of the trouble. At the same time, there is no doubt that some species exhibit innately poor viability in captivity, and that these are sometimes the most robust-looking, and not highly specialised in diet: thus, the gorilla is delicate as well as the walrus, and the capercailzie is the most difficult subject of all the game-birds. The walrus is not only interesting scientifically, but also is a good popular exhibit, for its face exhibits a curiously close caricature of humanity. It would seem, therefore, that Tacitus was playing the arm-chair critic when he cynically suggested ("Annals", ii. 24) that the "marine monsters, forms half-human, half-bestial", told of by returned legionaries of Germanicus after a storm in the North Sea which drove some of them as far as the coasts of Britain, might have been "conjured up by their fears"; for the walrus, which even at the present day occasionally visits our northern coasts, would no doubt have been well in evidence farther south at that date—the early years of the first century of our era. These men also reported "unknown birds", which were also probably not imaginary, as the Great Auk would be equally likely with the walrus to be present and attract attention there and then.

"Live and let Live", a plea for the preservation of wild life, is a pamphlet supporting the activities of the newly founded "Association for the Preservation of Game in the United Provinces" of India. Already the Forest Service of the Government has taken a firm stand for the preservation of the wild life within its jurisdiction, but more is required. This new Association is setting out to educate public opinion in the need for the protection of wild life, to encourage the study of natural history in schools and the protection of 'game' in private territories, to check unnecessary slaughter by the public, to co-operate with the Government along similar lines, and, lastly, to create and keep up a national wild game reservation in the United Provinces, where representative Indian animals shall be preserved for all time, and shall be available for the enjoyment and inspection of the people of India. The objects of the Association are worthy of the support of all interested in the preservation of wild life, and the pamphlet, which is signed by Hasan Abid Jafry of Agra and Major J. Corbett of Naini Tal and is countersigned by several Indian and English men of standing, appeals for members and for subscriptions towards the accomplishment of its aims. Contributions should be sent to the Honorary Secretary, Hasan Manzil, Shahgani, Agra, U.P., India.

In an article in the *Auk* (vol. 48, 1931, p. 22), Dr. Joseph Grinnell, who has done much for the interpretative study of birds in western America, sets out to discuss some problems of the migrations of birds from what he calls a rational point of view. He would shun all notions of mystery and unfathomableness and would attack each problem as if it were a simple thing capable of being "understood eventually in all its details upon the basis of facts discriminately gathered and rationally interpreted". The first batch of results from this inquiry are such as these: that "birds are primordially equipped easily and quickly to cover territory by flight through air" and that "they react in all sorts of ways with exceeding speed and accuracy", fairly obvious conclusions, though the latter in this very general form still requires proof. Dr. Grinnell further deduces that the migration habit in birds is due to a development of ordinary feeding journeys, that it is as easily acquired or discarded as any other habit, and that the factors that induce, maintain, and modify habits of migration are in all likelihood precisely the same as those which control general geographic distribution in all the higher vertebrates.

This is travelling pretty far along the line of assumption, reasonable though the assumptions seem to be. Nor does it seem very helpful simply to state that the senses used by birds in finding their way during long seasonal migratory flights are the same as those used in the course of their daily movements. The fact is that Dr. Grinnell, having accepted (curiously enough without proof) the assumption that wonder is inconsistent with rationality, puts the gloss of simplicity over the problems of bird migration. In all probability it is no more accurate to think that when a man wonders he stands with his mouth open and brain paralysed, than it is to assume that simplicity in Nature is necessarily more truthful than complexity and mystery. The fact remains that there is much in the migration of birds that is problematical or mysterious—the best two general books on the subject, English and German, use the word 'problem' in their titles, as Dr. Grinnell does in his—and the scientific approach by way of the analysis of the wonder-arousing phenomenon seems to us to be perfectly legitimate.

In view of the stories current in the tropics of both hemispheres of dangerous snakes resorting to a spot where a member of their species has been killed, a note in the *Field* of Aug. 8 (p. 218) deserves attention, although appearing over initials (E. P.) only. A milkman of Godalming, it relates, killed a grass snake, measuring 38 inches, and full of eggs, in the road; and, on revisiting the spot next day, found no less than 16 other snakes by the dead one, of which he killed all but two, and was apparently photographed along with them, since a photograph of a young man festooned with snakes of various sizes illustrates the note. He did not, it seems, know what the unfortunate reptiles were or that they were harmless. It is certainly a great pity that, with so limited a wild-life list as ours, such ignorant slaughter should still take place; but the congregation of all these snakes about a dead female, and that a pregnant one, certainly calls for inquiry into its cause.

THE presidential address of Sir Henry Miers to the Museums Association at Plymouth, like his former addresses to that body, marks a stage in the progress of museums in Great Britain. It is no exaggeration to say that to Sir Henry himself that progress is almost entirely due. There were strivings in many museums, and many curators were working towards new ideals, but the president of the Museums Association has been instrumental in crystallising rather amorphous efforts and in fixing the stages by which the ideal may be gradually attained. He enumerated some of the gains of the year that has passed. A summer school for the training of curators and assistants was held in London, and this year Edinburgh is to take a share in the instruction. An exhibition was organised in the County Hall, London, to illustrate the manner in which museum specimens and works of art are being distributed by the museums to schools; and a beginning has been made with the allocation of grants-in-aid to various deserving museums from the funds of the Carnegie Trustees. We are at one with him in his praise of the increasing efficiency of the *Museums Journal* under the editorship of Dr. F. A. Bather, and welcome the announcement that the Carnegie Corporation of New York has undertaken to place a sufficient sum at the disposal of the Association for the purposes of an Empire survey of museums. Co-operative sympathy between the museums of the Empire would be for the overwhelming good of all concerned.

THE completion of the Saluda Hydro-Electric Station near Columbia in South Carolina shows how the demand for electric power can alter the appearance of a country. When work was first begun on the project in the early part of 1927, the site of the development was an area of gracefully rolling hills, dotted with small farms and homesteads. The population was about four thousand, and there were three churches, six schools, and 193 graveyards in the area which is now inundated to make the largest reservoir in the world. The Saluda dam spans the river and valley for a length of nearly a mile and a half, and is almost a quarter of a mile wide at its base. Along the top of this huge wall of earth a concrete highway forming part of the State roads has been built. Motorists driving along this road have an excellent view of the reservoir, or rather, lake, as it is 41 miles long, 14 miles wide, and has a shore-line of 520 miles. It required more than a year's flow of the river to fill it. In comparison with the dam, the power station, which will have a capacity of 200,000 kilowatts, looks quite small. The Saluda development is a part of the power system of the Associated Gas and Electric Company. The power generated by water turbines is converted into electric power, transmitted at 114 kilovolts, and sold to power companies in South Carolina and neighbouring States. This should ensure the south-eastern part of the United States with an abundant supply of electric power. Photographs of the power station, the transmission lines, and the completed dam are shown in the *Westinghouse International* for August.

IN the *G.E.C. Journal* for August there is an interesting paper on discharge tubes and their technical applications, by N. L. Harris and H. G. Jenkins, which shows how rapidly this application of science to industry is developing. Tubes of many types, negative glow, positive column, hot cathode, etc., are now being manufactured. Reservoirs of various gases, including neon, argon, helium, and nitrogen, are connected to the pump system, so that the tube can be filled with any gas required at the required pressure, and direct current and alternating current voltages up to 1000 are available for 'glowing' the tubes. These tubes are used for sound-film recording, picture telegraphy, television, pyrometry, etc. Discharge tubes are also used for protective devices. For example, the Osram earthing lamp can pass 50 amperes for 1/40 sec. without damage. They can also be employed economically for dimming lamps by reducing the applied pressures in lighting circuits. Tubes for rectifying alternating currents are supplied which will give 50 milliamperes at 150 volts. The largest commercial application is the use of neon signs for advertising and decorative lighting. For night flying they are of great use as beacons, landing lines, boundary lights, and obstruction and wind direction indicators. In 1904, Moore introduced long high-voltage tubes filled with carbon dioxide gas at a pressure of about a millimetre of mercury for lighting. These tubes will probably again become popular, as the light they emit is pleasing, and improved technique in manufacture has remedied defects. In 1910, Claude introduced neon tubes for decorative lighting which give a rich red light and the luminous efficiency of which is about double that of the Moore lamps. They are particularly useful for danger signals.

STATISTICS prove that the use of telephony in large cities is continually increasing. In the statistics, taking into account data up to Jan. 1, 1930, published in *Electrical Communication* for July, we notice that the number of telephones in use per 100 of the population is 4·7 in Liverpool but 8·7 in London, the population in the latter city being seven times greater. In Paris the corresponding number is 12·5, in Berlin 11·9, and in Rome 4·3. In Copenhagen it is 17·3, in Oslo 18·1, and in Stockholm 30·5 or nearly one telephone for every three inhabitants. In New York it is 26·3, in Chicago and Los Angeles about 30, in Seattle and Denver 31·3, in Washington 32·7, and in San Francisco no less than 40·8 telephones for every 100 inhabitants. In the British Dominions, Toronto heads the list with 28·4 telephones for every 100 of the population.

THE standard frequency of alternating current supply in Great Britain is fifty cycles per second and electrical engineers are agreed that this frequency should be accurately controlled. Capt. Donaldson, the president-elect of the Institution of Electrical Engineers, has strongly insisted on the importance of having a time-regulated frequency, and this has been done in the case of the extensive system of the North Metropolitan Company, of which he is the chief engineer, for the last three or four years. It has been found possible to operate clocks from the ordinary electric mains of consumers connected to this company's networks. Such clocks can be purchased at prices ranging from three pounds upwards. It is quite possible that these synchronous clocks will gradually supersede hand-wound or hand-regulated clocks.

IN the *Journal of the National Institute of Industrial Psychology* (vol. 5, No. 7) there is a report of a lecture by Mr. Seebohm Rowntree on "Some Industrial Problems of To-day". He pointed out that, when the era of big-scale industry began, Great Britain started with immense advantages, owing to the fact that it had the cheapest coal and iron in the world, the best workmen, machines, mercantile marine, and banking system, with the result that it built up a huge export trade and maintained a higher standard of living than any other country in Europe. Gradually it has been losing ground. Mr. Rowntree attributes this partly to the debasing of currency by our creditors, to our very high real wages, to the money spent on the social services, to the conservativeness and inflexibility of employers and workmen. In the circumstances, he thinks we must either lower our standards or raise our efficiency, or maintain an ever-growing army of unemployed. Of these alternatives he discusses ways in which efficiency might be increased. He thinks that we have made more progress in dealing scientifically with the *material* side of industry than with the *human* side. We have lost in strikes and lock-outs during the last twelve years on the average more than 31 million working days. The nation that first solves the problem of how to induce a man to work as hard in the factory as if he were working for himself is secure in the industrial leadership of the world. As a step in this direction, Mr. Rowntree urges that a right selection of personnel by scientific tests should be made, so that people are assigned to the work for which they are best fitted. A good selection reduces labour turn-over, as well as the cost of training, alleviates monotony, and discloses ability that might otherwise be hidden. Next, the conditions under which the employees work must be good, and this necessitates a study of incentive systems, environmental conditions, etc. The article is suggestive and very interesting, and based on direct experience.

IN the "Summary of Progress of the Geological Survey of Uganda for 1919–1929" (Entebbe, 1931; price 4*s*.), Mr. E. J. Wayland, the director, presents an extremely useful and interesting statement of the knowledge gained during the ten years that have elapsed since his flourishing department was founded. Only a vague idea of Uganda geology was possible in 1919; now there is much to be said about the ten divisions of the geological column that are represented, about the long list of igneous rocks that have been investigated, from the Pre-Cambrian granites to the Tertiary and recent alkali-lavas of Mt. Elgon and the volcanic field of Bufumbiro, and about the tectonics and geological history. Useful minerals and water supply have naturally been given considerable prominence, since the Survey is primarily an economic one, but to geologists the chief interest of Uganda lies in such topics as its past climates, its earth-movements, rift valleys and reversed rivers, and not least in its volcanic activity. Mr. Wayland and his staff have undoubtedly one of the most fascinating countries in the world to investigate, and this admirable report, with the clearly printed provisional geological map which accompanies it, shows how enthusiastically and competently they have attacked the great problems that Uganda offers. Several excellent photographs by Mr. A. D. Combe have been effectively used as illustrations. The officers of the Survey are to be congratulated on a record of achievement of which they may be justly proud.

THE May number of the *Hong Kong Naturalist*, which is issued quarterly and edited by Dr. G. A. C. Herklots and Major H. P. W. Hutson, contains some valuable natural history articles. This is the second part of Volume 2, and in it Major Hutson continues his description of the birds of Hong Kong (Part 6), which is, as before, illustrated by beautiful coloured plates drawn by A. M. Hughes. The present part includes the kingfishers, and there are many species recorded. Not all the kingfishers are fish eaters, and those which live on insects, crabs, frogs, and small reptiles do not show any marked preference for the vicinity of water. Notes on colour, habits, nesting, and field identification make this series a peculiarly happy one. A new series entitled "The Crabs of Hong Kong" (Part 1), by Mr. Chia-Jui Shen, begins in this issue. The introduction gives instructions for collecting, preserving, and shipping, for great care must be taken when handling these often fragile creatures. The Dromiidæ, Raninidæ, Calappidæ, Leucosiidæ, and Parthenopidæ are described, and the work is well illustrated by photographic plates and line drawings. Mr. W. Fowler continues his synopsis of the fishes of China (Part 2), the herrings and related fishes, and an article on fresh-water sponges by Mr. Gist Gee with other smaller papers make up a good number of this interesting magazine.

THE *Proceedings of the California Academy of Sciences*, Fourth Series, vol. 19, No. 13, May 1931, contains the report of the president and that of the director of the Museum and of the Aquarium for the year 1930. One of the latest and most important acquisitions by the Department of Palæontology of the Museum is the large Baldwin collection of molluscs. David Dwight Baldwin was a famous shell collector, the shells being chiefly from the Hawaiian Islands, where he lived and collected for many years. Hawaiian land shells are noted for their beauty, wonderful colouring, and variability, especially the tree and ground snails, and this collection, representing years of individual labour, is unique. Besides collecting, Mr. Baldwin contributed several conchological papers to various scientific journals, including the well-known "Catalogue of the Land and Fresh Water Shells of the Hawaiian Islands". It is well that the Museum should have made this historic and valuable addition to its store, which has now been installed in the Academy's research series.

A reference to an article of interest to many English naturalists appears in *Svenska Linné-Sällskapets Årsskrift* (Årg. 14, 1931, p. 169). It is a short review of a paper by Dr. Knut Hagberg discussing the influence of Linnæus upon the great author of the "Natural History of Selborne", Gilbert White. The paper itself appeared in *Samf. Nios årsbok Vår tid*, vol. 11, 1930, and it traces the effects of White's correspondence with such disciples of Linnæus as Solander and Sir Joseph Banks. Indeed, in Dr. Hagberg's opinion, the Linnean nature study, through many enthusiastic followers, took a firmer grip in England than in Sweden, and through White's "Selborne" it influenced the poetry of such as Keats, Coleridge, and Wordsworth.

British Birds for August contains two very interesting records from northern Scotland. The first is that of the breeding of the whimbrel (*Numenius phæophus*) in Inverness-shire, and the most gratifying part of A. H. Daukes's description is that the young were allowed to hatch. In all the previous records of the nesting of this rare wader upon the mainland, the clutches of eggs were taken by the self-interested discoverers. The second record is that of the first occurrence in Britain of the red-headed bunting (*Emberiza icterica*) of Asia. The bird was seen in North Ronaldshay, in the Orkney Islands, by Col. G. Eardley Todd, and was shot so that the observation might have "real scientific value"!

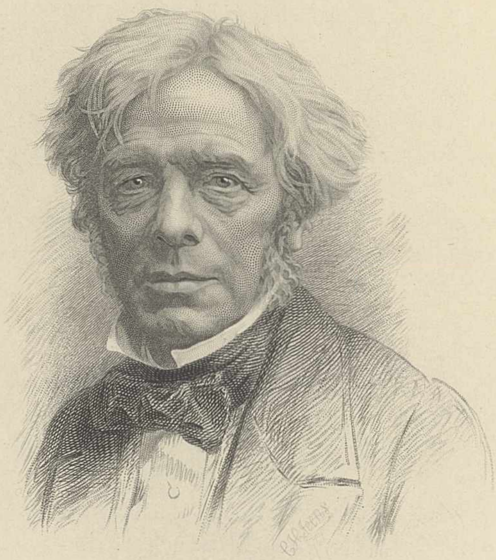
In view of the increased and continued prevalence of cerebro-spinal fever in England and Wales, the Ministry of Health has issued "A Review of Certain Aspects of the Control of Cerebro-Spinal Fever" (*Reps. on Pub. Health and Med. Subjects*, No. 65. London: H.M. Stationery Office. 6d. net.). A survey is given of the present incidence of the disease, the salient clinical, pathological, and bacteriological features, and its infectivity and mode of spread by healthy carriers. Control and treatment are discussed, and in regard to the last-named it is suggested that trial should be given of anti-meningococcus serum, supplies of which are available; and records of such treatment, if employed, are desired by the Ministry.

A large earthquake was recorded at Kew Observatory on Aug. 18. The first impulses at Kew occurred at 14 h. 30 m. 40 s. G.M.T. The records indicate that the disturbance originated about 3800 miles north-east by east of Kew. The epicentre was, therefore, in Northern Mongolia near the great Altai Mountains, and it appears to have been some 400 miles north of that of the very large earthquake which occurred on August 10.

The Council of the Zoological Society of London has agreed to confer the Society's Silver Medal on Mr. A. St. Alban Smith, in consideration of the very numerous donations he has made to the collection of the Society in 1927, 1928, 1929, and 1930, and of other valuable assistance he has given in Singapore. The actual number of specimens which arrived in London alive from him was 8 in 1927, 33 in 1928, over 200 in 1929, and more than 400 in 1930. They have included binturongs, leopards, a magnificent tiger, a gibbon, tree kangaroos, a number of valuable birds, and a very large number of reptiles, including the largest hamadryad ever seen in captivity, some rare gharials new to the collection, and a number of smaller snakes and lizards.

Following the recent exhibition of chemical apparatus in London on July 13–18 in connexion with jubilee celebrations of the Society of Chemical Industry and the Achema exhibitions organised by the Dechema, the German Society for Chemical Apparatus, a similar exhibition in Paris in 1932 is under consideration. The Achema has now received from France, from the Société de Chimie Industrielle, a proposal that these exhibitions should be held alternatively in each of the three countries concerned, an arrangement which would have the advantage not only of avoiding the simultaneous occurrence in different countries of such exhibitions but also of affording opportunities for the mutual study and comparison of the methods of production in the different countries. It is expected that an international exhibition of chemical apparatus and plant will be held in Paris in 1932, followed by a German exhibition (Achema VII.) in Cologne in 1933, and a similar British exhibition in London in 1934.

Applications are invited for the following appointments, on or before the dates mentioned:—A head of the building trades department of the Burnley Municipal College—The Director of Education, Education Office, Burnley (Aug. 31). A lecturer in physics and a lecturer in chemistry at the Denbighshire Technical Institute, Wrexham—The Director of Education, Education Offices, Ruthin (Aug. 31). A junior assistant in the pathological department of the Royal East Sussex Hospital, Hastings—The Secretary, Royal East Sussex Hospital, Hastings (Aug. 31). A full-time lecturer in engineering at the Sunderland Technical College—The Chief Education Officer, 15 John Street, Sunderland (Sept. 7). A demonstrator of biology at St. Bartholomew's Hospital Medical College—The Dean, St. Bartholomew's Hospital Medical College, E.C.1 (Sept. 10). A Clement Stephenson entrance scholar at the Royal Veterinary College—The Secretary, Royal Veterinary College, Camden Town, N.W.1. A teacher of mechanical science at the Croydon Central Polytechnic—The Principal, Central Polytechnic, Scarbrook Road, Croydon. An instrument maker and laboratory attendant in the electrical department of the Dundee Technical College and School of Art—The Secretary, Technical College and School of Art, Bell Street, Dundee.



M. Faraday

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Faraday and his Contemporaries.

By Engr.-Capt. EDGAR C. SMITH, O.B.E., R.N.

IN the introduction to his "Dissertation on the Progress of the Mathematical and Physical Sciences from 1775 to 1850", written during 1852–1854, and published in the eighth edition of the "Encyclopædia Britannica", J. D. Forbes mentioned as amongst the most eminent workers in physical science during the first quarter of the nineteenth century Young, Malus, Brewster, Fresnel, Arago, Volta, Dalton, Davy, Ørsted, Prevost, Leslie, and Fourier, while among those whose labours belonged to the second quarter of the century he included Faraday, Melloni, Gauss, Sir John Herschel, Poisson, Mitscherlich, Liebig, and Dumas. These were to Forbes some of the outstanding physicists and chemists of his own time, and in the course of his dissertation he reviewed the work of each and gave an estimate of the worth of their achievements.

The position of Forbes as an original investigator, his wide knowledge of contemporary scientific work, his relationship with many of the leaders of science, his judgment and impartiality, give to his summaries a permanent interest, and at the present time, when the centenary of the discovery of electromagnetic induction is being celebrated, it is worth while recalling what Forbes said of Faraday. Having in turn reviewed the work of Galvani, Volta, Davy, Wollaston, Ørsted, Ampère, and Seebeck, Forbes began another section of his history of electricity with the remark, "Immeasurably the larger part of what we know with regard to the nature and laws of electricity and its connexion with magnetism, so far as it has been developed since the discovery of Ørsted, is due to the genius and perseverance of one man—Michael Faraday"; while later on, when referring to the researches of Faraday as published in the *Philosophical Transactions,* he says, "It would be difficult to name in the history of any progressive experimental subject so large an amount of research prosecuted for so long a time in so methodical a manner and with such remarkable uniformity in plan, and with such unvarying success". It was with the experiments which led to the discovery of electromagnetic induction that those famous researches began.

Though, when Forbes wrote, Faraday had long been regarded as one of the foremost experimentalists of his age, his reputation had extended far beyond the world of science, and his name had become a household word. In the positions he occupied at the Royal Institution as director of the laboratory and Fullerian professor of chemistry, he became the nation's semi-official exponent of scientific advance, and his lectures rivalled in popularity those previously given by Davy. His great reputation, it is true, was not due to his lectures, but that it was much enhanced thereby there can be no question. For this work he had deliberately and assiduously prepared himself, and his success was unequalled. Men who had no particular interest in science heard him with pleasure, and long afterwards would speak of the impression made on them by his lucid explanations, his unfailing experiments, and his eloquence. When at the height of his powers, he was not only a man of science of international repute, but also a prominent figure in the life of the nation, and as such occupies a place in history beside his contemporaries, Dickens, Thackeray, Ruskin, Carlyle, Mill, and Huxley, as one of the intellectual leaders of his age. Of his private life and character much has been written, but as Sir William Bragg has said, " It is Faraday's public life that belongs to us ; it is one of the possessions of the nation, one of the great treasures ".

Faraday was born in London on Sept. 22, 1791, in the middle of the reign of George II., and died at Hampton Court on Aug. 25, 1867, in the thirtieth year of the reign of Victoria. His life therefore covered a period of vast social and economic development. He was a bookseller's apprentice when Trafalgar was fought ; a young man of twenty-four when Waterloo was won. His first journeys were by coach ; his first voyages made under sail ; the first books he read were printed by hand. Within his lifetime England was covered by a network of railways ; steamships found their way into every sea ; while books and newspapers were brought within the reach of all. Industries, manufactures, and commerce multiplied apace, and transport and communication were revolutionised. His was indeed an age of great men and great enterprises.

Faraday's own original work, however, done within the quiet of the laboratory, was of a different order from that of the Stephensons and the Brunels. Neither was it of a kind to attract widespread interest. Nothing he ever did took the world by storm as did the discovery of Neptune by Leverrier and Adams ; nothing he ever wrote raised such controversies as the works of Darwin and Huxley. It was of the same character as that of Lavoisier and of Joule, and it has proved to be of the same fundamental importance.

Faraday first gained distinction as a chemist. His first contribution to scientific literature was a chemical paper ; he is known to every chemist as the discoverer of benzene ; he was offered the chair of chemistry in the newly founded University of London ; he counted many of the greatest chemists as his friends ; a chemist delivered his *éloge* before the Paris Academy of Sciences, and his name is perpetuated by the Faraday Lecture of the Chemical Society. His earliest knowledge of the subject he gained when a boy from the " Conversations on Chemistry " of Mrs. Marcet, the wife of a Swiss doctor. In after life he came to know Mrs. Marcet and, after her death in 1858, in writing to Auguste de la Rive at Geneva, he referred to his debt to her.

The story of how Faraday's studies led to his being given a ticket to Davy's lectures at the Royal Institution, of how he appealed to Davy for employment, and of how he became Davy's assistant and accompanied him and Lady Davy to the Continent in 1813 is well known. The long visit to France, Switzerland, and Italy made a great impression on Faraday and, as Ostwald said, it proved for him a high school of incomparable value. Brewster also visited the Continent in 1814, as did Mrs. Somerville in 1816, and in their biographies, as in those of Davy and Faraday, are to be found much of interest regarding the scientific circles into which Faraday gained an insight. One outcome of the journey was the friendship of Faraday with the elder De la Rive, of whom Faraday once wrote, " I may say he was the first who, personally at Geneva and afterwards by correspondence, encouraged, and by that sustained me ".

Returning home with Davy in 1815, Faraday was re-engaged by the Managers of the Royal Institution and was thus brought into contact with Davy's successor, Brande. Described as " a model lecturer, gentlemanly, perfect of expression, exact of execution ", Brande occupied a high position in both scientific and official circles, but his vocation when lecturing with the assistance of Faraday was pronounced to be " lecturing on velvet ".

Among the most eminent chemists whom Faraday counted his friends were Graham, Liebig, Schönbein, Sainte-Claire-Deville, and Dumas. The correspondence of Faraday and Schönbein has been published in a separate volume, while among the letters from Liebig is that written from Giessen in 1844, in which Liebig openly expressed his admiration, affection, and esteem for Faraday. None esteemed Faraday's friendship more highly than Dumas, who when delivering his *éloge* on Faraday to the Paris Academy of Sciences, began with the sentence, " Je ne sais s'il existe au monde un savant qui ne fût heureux de laisser en mourant des travaux pareils à ceux dont Faraday a fait jouir ses contemporains et qu'il a légués à la postérité ; mais je suis sûr que tous ceux qui l'ont connu voudraient approcher de cette perfection morale qu'il atteignait sans effort ".

It was but natural that Faraday's first work should be in the realm of chemistry, but as Tyndall said, he was " swerving incessantly from chemistry into physics ", and it was as a physicist he gained his great fame. Just as he had obtained his first information on chemistry from the pages of Mrs. Marcet, so while still an apprentice he gleaned his first knowledge of electricity from the pages of the " Encyclopædia Britannica ". There, no doubt, he read of the experiments of Gilbert, Boyle, and Newton ; of the electric machine of Otto von Guericke ; of the lectures of Hauksbee ; of the experiments of Stephen Gray in the Charterhouse ;

of the invention of the Leyden jar, and of that " auspicious period when Dr. Franklin raised electricity to the dignity of a science, and connected it with that tremendous agency which had so often terrified the moral and convulsed the physical world ".

No branch of experimental science was more actively pursued during the eighteenth century than that of electricity. In Italy, in Germany, in France, and in England, thousands of experiments were made, and to the latter half of the century belong the labours of Coulomb, Aepinus, Priestley, Canton, Watson, Beccaria, Galvani, and Volta. Faraday was born in the year that Galvani wrote his memoir, " De viribus electricitatis in moto musculari commentarius " ; he was a boy of nine when Volta described his pile to Sir Joseph Banks. Yet in spite of all these advances, when Faraday was poring over the pages of the " Encyclopædia ", the sciences of electricity and magnetism were still unconnected, and it was not until 1820 that Ørsted at Copenhagen made known his epoch-making discovery of electromagnetism. Eagerly seized on by a score of investigators in all parts of Europe, Ørsted's experiments were quickly repeated and extended, and on Christmas Day 1821 Faraday called his young wife into the laboratory at the Royal Institution to show her a magnetic needle rotating around a wire carrying an electric current. That experiment was the direct outcome of Ørsted's discovery that by an electric current magnetism could be produced. Ten years later, Faraday himself set up another landmark in the history of electricity by showing how magnetism could be used to generate currents.

During the eleven years which elapsed between the discovery of electromagnetism and that of electromagnetic induction, Faraday was largely occupied with his researches on the condensation of gases, the alloys of steel, the compounds of hydrogen and carbon, and the manufacture of glass. But the new science of electromagnetism was developed in many laboratories. De la Rive in Switzerland was the first to give a public demonstration of Ørsted's experiment. In Paris in 1820, Arago, Savart, and Biot all began to work on electromagnetism, and in the same year, at Halle, Schweigger made the first galvanometer. Of especial importance was the work of Ampère, ' the Newton of electricity ', whose " Exposé des nouvelles découvertes sur l'Électricité et le Magnétisme de MM. Ørsted, Arago, Ampère, H. Davy, Biot, Erman, Schweigger, De la Rive, etc.", published in 1822, contained an account of his own researches as well as of those of his contemporaries. In 1824, Arago observed the damping effect of a plate of copper on an oscillating magnetic needle; in 1825, Sir John Herschel and Babbage caused a pivoted copper disc to move by spinning a magnet near it; and the same year, Sturgeon, the ex-artilleryman, presented the first electromagnet ever made to the Royal Society of Arts, and, as Silvanus Thompson said, thus furnished mankind " with a magnet the attractive power of which could be increased absolutely indefinitely by the mere expenditure of sufficient capital upon the iron core and its surrounding copper coils and the provision of a sufficiently powerful source of electric current to excite the magnetisation ". Two years later, Ohm, then on leave in Berlin, published " Die galvanische Kette, mathematisch bearbeitet " ; and in 1829, on the other side of the Atlantic, Henry, of Albany, " the first to undertake important original electrical experimentation in the United States since the time of Franklin", made his famous electromagnet capable of sustaining fifty times its own weight, which had 400 turns of silk-covered copper wire.

It was therefore no unsurveyed territory, no untrodden country that Faraday re-entered in the summer of 1831. He was but one of many pioneers who were advancing along different paths into this fruitful domain of electromagnetism. " In the history of discovery ", said Emerson, " the ripe and latent truth seems to have fashioned a brain for itself." The latent truth we associate with the name of Faraday is that of electromagnetic induction, the discovery of which was made with the historic iron ring wound with two separate coils of copper wire, and which is recorded in his diary on Aug. 29, 1831. But just as the theory of gravitation had simultaneously occupied the minds of Hooke, Halley, and Wren, as well as that of Newton, so electromagnetism was being studied by others than Faraday, and the observations on the production of an electric current by a magnet by Zantedeschi and Henry actually preceded that of Faraday. Francesco Zantedeschi, the Italian priest and physicist of Venice, it is claimed, published papers on the production of electric currents in closed circuits by the approach and withdrawal of magnets in 1829 and 1830, and Henry in August 1830, by sending a momentary current through the coils of one of his electromagnets, detected a current in a wire wound around the armature of the magnet. But Henry failed to make known his observation or to follow it up immediately.

In commemorating the centenary of Faraday's discovery, however, the world is commemorating not a single and isolated experiment but one which marked the commencement of that long and remarkable series of investigations which occupied Faraday for a quarter of a century, and an account of which is given in his "Experimental Researches in Electricity". The experiment of Aug. 29 was but the key to a Temple of Science as vast as that Temple of Art of which Lafcadio Hearn wrote in one of his letters: "The more you advance the more seemingly infinite becomes the vastness of the place, the more interminable its vistas of arches and the more mysterious its endless succession of aisles".

Having thus found the key, Faraday immediately began to explore further, and with remarkable success. "In ten days of actual work during the autumn months of 1831", as Sir Ambrose Fleming has said, "Faraday not only discovered the facts of current induction and magneto-electric induction as well, but embraced them all in the statement of one great generalisation of the utmost simplicity".

These researches alone led finally to the invention of the magneto-electric machine, the induction coil, the dynamo, and the transformer, but they were succeeded in the course of years by his electrostatic investigations and researches on specific inductive capacity, by his electrochemical researches and researches on voltaic action, and by his researches on magnetism and light; investigations which have engaged the attention of the most eminent physicists of nearly a century, and on some of which has been based that extended application of electricity to man's use we see around us to-day.

In the prosecution of these investigations, Faraday utilised every resource provided by his forerunners and his contemporaries, and his results he placed unreservedly at the service of his fellows. There are many aspects of his work in relation to that of his contemporaries which invite consideration, but to one only can reference be made here. The discovery of electromagnetic induction may be compared with that of the discovery of the pressure of the atmosphere. From the latter came the steam engine; from the former the dynamo. But just as half a century elapsed between the observation of Torricelli and the work of Huygens, Papin, Savery, and Newcomen, so more than thirty years passed before the discovery of Faraday was applied to the self-exciting electric generators of Varley, Ladd, Wheatstone, and Werner Siemens, to which the last gave the name dynamo-electric machines.

Many inventors like Pixii, Dal Negro, Saxton, Clarke, and Jacobi had made small magneto-electric machines in the early 'thirties; the induction coil was developed by Page and Ruhmkorff, and experiments were made with lighting by electricity generated by magneto-electric machines. But interesting as was the work done with these machines, when Forbes wrote, they were still regarded mainly as instruments for the laboratory, and the most important source of electricity was still the voltaic cell, the invention of which Forbes compared to that of the steam engine. From the invention of Volta and the discovery of Ørsted had come the use of electricity for signalling, and the grand achievement of the electricians of Faraday's lifetime was the electric telegraph. Gauss, Weber, Steinheil, Wheatstone, Cooke, and Morse were all contemporaries of Faraday, and it was they who laid the foundations of the great telegraph systems of the world. Five years before Faraday died, it was estimated that Great Britain had 15,000 miles of electric telegraph, Europe 80,000 miles, and America 45,000 miles. But no one had yet dreamed of the generation, transmission, and utilisation of electricity on a large scale. Even Faraday himself failed to see what his own child would grow into, and just as Watt would have nothing to do with the steam locomotive and the steam boat, so Faraday set down the magneto-electric engine along with mesmerism, odylism, the sympathetic compass, and perpetual motion as an ill weed which should not be cultivated.

Nevertheless, gradually, step by step, the difficulties were being solved, and with the work of Pacinotti, Wilde, Varley, Wheatstone, and Siemens a new chapter was opened in the history of the application of electricity. In the retirement of his home on Hampton Court Green, Faraday heard with interest of Wilde's machine, but when the dynamos of Wheatstone and Werner Siemens were described to the Royal Society, both his physical and mental powers were rapidly waning, and a few months later he passed away.

Nearly a century before Faraday died, Boswell had visited the famous steam engine factory of Boulton and Watt at Soho, and Boulton had proudly exclaimed to him, "I sell here, sir, what all the world desires to have—POWER". The demand of the world for power has been an ever-increasing one, and a multitude of discoverers, inventors, and engineers have contributed towards the satisfaction of that demand. Some live in history, some are forgotten, but among those whose names are imperishable is Michael Faraday.

Faraday and Ørsted.

By Mrs. Kirstine Meyer, Copenhagen.

ØRSTED'S discovery of electromagnetism came as a surprise to the scientific world and apparently without any preparatory work. It was communicated in a paper (July 1820), which in the briefest form possible gave an account of the conditions under which the experiments were made and of their results. His results have proved to be correct, but there are no drawings, no indications of the series of experiments he made,[1] or rather of the several series of experiments, to indicate the way these results were reached. It has been said that the whole discovery was due to chance; that was far from being the case. Ørsted had for years been seeking a connexion between electricity and magnetism, and the discovery was the result of his search.

The chief contents of the communication are as follows:

The electric current—in Ørsted's language, "the electrical conflict" in the conductor—acts on a magnetic needle; the direction of the force is sideways and outwards from the conductor, and it has been found in, one might almost say, every possible position of the conductor in relation to the magnet. A simple rule is given for finding the direction of the force. It is shown that the action of the force does not depend on the intermediate substance between the magnet and the conductor. The magnitude of the force is found to depend on the distance from the magnet, the power of the battery, and the quality of the connecting conductor. He also noticed that a circuit in the form of a polygon carrying an electric current attracts or repels the pole of a magnet. Finally, quite briefly, attention is directed to the fact that "the electrical conflict", judging from these experiments, is not restricted to the conductor, but is communicated to the surrounding space, and must be assumed to traverse circles the planes of which are at right angles to the conductor.

The experiments were extended and the results were published soon after, under the title "Neuere elektromagnetische Versuche", in the July number (1821) of *Schweiggers Journal für Chemie und Physik*. This work was evidently finished shortly after the first and should be regarded as coherent with it, as it forms an important supplement to it. It contains the following results:

(1) The effect of a conducting wire on the pole of a magnet depends on the quantity of electricity and not on its tension—in modern words, on the current and not on the electromotive force of the supply.

(2) The reaction effect is found by showing that a suspended closed circuit is turned by a magnet.

(3) It is established in a new way that a closed circuit has a north end and a south end just like a magnet.

From the moment that Ørsted's discovery became known, it created an enormous sensation. The results communicated were so astounding that they were received with a certain distrust, but they were stated with such accuracy that it was scarcely possible to entertain doubts. The treatise itself was thus a strong inducement to put the results to a test; as Ørsted had given no real description of his procedure, scientific workers made the experiments in a variety of ways. Many of those who repeated Ørsted's experiments were thus led to consider themselves and others to be Ørsted's equals in this field of research, and published their work as new discoveries, even if their results were in reality to be found in Ørsted's communication. The language of the latter also caused difficulty, and was responsible for the imperfect comprehension of its contents.

All were soon imbued with the excessive importance of the discovery, and the scientific journals were filled with electromagnetical essays. In England, too, the discovery received full credit. In 1821, Faraday wrote a historical survey of the evolution of electromagnetism up to April 1821.[2] Though only eight months had passed since Ørsted's communication, so much had already been written that Faraday found it very difficult to make head or tail of the many works, of what had been done and by whom, "in consequence of their great variety, the number of theories advanced in them, their confused dates, and other circumstances".[3] He then undertook to go through systematically, "with great labour and fatigue", everything that had appeared in journals and other places. He gives full credit to Ørsted's work; about the first communication he writes: "It is full of important matter, and contains, in few words, the results of a great number of observations; and, with his second paper, comprises a very large part of the facts, that are as yet known relating to the subject". He acknowledges Ørsted's discovery to be not only a lucky chance but also the fruit of a deliberate search: "Mr. Ørsted . . . has for many years been engaged in inquiries respecting the identity of chemical, electrical, and magnetic forces . . . his constancy in the pursuit of his subject, both by reasoning and experiment, was well rewarded in the winter of 1819–20 by the discovery of a fact of which not a single person beside himself had the slightest suspicion ; but which, when once known, instantly drew the attention of all those who were at all able to appreciate its importance and value ".

Faraday repeated almost all the experiments Ørsted described, and this led him in the beginning of September 1821 to discover a method of producing a continuous rotation of a wire with an electrical current round a magnet and of a magnet round the wire. Although the fact of the tangenial force between an electric current and a magnetic pole was clearly stated by Ørsted and clearly apprehended by Ampère and others, the realisation of the continuous rotation of the wire and the magnet required ingenuity for its original solution.

This article of Faraday's, containing his first work on electromagnetic problems, forced on his mind the facts that an electrical current and a magnet act on one another with forces which could create continuous rotations, that a closed electrical circuit could act as a magnet with a north pole and a south pole, that an electrical current could magnetise iron, and that all these results had been observed because Ørsted " had for many years been engaged on inquiries respecting the identity of chemical, electrical, and magnetic forces ".

From this time on, Faraday applied the full force of his mind to certain problems arising out of these results, and he kept them persistently in view even when, year after year, his attempts to solve them were unsuccessful. One of these problems was : " Convert magnetism in electricity ", as he writes in his note-book in 1822 ; he solved the problem in 1831. Another problem was to find a relationship between electricity and magnetism and light. In 1845 he found that magnetism exerts an influence on light.

The philosophical problem, the correlation of physical forces, interested Faraday as well as Ørsted. In the year 1834, Faraday gave a course of six lectures on " The Mutual Action of Electrical and Chemical Phenomena; . . . Relations of Chemical Affinity, Electricity, Heat, Magnetism and other powers of Matter ". In the last lecture he gives his first utterance on the correlation of physical forces : " Now consider a little more generally the relation of all these powers. We cannot say that any one is the cause of the others, but only that all are connected and due to one common cause." . . .

While the philosophical views of Faraday and Ørsted thus present similarities, a marked difference is also exhibited. In his youth, Ørsted had been strongly influenced by the German *Naturphilosophie* and was thereby led to accept too uncritically theories which rested only on speculation and had no sufficient experimental verification. Although through his experimental work Ørsted's connexion with this philosophy was gradually weakened, he was never so sceptical towards theoretical speculation as Faraday, whose critical mind is typically expressed in his attitude to the electromagnetic theory of Ampère ; nor, of course, was Ørsted so ingenious in seeking for experimental verification of theories as Faraday. The truth of the points here emphasised appears also clearly from the contributions of these two men in quite a different field of research.

The first important experimental work from the hand of Ørsted was among the publications of the Royal Danish Society of Sciences for the year 1807, and bore the title " Forsøg over Klangfigurer " (Experiments on Acoustical Figures). Influenced by his ideas about the universal importance of electricity in physical phenomena, he expected to discover electrical effects due to the oscillations causing the acoustical figures. The paper was based on several hundred experiments on acoustical figures produced on square plates of glass or metal, a few of them on circular plates. While Chladni used sand to make the acoustical figures visible, Ørsted employed lycopodium in most of his experiments, and with this fine powder the figures showed somewhat differently. He did not find electrical effects, but he became aware of certain phenomena which he supposed might afford an important insight into the mechanism of the production of a tone, and hence the treatise gives an account of the many experiments carried out in order to clear up this matter. A series of minor motions in the plate are revealed by the lycopodium ; in particular it is remarkable that small heaps of lycopodium accumulate where the vibration is greatest. He sets forth the idea that these minor motions show that every sonorous oscillation is composed of a number of minor oscillations. " Hence the nature of each tone seems to be more dependent on the relation between the subordinate oscillations and the main oscillation than on the mere number of main oscillations. Each tone thus seems an organisation of oscillations."

Savart took up the same investigation about twenty years later; he came to the same conclusions as Ørsted and explained them in a similar way, it being his opinion that the minor oscillations offer information about the overtones that determine the timbre of the plate.

Faraday took up the question for definite determination in 1831. He only mentions Ørsted's paper, his attention having been directed to the subject by Savart's paper. By a wonderful series of experiments he shows that the accumulation of light dust in certain places does not mean any secondary division of the plate according to overtones, but is only due to currents of air passing over the plate in motion.

In 1846 Ørsted visited Faraday's laboratory, and his interest was especially aroused by the great electromagnet which Faraday had used in his famous investigations on diamagnetism in 1845. Faraday demonstrated the results of these researches before Ørsted, who became so interested in them that on his return to Copenhagen he had a powerful electromagnet constructed and started an investigation on diamagnetic phenomena, the result of which was published in 1848. In consequence of these observations, Ørsted divided all bodies magnetically into three groups: those repelled and diamagnetic, those attracted and diamagnetic, and those that behave like iron. This division answers to that introduced in modern times: the diamagnetic, the paramagnetic, and the ferromagnetic.

Faraday's discovery of diamagnetism was thus the direct cause of the last published experimental work of Ørsted, but Faraday's activity had another influence on Ørsted which became of vital importance for the rest of his life. When Ørsted in 1823 visited England at the end of a longer journey, his work as a man of science received general recognition; in Paris he had received the mathematical prize of the Academy of Sciences, and in London he was elected a foreign member of the Royal Society. It might then have been expected that on his return he would devote himself entirely to the scientific investigations which he had started already. His visit to the Royal Institution, where Faraday was working, changed these plans. The object of the Royal Institution was to diffuse a knowledge of useful mechanical improvements and to promote the application of science to daily life. The manner in which this object was realised through the activities of Faraday made so strong an impression on Ørsted that he on his return founded a society in Copenhagen with similar aims. This society has had an important although indirect influence on the progress of the Danish community, and also on Ørsted himself, for it directed him away from purely scientific work to a large and unselfish activity in the education of his nation.

It is interesting to see that the character of the two men was evidently of the same type. It has been said of Faraday that he was entirely free from pride and undue self-assertion, and that in his old age he remained content and happy in the exercise of those kindly feelings and warm affections which he had cultivated no less carefully than his scientific power. The same could be said of Ørsted. A Danish poet, a friend of Ørsted, has said that he possessed what one might call a high degree of "mental innocence" and always thought that "everybody was guided by the same interest for science, by the same sense of justice and reason as he himself"; he thought that one who knows how to deal wisely and correctly will do so. One has the same impression of Faraday from his life and from his letters. Each man worked conscientiously and unselfishly for the community in which he lived.

[1] Kirstine Meyer: "The Scientific Life and Work of H. C. Ørsted", 1920, pp. lxxiv.-lxxxviii.; H. C. Ørsted, "Scientific Papers", vol. 1.
[2] *Thomson's Annals of Philosophy*. New series, London, 1821, vol. 2, pp. 195 and 274; vol. 3, p. 107.
[3] l.c., p. 195.

Gauss's Investigations on Electrodynamics.

By Dr. Clemens Schaefer,
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The greatness of the life-work of an investigator is revealed most clearly, perhaps, when we contemplate his influence on the scientific work of his contemporaries. I propose to endeavour to show the influence exerted by Faraday's discovery of electromagnetic induction on the physical investigations of C. F. Gauss, *princeps mathematicorum*.[1]

* Translated by Dr. R. W. Lawson.

Even in his youth Gauss was interested in physical problems, and we possess documentary evidence that, in the year 1806, he had already completed his theory of terrestrial magnetism, although it did not appear until 1839. As is well known, the theoretical nucleus of this theory consists of the development of the magnetic potential of the earth's field in spherical functions, the coefficients of which have to be determined empirically. Lack of observational data delayed the completion of this work by more than thirty years, and other physical investigations of Gauss suffered the same fate. Not until about the year 1830 did Gauss again turn his attention to physical investigations.

Meanwhile, however, the situation in science had been completely transformed, as the following statements will serve to show. Electromagnetism was discovered by Ørsted in 1820; in 1820–21, Biot and Savart formulated their fundamental law on the force exerted between a magnetic pole and a current element; and this was followed in 1822–24 by the fundamental researches of Ampère on the replaceability by a magnetic shell of a conductor bearing a current, and the establishment of Ampère's law. Then, in the year 1827, G. S. Ohm established his law of the galvanic circuit; in 1828, Green (Nottingham) published his paper on the theory of potential, which, incidentally, remained unknown to Gauss; and finally, in the year 1831, Faraday discovered induction, the counterpart of electromagnetism. The scientific situation was thus fundamentally changed when, in 1830, Wilhelm Weber was called to Göttingen as professor of experimental physics; and at this juncture, on these well-constructed foundations, Gauss's physical researches commenced.

Gauss's investigations were concerned first with terrestrial magnetism, and he showed us how to measure the earth's field exactly; at the same time, he originated the absolute system of units. But the general foundations had scarcely been developed by him, in conjunction with Weber, before he began to give attention also to the study of electrodynamics. On Oct. 22, 1832, Gauss carried out electromagnetic measurements for the first time, and these occupied him during succeeding years until about 1836. Although investigations on Ohm's law, due in particular to Fechner, were available even in the year 1832, they did not satisfy the high standard of attainment demanded by Gauss. Thus his first measurements were directed to testing Ohm's law under the most varied conditions. In this connexion (1833) Gauss discovered the laws of branched circuits, which to-day are known as Kirchhoff's laws, although Kirchhoff did not discover them until the year 1845. Gauss also found out the principle of minimum heat—which was likewise rediscovered later (1848) by Kirchhoff—according to which the heat produced by the current is a minimum for the actual current distribution. Furthermore, he supplied the exact proof of the identity of frictional electricity and that produced by galvanic elements and thermoelectric forces, of which identity by no means all physicists were at that time convinced. However, these were only the preliminary studies.

His chief interest was concentrated on the investigation of the laws of induction. The year 1834 resulted in the construction of an induction coil, and enabled him to recognise the damping of a magnet vibrating in a coil, as a consequence of the induced currents; this led him to the construction of a copper damper for his magnetic apparatus, and to the discovery of the phenomenon of 'sympathetic vibrations'. His work reached its zenith in the year 1835, for on Jan. 23 of that year [2] he formulated the law of induction, which is to-day designated the 'Franz Neumann law of potential', although Neumann formulated it ten years later, in 1845.

We will now pass on to the narration of this crowning accomplishment. The train of thought which guided Gauss was as follows: When a current-free conductor is moved relatively to a current-bearing conductor, a current is set up also in the first conductor, the induced current; at the same time, however, there are established between the two current conductors electrodynamic forces, which obey Ampère's basal law. The latter law is thus most intimately related to the phenomenon of induction. For this reason Gauss first took up the detailed study of Ampère's law, and immediately recognised that there can be added to the mathematical expression for the forces, differential expressions of such a nature that they vanish when integrated over closed current circuits. We can thus replace this elementary law by an infinite number of equivalent laws. By effecting various transformations of this kind on Ampère's law, Gauss also arrived at a law which was formulated ten years later (1845) by Grassmann, and differs in its outward form quite substantially from the fundamental law of Ampère. In fact, Grassmann did not recognise that his law was wholly equivalent to that of Ampère, and he proposed experiments to decide between the two laws, whereas Gauss perceived from the first that there cannot exist any *experimentum crucis* between the two, if only closed currents are available.[3] Gauss laid no great value on the formulation of Grassmann's law, evidently because he recognised that it contradicts the law of action and reaction for current elements, whereas Ampère's law obeys the last-named law also for the elements.

Gauss's next advance was concerned with the magnitude of the electrodynamic forces. He succeeded in showing that a so-called electrodynamic potential can be specified, the partial derivatives of which, with respect to the parameters that determine the position of the moving current conductor, yield the electrodynamic forces which tend to cause these parameters to increase. This is the first part of 'Neumann's law of potential'. Gauss then made use of the fact observed by Lenz, that the induced current has a direction such that the electrodynamic forces resist the motion, so that in consequence positive work is performed during this motion. On this basis he derived from the law of the electrodynamic forces the law of the phenomena of induction, which latter are therefore likewise closely linked with the expression for the 'Neumann-potential.' This is precisely the same train of thought which was followed later also by Franz Neumann and finally by Helmholtz in his famous paper, "Über die Erhaltung der Kraft" (on the conservation of force), a train of thought that can be formulated in modern terms by the statement that the phenomena of induction can be deduced from the law of electromagnetism and the energy principle, or that the laws of electromagnetism and of induction together are compatible with the energy principle. Finally, we again meet with the same train of thought, for example, in the derivation of Poynting's theorem from Maxwell's equations. The discovery of these relations may well be designated the pinnacle of Gauss's achievements in physics.

Nevertheless, Gauss was not content with what he had already achieved. In those days the problem was not regarded as having been solved until it was possible to trace it back to the position and motion of electrical charges, that is, the general fundamental law was sought for in a generalisation of Coulomb's law. This process of thought had its ultimate foundation in the unique authority of Newton's law of gravitation, with which Coulomb's laws agreed in their form. The true key to Nature was descried in generalisations of these laws. These endeavours culminated in the well-known law of Weber (1845–47). Gauss had also attempted to formulate such fundamental laws (1835), and one of them, designated Gauss's fundamental law, is examined in detail, for example, in Maxwell's "Treatise". Gauss himself had already proved that the basal law represents correctly the electromagnetic phenomena; on the other hand, Maxwell showed that it fails with the phenomena of induction. We are probably right in assuming that Gauss also recognised this deficiency, for he did not publish this law. In fact, practically all of the physical discoveries mentioned here first became known when his unpublished papers became available.

Whereas these developments of Gauss's ideas stand in diametrical contrast to Faraday's ideas of a field action, in later years Gauss nevertheless drew nearer to Faraday's view. This is clear from a celebrated letter written to Wilhelm Weber in the year 1845. In this Gauss states that the generalisations of Coulomb's law had not satisfied him, because they assumed an instantaneous ("instantanen") propagation, whereas *his* real aim had been the derivation of the forces from an action which is not instantaneous, but propagated in time in a similar manner to light. (In his letter to Weber, Gauss refers to a "nicht instantanen, sondern auf ähnliche Weise wie beim Licht in der Zeit sich fortpflanzenden Wirkung.") He frankly asserts that, in view of the fact that he did not succeed in arriving at the solution of this problem, he could see no justification for publishing anything about these electrodynamic investigations. We see here how closely Gauss's conceptions approach those of Faraday, and it is perhaps not entirely chance that Gauss's pupil, Bernhard Riemann, was the first to attempt, in 1858, to replace Poisson's equation for the potential $\Delta\phi = -4\pi\rho$, by the equation, $\frac{1}{c^2}\cdot\frac{\partial^2\phi}{\partial t^2} - \Delta\phi = 4\pi\rho$, which would result in propagation of the potential with the velocity of light, c.

It is clear from the above considerations that the discoveries of the years 1820–31, and especially the discoveries of Ørsted and Faraday, supplied Gauss with the material for his investigations. He was not really a physicist in the sense of searching for new phenomena, but rather always a mathematician who attempted to formulate in exact mathematical terms the experimental results obtained by others. Thus the brilliant achievements of Gauss would have been impossible had it not been for Faraday's discovery of induction, the centenary of which we are celebrating this year.

May then this brief outline also redound to the glory of Faraday, to whom in very truth those words apply which are to be found on Newton's grave:

> "Congratulentur sibi Mortales,
> tale tantumque exstitisse decus generis humani."

[1] Only since 1929 has it been possible to review with certainty Gauss's accomplishments in the field of electrodynamics in their entirety. Readers who are interested in this matter may refer to my essay "Gauss' physikalische Arbeiten" (Julius Springer, 1929), which has also appeared in "Gauss' Werken", vol. xi, 2.

[2] "Morgens 7 Uhr vor dem Aufstehen" (At 7 o'clock in the morning, before rising); these are the words of Gauss's entry.

[3] It was not known until recently that Gauss was also the discoverer of the law of Grassmann. We must ascribe blame for this to a slip on the part of Gauss, which has been overlooked hitherto, and which rendered his formula unintelligible.

Italian Physicists and Faraday's Researches.

By Prof. Vito Volterra, For.Mem.R.S., Royal University, Rome.*

THE discoveries made by Faraday were so numerous and important that they brought about a new and immense development of physics, and inspired the most varied and remarkable practical applications. The concepts that guided him in his famous experiments modified our ideas of natural phenomena so profoundly that a new epoch in the history of natural philosophy begins with him.

There has been no worker in the field of physics in recent years whose labours have not been more or less directly linked up with Faraday's. For that reason, if one wanted to mention all those who can claim to have continued his work or who have taken advantage of its results, one would have to name every physicist of modern times. This is as true of Italy as of other countries. This is not the place to embark upon the history of physics in Italy during the last hundred years, and I propose to deal rather with those researches which were most directly inspired by Faraday's, particularly at the time when the latter were first made known and had their greatest success and most important applications.

I will therefore go back to the autumn of 1831, when Faraday's attempts to obtain electric currents by means of the action of magnets were finally crowned with success. The results were not communicated to the Royal Society in London until November of that year, but the publication of the memoir was delayed, and the French translation only appeared in May 1832, in the *Annales de Chimie et de Physique*. In order to make up for this delay, Faraday wrote a very concise letter on the subject to Hachette of Paris, who brought it before the Academy of Sciences in December 1831.

Nobili, of the Museum at Florence, a physicist of unusual ability, who was already well known for his astatic galvanometer and his thermoelectrical studies, among other things, heard of the discovery from Amici, who had read of it in the *Temps*. Realising at once its vast importance, he set about repeating Faraday's experiments with the assistance of another Florentine physicist, Antinori. Their first memoir appeared in January 1832, and is explicitly so dated, but it was published in the *Antologia* for November 1831, which was very late in appearing.[1] Further papers came out in subsequent numbers of the same journal.

The two Florentine physicists obtained induced currents by approaching a closed circuit to the pole of a magnet, by breaking a circuit formed by a horseshoe magnet and its keeper, by reversing the current in a helical circuit arranged parallel to a dip needle, and by introducing a core of soft iron into a helix forming part of a closed circuit.

These experiments would not have provoked a controversy (one of the few in which Faraday engaged) but for the observations that accompanied them, particularly with reference to Arago's magnetism of rotation and the induction spark. The delay in receiving the authentic text of Faraday's memoir, and the misinterpretation of his letter to Hachette, contributed to the creation of the misunderstandings which gave rise, as Naccari points out, to the controversy mentioned above.[2]

The study of induction was carried on in Italy, in particular by Matteucci, who gave his attention to the distribution of the currents in Arago's rotating disc and to the magnetism of rotation, and published in 1854 his " Cours spécial sur l'induction, le magnétisme de rotation . . .", which gave an extensive account of as much as was then known with regard to the phenomena of electromagnetic induction.[3]

There is, however, a work of much greater philosophical and experimental importance, the memory of which I should like to revive. In 1852, Felici, who was at that time Matteucci's assistant and afterwards succeeded him in the chair of physics in the University of Pisa, began the publication of three memoirs entitled " Sulla teoria matematica dell' induzione elettro-dinamica ".[4]

F. Neumann had already given his famous formula in his two works of 1845–47, and Weber's had appeared in 1846. Felici left the paths which these two scientific workers had trodden, and set himself to obtain the formulæ expressing the laws of electromagnetic induction by going step by step along the road of pure experiment by which, a quarter of a century earlier, Ampère had arrived at the mathematical expression of the mechanical force which two elements of current exert on one another. Like Ampère, Felici rested his case in his first memoir solely on experiments involving balance methods. By an ingenious arrangement, he intensified the effect of the induction, repeating the making and breaking of the current, and integrated with his galvanometer the intensities of the repeated induced currents of the same direction. He thereby obtained a formula which gives the electromotive

* Translated by T. Mark.

force corresponding to the action of elements of current—a formula containing a term which vanishes when the electromotive force round closed circuits is integrated. Thus Felici's formula, besides telling us something more, supplies experimental proof of that obtained by Neumann by means of special hypotheses in extension of Lenz's law.

In his subsequent memoirs, Felici studied induced currents, not only in filiform circuits, but also in conductors of more than one dimension, thus linking up with Matteucci's experimental researches set forth in the " Cours spécial " referred to above.

Ottaviano Fabrizio Mossotti, one of the most eminent Italians of last century, was teaching in Pisa at the time when Matteucci and Felici were working there. Born at Novara (Piedmont) in 1791, he obtained his doctorate at Pavia, studied there with Brunacci, and also heard Volta. Political persecution forced him to leave Italy, and he went to France and to England, where he was received with great esteem and had many friends. He was first invited to Argentina, then went as a teacher to Corfu while it was under English protection, and finally to Pisa in Tuscany, where he founded an astronomical and physico-mathematical school which has been of great importance in the recent history of science in Italy.

Among Mossotti's numerous and beautiful researches, the one that now stands out as the most important, and to which he chiefly owes his fame, is the theory of dielectrics. Faraday devoted the eleventh and twelfth series of his " Experimental Researches on Electricity " to the study of the action of dielectrics in the phenomena of electrostatic induction. This effect had already engaged the attention of Avagadro [5] for many years, but Faraday's famous and decisive experiments established its nature and led to the theory of the polarisation of dielectrics.

Mossotti's great merit is that he showed the relation of the theory of electrical induction in dielectrics to the theory of magnetic induction. Now, Poisson had supplied the mathematical theory of magnetic induction ; so one had only to read in the language of *electricity* what Poisson had arrived at in terms of *magnetism* in order to obtain a mathematical theory of dielectrics based on the concepts of Faraday. Indeed, part of Mossotti's memoir of 1846 [6] is, as the author himself points out, nothing but a reproduction of Poisson's. The remarkable and elegant conclusions that Mossotti drew from it, and the interesting applications that have been made of it by others, such as Clausius, for example, who applied it to oscillating discharges, make Mossotti's work particularly valuable.

This brings us to Mossotti's own concepts with regard to the constitution of matter, a subject to which he frequently returned, as in a memoir dedicated to Plana [7] in the foreword to his Corfu lectures,[8] and on other occasions. Faraday, in the nineteenth series of his " Experimental Researches ", shows his approval of these ideas of Mossotti's, which corresponded in a measure to his own. They deserve to be re-read to-day, to be pondered over and compared with the most modern theories, for, although the fact that they were thought out before the development of thermodynamics renders them remote from the present conception of many phenomena, they nevertheless may contain the germ of many fertile ideas.

The study of dielectrics, which had been fully investigated by means of Mossotti's mathematical analysis, did not come to a halt in Italy, but was continued in various works, among which I may mention those of Belli, Matteucci, and Felici on dielectric constants, and Felici's own investigations on the viscosity of dielectrics. Theoretical and practical researches of this kind have been continued down to our own days in the writings of Italian physicists and electro-technicians.

Mossotti's analysis is an example of the adaptability of Faraday's ideas to treatment in mathematical form. It is not the only example, nor is it the most famous, and indeed it is well known that Maxwell succeeded in translating Faraday's concepts into the equations of the electromagnetic field, and discovered in them the germ of the electromagnetic theory of light.

Faraday did not possess the technique of the analytical mathematician, but he could express accurately in words all that is told us by formulæ. The same thing may be said of Volta. If I wished to draw a parallel, after the manner of Plutarch, between these two heroes of science, I should have to bring out this similarity between the minds of the English physicist and the Italian, which were also so much alike in other ways. Both had mathematical minds in the truest sense, for analytical symbols and devices are not the substance of mathematics but only its outward aspect.

The problem of the electric motor, and its converse, that of generating the electric currents first obtained with Volta's pile, and then, thanks to Faraday's principle of induction, by a method capable of practical application on a large scale, were certainly ' in the air ' when a very ingenious solution was supplied in 1860 by Antonio Pacinotti, who constructed his celebrated ring armature in the Technological Physics Laboratory of the University of Pisa. It was not until 1864 that the inventor set down in writing a description of his apparatus, which he modestly styled " una machinetta elettromagnetica " (a small electromagnetic machine), and he published it in 1865 in the *Nuovo Cimento*.[9]

I do not think it worth while to give this description here, for it appears in most elementary treatises on physics and electro-technics. The brilliant solution of the problem proved to be adapted to the most extensive and important industrial applications, which the inventor himself had at once foreseen, and the machine became one of the most useful and most widely employed in the world. There is no need to repeat the well-known story of its rapid dissemination and the controversies, now concluded, to which it gave rise.

As we have already said, the researches connected with Maxwell's theories cannot be dissociated from the memory of Faraday, to such an extent are the theories themselves derived from his experiments and concepts. The pressure of light, which Maxwell arrived at as a consequence of the electromagnetic theory, was demonstrated by Bartoli, by a new and original method, described in a memoir published in 1876, which was practically devoted to the study of the radiometer.[10] Bartoli imagines four concentric spherical enclosures : the outermost and the innermost are perfectly black ; the two in between are perfect reflectors. By means of a cycle, which may be repeated as often as desired, he makes heat pass from the outermost enclosure, which may be assumed to be the coldest, to the innermost, which may be assumed to be the warmest. In accordance with the second law of thermodynamics, before the cycle can be completed a certain amount of work must be changed into heat, and then, by virtue of the radiation of the black body on the inside, a pressure is exerted on the adjacent enclosure. From this follows, as a consequence, the pressure of light.

This is the most celebrated of Bartoli's numerous investigations, and it is undoubtedly with this that his name is always associated. The curious thing is, however, that Bartoli, who died in June 1896, before the pressure of light had been experimentally verified, was doubtful of its reality and strove to interpret his reasonings in various other ways ; but he always kept his doubts to himself while he lived, and they were only revealed later on.

We must also mention Bartoli's researches in electrolysis, and in particular his investigations into the possibility of decomposing water even with the weakest electromotive forces.[11] They are allied to Faraday's studies in his fifth and following series of " Experimental Researches ".

The prime characteristic of Faraday's thought lies in his transference of the seat of electromagnetic phenomena into the dielectric, where he perceived and followed the movement and the changes of the lines of force which were the embodiment of the conception he had used to explain electrodynamic action.

One of the most luminous and inspiring expositions of Faraday's conceptions, and of the manner in which they were developed by Maxwell and Hertz, was the address on the electrical transmission of energy delivered by Galileo Ferraris to the Academy of the Lincei in June 1894.[12] But an address of this kind would only be remembered as a happy popularisation of the concepts of the localisation and flux of energy, at that time novel to the public at large, if it did not serve to show us a good deal more, namely, the quality of Ferraris's intimate insight into the nature of electrical phenomena, which had been the point of departure for his discovery, nine years earlier, of the rotary magnetic field. Indeed, it was seeing 'in his mind's eye ' the electrical vibrations completing themselves, not within the confines of the conductors, but in the common medium external to them, and thus persuading himself of the possibility of superimposing two alternating electrical currents at right angles to one another—a vision that came to him like a flash as he was taking a lonely walk one night through the streets of Turin—that led Ferraris to the discovery to which he chiefly owes his fame.[13] This brilliant achievement had been preceded by lengthy and searching studies of transformers, of which Ferraris provided a complete theory which led him to establish the well-known law of phase-displacement and to work out the power of a transformer. This served to dissipate the mistaken views then prevalent regarding the output of a transformer, and to show the full importance, in its industrial applications, of this fundamental piece of apparatus, the direct offspring of the principle of induction, occupying in electro-technics the place of the lever in mechanics.[14] The transmission of energy over a distance by the use of alternating currents, from which all our industries have received so great an impetus, was the practical outcome of these studies.

The history of the evolution of Faraday's ideas, which led to Maxwell's mathematical theory, then to the experiments of Hertz, would not be complete without some reference to wireless telegraphy, in which the memorable cycle reaches its astounding close. In Italy, Righi, among others, repeated and successfully extended Hertz's experiments, following out in every particular the analogies between the phenomena of optics and those of the electromagnetic waves.[15] Then Marconi, with amazing perseverance, availing himself of the most ingenious and varied methods, succeeded in carrying out actual transmission over a distance by means of electromagnetic waves. The rapid progress of radiotelegraphy and radio-telephony is going on every day before our eyes, and is being followed with interest and wonder throughout the world.

I cannot enlarge on numerous other questions, interesting though they are—electrolysis and electrophysiology, for example—or recall Matteucci's studies [16] and his correspondence with Faraday,[17] nor must I go back to the chemical theory of the Voltaic pile, which Faraday preferred to the contact theory, thus associating himself with the ideas first put forward by Fabbroni.[18] It is impossible for me to say anything on the question debated by Faraday, whether electricity, however generated, is always the same, follows the same laws, and produces the same effects; Volta himself considered this problem, and has been the subject of recent studies by living writers. I will only mention the observations communicated by Father Bancalari in 1847,[19] and the subsequent memoir by Zantedeschi on the magnetism of flames,[20] which attracted Faraday's attention to the magnetism and diamagnetism of gases.

Let me close with a reference to magneto-optics, which takes its rise from one of Faraday's most famous discoveries, that of rotatory magnetic polarisation. Righi gave the dynamic explanation of the phenomenon, which later researches have associated with Zeeman's great discovery. Righi himself took advantage of the property of a sodium flame traversed in the direction of the field by a beam from two crossed Nicols, which permits of the observation, by simple means, of Zeeman's converse phenomenon.[21] It is very curious that this experiment should have been carried out with apparatus analogous to that devised by Faraday, who, however, failed to obtain the result, an occurrence extremely infrequent in the course of this great observer's researches.

We are to-day recalling and commemorating the work of Faraday, as we did that of Volta and of Ampère a few years ago. These three great men of science, belonging to different countries, lived their lives remote and apart from each other, but their minds worked together in harmony for the progress of natural philosophy and the discovery of new and marvellous devices of use to human society. The influence which each of them exercised beyond the confines of his native land availed to direct towards similar ends minds very diverse in their racial origin, which acquired fresh virtues by taking part in the common effort.

The aim of my brief essay has been to throw light on the influence which Faraday's work had in Italy. From the philosophical point of view, this influence was enormous, and, as we have seen above, when the discoveries of the English physicist penetrated into Italy, they gave rise to new and original discoveries there, of singular importance even from the point of view of their practical applications, which awakened the enthusiasm not only of men of science but also of the whole of the civilised world for which they have provided such benefits and advantages. The feelings of admiration and gratitude cherished in Italy towards the great British thinker and experimenter are widespread and profound.

1 "Sopra la forza elettromotrice del magnetismo," *Antologia* No. cxxxi.; "Nuove esperienze elettromagnetiche e teoria fisica del magnetismo di rotazione", *Antologia* No. cxxxiv.; "Descrizione delle nuove calamite elettriche ed osservazioni sulle medesime . . . ", *Antologia* No. cxxxvi.; "Sopra varî punti di magneto-elettricismo", *Antologia* No. cxxxviii. By Signori L. Nobili and V. Antinori. "Teoria fisica delle induzioni elettrodinamiche", by L. Nobili, *Antologia* No. cxlii.

2 "La vita di Michele Faraday": Padua, 1908.

3 "Cours spécial sur l'induction, le magnétisme de rotation, le diamagnétisme et sur les relations entre la force magnétique et les actions moléculaires": Paris, 1854.

4 *Annali delle Università Toscane*, vol. 3. Felici's three memoirs were translated into German and issued in "Ostwalds Klassiker der exakten Wissenschaften".

5 "Considérations sur l'état dans lequel doit se trouver une couche d'un corps non-conducteur de l'électricité lorsqu'elle est interposée entre deux surfaces douées d'électricité de différente espèce", *Journal de Physique, de Chimie et d'Histoire Naturelle et des Arts*, by J. C. Delamétherie: Paris, vol. 63, July, 1806; Suite des considérations, etc.; Avogadro, "Saggio di teoria matematica della distribuzione dell' elettricità sulla superficie dei corpi conduttori nell' ipotesi dell' azione induttiva esercitata dalla medesima sui corpi circostanti per mezzo delle particelle dell' aria frapposta", *Memorie della Società Italiana delle Scienze*, vol. 23, 1844.

6 "Discussione analitica dell' influenza che l' azione di un mezzo dielettrico ha sulla distribuzione dell' elettricità alla superficie di più corpi elettrici disseminati in esso," *Memorie della Società Italiana delle Scienze*: Modena, part 2, vol. 24, 1846.

7 "Sur les forces qui régissent la constitution intérieure des corps." Taylor's "Scientific Memoirs", vol. 1: Turin, 1836.

8 "Lezioni elementari di fisica matematica": Florence, 1843.

9 "Descrizione di una macchinetta elettromagnetica del Dott. Antonio Pacinotti", *Nuovo Cimento*, June 1864, published May 3, 1865.

10 "Sopra i movimenti prodotti dalla luce e dal calore e sopra il radiometro di Crookes": Florence, 1876.

11 We may mention among various memoirs by Bartoli on this subject "Su le polarità galvaniche e su la decomposizione dell' acqua con una pila di forza elettromotrice inferiore a quella di un elemento Daniell", *Nuovo Cimento*, 1879.

12 Address before the Royal Academy of the Lincei, at the special meeting of June 3, 1894.

13 "Rotazioni elettrodinamiche prodotte per mezzo di correnti alternate," *Atti della R. Accademia delle Scienze di Torino*, vol. 23, Mar. 18, 1888.

14 "Ricerche teoriche e sperimentali sul generatore secondario Gaulard e Gibbs," *Memorie della R. Accademia delle Scienze di Torino*, vol. 37, series 2, Jan. 11, 1885. "Sulle differenze di fase delle correnti, sul ritardo dell' induzione e sulla dissipazione di energia nei trasformatori", *Memorie della R. Accademia delle Scienze di Torino*, Dec. 4, 1887.

15 "L' ottica delle oscillazioni elettriche": Bologna, 1897.

16 "Electro-physiological Researches," *Phil. Trans.*, 1845–1850; "Lezioni sui fenomeni fisico-chemici dei corpi viventi": Pisa, 1846.

17 Dr. Bence Jones, "The Life and Letters of Faraday", vol. 2.

18 "Sur l'action chimique des différents métaux à la température de l'atmosphère et sur l'explication de quelques phénomènes galvaniques": Paris, 1796. "Dell' azione chimica dei metalli nuovamente avvertita": Florence, 1793.

19 "Über seine Entdeckung des Magnetismus der Flamme", *Pogg. Ann.*, vol. 73.

20 *Raccolta fisico-chimica Italiana*, vol. 3.

21 "Di un nuovo metodo sperimentale per lo studio dell' assorbimento della luce nel campo magnetico." Two notes, *Rendiconti della R. Accademia dei Lincei*, series 5, vol. 7, part 2, 1898.

Faraday and French Physicists.*

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EVEN if it is one of the essential tasks of the historian of science to find exactly what work was done by certain savants, he should still aim at showing the continuity of effort and research—if not of discoveries—by determining the place of the piece of work in question, its antecedents and consequences, what discussion was centred on it, and the depth and rapidity of its penetration into scientific thought. The necessity for consideration of environment would appear to be less if the savant belongs to a fairly recent period, since the speed with which discoveries become generally known has increased steadily through the centuries with the development of what may be called the internationalisation of science.

In the case of Faraday we are naturally led to inquire into the relation between his work, that of his own countrymen, and that of foreign savants. Even when we limit our study to that of the French physicists, under the last head, we are still left with a large field, and are compelled to restrict it further for the purposes of the present article. Without attempting, then, to give an exhaustive treatment, and passing over bibliographic matter—this would involve a very large number of references, and we should have to refer in particular repeatedly to thirty or forty numbers of the *Comptes rendus de l'Académie des Sciences* and as many volumes of the *Annales de chimie et de physique*, without counting a certain number of issues of the *Bibliothèque universelle* of Geneva and of *Poggendorffs Annalen*, where the French savants also published articles—we should like to point out specially, in a general way, what were the main lines of thought.

In the report on the founding of a prize for electricity presented by Biot to the Institut on July 1, 1802, which is signed by Laplace, Halle, Coulomb, and Hauy, an epitome of the history of electricity makes it appear that a second phase had started with Volta. The work of the Italian physicist had indeed not been long in making its effects felt in France, and had been taken up with some enthusiasm and had soon raised exaggerated hopes. Dumas alluded to this in his *Éloge de Faraday* when he referred his hearers "aux souvenirs d'une époque où les professeurs de physique exposaient à leur auditoire étonné la théorie mystérieuse de la pile voltaïque ; le simple contact de deux métaux, qui ne perdaient ni ne gagnaient rien, disaient-ils, faisait néanmoins sortir de cet appareil magique des effluves capables de rivaliser avec l'éclat du soleil . . . ." [1]

The first to question seriously this 'mystical theory' of contact was Becquerel, in France, who communicated a paper to the Academy of Sciences on May 19, 1823, dealing with his researches on thermoelectric phenomena and the electric effects of chemical reactions. His memoir of July 7, 1823, on the electric effects which develop during various chemical reactions, is of capital importance ; it was followed on Sept. 22, 1823, by another paper in which he described a method for measuring the intensity of a chemical reaction by the resulting electrical effects. He described other experiments in November 1823. Finally, he completed his work on April 12, May 31, July 5, and Oct. 3, 1824, by giving an account of a theory of the distribution of electricity in the voltaic cell, and by a discussion of various points arising out of his previous work. This established the general laws of the production of electricity by chemical action. Becquerel was able to construct a cell giving a steady current in 1829, after a first attempt in 1826.

Electricity produced chemically was studied after Becquerel by Pouillet, who presented two very important papers to the Academy of Sciences in 1825 (he also gave the results of his researches on the electricity of elastic fluids and on the origin of atmospheric electricity), and continued this work until 1828.

Whilst the work started by Volta was being developed in France on these lines, the experiment of the Danish physicist, Ørsted (July 21, 1820) was opening up the way for Ampère's and Arago's discoveries in electromagnetism. It would be interesting to give some details of Ampère's experiments. However, to keep strictly within the plan of this study, we shall merely recall the main features of the work, during the course of which the author established the basis of electromagnetism in a few months. The paper presented to the Academy of Sciences on September 18, 1820, is particularly worthy of attention, not only as the first, but also because the views expressed there contain the germ, so to speak, of all the subsequent work. We find established here the existence of an effective electrodynamic force in all parts of the conducting wire as well as in the cell, the notion of the direction of a current, the means of recognising this direction, and

* Translated by Dr. K. G. Emeléus.

finally the general law determining the sense in which the current deviates the needle. Further, Ampère gave there a description of some instruments which he had designed, and elaborated some remarks tending towards an explanation of the properties of magnets. The papers of Sept. 25 and Oct. 9 were devoted to the study of the action of one current on another. During this time, Arago, following up some experiments with Gay-Lussac, had demonstrated the magnetisation of a needle placed in a spiral of wire carrying a current and the attraction of a conductor for iron filings; [2] and announced on Nov. 10, 1820, in the *Moniteur universel* that he had magnetised iron needles by electric sparks.

Whilst Biot was communicating results of experiments he had undertaken with Savart to the Academy at the meeting on Oct. 30, and formulated the law which goes by their names, Ampère was continuing to publish his work, his concluding communications being made on Oct. 30, Nov. 6, and Dec. 4 (1820), and on Jan. 8 and 9 (1821).

At the end of this year (1821) Faraday's work and Ampère's work became closely connected for the first time. It was indeed Ampère's experiments which had given Faraday the idea of making a current element rotate by means of a magnet (we may note that Wollaston had already had this idea) and had made him try the converse experiment. The result of this double experiment in turn led Ampère to extend it, at the same time making his theory of magnetism more exact, and also to remedy its partial failure by improving certain faulty arrangements.

Ampère established the production of electric currents by induction so early as 1822. "Il s'établit", we read in "Recueil d'observations électro-dynamiques" (p. 321), "dans un conducteur mobile formant une circonférence complètement fermée un courant électrique par l'influence de celui qu'on produit dans un conducteur fixe, circulaire et redoublé, placé très près du conducteur mobile, mais sans communication avec lui." About this time Ampère also arrived at the fundamental law of electrodynamics by studying the phenomena of rotation of current elements by means of two circuits.

Whilst other physicists entered the field of electromagnetism, Ampère and Arago persisted in their research, and in 1824 the latter, following up an experiment of Gambey (1824), made the new discovery of magnetisation by rotation. He first ascertained that a magnetised needle returns much more rapidly to its position of rest when oscillating if it is put over a non-magnetic metallic disc, and then showed that the needle was deviated when a non-magnetic metallic disc was rotated above or below it. Arago went still farther and found the direction of the resultant action of the disc on the needle (1826). Before he had taken his analysis of the phenomenon even thus far, however, Prévost and Colladon, working in conjunction with Ampère, recorded (1825) the damping action of a fixed intercalated disc, and in 1826 Ampère showed in collaboration with Colladon that a spiral of wire passing a current was acted upon by the disc like a magnet. Physicists were very puzzled, nevertheless, when it came to explaining these phenomena. It was at first thought that it was a question of induced magnetism, all bodies being supposed to be capable of showing magnetic properties (an idea put forward by Coulomb in 1812), but this suggestion was soon discredited by Arago himself (1826). We can see from this how very far he had progressed towards the idea of induced currents, and how in quite a different way from Ampère, but just as directly, he had reached, so to speak, the frontier of the discovery reserved for Faraday.

There is no doubt that the ground had been prepared for Faraday's work in this way in all directions by the French physicists; and when their contemporaries mentally compared Arago and Ampère with Faraday they let themselves be guided by a proper understanding of the connexion between Faraday and his French rivals. Dumas wrote in his *Éloge de Faraday* that "Quand l'électricité aura trouvé son Newton, on pourra dire que, si Ampère en fut le Kepler, Faraday en fut le Galilée". He then drew a parallel between "ces deux hommes, si divers par les dons de la nature, si rapprochés par le génie et par les travaux", "inséparables dans le tableau du mouvement scientifique dont l'électricité a été l'objet, comme dans le souvenir de ceux qui les ont vus à l'œuvre". We do not think it is correct to add that "ce que l'un a fait, l'autre aurait pu le faire", or to write, as Becquerel did, that "si Ampère eût cherché à vérifier par expérience quels étaient les effets produits par les courants électriques sur les corps à l'état neutre, ainsi qu'il l'avait annoncé, il aurait enlevé à Faraday l'honneur de la découverte de l'induction". Nothing is less certain and more fallacious than a retrospective prediction after an event has taken place. Scientific discoveries have their origin in spontaneous inspiration, which is not part of a logical development and outside the range of extrapolation. The historian of science has done enough when he has established connexions and priorities and his function ends there.

The effect of Faraday's discovery in France, when it was announced to the Academy of Sciences by Hachette on Dec. 17, 1831, can be readily imagined. Not only did his results support Ampère's ideas on the structure of magnets, and by making it possible to pass from magnetism to electricity bring out clearly the identity of the two sets of phenomena, but also the idea of induction seemed especially fruitful from the fact that the existence of induced currents explained satisfactorily what Arago had found about magnetisation and rotation. In fine, Faraday gave a new cohesion to discoveries which had remained, if not isolated, at least somewhat separate; he imparted some sort of unity to convergent ideas which were not obviously comparable, his work being at once synthetic and explanatory.

In another connexion, Faraday's researches on cells led him to reject completely contact action, by his insistence on the chemical origin of the electrical energy of the cell. His influence in France in this matter was a powerful contributory factor in the overthrow of the contact theory, which still persisted in spite of Becquerel's work. Seen from this angle, Faraday's rôle was to supply the necessary support to a piece of work which had not been completely accepted, and which received in this way the authority needed for it to become properly established.

After this, French physicists undoubtedly paid more and more attention to Faraday's researches, and looked to them both for suggestions and direction. For example, shortly after Faraday discovered self-induction, Masson was engaged in 1837 in finding the conditions under which currents could be produced by this means. He succeeded later in finding the relation between the tension of the currents and the sense of the induced currents. Moreover, following up a remark of Faraday's, he and Bréguet studied the conditions which determine the static effects which occur when currents are induced. Abria (1843) and Verdet tried especially to develop the results obtained outside of France by Henry (1839), but the induced currents of various orders studied by him constituted, nevertheless, a sort of extension of Faraday's discovery, and the two French physicists worked under the inspiration of the great English physicist. Still later, to quote only a few examples, it is perfectly certain that the experiments which Lallemand did between 1848 and 1851 on the mutual attraction and repulsion of induced currents, and Foucault's discovery of the heat developed by induction of currents (1855), are closely connected with ideas which originated with Faraday himself.

In sketching above the electrical research done in France prior to Faraday's work, we have ignored two small pieces of work which were too isolated to have any immediate effect. These were Le Baillif's observation of the repulsion of bismuth by a magnet, and Becquerel's observation (1827) of the repulsion of antimony under the same conditions. It was again left to Faraday to find the explanation by discovering diamagnetism, which groups these with other phenomena; even this mention of them, however, gives them rather undue prominence, since it can scarcely be maintained that Faraday's work was anticipated in France. On the other hand, he very soon had pupils, notably Ed. Becquerel, who first showed how to measure the attraction and repulsion of a magnet for different bodies in 1849, and perfected his method the following year and made it possible for Faraday to take up the problem again in the same way and push the solution much farther.

Finally, Faraday's letter to Dumas on Jan. 17, 1845, in which he announced the discovery of rotary magnetic polarisation, had an immediate effect in France. It was the origin of the work of Pouillet (1846), Ed. Becquerel (1846), and again of that of Verdet (1854). We cannot even make a brief study of these researches, and merely mention them to indicate the trend of later work, and the many directions in which the work of French physicists was orientated by Faraday. They were, moreover, not merely distant pupils; they found a living example in their teacher, who was to all intents and purposes a valuable collaborator, always ready to advise them, or to encourage them by some expert suggestion. Dumas tells us that "Foucault, dont les procédés avaient tant d'analogie avec ceux de Faraday dans l'art de consulter la nature, ne fut jamais plus heureux, peut-être, que dans les occasions où il l'avait pour témoin intime de ses admirables expériences". One can appreciate the prestige of the great English savant amongst his contemporaries, and his enthusiasm for scientific research, when one considers the admiration implicit in the following passage from Dumas, describing how Faraday allowed him to be present at one of his experiments: "Ses yeux pleins de feu, sa physionomie animée, témoignaient du sentiment passionné qu'il portait à la découverte de la vérité".

[1] It is interesting to notice that Biot himself spoke in his report with some wonder of electricity being put into motion 'by simple contact'.

[2] Arago having shown this experiment to Ampère, the two then collaborated in new work.

Faraday's Connexion with Switzerland and Swiss Industrial and Economic Development.

By Ch. Eug. Guye, Honorary Professor of Physics in the University of Geneva.*

IT was through being assistant to Sir Humphry Davy that Faraday came into contact with the Swiss savants, and most particularly, at Geneva, with Gaspard de la Rive, then professor of chemistry in the Academy of that town, and with his son Auguste de la Rive, the great physicist, well known for his treatise on theoretical and applied electricity, his theory of the Volta cell, and his discovery of electro gold-plating, etc.

Apart from his invention of the miners' safety lamp, which made his name so popular, Sir Humphry Davy discovered the electric arc, that extremely valuable aid to science and industry, which has made possible the attainment of very high temperatures in the electric furnace and has revolutionised both illumination and the metallurgical industry.

Switzerland is, however, indebted to Sir Humphry Davy not only for his discovery of the electric arc, which benefits its industry, but also for taking Faraday to Switzerland and introducing him to the savants of the country. Geneva is greatly honoured in having and caring religiously for the tomb of the illustrious English chemist in the ancient cemetery of the Plainpalais commune.[1]

We may perhaps recall the circumstances which took Faraday to Switzerland.[2]

Faraday had been filled with enthusiasm by the lectures which Sir Humphry Davy gave at the Royal Institution in 1812, and he sent his notes on the lectures to Davy. In the following year a vacancy occurred for the post of laboratory assistant, and Faraday was appointed to it by Davy, giving up the work in a bookseller's shop in which he had been engaged for several years. A little later, Davy discontinued his work as professor at the Royal Institution to travel through Europe with Lady Davy to study. Faraday accompanied him as his laboratory attendant. They took with them a small portable cabinet which allowed them to do some chemistry on the way. They went first to Paris, which they reached on Oct. 27, 1813, and where Davy presented various notes to the Academy. On Dec. 13, this body appointed him as one of its associate foreign members in the first class. Leaving Paris, Davy, still accompanied by Faraday, stopped at Montpellier, where he met the celebrated Geneva botanist, A. P. de Candolle. We see him in Italy in 1814, and finally, towards the middle of September in the same year, we find him at Geneva, where he remained until the beginning of winter. He finally proceeded to London in the spring of 1815 by way of Austria and Germany.

Thus it happened that by accompanying Sir Humphry Davy on his travels, Faraday had the opportunity of coming into contact with Swiss savants, and particularly with Gaspard and Auguste de la Rive, with whom he kept up a sustained correspondence afterwards, which is now deposited in the public University library of Geneva.[3]

These letters make it clear that Faraday and the Geneva savants were in communication for many years on scientific matters, exchanging opinions from time to time on each other's work. There is neither time nor space at present to go into this in detail, but we can perhaps return to it at some future date. There does, however, emerge from this intimate correspondence an impression of mutual confidence and of profound friendship. We may be permitted to quote in this connexion a letter which Faraday wrote, dated Oct. 16, 1852, when, having reached an age of some sixty years, he felt the first touches of age, although his exceptional activity might still make many a savant envious. A vein of modesty and sincerity brings out all the sympathetic greatness of this choice nature.

à Monsieur Auguste de la Rive,
Presinge
Geneva, Switzerland.

Royal Institution,
16 October 1852.

"My dear De la Rive,

From day to day and week to week I put off writing to you, just because I do not feel spirit enough ; not that I am dull or low in mind, but I am as it were becoming torpid : a very natural consequence of that land of mental fogginess, which is the inevitable consequence of a gradually failing memory. I often wonder to think of the different causes (naturally) of different individuals, and how they are brought on their way to the end of this life. Some with minds that grow brighter and brighter but then physical powers fail ; as in our friend Arago ; of whom I have heard very lately by a nephew who saw him on the same day *in bed* and at *the Academy* : such is his indomitable spirit.—Others fail in mind first, whilst the body remains strong, others again fail in both together : and others fail partially in some faculty or portion of the mental powers, of the importance of which they were hardly conscious until it failed them. We may, in our course through life, distinguish

* Translated by Dr. K. G. Emeléus.

numerous cases of these and other natures; and it is very interesting to observe the influence of the respective circumstances upon the characters of the parties and in what way these circumstances bear upon their happiness. It may seem very trite to say that *content* appears to me to be the great compensation for these various cases of natural change; and yet it is forced upon me, as a piece of knowledge that I have ever to call afresh to mind, both by my own spontaneous and unconsidered desires and by what I see in others. No remaining gifts though of the highest kind; no grateful remembrance of those which we have had, suffice to make us well and be content under the sense of the removal of the heart of these which we have been conscious of.

I wonder why I write all this to you: Believe me it is only because some expressions of yours at different times, make me esteem you as a thoughtful man and a true friend.—I often have to call such things to remembrance in the cause of my own self examination and I think they make me happier. Do not for a moment suppose that I am unhappy. I am occasionally dull in spirit but not unhappy; there is a hope which is an abundantly sufficient remedy for that, and as that hope does not depend on ourselves, I am bold enough to rejoice in that I may have it. . . ."

Now that we have recalled the circumstances which took Faraday to Switzerland, let us see what consequences his discoveries, in particular his discovery of electromagnetic induction, have had in the industrial development of our country.

It is no exaggeration to say that Faraday's discovery is, with that of Ampère, one of those which has contributed the most to our civilised life. Its influence on pure physical science has been admittedly fundamental. Without dwelling on the scientific consequences of this work, we may recall that the discovery of induction, taken up and developed by the illustrious English physicist Maxwell, has become the explanatory basis of the theory of light, and, more generally, of all electromagnetic wave phenomena, which embrace more and more the whole of physics.

It is, however, above all, in its numerous applications that the discovery of induction has been so marvellously fruitful; as we know, these applications have altered the very face of our civilised world.

This transformation has been particularly significant in Switzerland; applications of electricity have rapidly assumed a place of first-class importance in this country. The immense water power which Switzerland employs has in fact only become available through the possibility of transforming it into electric energy, which permits of carrying and distributing it through the whole country, including the most secluded valleys.

To attain these marvellous results, it has been necessary in the first instance to build generators, motors, and electric transformers, the operation of which is controlled fundamentally to a considerable extent by the laws of induction, the discovery of which is due to Faraday's great genius.

At the present moment, the power in use for the production of electric energy in Switzerland is more than a million kilo volt-amperes and the electric energy produced annually by the whole of these installations now reaches about four milliard kilowatt-hours (kw.h.).[4]

The establishment of immense hydraulic works was, however, necessary to capture this enormous energy; moreover, to obtain sufficient regularity in the utilisation of this water power (it is well known how a watercourse varies from one season to another), it has been necessary to accumulate immense reserves; to create by dams large artificial lakes, or to harness by more or less important pieces of work large lakes already in existence. The hydraulic energy accumulated in this way in these immense reservoirs exceeds four hundred million kw.h.

Amongst the artificial lakes made to provide the necessary reserve of energy, we may mention specially Lake Barberine (Valais), with a capacity of nearly thirty-five million cubic metres, and Lake Dixence (Valais), now in active course of construction and with a capacity of fifty million cubic metres.

At the same time, for topographical reasons, Swiss industries have been called upon to make use of considerable heads of water. The installation at Fully (Valais) employs a head of 1650 metres, necessitating conduits and turbines working at pressures of about 165 atmospheres. Even this record will shortly be beaten by the Dixense installation, which will utilise a head of 1750 metres.

All this hydraulic energy is transformed into electric energy in large installations by means of generators and sets of transformers; not only is it used to light towns and even the most remote villages in the high mountains, but also industry in all its forms absorbs a considerable proportion. Mechanical and electrochemical and electrometallurgical industries have grown up rapidly through the marvellous adaptability of the 'electric fairy' for distribution. In the first rank of the Swiss electrochemical industries one finds the Aluminium Company, with large factories at Neuhausen, Chippis, etc., the manufacture of ferrosilicon, and that of calcium carbide, finally used to a large extent for the manufacture of nitrogenous manures (cyanamide). Finally, the whole network of the Swiss railways has been completely electrified quite recently, and this change represents an annual consumption of about a half-milliard kw.h. Quite apart from the many advantages of electric traction, notably from the point of view of multiplicity of trains, the rapidity with which they can start from rest, the absence of smoke, etc., this electrification is a very considerable economy for Switzerland. It obviates the necessity for importing a quantity of coal worth some tens of millions of Swiss francs annually.

Such is a very brief account of the use of our natural resources in Switzerland, which has been made possible in the first instance through Faraday's fortunate discovery. It will be readily understood why the country which has had the privilege of giving birth to a genius whose work has been so astoundingly productive should have decided to honour his memory, and to celebrate the anniversary of one of the discoveries the consequences and repercussion of which have played so important a part in the whole of our civilisation.

[1] Sir Humphry Davy died at Geneva on May 29, 1829. He was buried on June 1 in the Protestant Cemetery at Plainpalais; the Conseil d'État granted a concession for 99 years, which was renewed a few years ago at the instance of the Faculty of Science of the University. In gratitude, Sir Humphry Davy's widow left to the Academy a sum to found a prize for the encouragement of scientific research.

[2] We take these details from an account of Sir Humphry Davy by the late Prof. Ph. A. Guye, of the University of Geneva.

[3] This correspondence contains about ten letters to Gaspard de la Rive (between 1818 and 1832) and about twenty-five letters to Auguste de la Rive (between 1840 and 1861).

[4] A kilowatt-hour corresponds to the energy developed by a machine of 1·36 horse power in an hour.

Faraday and Austria.*

By Prof. KARL PRZIBRAM, Institut für Radiumforschung, Vienna.

IN the autumn of the year 1814, towards the end of the Napoleonic drama, a travelling coach wended its way southwards over the picturesque mountain roads of the Austrian Tyrol. Its three occupants were the celebrated Sir Humphry Davy, his haughty wife, and a modest young man who played the part of a scientific assistant, and also, but with suppressed reluctance, that of valet. Waterfalls thundered down into the valleys, and the eyes of the young man followed them in wonderment. What were his thoughts? Deeply religious by nature and upbringing, was he simply admiring the works of the Almighty, or had he a glimmering presentiment of the possibility of harnessing these vast sources of energy for the benefit of mankind, to the realisation of which his later discoveries were to supply the key?

Young Faraday passed through the Austrian Tyrol twice during that memorable tour; but the influence which he exerted by his later discoveries, not only on Austria but also on the whole world, is in no way to be assessed by these fleeting visits. Is not water power an important asset of our sorely stricken country, and its present and future utilisation directly due to that flutter of a magnetic needle by which the first induction current revealed itself in Faraday's laboratory a century ago? We may recall to memory here two Austrians who though very different in station and in temperament, have both contributed to these extensive developments: first, the brilliant engineer and author, J. Popper-Lynkeus, who, far in advance of his time, upheld the possibility and necessity of electrical power transmission, in a thesis presented to the Vienna Academy of Sciences in the year 1862; and secondly, the university mechanician, Kravogel, of Innsbruck, who anticipated Gramme's ring in an electro-motor of his own construction.

Just as Faraday's discoveries opened up new avenues in engineering, so also, as a result of his novel ideas, translated into the language of mathematics by his great fellow-countryman, J. Clerk Maxwell, was physics confronted by new problems, in the solution of which Austria played no mean part. From amongst the four first magnitude stars in the constellation of Austrian physics—Doppler, Loschmidt, Stefan, and Boltzmann—the last two at least can be brought into direct relation with Faraday; Stefan by virtue of his researches on electrodynamic and diamagnetic induction, and Boltzmann as one of the first and most ardent protagonists, on the Continent, of the ideas of Faraday and Maxwell. Boltzmann's famous experimental investigations on the dielectric constant of gases and of sulphur can be regarded as a direct continuation of Faraday's pioneer work. We are moved as by a breath of Faraday's characteristic homeliness and devotion to his work when we hear of young Boltzmann waiting for hours for admittance to a classical performance in the Vienna Burgtheater, wedged in a crowd of art enthusiasts, and meanwhile, much to the displeasure of those around him, unremittingly polishing the sulphur spheres which he requires for his experiments.

Faraday's experiments on the liquefaction of

* Translated by Dr. R. W. Lawson.

gases were continued in Austria by Natterer, who constructed the first reliable machine for liquefying carbon dioxide; and Boltzmann's successor, Fritz Hasenöhrl, to some extent united the two last-named fields of Faraday's researches, dielectrics and the liquefaction of gases, by determining the dielectric constant of liquid air. Hasenöhrl fell in the War, in the defence of those selfsame Tyrolese mountains upon which Faraday's gaze may have rested little more than a hundred years earlier.

In view of the far-reaching influence of Faraday on contemporary physics, the selection of Austrian physicists referred to in this note is necessarily somewhat arbitrary. We might well also have drawn upon names such as E. Mach, V. v. Lang, L. Pfaundler, E. Lecher, and Franz Exner.

May the spirit of Faraday continue to dwell amongst us. It would be a sad prospect for science were those two complementary characteristics of Faraday's genius to depart from us—creative imagination and unconditional devotion to experiment.

The Faraday Festival.

By Prof. Bohuslav Brauner, Prague.

The whole scientific world will join in celebrating Faraday's discovery of electromagnetic induction, and it will certainly not be passed over in Bohemia. I may be excused if I begin with myself. In our middle school (gymnasium) we had a most excellent teacher of physics, Prof. Pokorný. In his clear and beautiful lectures, which would have served as a model to those given at a university, he taught us in 1870 the principal discoveries in the domain of electricity. He spoke of Galvani, Volta, Carlyle and Nicholson, Ørsted, Ampère, and others, but before all he praised the discoveries of Faraday.

Pokorný accompanied his lectures by the most delicate experiments. We became so enthusiastic about the matter that we constructed many of his pieces of apparatus at home. I myself constructed first a Daniell cell, but for want of the necessary means the porous diaphragm was made of paper cardboard coated on both sides with plaster of Paris. A series of such elements gave a distinct spark between carbon poles. Further, I constructed a Neff's hammer, an electric alarm bell, an induction coil with condensers and a regulator, an electric telegraph for reaching a distance of a mile, an electric contact-thermometer showing the temperature at a distance and ringing the alarm bell to avoid an explosion—such as that which occurred in the dynamite works near Prague—and last of all an electric 'waker-up', ringing an alarm-watch. They were novelties in 1870, sixty-one years ago. It must be remembered that the art of 'electrotechnics' was founded only eleven years later, namely, in 1881, at which time the new electric units were established, the one mostly used up to that time having been the B.A. unit. Fifty years of Nature, with which I became acquainted in 1880, has kept me well informed of further developments of electrical science.

Not only apparatus made by enthusiastic students, but also more serious investigations were made by some of our countrymen. Prof. František Petřina, a Bohemian, born in Semily in 1799, from the year 1844 ordinary professor of physics in the University of Prague, has done research work in galvanism, especially in telegraphy, as is seen from his many publications in *Poggendorfs Annalen* and those of the Vienna Academy of Sciences and so on. While teaching in Linz (1837–44) he constructed a simple instrument for 'faradisation': one magnet wound with insulated wire standing and another magnet on the top which could be turned round, so that the poles were changing. I saw the original model and also 'Petřina's spiral' largely used.

In the Bohemian University the theory of Faraday's discoveries was analysed by Prof. Koláček, professor of theoretical physics, but his work was rather to follow up that of Maxwell.

Prof. František Žáček, physicist of the Bohemian University, has given me information upon the experimental significance of Faraday's discovery of electromagnetic induction: without Faraday's work, many aspects of electricity and the whole of electrotechnics could not be thought of. But also from the purely scientific point of view the value of this discovery is enormous, for it is a step showing a further connexion between electrical and magnetic phenomena, following on from Ørsted's discovery of the magnetic action of the electric current.

A further important discovery of Faraday is that of the chemical actions of the electric current and of the laws which it obeys. Besides the experimental importance of this work, due weight should be given to the theoretical side in connexion with our present views on the composition of matter and the atomic structure of electricity.

For the further development of electrical theory, Faraday's views on the relation of electric and magnetic phenomena, on the spreading out of the electric and magnetic forces through the dielectric, on the rôle of the same, on the tubes of force and so on, are highly important. In this respect Faraday may be regarded as the father of modern electrical theory, and he is the creator of the *Nahewirkungstheorie*. Faraday's views were further developed by Maxwell, and we find the fertile consequences not only in the purely scientific field (the electromagnetic theory of light), but also in the practical field (electromagnetic waves and radiotechnics). In this connexion, Prof. Žáček would like to direct attention to the fact that Faraday had a presentiment of the close connexion between electrical and optical phenomena, in pursuit of which he discovered the rotation of the plane of polarisation in the magnetic field.

Faraday's Researches and the United States.

By Prof. Willis R. Whitney,
Director of Research, General Electric Company, Schenectady, New York.

THE spirit and method of Faraday are as worthy of study as the results that flowed from them. Almost anyone could rehearse his cardinal contributions to present-day understanding of magnetic and electric fields, and could cite his electrochemical researches and his studies of magneto-optic and diamagnetic phenomena. No one ever before covered so wide a field of pure research, or discovered and disclosed such a grand territory of expanding and continuing usefulness. No one ever tapped so many sources from which living water flowed. But for anyone, however closely connected with that particular field of pioneering, to attempt to enlarge upon Faraday's work, seems to be lifting one's self by mere words into a position where the light of Faraday's character warms the writer without of necessity illuminating the rest of the world.

In his writings, Faraday touched the spiritual side of life lightly but revealingly when he said, "Yet even in earthly matters I believe that the visible things of Him from the creation of the world are clearly seen, being understood by the things that are made, even His eternal power of Godhead: and I have never seen anything incompatible between those things of man which can be known by the spirit of man which is within him and those higher things concerning his future, which he cannot know by that spirit."

The establishment of publicly supported institutions for the advancement of physical knowledge which was marked by the Royal societies and academies about 1700, looks, at this distance, like an attempted answer to Bacon. Nearly two hundred years before Faraday, Bacon advocated experimental science and orderly collections of physical facts. He saw a continually changing world, and wanted to direct the changes toward utility for all men, not 'before' but 'after' the events of research. "The subtility of nature", he declared, "is far beyond that of sense or understanding", and, again, "The real legitimate goal of the sciences is the endowment of human life with new inventions and riches."

The history of the Royal Institution, when Count Rumford interested the English public in establishing it as a laboratory for research and exposition about 1800, reads also like a continuation of the plan to acquire new knowledge by the direct, efferent method, and to encourage organised methods of dispensing and utilising it. It is scarcely too much to say that, if Francis Bacon could have had the Royal Institution and Michael Faraday in mind when he tried to point the way for useful development of science, he need have foreseen no other means.

It is well for us to realise not only Faraday's natural endowment, but also his artificial environment. Under Davy, he had become equipped with the best physical knowledge of his time. Thus, when he joined the Royal Institution as assistant in the laboratory, he was like some highly sensitive, but very young, plant in a new environment perfectly suited for growth. No other position in the world afforded such an opportunity for a young man who was interested in new science. His driving motive was never an immediate commercial or technical one, but purely the inquisitive searching of the infinite possibilities of Nature. He placed the highest value on new knowledge as such. He was ever ready to fit the theory to the fact. "In knowledge," he said, "that man only is to be contemned and despised who is not in a state of transition." Keenest and most unprejudiced of observers, he was a master of method, and recorded his observations in a manner to make them of maximum usefulness to others. I would estimate as not the least of his contributions to science the way in which he wrote those notes, their fullness, even the distinctly separate and numbered paragraphs. Those seemingly simple methods must have started many a young scientific worker along the way of careful observation and orderly record.

Francis Bacon, Benjamin Thomson (who, with the support of such Englishmen as Joseph Banks, established the Royal Institution), Humphry Davy, Michael Faraday, and their followers at the Institution, form what must be called a world pioneering group. These men had human welfare in mind, and each one showed plainly that while he did not know the particular utilisations to be made of new knowledge, he was certain that service always resulted from new material facts. They worked for civilisation and for more and better types of it. They were insistent on experiment because they were anxious to be led by Nature. While accepting the value of the deductive sciences, they indicated by the successes of their undertakings that taboos, general principles, theories, and laws were largely useful through the values produced on questioning and testing them.

It is difficult to imagine now that Faraday could not foresee the great expansion which would occur in electricity. On the foundations which he laid, all the civilised countries of the world ultimately began building electrically. Electric lighting systems, power transmission systems, transportation systems, telegraph, telephone, and radio are all based on his demonstrations of the relationship between magnetic field and conductors. Here was no sudden flash of intellectual legerdemain. Rather the inspired and tireless work of a master builder. On those impregnable foundations he erected a structure of beauty and utility to which his followers may for ever add.

Developments in the United States of the researches of Faraday are not particularly different in kind from those of other civilised countries, but I can write more intelligently of them. As a nation the United States now uses as much electric energy as the rest of the world combined. It is difficult to realise that one short century ago Faraday was showing the race which had so long known lightning, animal electricity, 'static', and voltaic currents, that these, together with the new magnetically produced currents, were tokens of the same thing. Since that time, all the aluminium and much of the copper in the world has been produced by application of his magnetic induction method for current generation and in accord with his quantitative electrochemical laws. While his first dynamo was described in 1831, it took more than thirty years for appreciation of what such generated current might do technically. We credit him with both the principle of the electric motor and the dynamo or generator, because his first new electrical machine of 1831 produced electric current by the rotation of a copper disc bearing suitable brushes between the poles of the magnet, and as a motor he had forced a wire carrying current to rotate around a magnetic pole. No one supposes that Faraday foresaw the unlimited application of generator and motor which is following in orderly manner the systematic researches he performed. It is this fact which seems to me to connect him inseparably with Francis Bacon, who predicted such results of orderly scientific studies.

The present investments in the United States in the electric power and light industry are about twelve thousand million dollars. To this we must add more than five thousand million for electric railways, and another five thousand million for telephone and telegraph companies. A half million new customers are being added to light and power lines each year (in the United States), and about two thousand million dollars (400 million pounds) is received as income annually.

Even these data are an inadequate expression of value, because the yearly increment in the electric light and power field alone is more than five hundred million dollars annually (100 million pounds a year). About two-thirds of all the homes in the United States are now electrically lighted. More than twenty million houses are now 'wired'.

The value of electrical 'goods' made in the United States in 1929 exceeded two and a half thousand million dollars. In 1930 there were about seventy-five million dollars worth of incandescent lamps sold, and by 1930 there were sold about six hundred million dollars worth of electric household refrigerators.

Statistics and estimates are tiresome and prosaic. It is impossible even to mention many important electrical applications without making an unreadable list, but among those which exceeded a million units in use in 1931 are the flat irons (more than 19 millions), vacuum cleaners (9 millions), radio sets (10 millions), washing machines (7 millions), fans (3·9 millions), toasters (8 millions), percolators (6 millions), refrigerators (2·6 millions), space heaters (3·4 millions). Even such minor products as dry cells, storage batteries, and voltaic batteries were made to the value of 145 million dollars in 1929.

Thus far economy of electrical power production has risen with the sizes of individual generators, so that machines of 160 thousand kilowatt capacity have recently been made.

Probably, also, in no other line of commercial undertaking has an equal development of almost public ownership taken place. In the various electrical industries, including operating companies or ' utilities ', there is wide distribution of stock, especially among the employees of the various organisations. This growing modification of participation by employees in the profits of their work is a promising evolution. There are more than 100,000 stockholders in the General Electric Company, more than 500,000 in the Telephone Company, about 675,000 in the three utilities, Cities Service, Electric Bond and Share, and Commonwealth and Southern, and about 85,000 in the Radio Corporation.

Generally speaking, lighting, which once was the major use of electric current, is being exceeded by other uses even in the average homes. There are many home devices coming into use which consume much more energy and save more human effort than lighting does. Electric heating and cooking, electric laundry and refrigeration devices are increasing in number and improving in quality, so that Faraday's utility contribution is just well under way.

Our farmers, because of their scattered or remote condition, have not been receiving much of Faraday's contribution, but 90,000 farms were connected to power lines for the first time last year. The total of electrified farms is now nearly 700,000, and this will rapidly increase because cross-country power lines are being interconnected into immense interlocking ' net works '. More than a tenth of the power is already used in States in which that particular power was not generated. The distance to which electric power may be economically sent is continually increasing.

It is not enough to confine one's self to past developments based on Faraday's work, nor is it correct to attribute every modern electrical advance to his personal researches. The world had to pass through those experiments and to others dependent upon them. But this is an occasion when there is no harm in indicating the potential values as well as the past services. Certainly the applications of electricity to the extent now seen in the United States will be exceeded and extended over the rest of the world. Thus Faraday, whatever he did, is bound to do much more as time goes on.

Then, too, the spread of electrical conceptions is not geographical alone. In the fields of science itself electricity in some form is become broadly basic. We now glibly speak of all matter being electrical, of about all phenomena being traceable in some way to electrical phenomena, and this reaches even to the processes of our nerve and muscle reflexes, our senses, and even our thinking.

It is a far cry from the first little machines of Faraday to the application of electricity to railroads, which at present so interests both England and America. From those machines, too, it seems a far cry to X-rays, to photoelectric cell applications, to the telegraph, the telephone, to radio, and to television. But we must remember in this connexion that it was Faraday himself who first demonstrated the identity of the unknown stuff we call electricity as he found it in the amber, the cat's fur, the electric eel, the voltaic cell, the lightning, and his electromagnetic fields.

We say blandly that electrical applications are certainly revolutionary, but do we realise yet that modern human revolutions are usually due to the natural desire for greater freedom from exhausting or forced physical work, and that Faraday's work has freed more slaves than any other revolution ? It can apparently continue this service in ever-expanding degrees and ways. The South Sea islander who learned to want his first red loin-cloth may have killed a missionary to get it, but that is not now the general method. As men grow less and less savage they appreciate their missionaries better and better, and Faraday was supported by the intelligent part of a most advanced community. Perhaps that work will some day bring about co-operative international research institutions, in which more equitable distribution of responsibility and financial support will include the diverse benefited nations, and work be undertaken which is not, strictly speaking, the duty of any one nation to perform.

It is quite probable that the work of Faraday, supported by the Royal Institution, whose aim was discovery and disclosure of new physical facts, had much to do with the development of research laboratories all over the world. There are thousands now where there was none a century ago. Most of them, probably actuated by the motives which influenced the Royal Institution, still provide for broadcasting results of research of possible public value or interest. This was not always an obviously good policy in commercial organisations. But one can say, on looking over the past century's scientific and industrial accomplishments, that it has evidently been to the world's advantage that new scientific work in each of the civilised countries has been so generally and completely published. The completeness and accuracy, even the readability of all the publications of Faraday, set investigators a wonderful example, and science will never go back to the period when important or generally useful truth died out with the individual discoverers.

Electricity has had a marked effect on civilisation. True! Steam-engines broadened our physical and mental territories. But Faraday's researches, which were apparently at the time purely of academic importance, constituted peculiar and bold anticipatory effort. It was an attempt at appreciation of natural phenomena where the word appreciation involves extensive orderly investigations and understanding, followed by efforts at serviceable utilisation. Emulating Faraday—the experimenter—large numbers of industrial pioneers have been advancing into new electrical territory, both geographically and economically. They were probably influenced by the same kind of natural impulse which actuates all our explorers. This new activity is recorded in the modern literature of science, and is seen also in manufacturing and power developments.

The pioneer electrical spirit is evinced by the man who gathers capital to develop an extensive water-power in some remote district. There may be at the time no economic need for the power locally, and often none at any place, but such pioneers build in the faith that advance and change is continuous. It seems that new scientific knowledge does not long remain idle, and that if cheap power can be generated in some neck of the woods, then it is highly probable that worth-while uses will be made of it. In other words, the direction Faraday took into the untilled field of electric research is being pursued now by what we call hard-headed business men. They extend telephone, light, and power lines to connect countless different centres and sources, having the faith that as population increases, manufacturing expands, wants increase, and civilisation grows, they will be met by descending average costs of electric supply.

It is already evident that American factories have now been so completely electrified, that further effort at substituting motors for local steam plants or switches for endless belts is poor business. It is now more intriguing to substitute electrical devices for much of the operating and control of the machines themselves. The aim is to free the mechanical worker as much as possible. Countless electrical devices now take the place of his eyes, his ears, his hands, and his muscles. But as nothing takes the place of brains, these will be put to work in new ways. The millions of young people who now insist on getting advanced education far beyond the wildest hopes of ideal education a century ago, are bound to do for the general welfare much the same kind of useful research that Faraday did in his field; and evidently the way it is all going to work out is still as dim but certain as electric power was when Faraday's magnetic field first forced rotation on his current-carrying wire.

The Modern Electric Age in Relation to Faraday's Discovery of Electromagnetic Induction.

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THE Faraday centenary celebrations in London in September will commemorate the discovery of electromagnetic induction by the great experimental scientific worker, Michael Faraday, one hundred years ago, in the laboratory of the Royal Institution. The principle involved in that discovery has proved of the greatest importance to the whole civilised world during the century which has since elapsed. The whole world, therefore, joins in the commemoration of an event which, in salient measure, has led up to practical electrical applications tending to interlink many nations in the conjoint use of electric power.

It may be of interest to outline very briefly the part which this discovery has taken in electrical engineering development.

Frictional or High-Tension Electricity.

Up to the year 1800, electricity was recognised only in the type that we call 'frictional', that is, capable of being produced by the mutual friction of unlike substances, and characterised by the properties of relatively high voltage, small quantity, and brief impulsive currents. Although in the year 1800 a very wide field of experimental knowledge had been developed in frictional electricity, by investigators in many countries, the number of its practical applications had proved to be very limited. Frictional electricity was hard to insulate and to control.

Low-Tension Electricity.

Volta's announcement, in 1800, of the discovery of low-tension electricity, associated with the contact of different metals and attendant electrochemical action, added a new chapter to the history of electrical development. The voltaic pile, as an electric source, was so different from the frictional machine or the influence machine, that it is no wonder doubts were raised, at first, as to whether voltaic electricity was really the same as frictional electricity. With frictional electricity no electric circuit seemed to be necessary, whereas with voltaic electricity a conducting circuit had to be provided. In this circuit the voltage was relatively low ; but the current produced might be relatively strong and steady. It took several decades for scientific workers to establish the voltaic battery on a firm basis of practical reliability.

Volta's name became incorporated in the list of practical electrical units by the Paris International Electrical Congress of 1881, under the unit name *volt*.

Relationship between Electricity and Magnetism.

Up to the year 1820, electricity and magnetism were studied as separate and independent branches of science, electricity being both frictional and voltaic, while magnetism was the innate property of certain iron minerals called ' lodestones ', capable, however, of being imparted, by contact, to previously neutral steel bars or needles. In that year, however, Ørsted, of the University of Copenhagen, discovered that any wire, carrying a steady current from a voltaic battery, was capable of deflecting a magnetic needle suspended in its vicinity. Here was an interrelation between magnetism and electricity in motion, with the birth of a new branch of science—electromagnetism. Ørsted's name was incorporated among the list of magnetic units, under the title *oersted*, by the International Electrotechnical Commission (I.E.C.), at Oslo, in 1930.

Closely following upon Ørsted's discovery, came the work of Ampère, who further strengthened the link of electromagnetism between magnetism and electricity by showing that electric currents exert mutual attractions and repulsions, like magnetic poles. He succeeded in placing these electromechanical forces on a firm mathematical basis. The name *ampere* was assigned to the practical electromagnetic unit of current by the International Electrical Congress of Paris in 1881.

The work of Ørsted and Ampère opened the path of development for electromagnetic current-indicating instruments and galvanometers, which were badly needed. It also provided the starting-point for electromagnets and the electric motor, the movement of a compass needle by a current flowing in a wire being the initial step towards continuous rotation ; but much had to be invented and devised by Faraday, Wollaston, and others, before the first small electromagnetic motor was produced, embodying rotation.

The Royal Institution.

The Royal Institution, made so famous by the work of Davy and Faraday, was planned and financed by Sir Benjamin Thompson, Count Rumford, in 1799, in conjunction with Sir Joseph Banks, then president of the Royal Society. Count Rumford was born at Woburn, Massachusetts, a suburb of Boston, in 1753, and studied at Harvard College. As a young man he taught in a school in a town of New Hampshire, at that time named Rumford ; but renamed Concord (the State capital) in 1763. He went to England, and after publishing scientific researches there, he was elected a fellow of the Royal Society. In 1796 he established the Rumford Medals by an endowment gift to both the Royal Society in London and the American Academy of Arts and Sciences in Boston, for conferring medals upon persons in Europe and in America, respectively, who made notable contributions to the subjects of light and heat.

It appears that Count Rumford invited Sir Humphry Davy to be the first lecturer at the Royal Institution. Sir Humphry Davy accepted the invitation, and proceeded to establish the fame of the Institution by his lectures and researches in chemistry and physics. Sir Humphry Davy, in 1813, invited Michael Faraday, then twenty-two years of age, to come to the Royal Institution as an assistant. Faraday accepted the post, and later, as we know, succeeded Sir Humphry Davy as the lecturer, researcher, and scientific head of the Institution, which his discoveries made yet more renowned.

Faraday's Electromagnetic Researches of 1831.

Faraday kept for many years, at the Royal Institution, a diary of his scientific work, which has since revealed more kinds of utility than its author may then have imagined. This diary is to be published in full as a valuable permanent appendix to the Faraday centenary celebration of the present year. It is clear from the diary that Faraday suspected there must be some interconnecting link between electricity and magnetism other than that already discovered by Ørsted in 1820. The diary records the details of the crucial experiment that caught the suspected missing link, on Aug. 29, 1831. The apparatus is virtually an elementary type of what we should to-day call a transformer, with primary and secondary windings on a solid iron ring core. On making and breaking the primary circuit, excited by a voltaic source, momentary induced currents were observed in the secondary circuit, closed through a galvanometer. This must have been regarded as an extraordinary new phenomenon at that date. The development of this discovery led on to the dynamo-electric generator.

It might naturally be supposed by any student of modern electrical engineering that the electric generator was first produced, then the electric motor, and thirdly the alternating current transformer. It would seem, however, that, historically, the order in discovery of fundamental principles was first the motor, then the transformer, and thirdly the generator.

Contemporaneous Researches of Henry in Electromagnetics.

While Faraday was engaged upon his experiments on magnetic and electric interconnexion, in 1831, at the Royal Institution, at least one other scientific investigator was at work in the same field. Joseph Henry was born at Albany, New York, on Dec. 17, 1799, which happens to have been also the birthday of Sir Humphry Davy in 1778. Albany, some 250 km. up the Hudson River from New York City, and now the capital of New York State, was first settled in 1624, under the title of Beaverwyck. The name was changed in 1664 to Albany, in honour of the Duke of York and Albany, afterwards James II. of England. It was a centre of the fur trade and in 1800 was an active town. Henry studied at the Albany Academy, and was appointed its professor of mathematics and natural philosophy in 1826. It was a remarkable coincidence that Faraday and Henry, so remote from each other, and working under such different surroundings, should be investigating simultaneously the same field of electromagnetics. Faraday was in the Royal Institution, probably one of the best-equipped laboratories of that period, while Henry was in the schoolhouse of a remote American country town. Much time must have been required, at that date, to exchange scientific information between researchers in London and Albany, New York.

It would seem that each independently discovered, through different experimental apparatus, the production of electric currents from the excitation and de-excitation of a magnetic circuit linked with a secondary coil; but whereas Faraday recorded his observations in August 1831 and published them in November 1831, Henry did not publish his observations until July 1832.[1] The field of electromagnetics is, however, so large, and the scientific accomplishments of both these eminent pioneers was so outstanding, that there has been abundant recognition of each. The names of both Faraday and Henry have been included in the list of international electrical units, by international congresses, under the respective titles of the *farad* and the *henry*.

It is curious to note that while Faraday worked for more than fifty years in the Royal Institution, established in large measure by an American, Count Rumford, Henry worked for more than thirty years as the first secretary and director of the Smithsonian Institution, at Washington, D.C., a scientific organisation established by a legacy to the United States from James Smithson, an English chemist and a fellow of the Royal Society.

Intermediate Stages between the Discovery of Electromagnetic Induction and its Large-Scale Industrial Utilisation.

Since the discovery of the fundamental principle of electromagnetic induction in 1831, it has required the intervening century to bridge the wide gap between that achievement and the existing stage of its utilisation for electric lighting and power distribution. It was necessary for physicists and mathematicians, in different countries, to place the discovery on a quantitative basis. This work, conducted by such leaders as Gauss, Joule, and Maxwell, occupied many years. All these three have had their names incorporated in the list of international electric and magnetic units.

Then there had to come the work of scientific inventors, to utilise the principles established for satisfying practical needs. Several of these great electrical inventors are still at work with us. After these had to follow a large number of financiers and business men, sufficiently persuaded of the practicability of the inventions to venture expenditure of capital upon them. Next had to be trained and equipped a corps of engineers and designers, to prepare, construct, and install the machines and apparatus in the electric transmission and distribution systems. Next in turn had to be trained an increasing army of operators, inspectors, and repair men to keep the systems in successful continuous operation.

Finally, and by no means least important, the public at large had to become acquainted with, and experienced in, the use and maintenance of the electrical apparatus placed at their disposal. This expanding process of education and training is constantly going on, and has been necessary for the industrial success of the original discovery. So, in our modern civilisation, a scientific discovery of the type here considered has to permeate the minds of millions of people in order to become an international industrial success.

Importance of the History of Science.

It is only necessary to make superficial inquiries into any important scientific discovery, such as that of Faraday in electromagnetic induction, to realise how little attention is devoted in the world's universities, colleges, and schools to the history (1) of basic science such as in mathematics and physics, (2) of applied science or engineering, and (3) of science in industrial practice. The study of the history of science is surely as worthy and important as the history study of either art, literature, or sociology. A beginning has indeed been made towards establishing university chairs in the history of science; but only a beginning. This study is fully as exacting as that of any other type of history, in regard to scholarship, training, and ability. It needs a knowledge of several languages, and each branch of science, as well as each period of the world's scientific history, demands its own group of working languages. It needs special gifts in exposition; because a historian of science who makes his story technical greatly reduces the number and the interest of his readers. As times goes on, it is to be expected that in each progressive country there will be established at least one university chair for the history of either basic or applied science. But, in all histories of electromagnetics, the date of Aug. 29, 1831, may be looked for as a red-letter day.

[1] " A Memoir of Joseph Henry ", William H. Taylor: Philadelphia, 1879. " A Memoir of Joseph Henry ", Simon Newcomb: Washington, 1880.

Faraday and Electrical Science in Russia and the U.S.S.R.

By W. Th. Mitkewich, Polytechnic Institute, Leningrad.

FARADAY'S experimental researches in electricity and magnetism, his great discoveries and deep analysis of our physical conceptions, have produced an exceptional influence upon scientific thought throughout the world. His ideas have impressed themselves on the scientific work of all who were and are studying electromagnetic phenomena, as well as all natural phenomena that have any connexion with electricity and magnetism. All that has been done after Faraday in that domain of science is linked directly or indirectly to the fundamental ideas expressed and developed by him.

The principal idea which guided Faraday in all his works, and formed, so to say, the invariable background of his scientific thinking, was that all the interactions in Nature, and consequently also those of an electric and magnetic character, can exist only when some special physical conditions or phenomena are taking place between the interacting bodies and around them. He would not allow of the possibility of the conception of 'action at a distance' when studying and investigating any natural phenomenon. In his reasoning, he referred to Newton's authority; Newton had quite a definite opinion on that subject (see Newton's third letter to Bentley). Thus, where other physicists saw centres of forces acting at a distance, Faraday in his mind's eye saw physical lines of force traversing all space. From mathematical fictions which were used, and still continue to be used by some, Faraday's point of view leads us to a closer contact with what is actually going on. This may be considered as the first general reason for the great fruitfulness of Faraday's ideas.

The second fundamental consideration that guided Faraday's investigations and led him to a series of discoveries, was that between all the phenomena of Nature, and in particular between the phenomena of electricity and those of magnetism, there must exist some close connexion. He possessed an intuitive bent of mind that enabled him to inquire into the relationship of phenomena. He seems never to have deemed any physical relation complete in which discovery had not been made of the converse relation for which instinctively he sought. Not by chance, but by following up his general views of natural phenomena, Faraday made a hundred years ago, in 1831, his greatest discovery: he succeeded in generating the electric current by means of electromagnetic induction; this discovery is the true basis of modern electrical engineering and all the applications of electrical energy. Faraday saw from the beginning that peculiar properties of magnetic flux are manifested in the phenomenon of electromagnetic induction.

It should be stated * that the conception of the magnetic flux, as such, belongs fully to Faraday himself. Faraday was the founder of the doctrine of the physical properties of magnetic flux. Experimental methods discovered by Faraday permit us, in the right sense of the word, to feel the invisible magnetic flux as something real. Faraday was the first who showed the real existence of magnetic flux, which is of primary importance in all the manifestations of electric current; magnetic flux bearing all the energy of electric current. Faraday was the first who realised the insufficiency, the complete one-sidedness, and even the fallibility of our usual conceptions of the electric current, those conceptions being connected, owing to purely historical circumstances, with the process of movement of electrical fluids. He directed scientific research to the space round the conductor carrying the current, to that space where the energy of the electric current is located. Faraday showed his remarkable power of penetrating to the very nature of things when analysing the specific rôle of magnetic flux in electromagnetic phenomena, and particularly in the electromagnetic complex called by us the electric current flowing through a conductor. Faraday's mind was possessed more and more by this idea, which completely dominated him to the end of his scientific activity (see Faraday's "Experimental Researches in Electricity", beginning with Series XIX.).

Clerk Maxwell, the great interpreter of Faraday's ideas, accepted fully his principal points of view and developed them. Maxwell's differential equations of the electromagnetic field and the modern successes of wireless telegraphy and telephony are the direct development of Faraday's ideas. There is not a branch in the domain of electric and magnetic phenomena which was not considered and investigated by Faraday. His work in studying the properties of the electric field has proved of equal value to pure science as to technical applications of electrical energy. Faraday's discovery of the rotation of the plane of polarisation of light by magnetic action is the direct result of his line of thought; that discovery has revealed the electromagnetic nature of light and enabled Clerk Maxwell to describe the vortex motion in the magnetic field. In discovering the laws of electrolysis Faraday threw a bridge across between chemical and electromagnetic phenomena, and at the same time he laid the foundation for the conception of the atom of electricity that has led in turn to the conception of the electron. On the other hand, Faraday's studies also became the foundation of modern applied electrochemistry. In short, Faraday's work created a specific conception of natural phenomena and gave a powerful impulse to all kinds of practical applications of electrical energy, transforming entirely the general conditions in which modern mankind exists.

It is clear, of course, that the growth of new ideas arising from Faraday's scientific work, and the construction of electromagnetic machinery and other apparatus embodying these ideas, was the source in this field of the work of many other physicists and of many inventors. But it is undeniable that the whole army of those who worked theoretically and practically, and carried on Faraday's task, has been always inspired and supported by the genius of that great man. At the same time, it is undoubtedly true that many of Faraday's scientific achievements are not yet sufficiently understood and appreciated. His "Experimental Researches in Electricity" remains 'an Arabian book under seven seals' for those who, owing to the excesses of purely formal methods of investigation, have lost, in some degree, the capacity of understanding thoughts expressed in simple words. Faraday gave us the highest model of what physical thinking should be. He was a true natural philosopher. Every deviation from Faraday's method of study and analysis of physical phenomena leads to uncertain results. The roots of the modern crisis in physics must be sought to a great degree in this direction.

As noted above, Faraday's works have had a deep influence on the progress of physical thought all over the world. In particular, the discovery of electromagnetic induction of current attracted the attention of a number of Russian physicists. E. Lenz, member of the St. Petersburg Academy of Sciences, was much taken by the studies of this phenomenon. In 1834, that is three years after the discovery of electromagnetic induction

* W. Th. Mitkewich, "The Work of Faraday and Modern Developments in the Application of Electrical Energy". Paper read before the Second International Congress of the History of Science and Technology, London, 1931.

by Faraday, E. Lenz enunciated the relation between this phenomenon and the mechanical action of electric currents. Lenz's law is as follows:—If a constant current flows in the primary circuit A, and if, by the motion of A, or of the secondary circuit B, a current is induced in B, the direction of this induced current will be such that, by its electromagnetic action on A, it tends to oppose the relative motion of the circuits. In Lenz's law we meet with the first clear indication that in the phenomena of electromagnetic induction we have the manifestation of the conservation of energy. In the later works of Helmholtz, Sir William Thomson (Lord Kelvin), and Clerk Maxwell we have the completion of this idea. Further, in 1839, E. Lenz stated, in spite of the opinion of many of his contemporaries, that induced currents do not possess any special properties, as compared with currents of galvanic batteries. E. Lenz proved, too, the independence of the induced electromotive force of the diameter of wire and of its substance. In his numerous researches on electromagnetic apparatus, E. Lenz established a series of most important statements having an important rôle in the modern theory of dynamos. It may be mentioned that in 1844 he described the phenomenon which is called now the armature reaction, and stated clearly the principal conditions for the proper position of brushes on the commutator of a dynamo.

In 1837, M. H. Jacobi, member of the St. Petersburg Academy of Sciences, invented electroplating. In 1839 he sent some specimens of electroplate deposit to A. Humboldt and to the Paris Academy of Sciences, which bestowed on him a gold medal for his scientific inventions. In his reports and writings, dealing with this subject, M. H. Jacobi gives a detailed account of all the conditions affecting the character of deposition and shows the quantitative relations and examples of calculation, based on the laws of electrolysis discovered by Faraday. It was M. H. Jacobi, too, who pointed out the possibility of making use for electroplating of currents generated by electromagnetic induction. M. H. Jacobi studied also the theory of electromagnetic machines, in particular of electro-motors. He built a special electro-motor, by means of which in 1839 he put in motion on the Neva, against the current of the stream, a boat carrying fourteen persons. Studying the work of electromagnetic motors, M. H. Jacobi established in them the presence of the back electromotive force, which arises according to Faraday's law and is overcome by the electromotive force of the battery. Thus M. H. Jacobi originated the calculation of the energy balance in the process of transformation of electrical energy into mechanical work.

Electrical lighting was the first broad practical application of electrical energy, generated by dynamo-electric machines constructed according to principles indicated by Faraday. Many Russian scientific men and inventors, as Jablotchkoff, Lodygin, Tchikoleff, and others, were interested by this field. Much was done, especially by Jablotchkoff, whose 'candle', invented in 1876, contributed in large measure, thanks to its simplicity, to the development of electrical lighting, and was widely used in many countries, mostly in France. In 1877, Jablotchkoff patented the system of electric light distribution by means of transformers.

In the domain of dynamo construction the merits of the Russian inventor and scientist M. Dolivo-Dobrovolsky are especially to be noted. He studied the physical properties of the magnetic flux, worked out the first sufficiently perfect electro-motors with rotary magnetic field (asynchronous motors), and was the initiator of the application of three phase currents for power transmission (1887). In 1891 he took part in accomplishing the transmission of electrical energy by three phase current from Lauffen to Frankfurt, covering 175 km. This transmission line was of historical importance and was the first experiment that had an industrial significance.

Electrical discharges through gases, to which Faraday contributed with a number of his investigations, were studied by many Russian scientists (Stoletoff, Sluginoff, and others). In 1888, Prof. Stoletoff discovered the photoelectric effect.

In 1900, Prof. Lebedeff published investigations, in which he succeeded, for the first time, in observing and measuring the pressure of light, which was predicted by Clerk Maxwell's electromagnetic theory of light; this theory being, in its essence, an interpretation and a further development of Faraday's cardinal ideas.

It may be permitted to state here that electric welding by means of the electric arc originated in Russia, under the stress of general interest in the domain of practical applications of electrical energy. This method is now widely applied in the Unites States and Europe for shipbuilding, construction of dynamos, and, in general, for metallic constructions. The originators of this method were Russian engineers, Benardos (1882) and Slavianoff (1885).

In 1895, Prof. Popoff made his first experiments in the reception of electromagnetic waves, and in May of the same year he read a report to the Russian Physical Society, in which he demonstrated his receiver for wireless communication. This receiver possessed already such essential parts as a receiving antenna and ground connexion, and was similar in every way to the wireless receivers that were later applied for some years everywhere in wireless telegraphy.

Since 1918 the Government of U.S.S.R. has organised special centres for scientific research, so indispensable in connexion with the technical reconstruction of the Soviet Union. In particular, electrical research laboratories and institutions have been created in Leningrad, Moscow, Nijni-Novgorod, and so on. Out of a large number of Russian scientists working in these institutions we may name Prof. A. Joffe (the theory of disruptive discharge in insulating materials), Profs. M. Bonch-Brujevich, W. Lebedinsky, L. Mandelstam, and N. Papalexy (all working on wireless telegraphy and telephony), Profs. A. Tchernyshoff, A. Smuroff, and L. Sirotinsky (all working on high tension power transmission), Profs. A. Tolvinsky, K. Shenfer, and M. Kostenko (all working on dynamo-electric machines). The investigations of these scientists have an importance in practice, besides their purely scientific interest, as all the research institutions are linked to corresponding electrical factories. At the same time, scientists working in the U.S.S.R. on electricity in most cases are in close connexion with the technical reconstruction of the country, based on the growth of practical applications of electrical energy. During the past few years in the U.S.S.R. there have been erected a series of electric power stations and a number of power transmission lines. For example we may mention the following power stations: Volkhov, Shatura, Kashira, Shterovka, Nijni-Novgorod, Zemavtchaly (with a total power of 460,000 kw.), all these stations feeding transmission lines 100 km.–150 km. in length and at 110 kv. pressure). The following power stations are in construction: Dnieper, Svir, Bobriki, Tcheliabinsk, Ivanovo-Voznessensk (with a total power of about 1,200,000 kw., including the 550,000 kw. of the Dnieper). These power stations will feed a series of transmission lines, 100 km.–250 km. in length and at a tension of 160 kv.–220 kv.

Faraday's investigations have had a wide and deep influence upon electrical science and its practical applications in Russia and the U.S.S.R., in the course of the hundred years which have passed since the discovery of electromagnetic induction.

India's Debt to Faraday.

By Sir C. V. RAMAN, F.R.S., University of Calcutta.

THE idea of a life dedicated and consecrated to the service of humanity and involving the renunciation of personal advantages makes a powerful appeal to the mind of India. It is doubtful if, amongst men of science, a finer example of such a life could be discovered than that of Michael Faraday. His ideas and discoveries have benefited all mankind, and, in common with the rest of the world, India owes him a debt which can never be repaid. I consider it a great privilege to be allowed, on behalf of India, to offer my humble tribute of homage to the immortal soul of Faraday.

So long as seventy years ago the career and achievements of Faraday had made a profound impression in India. It is sufficient to mention the fact that, when the late Dr. Mahendra Lal Sircar in the sixties of the last century laboured to promote science in India, he adopted the Royal Institution of Great Britain as the model to follow in establishing a centre for scientific research. The Association for the Cultivation of Science, which he founded at Calcutta in 1876, is thus itself an Indian memorial in honour of Faraday. It has been the great privilege of the present writer and of his numerous collaborators from all over India to have enjoyed the unique facilities for research provided by this institution during the last quarter of a century.

Amongst Faraday's discoveries, the most significant in its theoretical implications was the magneto-optic effect known by his name. It established an experimental connexion between light and electromagnetism, and thus paved the way for the demonstration by Maxwell and Hertz that light is itself an electromagnetic influence propagated through space. But a further implication of the discovery was that the particles of matter which are disturbed during the propagation of light are capable of being influenced by a magnetic field and are therefore themselves electromagnetic in their nature. It required the labours of Larmor, Lorentz, and many others to elucidate and develop this implication of the Faraday effect. But let it be emphasised that the discovery of magneto-optic rotation by Faraday was the seed from which grew the mighty tree of the electron theory of the dispersion and scattering of light.

It was the hope that fundamental advances in knowledge would result from a study of the relation between dispersion and scattering of light that induced me to make it the principal subject of my activities during the last ten years. The hopes which inspired the work have not been unfulfilled. Incidentally, the researches it involved have had the result of taking the workers in Calcutta into other fields of work in which Faraday was also the pioneer. Amongst these may be mentioned diamagnetism, magne-crystallic action, and magneto-chemistry. The scattering of light by molecules stands in close relation not only with their optical dispersion but also with their magneto-optic behaviour, and especially the magnetic birefringence exhibited by fluids. The result of computations, based on the theory of magnetic birefringence, is to indicate that the molecule of benzene, the aromatic hydrocarbon discovered by Faraday, and even more so, the molecules of naphthalene, anthracene, and so on, possess an astonishing degree of magnetic anisotropy. Experiments undertaken at Calcutta led to the discovery that the aliphatic hydrocarbons also exhibit magnetic birefringence, but this is extraordinarily *feeble*, and *negative* in sign, while the magnetic birefringence of the aromatic hydrocarbons is known to be *strong* and *positive*. The significance of this discovery is, in the first place, that the magnetic anisotropy of the aliphatic molecules is very small. In other words, the chemical difference between the two classes of organic compounds corresponds to a striking magnetic difference. In the second place, the relations between the optic and magnetic axes of the two kinds of molecules are curiously different, and this gives rise to the difference in the sign of the magnetic birefringence. Experimental studies by Mr. S. Bhagavantam of the magne-crystallic behaviour of organic solids, especially of naphthalene, anthracene, and hexamethylbenzene, gave results in striking agreement with those inferred from magneto-optical experiments with solutions of these substances.

The importance of studying magne-crystallic behaviour, both of diamagnetic and of paramagnetic substances, cannot be over emphasised. Mr. K. S. Krishnan has taken up this subject enthusiastically at the University of Dacca, and has developed very precise methods of measurement, and examined a large number of compounds both inorganic and organic. He has further attempted to correlate the magnetic results with the crystal structure of the substance wherever this is known from X-ray investigations. In the case of diamagnetic crystals, and especially of non-polar substances, we are probably justified in assuming the molecular susceptibility to be a constant characteristic of the substance. On the basis of this assumption, which admits of ready experimental test, it is possible to discuss the question whether the crystal structure assigned by X-ray workers is in accordance with the observed magnetic character of the crystal and the magnetic anisotropy of the molecule ascertained from magneto-optic experiments. It is possible, in fact, to determine what orientations of the molecules are possible within the crystal lattice which are consistent with its observed magnetic properties. This new method of crystal analysis developed by Krishnan appears to be full of promise.

The interpretation of the Faraday effect is itself at the present time not completely free from obscurity. Recent work by J. Becquerel, Ladenburg, and others indicates that we have to distinguish between two kinds of magneto-optic rotation, one associated with paramagnetic substances and the other with diamagnetic bodies. For the latter class, the theory originally suggested by Larmor indicates that the frequency of the 'Larmor precession' in the magnetic field, taken in conjunction with the known optical dispersion, determines the coefficient of magneto-optic rotation. Unfortunately for the theory, however, the observed rotation in many cases falls much short of the calculated value. It seems likely that this anomaly is connected with the known optical and magnetic anisotropy of the molecules, which is not taken into account in the Larmor theory of the Faraday effect. The consideration further suggests itself that, just as we have two kinds of Faraday effect, we should also have two kinds of magnetic birefringence in fluids. In addition to the diamagnetic type of birefringence which is already known, there should be a paramagnetic type of birefringence. Experiments made at my suggestion by Mr. S. W. Chinchalkar indicate that solutions of salts of the rare earths, such as cerium chloride, actually exhibit such an effect. How this special type of birefringence actually arises is not clear. But it seems possible that the cerium ion is optically anisotropic, and that in consequence of the magnetic moment it possesses tends to orientate in the field.

The study of the magnetic behaviour of gases and vapours is a special field of great interest in which Faraday was a pioneer. The experimental technique is very difficult, especially in the case of diamagnetic bodies where slight traces of oxygen as impurity would wholly vitiate the result. Recently the subject has attracted much interest owing to the reported discovery by Dr. Glaser of a curious anomaly at low pressures. The subject was taken up by Dr. V. I. Vaidyanathan, who showed that in all probability the Glaser effect was spurious. Further, he found that ozone and ethylene are diamagnetic gases and not paramagnetic ones as had previously been reported by other workers. Measurements were also made and reported by him for a number of other gases and organic vapours.

The question arises whether diamagnetism is purely a molecular property or whether it is also influenced by the state of aggregation of the substance. The accuracy of measurement in the case of vapours is not sufficient to enable this question to be decided for the transition from the gaseous to the liquid condition. *Prima facie* we should not expect any appreciable changes in passing from the liquid to the solid state except in the case of metallic bodies and electrically polar substances where questions of molecular association enter into consideration. In certain well-known cases, for example, that of metallic bismuth and graphite, large changes with temperature have been reported, and the susceptibility of bismuth is reduced to a very small fraction of itself on fusion. In such cases, the interesting question arises whether mechanical subdivision of the substance into a fine colloidal state would influence susceptibility. From experiments reported from Chidambaram, by Dr. V. I. Vaidyanathan, and more recently by Dr. S. Ramachandra Rao, it would seem that this is actually the case.

Closely related to the general question of dependence of diamagnetism on the state of aggregation is the problem whether the susceptibility of a liquid mixture strictly obeys the additive law in respect of the mass proportions of its constituents. In those cases where anomalies in density and other properties are known, we should expect small deviations from additivity of molecular susceptibilities. A high degree of precision in measurement is necessary to decide this question, and this has been attained by a special optical method developed at Calcutta by Mr. S. P. Ranganadham. It would seem that in certain cases, for example, water and alcohol mixtures, distinct deviations from a straight-line graph are actually obtained.

Before leaving the subject of magneto-chemistry, reference should be made to the work of two notable Indian exponents of the subject, Prof. D. M. Bose of Calcutta and Prof. S. S. Bhatnagar of Lahore respectively. The former has done extensive and valuable experimental work in tracing the relation between paramagnetic susceptibility and chemical constitution and correlating it with atomic and molecular structure. The theoretical considerations advanced by him in regard to the paramagnetism of the compounds of the transition group of elements lay emphasis on the magnetic moment derived from electron spin and yield results different from those indicated by the well-known theory of Hund. They appear to agree better with the experimental facts than the results of Hund's theory. Prof. Bhatnagar is the author of a systematic treatise on magneto-chemistry. He has devised a sensitive interference apparatus for measuring the susceptibilities of small quantities of substances, and discussed very fully the relation between chemical constitution and diamagnetic susceptibility in organic compounds.

Limitations of space do not permit detailed mention of the work of Dr. J. C. Ghosh and others in the field of electrochemistry, in which Faraday was a great pioneer. Reference may, however, be made to the subject of dielectric behaviour, which has received much attention from Indian workers. The study of light-scattering leads one very naturally to consider the question of dielectric behaviour. The birefringence shown by a gas or liquid in an electric field may be connected quantitatively with the electric polarity and anisotropy of its molecules. As was shown by the present writer with Mr. Krishnan, it is actually possible to compute the electric moment of the molecule, and even to indicate its geometric position in the molecule from such considerations. Further, the connexion between dielectric behaviour and electric birefringence indicates that in the case of viscous liquids we should expect at low temperatures or in rapidly oscillating fields a disappearance, or even reversal, in the sign of their electric double refraction. Experiments by Mr. S. C. Sircar and the present writer appear to indicate that the suggested phenomenon is actually observed. The interest of this observation lies in its furnishing a demonstration that the electric polarisation of a polar molecule is of two kinds, one arising from its deformation and the other from its orientation under the action of the field.

Faraday's Researches on Magneto-Optics and their Development.

By Prof. P. Zeeman, For.Mem.R.S., University of Amsterdam.

In connexion with the forthcoming celebration of the centenary of Faraday's greatest discovery, which predominantly has influenced our concepts of Nature and our present electrical industry, there is room in Nature for an article on magneto-optics which may also direct attention to Dutch scientific work in relation to Faraday's researches and discoveries.

On Sept. 13, 1845, Faraday found the first indication of what is now called the magnetic rotation of the plane of polarisation in transparent isotropic substances, the Faraday effect. The nineteenth series of the "Experimental Researches in Electricity" labelled the discovery "the magnetisation of light and the illumination of magnetic lines of force". His discovery showed that while the vibrations of linearly polarised light propagated parallel to the lines of magnetic force are always normal to the ray of light, the vibrations of the emergent beam make an angle with those of the incident light. The first substance giving a positive effect was Faraday's own "heavy glass" —boro-silicate of lead—which had been found by him in attempts to improve the qualities of optical glass. These investigations (1825–1829), dating from the first period of his scientific life, undertaken conjointly with Dollond and Herschel, had cost him nearly four years of precious labour, and had not led to the object aimed at, which was only attained much later by Schott and Abbe. In the brilliant discovery of a relation between magnetism and light, he now obtained the reward for all the patience and energy bestowed on this early work.

The theoretical views which guided Faraday in his experiments are given in the opening paragraphs of Series XIX. of his "Experimental Researches":

§ 2146. "I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one in another, and possess equivalents of power in their action. In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forms."

Faraday knew what a delicate means for investigating the structure of transparent bodies we possess in the use of polarised light. Already, at the very beginning of the nineteenth century, Arago (1811) and Biot (1813) discovered the natural rotation of the plane of polarisation in quartz and other substances, and soon afterwards Brewster (1815) found the phenomena of accidental double refraction.

Faraday's arrangement may be described in his own words (§ 2150 "Exp. Res."):

§ 2150. "A ray of light issuing from an Argand lamp, was polarized in a horizontal plane by reflexion from a surface of glass, and the polarized ray passed through a Nicol's eye-piece revolving on a horizontal axis, so as to be easily examined by the latter. Between the polarizing mirror and eye-piece two powerful electro-magnetic poles were arranged, being either the poles of a horseshoe magnet, or the contrary poles of two cylinder magnets; they were separated from each other about 2 inches in the direction of the line of the ray, and so placed, that, if on the same side of the polarized ray, it might pass near them; or if on the contrary sides, it might go between them, its direction being always parallel, or nearly so, to the magnetic lines of force. After that, any transparent substance placed between the two poles, would have passing through it, both the polarized ray and the magnetic lines of force at the same time and in the same direction."

Then comes a reference to the "heavy glass", and then in § 2152 the experiment with a positive result:

"A piece of this glass, about 2 inches square and 0·5 of an inch thick, having flat and polished edges, was placed as a *diamagnetic* [a term used by Faraday strictly analogous to *dielectric*], between the poles (not as yet magnetized by the electric current), so that the polarized ray should pass through its length; the glass acted as air, water, or any other indifferent substance would do; and if the eye-piece were previously turned into such a position that the polarized ray was extinguished, or rather the image produced by it rendered invisible, then the introduction of this glass made no alteration in that respect. In this state of circumstances the force of the electro-magnet was developed, by sending an electric current through its coils, and immediately the image of the lamp-flame became visible, and continued so as long as the arrangement continued to be magnetic. On stopping the electric current, and so causing the magnetic force to cease, the light instantly disappeared; the phenomena could be renewed at pleasure, at any instant of time, and upon any occasion, showing a perfect dependence of cause and effect."

Faraday then goes on making all kind of control experiments and investigating other transparent solids and a number of fluids and solutions. They all exhibited the effect, which apparently is a general property of matter. With air and other gases Faraday could not ascertain any effect. Relatively late (about 1880) H. Becquerel, and Kundt and Röntgen, by means of special appliances could demonstrate the small effect. Accurate measurements are due to Siertsema (1899) and M. de Haas.

A very large rotation in a gas was observed in 1898 by Macaluso and Corbino, when they passed plane polarised light, differing but little in frequency from that of the *D*-lines, through sodium vapour in a magnetic field, along the lines of force.

It is interesting to note what Faraday tells us in § 2182:

"With some degree of curiosity and hope, I put gold leaf into the magnetic lines, but could perceive no effect. Considering the extremely small dimensions of the length of the path of the polarized ray in it, any positive result was hardly to be expected."

This last observation reminds us of the observations of Kundt (1884). With thin transparent films of iron, Kundt found that in a distance of 0·02 mm. the rotation already amounts to a full revolution. The exceptional position of iron (also of nickel and cobalt) as to magnetic rotation disappears if referred to the same magnetisation.

The essential difference between the natural rotation of quartz and the magnetic rotation of light was, of course, immediately ascertained by Faraday and applied in his multiple reflection method in order to increase the effects with the magnet.

In § 2224, Faraday makes the interesting remark that "the magnetic forces do not act on the ray of light directly and without the intervention of matter, but through the mediation of the substance in which they and the ray have a simultaneous existence". All future experience is in agreement with Faraday's remark.

In 1876, Dr. Kerr showed that a magnetisation of an iron mirror modifies the properties of incident polarised light.

In most cases the reflected light becomes elliptically polarised. The ellipticity is rather small, and the effect can be regarded approximately as a rotation of the plane of polarisation. The rotation of red light from the magnetically saturated mirror amounts to 23′ for iron, 21′ for cobalt, 3′ for nickel. These amounts are small but, nevertheless, would have been within reach of Faraday's means, at least for iron, if only a plane well-polished iron mirror had been at his disposal. The publication of Faraday's diary probably will give us details about this point.

A complementary phenomenon to the Faraday effect was found in 1910 by Cotton and Mouton by their discovery of the magnetic double refraction of pure liquids.

We now come to a discovery which undoubtedly would have been made by Faraday, if the times had been ripe for it. I mean the phenomena produced in spectroscopy by a magnetic field. These involve the splitting up of the lines of a line spectrum of a substance, when immersed in a strong magnetic field, each line being resolved into several components, each of characteristic frequency and characteristic polarisation and intensity. This effect has proved a most powerful means of discovering the nature of the forces in the atom.

In 1862, Faraday made the relation between magnetism and light the subject of, it is said, his last experimental work. He endeavoured, but in vain, to detect any change in the lines of the spectrum of a flame when this is under strong magnetic influence. The technique of obtaining strong magnetic fields and powerful spectroscopes was, however, inadequately worked out at the time. But in 1881 the Rowland grating was discovered, and its great resolving power enabled physicists to see details of spectra hidden to a former generation.

During several years I was occupied (for my thesis) with experimental work on the Kerr effect and studied the theories proposed to account for this phenomenon. Stimulated by the reading of Maxwell's sketch of Faraday's great life, I was able to discover in 1896 the magnetic resolution of the spectrum lines. Quite independently of a special theory, I had the idea that when the forces acting during the propagation of light in the Faraday effect were also present in a radiating flame under magnetic influence, possibly some new effect would manifest itself. It might have been otherwise indeed. At a much later date (1918) Lorentz said: "Then Zeeman could discover, as he has done, quite independently of any special theory, and without any previous consultation with myself, the magnetic resolution of spectrum lines ; he could not have succeeded, if the mass of the electrons had been ten times greater with the identical electric charge ".

Indeed, guided by Lorentz's theory I made a rough determination of the specific charge at a very early stage (*Proc. Roy. Acad. Sci.*, Amsterdam, October, November, 1896), when the effect was only seen as a slight broadening of the sodium lines ; I found for the ratio of charge to mass the high value 10^7 c.g.s., quite different from the electrolytic ratio for hydrogen. I may be permitted to mention here that having come to this conclusion, I immediately went to Lorentz to tell him. He remarked : " That looks really bad ; it does not agree at all with what is to be expected ".

I now propose to give a rather long quotation from an extremely interesting lecture, delivered in May 1929 to the Institute of Metals (*Jour. Inst. Met.*, vol. 41, No. 1, 1929) by Sir Oliver Lodge, entitled " States of Mind which make and miss Discoveries, with some Ideas about Metals". This paper contains several remarks of importance about metals, but still more instructive are perhaps those where Sir Oliver Lodge speaks to us as educator and philosopher. All young physicists should read his words, often expressed with deep humour, and try to formulate his lessons for themselves.

" *Zeeman's Discovery.* The Zeeman effect, too, is rather instructive from my present point of view in its incipient stages. Larmor's theory of radiation, before the era of electrons, had shown virtually that if a source of radiation were plunged in a magnetic field, the lines of the spectrum ought to be broadened, because a radiating atom would be influenced by any magnetic field in which that revolving or vibrating atom constituted an electric current. It was well known that an electric current was perturbed by magnetism, and this perturbation ought to show itself in the lines of the emitted spectrum. Instead, however, of getting an experimenter to try this with modern devices, that is, with a Rowland grating and a very strong field, Larmor—perhaps deterred by the knowledge that Faraday without theoretical clue had looked for some such effect by the aid of prisms and other inadequate devices known in his day, and had failed to find it in spite of his experimental skill—Larmor, I say, proceeded in a state of mind which I may call that of super-theoretical knowledge, to calculate quantitatively how much effect was to be expected ; i.e. how much could be expected from any reasonable field, acting, let us say, upon sodium light. He found it surpassingly small, and therefore gave up the quest. He had no idea at that time of anything smaller than an atom that was likely to radiate ; and if it were the whole atom that radiated, the effect of a magnetic field would be hopelessly small ; for theory showed that it would depend on the ratio of charge to mass, and the mass of an atom is much too big : nearly 2000 times too big.

" Zeeman, however, undeterred by super-theory and quite independently of it, proceeded to repeat Faraday's old experiment, by examining the spectrum of a sodium flame immersed in a strong magnetic field, by means of a Rowland grating. He found the effect—small indeed, but not null ; the lines were slightly broadened. Directly this preliminary observation was announced, Larmor wrote to me at Liverpool asking me to repeat Zeeman's experiment, which (having a concave Rowland grating in the cupboard and a three-inch telescope) I promptly did. In about a week I had verified it, and showed the broadening of the lines at a Royal Society soirée [May 20, 1897] immediately afterwards. By that time we knew the reason why Zeeman had succeeded, for the rough measurement admitted an estimate of the amount of broadening. The ratio of charge to mass, instead of being something under 10^3 or 10^4, came out 10^7, or about 2000 times bigger than any atom could have shown. In fact, the radiating particle, thus perturbed by the magnetic field, could not be an atom but only the charge of an atom.

" This illustrates that an experimenter should seldom be deterred by a theoretical difficulty ; for the data on which the theory is dependent *may* be erroneous. The theory mathematically may be right enough, but the data, the essential physical machinery, may be different from what had been anticipated. Zeeman's effect was observable because the radiating particle was a unit electric charge, and because the minute mass of the electron was soon afterwards brilliantly ascertained by Sir J. J. Thomson ; and so the outstanding difficulty was removed. The magnitude of Zeeman's effect, in fact, proved that the electron was the real radiator—a far-reaching discovery applicable to light of all kinds.

" Then came H. A. Lorentz, who applied his super-theoretical knowledge to an electron revolving like an electric current in a magnetic field ; and predicted that the lines should not merely be broadened but should be doubled or trebled according to the way the source of light was looked at, whether along the lines of force or across them, and further, that the lines would be polarized in certain definite fashion. Zeeman immediately proceeded to re-examine the phenomenon with still greater power, and verified every detail of Lorentz's prediction, subsequently finding out many other details about the lines—one of the sodium *D*-lines being quadrupled, and the other sextupled, for instance ; all which is now explained by a further elaborated theory, and has become part of modern physics."

In the second volume of Sir Joseph Larmor's " Mathematical and Physical Papers " we find a historical footnote concerning the beginning of the new chapter. I must resist the temptation to reproduce it here, because I want to say something about the more recent developments of the subject.

The theory of the triplication of the lines is most conveniently described by a beautiful theorem of Larmor (*Phil. Mag.*, December 1897), which affirms that the magnetic field is equivalent to a rotation. The standard triplet as foreseen by Lorentz's theory soon proved to be the exception rather than the rule. The great majority of spectrum lines are resolved into patterns with many components (as many as 21 components have been observed). The 'anomalous effect' is the collective name of all the cases of complicated resolution. When the magnetic field is increased, the anomalous effect degenerates in a remarkable manner, discovered by Paschen and Back. A rearrangement of the components takes place which, for very strong fields, ends with the standard triplet.

The general theory of these effects has a long and complicated history. Landé, on the basis of quantum theoretical results and the exact experimental data of Back, derived a formal theory culminating in a vector model. The introduction into the theory by Goudsmit and Uhlenbeck of the hypothesis that the electron is itself a magnet, made it possible to explain the anomalous effect.

The anomalous effect has proved of the utmost value in disentangling the structure of spectra. Many examples could be given, but I mention here the work done in the Amsterdam Laboratory by de Bruin on ionised potassium and ionised neon and other gases. We now can predict the anomalous effect in many cases by a formula due to Landé. This formula is remarkable because it contains different quantum numbers, but none related to the magnetic field, yet the resolution in the field comes out surprisingly well. Deviations occur, however, for the 'heavier' elements.

Bakker, working in Amsterdam, very recently published the results of experiments on the effect in the noble gas spectra in connexion with 'anomalous' coupling of quantum vectors.

The magnetic resolution has been applied to two recent physical problems. The first relates to the mechanical moment of the *nucleus* of the atom. It was shown by Pauli that in order to explain the hyperfine structure of spectrum lines, intensity variations of band spectra (Heisenberg, Hund), and related problems, it is necessary to ascribe a nuclear spin moment to the nucleus of the atom. In a strong magnetic field, the different orientations of the nucleus are exhibited by a hyperfine structure of each line of the magnetic pattern, and the spacing of the hyperfine structure immediately gives the mechanical moment of the nucleus.

The second problem relates to the question of 'forbidden' transitions between spectral terms. The resolution pattern from a transition arising by quadripole radiation is quite different from that by electrically disturbed dipole radiation. The green auroral line has been proved to be of quadripole origin by its behaviour in magnetic fields.

Jean Becquerel (1907) in Paris, afterwards in collaboration with Kamerlingh Onnes and W. J. de Haas in Leyden, and independently H. du Bois and G. J. Elias, then in Berlin, made beautiful experiments at low and extremely low temperatures on the magnetic resolution of absorption spectra of crystals of the rare earths, of their salts, and of some artificial gems.

Recently Jean Becquerel, working with W. J. de Haas in the Leyden Laboratory, at temperatures near the absolute zero, were able to give decisive proof of the existence of the paramagnetic rotation of the plane of polarisation, resolving the Faraday effect into two effects of different origin. Their curves for tysonite and xenotine illustrate admirably the existence of a saturation rotation.

A practical application of the magnetic resolution of the spectrum lines is the proof by its means of the existence of powerful magnetic fields in sunspots and of a general magnetic field of the sun, two discoveries made by Prof. G. E. Hale at Mt. Wilson. When Lorentz visited Pasadena he made a trip to Mt. Wilson, and he tells us about his impressions there : "We had a glorious sunset and enjoyed the view on the plain stretching toward the Pacific with the thousands of lights of Pasadena and Los Angeles, and when night had wholly fallen, Mr. Hubble allowed us to see in one of the giant telescopes some of the marvellous nebulæ which he is constantly examining in all their details. But the spectacle that, perhaps, impressed me most of all was the Zeeman effect in the sunspots."

Of course, no attempt has been made to make this survey complete. Attention has been directed to some of the fruits which have grown on the tree planted by Faraday. We may be sure that he would have enjoyed their development. They exhibit a richer variety than he could ever have conceived.

Dynamical Aspects of Electromagnetism.

By Prof. V. K. F. Bjerknes, University, Oslo, Norway.

Science develops side by side with a number of fundamental questions, some of which, if not all, are answered differently or even in an entirely contradictory manner by different investigators and at different periods. They return in ever-changing form; they will perhaps never get their final answers, and precisely for that reason always stimulate investigation. One such question, formulated by the natural philosophers of antiquity, is this. Is space empty or filled?

Anaxagoras and Demokritos gave opposite answers, Demokritos postulating empty space in which his atoms were free to move, Anaxagoras believing that space was full, and that the medium filling it would not prevent the motion of bodies any more than water prevents the motion of fish. When modern science began, Descartes and his school demanded the filled space. But, if perhaps not Newton himself, then at least his followers for more than a century, denied the possibility of the medium claimed by Cartesians, as its resistance would retard the motion of the celestial bodies, and spoil the harmony of the Newtonian world system. The theory of empty space and of action at a distance through it seemed to be secured for ever.

Still Young and Fresnel returned to the need for a space-filling ether-propagating light. Faraday joined them, demanding a 'dielectric medium' as a carrier of the electric and magnetic fields, which his mind's eye saw in the space between the visible bodies. Maxwell united the separate demands of Young, Fresnel, and Faraday in a single one through his electromagnetic theory of light. Finally, the experiments of Hertz brought their brilliant confirmation of the Faraday-Maxwell theory. The doctrine of an ether filling space and propagating effects which have the aspect of action at a distance, seemed to be definitely established.

The victory was not, however, a complete one. No positive theory had been given for gravitational action at a distance, and even within the domain of electromagnetism the most central question remained unanswered. It had been proved that the field produces a force, but nobody could answer the question of how the field produces the force. Faraday's suggestive idea of a tension along the lines of force combined with a mutual repulsion between them, and Maxwell's admirable mathematical transcription of this idea in his stress theory remained *ad hoc* hypotheses. Maxwell did not succeed in incorporating these dynamical views organically in the field theory contained in his equations, which would have cleared up the dynamical side of electromagnetism. To quote in his own words this fundamental defect of his theory:

"It must be carefully borne in mind that we have made only one step in the theory of the action of the medium. We have supposed it to be in a state of stress, but we have not in any way accounted for this stress, or explained how it is maintained. . . . I have not been able to make the next step, namely, to account by mechanical considerations for these stresses in the dielectric."

This next step has not yet been taken. Electromagnetism and dynamics are interconnected in the most intimate way, but we do not know how. Concerning the importance of clearing up this question we may quote Planck ("Elektricität und Magnetismus"):

The whole of electric and magnetic or electrodynamic phenomena constitute a self-contained unit, which is clearly separated from mechanics or the movement of material particles. . . . The final and complete fusion of these two classes of phenomena, which alone would set the crown to theoretical physics, must still be left to the future.

Other difficulties also remained, especially in connexion with optical phenomena observed on or from the moving earth. But here Einstein's 'special' theory of relativity gave a convenient means of escape, and his 'general' theory of relativity opened a new way of approaching the central problem of action at a distance, making gravitation depend upon the properties not of a space-filling medium but of space itself, or more precisely of the generalised space-time. The existence of the ether claimed by Faraday and Maxwell was denied, if perhaps not by Einstein himself at least by his most ardent followers. The problem became the development of a general field theory from the properties not of a medium filling space but of space-time itself.

The development from antiquity up to the present time thus shows oscillations like those of a pendulum between two extremes, full space and empty space. Each oscillation has been connected with some great advance in our knowledge, or in our way of formulating the fundamental questions. But no advance has been so decided that one could say if or where the oscillations would stop: at a Faraday-Maxwell ether, of which we may hope some day to know the dynamical properties, or at an Einstein space which makes this ether superfluous, if it does not perhaps ultimately identify itself with it.

For the answer to questions of this kind, namely, the power of a medium to produce action at a distance, or how a field can produce a force, the hydrodynamic phenomena discovered by C. A. Bjerknes (1825–1903)—the complex of hydro-electric and hydromagnetic phenomena—may some day become of importance. By reading as a young man the polemics which in the eighteenth century Euler had conducted in vain against the victorious theory of action at a distance, C. A. Bjerknes was inspired by ideas remarkably analogous to those of Faraday and Maxwell. Studying abroad and listening to Dirichlet's lectures on hydrodynamics at the University of Göttingen in 1855, he was struck by that result of mathematical analysis which shows that a body can move with uniform velocity through a perfect fluid without experiencing any resistance. This seemed to him to refute the fundamental argument of the Newtonians against the Cartesians, that the existence of a medium in interstellar space would necessarily retard the motion of the stars, and contradict Newton's first law of motion, that of inertia. This induced him to take up the problem which occupied him for the rest of his life: the examination of the motion of any number of bodies in a fluid, in order to see if there would or would not appear mutual influences from body to body, comparable to the actions at a distance observed in Nature.

The conditions of his life did not allow him to advance very quickly with his great problem. A quarter of a century was to pass before he was able to show experiments which gave a complete verification of his mathematical results. He never succeeded himself in working out for final publication the results of his combined mathematical and experimental investigations. For this reason his researches were not able to exert any direct influence during his own time.

The main result of his investigations may now be stated thus. When seen from the proper point of view, a moving fluid system presents during every phase of its motion a most striking and most peculiar analogy to a perfectly definite electrostatic or magnetic system. The analogy consists of two inseparably joined partial analogies, a direct geometric and an inverse dynamical one: the hydrodynamic field has identically the geometrical structure of the corresponding electrostatic or magnetic field; and it produces forces equal in magnitude but opposite in sign to those produced—in an unknown way—by this electric or magnetic field.

We can thus compare on one hand the electric or magnetic field, the internal structure of which is unknown to us, with, on the other hand, the hydrodynamic field of which, in virtue of the hydrodynamic equations, we know everything, and which we describe by vectors as familiar to us as velocity (corresponding to electric displacement or magnetic induction) and the product of velocity and density, that is, specific momentum (corresponding to electric or magnetic field intensity). From the hydrodynamic equations, or even from remarkably elementary dynamical considerations, we derive both the geometrical structure of the field and the forces produced by it. The simple hydrodynamic pressure does both, no stresses of the complicated Maxwell type being required, either for maintaining the field or for producing its forces.

C. A. Bjerknes thus succeeded in showing how Nature with the greatest ease knows how to realise a field which produces a force, though in the case discovered by him it was a force equal but opposite to the force of the analogous electrical or magnetic field. But the importance of this contrast should not be overestimated. To an acting force always belongs a reacting force, and in connected systems the kinetic energy of one part of the system may play the part of the potential energy of the other part, making the reacting force (thus a force of the same direction as that of the electric or magnetic field) that one which produces the visible motions. The analogy provided by C. A. Bjerknes also gives only a first example of deep analogies existing between the electromagnetic fields and the fields of motion in material media. Already in pure hydrodynamics a second very remarkable analogy exists, which, by generalised properties of the medium, extends practically to the whole of electromagnetism. Nobody knows how far one may proceed still further along this line, not for inventing or constructing models, but of *discovering* deep analogies between dynamics and electromagnetism. The future will show whether we can advance far enough along this road to find the bridge joining these two vast domains of physics, just as the analogy discovered by Maxwell between electromagnetic and optical phenomena led ultimately to the discovery of the bridge joining these two provinces of physical science into one great domain.

What here seems promising is the depth of the analogy discovered by C. A. Bjerknes, a depth which is proved by the fact that it contains no suppositions or hypotheses, but merely the discovered *fact*, showing that the fluid system cannot move in any other way than in full conformity with this analogy.

In spite of this universality of the analogy, the motion of a fluid system only exceptionally takes such a form that the analogy presents itself *visually* to our eyes. Such an exceptional case presents itself when the motion consists of synchronous oscillations. In that case the analogy can be illustrated by striking experiments. Pulsating bodies (that is, bodies changing volume periodically) attract each other when in the same phase, and repel each other when in opposite phase, the law of distance being that of Newton. Thus, if space be filled with a homogeneous incompressible fluid, and if atoms were pulsating all in the same phase with intensities proportional to their masses, we should have a world in which all bodies attracted each other according to Newton's law for gravitation. When both phases come into play, we have the complete analogy to the law of Coulomb, with the difference that like attract and unlike repel each other. Further, in all mutual positions, and if free to perform any kind of translational or rotational motion, oscillating bodies interact precisely as if they were electric dipoles or magnets, of which like poles attract and unlike repel. Finally, the pulsating or oscillating bodies set up in neutral bodies induced oscillations corresponding to the induced magnetism acquired by neutral bodies in the magnetic field. As a consequence of these induced oscillations and the reversed pole law, a body lighter than the fluid moves in the direction of decreasing field intensity, and a body heavier than the fluid moves in the direction of increasing field intensity, just the opposite of what the corresponding ferromagnetic or diamagnetic bodies do according to Faraday's law.

This series of experiments shows visibly both the field and the forces produced by the field, as phenomena perfectly understood in virtue of the laws of dynamics. They seem to contain a promise that we shall some day, even if the way may still be long, arrive at a corresponding understanding of the electromagnetic field and its dynamical properties.

Faraday's "Chemical Manipulation".

By Sir Robert Robertson, K.B.E., F.R.S., and B. A. Ellis.

CHEMISTS, in view of the immense strides which have been made in their science during the past few decades, are rather apt, unless they have delved into the historical side of the subject, to overlook the fact that much of the present-day technique was known and practised by their colleagues of a hundred years ago; indeed, in many ways their relative skill was greater then, since facilities for learning were very much less, and at the same time they themselves had to construct much of their own apparatus. The excellence of much of their work is no small tribute to their skill as craftsmen.

These thoughts devolve from the forthcoming Faraday celebrations, coupled with the fact that in 1827 Faraday published a book on "Chemical Manipulation" running into well over six hundred octavo pages; this passed in the course of fifteen years into a third edition, the text of which, however, from a variety of circumstances, differed but little from that of the original. This was somewhat unfortunate, since the intervening years were not unfruitful, particularly in the analytical field.

There is no single modern volume quite corresponding with this by Faraday, who, it is interesting to note, offered it with an apology for adding "a new work on chemistry to the many excellent productions which previously existed". Faraday described himself as an experimental philosopher, and chemistry as an experimental science involving a constant appeal to facts; as the number of these presented to us naturally is so small, it is necessary to compensate for this deficiency by experiments, which have first to be devised and then performed. The description of methods for this "mere performance" or "manipulation" is the particular *raison d'être* of Faraday's book, which was to inculcate practice, not principles, the art of experimenting and not the habit of reasoning; it was thus to serve as a supplement to all the other books.

The modern student would find the text rather wordy, whilst some of the detail would appear unnecessary and over-elaborate; the latter must largely be attributed to differences in conditions, in particular of facilities and of teaching. Nevertheless, no exception can be taken to the clearness with which the details of instructions for the use of students are set out, to the wise maxims regarding procedure and the performance of operations, with especial reference to whether they are exploratory or of a final character, to the insistence on immediate and systematic noting of experiments—in short, to the general soundness of the advice on details embodied in much of the technique of the chemical laboratory of to-day.

These features are the more remarkable when the limitations then imposed upon the experimenter are considered. Thus heating was for the most part by means other than gas, and there was no bunsen burner, though certain matter, excluded from the third edition, showed that Faraday had experimented with burners embodying an air-supply, but with limited success. There was no rubber tubing for the conveyance of water, but only such small lengths, suitable for making connexions, as could be made in the laboratory from sheet rubber. There was no Liebig condenser for distillations, although by suitable devices cooling water was used for effecting condensation of vapours. There was no wash-bottle of the modern type, no water-oven for drying precipitates, nor were there glass taps. Despite all these drawbacks, the accuracy which Faraday attained in quantitative analysis is exemplified in his research on the composition of benzene, involving weighings, combustion, and measurement of gases, the whole forming a sequence of operations, often involved but of a perfectly logical character, and in the result, of surprising accuracy.

Let us, therefore, take a hasty stroll through these century-old pages: among the points to be considered in the general lay-out of a laboratory regard must be paid to lighting; a side light is necessary for observing the action of reagents and direct sunlight for promoting many chemical effects. One chair is permissible; more might encourage persons not engaged in the laboratory operations to remain. A separate room is recommended for housing balances, for the care, testing, and use of which excellent directions are given; weights and measures must be calibrated, and the methods are carefully described.

The mouth blow-pipe was an instrument much in favour in those days, and many pages are devoted to describing the mode of obtaining an even blast, and to bending, joining, and sealing glass tubing. The effect which we now call 'correction for emergent thread' of a thermometer was realised, but was regarded more in the light of an error than as a correction. Thermo-electric junctions were just coming in.

The subject of comminution, usually now dismissed in a paragraph or so except in books dealing expressly with rock analysis, is very fully reviewed, and special hints are supplied for powdering such diverse materials as flint, charcoal, and camphor. Simple elutriation was effected in a mortar, and the method for dividing certain metals is essentially that now used for making aluminium powder.

No practical distinction was drawn between physical and chemical solution. Variations in solubility arising from the presence of other substances were realised; tartaric acid served to prevent the precipitation of many metallic hydroxides by ammonia; oxidation was effected by nitric acid and *aqua regia*, and reduction by alcohol, sugar, and the like.

Distillation and sublimation, being essentially the same phenomenon, are described together; they were carried out in retorts or flasks. Essential oils and naphtha were distilled in a current of steam.

Reflected light was recommended for the comparison of colours or turbidities; this is used in our modern photometric methods. Various devices, described for the coagulation of such precipitates as silver chloride, barium sulphate, prussian blue are still utilised.

Special paper for filtering purposes was not manufactured; it was necessary to search among stationers' stocks for material of suitable quality, and the advice to 'look-through' the paper is still not always in vain. Crystallisation served for purification and for the purpose of identification by means of the goniometer; crystalline form was known to be affected by the presence of other substances in solution. Evaporation was hastened in an exhausted vessel containing sulphuric acid or other desiccating agents.

Volumetric analysis was, it must be admitted, in a somewhat primitive state at that time, being confined to simple acidimetric and alkalimetric titrations with vegetable indicators such as red cabbage, litmus, and turmeric, and a very crude form of burette, in which the thumb was used to regulate the flow of solution from a tube when inverted. It was about this period that Gay-Lussac laid the foundations of the more extended applications of volumetric methods, and, even so, it was many years before these were fully appreciated and generally adopted.

Crucibles of various forms and materials, including platinum and silver, were available; among the fluxes used were potassium carbonate (for decomposing silicates), bisulphate, borax, and, for effecting reduction, charcoal. Liebig employed tubes of potash glass in his analyses of organic bodies, and it was appreciated that the pyrolytic decomposition of vapours was favoured by increasing the surface of contact and by the presence of certain other bodies. The catalytic power of spongy platinum is also recorded, though not under that name.

The advantages of mercury as a confining medium for gases had been put forward by Priestley. The mean conditions for computing gas volumes were taken as 60° F. and 30 inches of mercury; the correction for temperature is slightly different from that in use to-day; a table is provided to correct the volume of the gas for saturation with water vapour. The manipulation of gases is very fully described, covering some eighty pages.

Of all the branches of chemistry, we are apt to look on that of micro-chemistry as belonging almost entirely to this century. To read the chapter on "Tube Chemistry" in Faraday's volume is, therefore, quite salutary, for, whilst this includes the description of ordinary test-tube work, it continues with the application of tubes to the performance of all the usual procedures of chemistry, the tubes being suitably moulded for the various purposes. Faraday called this "minute chemistry", and it is interesting to note that despite the primitive macro-burette mentioned above, a forerunner of a modern micro-model is recorded.

It would be surprising, indeed, had Faraday neglected to consider the application of the powers of electricity to chemistry, and, though the electrical apparatus to hand at that time was simpler than to-day, it was usefully applied to the analysis of gases and to the decomposition of electrolytes; both electrical machines and voltaic cells were available in various forms.

An account of lutes and cements, rendered more necessary then by reason of the more primitive apparatus, served to facilitate the selection of that most fitted for a particular purpose; an important treatise on glass-blowing is included.

Cleanliness was insisted upon in every direction, and detailed instructions are given for cleaning mercury and all kinds of apparatus. In a series of general rules for young experimenters, the importance of entering observations immediately is reiterated; some early forms of nomograms are described. The modern chemical student who worked conscientiously through the series of exercises with which Faraday's volume concludes could face any problem with equanimity so far as actual manipulative skill was involved.

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Letters to the Editor.

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Superconductivity a Polarisation Phenomenon.

WITH the collaboration of my research associates, Messrs. A. C. Burton, A. Pitt, and J. O. Wilhelm, evidence has just been obtained that an orientation effect of some kind must be involved in the phenomenon of superconductivity in metals either directly or in its demonstration in ordinary direct current experiments.

We have been investigating the high frequency resistance of lead wires, and have found that while this resistance steadily decreased with lowering temperature, no abruptness occurred when the critical temperature of lead, 7·2° K., was reached. The experiments were carried down to 2° K. without any superconductivity discontinuity being observed. In these experiments frequencies as low as 12×10^6 per second have been used, and other experiments with lower frequencies are now in train.

The experiments show that 'the time of relaxation' of the orientation phenomenon for lead is large compared with the time period of the longest of the oscillations used, namely, 10^{-7} sec.

It seems clear that with lead maintained at the temperature of liquid helium, 4·2° K., superconductivity must appear with the application of electric fields with a frequency somewhere between 12×10^6 seconds and zero. The results obtained would seem to indicate a promising path to follow for the elucidation of the phenomenon of superconduction in metals.

J. C. MCLENNAN.

Physical Laboratory,
University of Toronto,
Aug. 1.

Chemical Effect of a Mendelian Factor for Flower Colour.

IN a letter published in NATURE of June 27, 1931, Miss Scott Moncrieff mentions an interesting case of flower-colour inheritance in *Pelargonium*. On selfing, a rose-pink variety gave seventeen offspring like itself and three others producing salmon-pink flowers. The rose-pink petals contained the anthocyanin pigments, cyanin and pelargonin (the latter only as a trace); the salmon-pink petals, pelargonin only. That is, the dominant factor in colour inheritance causes cyanin to be formed almost entirely instead of pelargonin. This factor, therefore, as pointed out by Miss Scott Moncrieff, brings about the insertion of a hydroxyl group in the phenyl ring, which process may be regarded as one of oxidation.

Such a phenomenon as that outlined above is not necessarily limited to colour-varieties. Among the higher plants, one finds, for example, in some phyla, the dihydroxy grouping (characteristic of catechol) dominant among the compounds formed in the metabolism of aromatic substances. In others, apparently, the trihydroxy grouping (characteristic of pyrogallol) prevails. Thus, there is, on the whole, a restriction of catechol tannins to some genera and orders and of pyrogallol tannins to others. Again, in regard to the flavone pigments—compounds closely resembling the anthocyanin pigments in structure—apigenin (one hydroxyl group in the phenyl ring) is found in some genera, luteolin (two hydroxyls in the phenyl ring) in others, and so forth. Or, in regard to varieties, the ivory-flowered variety of *Antirrhinum majus* contains apigenin, the yellow-flowered, luteolin. Here, again, a difference of one hydroxyl in the structure of the molecule represents a factorial difference, as in the case of *Pelargonium*. In the flavone pigments of *Antirrhinum*, however, in contrast to the anthocyanin pigments of *Pelargonium*, the dominant factor suppresses oxidation.

It is a natural desire to interpret such Mendelian factors in biochemical terms. Such an interpretation has apparently defied the biochemist for many years. Some seventeen years ago, Willstätter had identified the anthocyanin of the type of the cornflower (*Centaurea cyanus*) as cyanin; of the pink variety, as pelargonin. To students of genetics, it is clear that here, between type and variety of *Centaurea*, there is, in all probability, one Mendelian factor. The biochemical interpretation of factors for colour is, however, part of a greater problem, namely, that of the origin of anthocyanin in the plant. Clearly defined cases of factorial differences between anthocyanin types and albino varieties have been known for many years in the sweet pea, stock, *Antirrhinum*, and other plants. Here, different varieties incapable of producing anthocyanin exist which, on crossing together, give types fully coloured with this pigment. In these well-known varieties lies the secret, as yet unrevealed, of the biochemical reactions which control the formation of anthocyanin.

From more general considerations, some suggestions may be made. Here they can only be mentioned in outline, and many subsidiary points remain unexplained. Anthocyanin pigments are found, on the whole, in flowers, fruit, young leaves, autumnal leaves, and leaves subjected to drought and injury. They are, apart from varieties such as the copper beech, not found in the normal green assimilating leaf. Two fundamental conditions are characteristic, in general, of organs producing these pigments as contrasted with those from which the pigments are usually absent.

First, in flowers, fruits, young leaves, and autumnal leaves, photosynthesis is less than in the normal leaf, or may have ceased altogether. This, as recent work on nitrogen metabolism has demonstrated, leads to hydrolysis of proteins and subsequent de-amination, with production of the residues of amino-acids, both aliphatic and aromatic. Secondly, in some of the organs quoted above, there is relatively little protection against loss of water, and, moreover, in the case of petals, fruits, and autumnal leaves, approaching separation from the parent plant and other causes render supply of water increasingly difficult. The connexion of appearance of pigment with lack of water from the soil may be very obvious. I have at the moment under observation a young plane tree, a few feet high, growing in a very dry situation. All the developing leaves are brilliantly red, giving the effect, from the distance, of a plant in flower. Such an abundance of pigment is not usual in the normal young leaf of the plane.

The deduction drawn from many observations connected with the two conditions mentioned above is that anthocyanin pigments are produced from the residues of aromatic amino-acids after de-amination. Under conditions of relative desiccation, condensation among these residues takes place with formation of anthocyanin pigments. As recently shown from the researches of Ruhland and his co-workers, de-amination of amino-acids occurs both in young leaves in active growth and in leaves in which photosynthesis has ceased; the latter state, moreover, is characteristic of petals, fruits, and autumnal leaves.

How then may such an interpretation bear on the problem of genetical factors? The aromatic amino-acids affording a benzene ring residue are phenylalanine and tyrosine. An attractive supposition to explain the presence, in one group or variety, of a *p*-hydroxy grouping (pelargonin) and, in another, of the *o*-dihydroxy grouping (cyanin) would be that dihydroxyphenylalanine is a component of some proteins. Then, by segregation, this amino-acid might be missing from the protein molecule of a variety. But, though dihydroxyphenylalanine is found in certain plants, it can scarcely be so widely distributed a component of proteins as such a hypothesis demands without hitherto being detected. Moreover, even the inclusion of this substance in the protein molecule would leave unexplained the existence of a trihydroxy grouping (delphinin).

We then fall back upon the hypothesis of oxidation as being the cause of the existence of the dihydroxy and trihydroxy groupings in condensation products from aromatic residues.

From investigations upon the oxidation of aromatic acids by Dakin and others, it would appear that, on oxidation of monohydroxy acids, a hydroxyl group is inserted in the *ortho* position to the group already in the molecule: that is, *p*-hydroxy benzoic acid is, by oxidation, converted into protocatechuic acid. Such a change may be brought about in many ways, as by hydrogen peroxide, or by a catalyst. The catechol oxidase cannot, it would appear, be connected with anthocyanin formation, since it is absent from many plants which develop anthocyanin. Any number of catalysts of the dehydrase type may be postulated which, on addition of a molecule of water and subsequent removal of two atoms of hydrogen, might insert a hydroxyl group into the benzene ring. Or the extent of oxidation in the phenyl ring resulting in cyanin or delphinin may be controlled by the reaction of the tissue before condensation takes place. Then, after condensation, there would be no further fundamental change in the anthocyanin molecule, though the colour might be modified by acid or salts. The amount of oxidation, moreover, need not be rigidly maintained, and mixtures of pigments may sometimes ensue. Or, finally, the position of insertion of subsequent hydroxyl groups may be controlled by the nature and position of the substitution groups already attached to the molecule.

M. W. ONSLOW.

Cambridge, July 30.

A Hard Component of the β-Radiation of Potassium.

THE investigations made up to now on the radioactivity of potassium have brought to light a very inhomogeneous β-radiation. The absorption coefficients derived by various workers vary from 27·2 to 11·2 cm.^{2}/gm., and it is difficult from these discordant data to deduce its spectral distribution; all one can say is that the velocity of the harder component, derived from absorption measurements, is about 0·82*c*. On the other hand, the feeble activity of the element does not admit of our using any of the methods of magnetic analysis, which has already given us accurate measurements of stronger radioactive radiations.

The method recently adopted by Occhialini [1] for studying rubidium is so powerful that, by sacrificing some of its resolving power, it can be applied to potassium. Fig. 1 shows the apparatus in section. A Geiger-Müller tube-counter *C*, made of a sheet of aluminium 0·0007 cm. thick, 1·5 cm. high, and 1·5 cm. in diameter, is placed in the centre of a brass cylinder *B*, 2 cm. high and 7·2 cm. in diameter; the ends are closed with ebonite stoppers, and the air inside is exhausted to a pressure of 4 cm. of mercury. The potassium salts are spread over the inner surface of the cylinder, which is then placed in a magnetic field, the lines of force of which are parallel to the axis of the counter. The β-particles emitted are deflected in circular arcs, and can only reach the counter when their radius of curvature exceeds half the distance between the active deposit and the counter. By increasing the intensity of the field, the softer rays will be gradually eliminated, so that the derivative of the intensity curve as a function of the field gives, approximately, the spectral distribution of the β-radiation (*vide* Occhialini *l.c.*). When the field is sufficiently intense, no electron reaches the counter, so that it only records the spontaneous impulses, that is, those due to the penetrating radiation and to the radioactivity of the apparatus and its surroundings. By protecting the apparatus with a lead shield, the number of spontaneous impulses could be reduced to 1·5 ± 0·1 per minute, as found by actual experiment without the salts. The impulses were amplified by a system of thermionic valves and were recorded automatically.

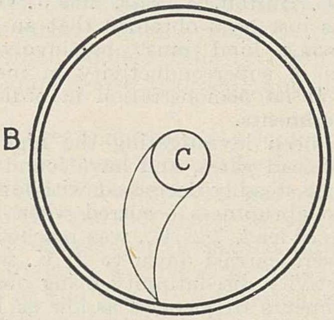

FIG. 1.

The first experiment was carried out with a thin layer of potassium chloride, about 0·014 gm./cm^2., on a silver lamina. It was found that, as the field increased, the intensity, as recorded by the counter, was constant at first, and then decreased rather rapidly between 580 and 1810 gauss, showing a large number of β-rays with a velocity less than 0·83*c*. The frequency of the impulses decreased slowly with fields of still greater intensity, but even with a field of 2200 gauss, the maximum available, the frequency was sensibly greater than that of the spontaneous impulses. From this it appears that there is a component less intense but much harder associated with the known β-radiation, and that its velocity is certainly greater than 0·90*c*.

To confirm this result, the analysis of the lower end of the curve was repeated, using a thicker layer of salts, about 0·1 gm./cm.^{2}, on an aluminium plate. The results were as follow:

Field (gauss) . .	0	1870	2100	2200
Impulses/minute	18·31 ± 0·32	7·62 ± 0·39	6·35 ± 0·35	5·80 ± 0·33

They show that the impulses recorded with maximum field exceed the spontaneous ones by more than twelve times the mean error. A layer of potassium bromide of the same thickness gave concordant results.

Although it appears to be highly improbable that the impulses observed with a field of 2200 gauss are due either to an α- or a γ-radiation, yet, to make certain, a rough absorption test was made by covering the counter with a silver leaf, 0·1 gm./cm.^{2} thick. Under these conditions, the potassium chloride gave a mean of 4·21 ± 0·2 impulses without the magnetic field and 3·64 ± 0·2 with a field of 2100 gauss. It will be noted that while the silver leaf absorbs the softer part of the β-radiation very strongly, it reduces the intensity of the component, which is not deflected by nearly one-half. The results obtained are not sufficiently accurate to determine the absorption coefficient of this radiation, but they appear to confirm very definitely that it is to be considered a β-radiation.

The probable existence of a hard component of the β-radiation of potassium has been recently put forward by Behouneck as the result of his researches on the γ-radiation of this element. The results above seem to confirm his suggestion.

I wish to express my warmest acknowledgments to Prof. Rossi, who has afforded me valuable assistance and advice in my experiments.

DARIA BOCCIARELLI.

Physical Institute, University of Florence,
Arcetri, Italy, July 18.

[1] G. Occhialini, *Rend. Lincei*. In the press.

The Atomic Weight of Fluorine.

THERE is a good deal of evidence from chemical sources that the atomic weight of fluorine is greater than 19·00. In recent years the ratio of sodium fluoride to sodium chloride has been determined by McAdam and Smith,[1] who find the value 19·009. In addition, from the limiting density of silicon fluoride, Germann and Booth [2] find the value 19·010, assuming that the atomic weight of silicon is 28·06. The only work which supports the value 19·00 is that of Moles and Batuecas [3] on the limiting density of methyl fluoride. Since methyl fluoride is a difficult gas to prepare in a state of purity by the method employed by Moles, and since, moreover, his density determinations show divergences far in excess of the experimental error, we have recently carried out a redetermination of the limiting density, using the same microbalance method as that employed for xenon.[4]

Methyl fluoride was prepared by Collie's method, that is, the action of heat on tetramethyl ammonium fluoride, and after purification with potash was liquefied and fractionally distilled several times until no alteration in density could be detected on further fractionation. The balancing pressures of oxygen and methyl fluoride were then compared at two densities giving the mean ratios 1·06726 and 1·06550 for pressures of oxygen of 335·61 mm. and 156·86 mm. respectively at 21° C. On extrapolation to zero pressure the limiting ratio is found to be 1·06395, corresponding to a molecular weight of 34·046. If now we assume for the atomic weight of carbon 12·010, a value which we obtained a few weeks ago from the limiting density of highly purified ethylene, we get for the atomic weight of fluorine 19·013. It may be noted that any probable alteration in the atomic weight of carbon would make that of fluorine higher.

From our results, the compressibility coefficient $1+\lambda$ of methyl fluoride at 21° C. is 1·00823. We can calculate the corresponding value of $1+\lambda$ at 0° C. with a very fair degree of approximation by assuming a slightly higher coefficient of thermal expansion than that of carbon dioxide, which is well known. Such a calculation carried out on our results for ethylene gives a compressibility coefficient in excellent agreement with the accepted value. For methyl fluoride, on the other hand, we find a value 1·0109 at 0° C., in complete disagreement with the value found by Moles, namely, 1·0180, but in general accordance with those for gases of similar critical constants. It may be remarked that, even if we assume that methyl fluoride has as large a coefficient of expansion as sulphur dioxide, it would be impossible to bring our coefficient higher than 1·012. In view of the fact that the critical temperatures and pressures of carbon dioxide and methyl fluoride are 31° C. and 45° C. and 73 atmos. and 62 atmos. respectively, whilst those of sulphur dioxide are 158° C. and 78 atmos., there can be little error in the compressibility coefficient which we have calculated at 0° C. Moreover, if we calculate the coefficient of thermal expansion of methyl fluoride from Moles's value for the normal density and our value for the density at 21° C., we get the highly improbable value of 0·0042. We may say that a similar calculation applied to ethylene gives the value 0·00369 for the coefficient of expansion. We must therefore conclude that Moles's values for both the density and compressibility coefficient are far too high, though by a partial compensation of errors they lead to an atomic weight of fluorine in accordance with mass spectrograph measurements. It seems likely that Moles's gas was contaminated with a few per cent of methyl ether, an impurity which he himself recognises as being possible, but which cannot occur in our method of preparation.

There seems to us, therefore, to be strong evidence that the atomic weight of fluorine lies in the neighbourhood of 19·010 rather than of 19·000. This would appear to indicate the presence in small quantities of a higher isotope.

H. S. PATTERSON.
R. WHYTLAW-GRAY.
W. CAWOOD.

The University, Leeds,
July 23.

[1] Carnegie Institution Report, No. 267, p. 47; 1918.
[2] *Jour. Phys. Chem.*, vol. 21, p. 81; 1917.
[3] *Jour. Chim. Phys.*, vol. 18, p. 353; 1920.
[4] NATURE, vol. 127, p. 970; 1931.

Acromegaly in the Far North.

THE question raised by Prof. Seligman [1] tempts me to proffer some speculations which I have for some time entertained. They are drawn from the field of experimental zoology, and would not merit consideration if it were not for the circumstance that they are capable of being tested experimentally. The determination of seasonal changes in animals is closely akin to the question which Prof. Seligman propounds. I suggest that inquiry directed to elucidate the significance of the pituitary gland to functional changes which exhibit a seasonal periodicity might provide the answer. The following circumstances suggest that there may exist a close relationship between pituitary secretion and seasonal states.

(1) It is now known that the co-ordination of amphibian colour change is determined by the reflex secretion of the pituitary gland. The effective stimuli are light, temperature, and humidity—the three chief agencies through which seasonal influences presumably act upon the animal body. In addition to a hormone secreted by the pars intermedia, a second hormone secreted by the pars tuberalis of the gland now seems to be involved (Hogben and Slome, 1931) in amphibian colour change.

(2) Work in my laboratory at Cape Town recorded in a paper now in the press (Hogben, Charles, and Slome) shows that removal of the pituitary in amphibia brings about drastic retrogression of the ovaries, while injection of anterior lobe extracts produces ovulation. Thus the pituitary has the same functional relationship to the ovaries in amphibia and mammals. It was further found that perceptible retrogression of the ovaries occurs in eyeless animals. Taken in conjunction with the fact that continuous illumination stimulates egg production in fowls, there is some encouragement for the supposition that the reflex stimulation of the pituitary by light is not restricted to the secretion of the hormone or hormones which

evoke melanophore response, but that light reflexly activates secretion of the pituitary gland as a whole.

(3) Functional changes associated with seasonal periodicity in mammals are of two principal types. One is the anœstrous inactivity and partial retrogression of the gonads. The other is winter sleep, which involves a greatly reduced basal metabolism. Both these phenomena have features which are highly reminiscent of the results of removing the pituitary gland. Dr. Charles obtained some evidence that amphibia have a low basal metabolism in darkness.

On the basis of these indications and others which we obtained during the past four years at Cape Town, it had been my intention to probe more deeply into the possible significance of the pituitary in connexion with seasonal phenomena. This body of investigations has now been interrupted, and I proffer these somewhat speculative remarks for the encouragement of others who are interested in the same problems. I believe that our work provided substantial evidence that the reflex activation of the pituitary by light is not confined to the secretions which control colour change. Perhaps the prolongation of the day in the arctic regions might suggest a clue to Prof. Seligman. The growth principle of the anterior lobe involved in acromegaly is not the same substance as that which activates the ovary, nor is it the same as that which influences basal metabolism by activating the thyroid. However, it is now certain that the functional relations of at least four of the six or more hormones secreted by the pituitary gland are alike in mammals and amphibia. A comparison of the effect of continuous illumination and total darkness respectively upon growth and metamorphosis in the latter would be well worth undertaking.

LANCELOT HOGBEN.

Department of Social Biology,
University, London, Aug. 10.

[1] NATURE, 128, p. 221, Aug. 8, 1931.

Biological Effects of Cosmic and γ-Radiation.

ACTINIC rays have been an important normal factor in the environment of organisms during the course of evolution, and now it is clear that rays of another category, the cosmic rays, must be regarded as having formed part of the normal environment. It is a working assumption in all bionomical investigations that every factor in the environment must be considered in regard to its possible effect upon the life of an organism: it is also possible—or even probable—that every factor in the environment has an effect upon, or is utilised by, some organism. Hence the practical demonstration of the continuous earthly incidence of the so-called cosmic rays brings a 'new' factor into the field of biology, and its effect needs to be assessed. Since it may now be accepted that these rays are and have been continuously incident upon and in the surface layers of waters (although the degree of their penetration into sea-water has apparently not yet been determined) as well as upon the land, most organisms are, or have been in time, subjected to them, and it is reasonable to look for some biological response.

It is difficult to connect any definite biological processes with the new kind of radiation now described, but the resemblance of the cosmic rays to hard γ-radiation [1] gives us one preliminary approach to an estimation of the biological effects of these rays; for it is known that one important effect of γ-rays is to inhibit such pathological growths as occur in mammals in cancerous tissues. The effect of the addition of γ-rays to an organism—which is exhibiting abnormal growth—suggests that possibly these rays are supplying and substituting a deficiency in that organism, and that the deficiency is some kind of ray similar to the γ-rays. The likeness of these to cosmic rays further suggests that the rays entering the earth from space may be a normal biological requirement of certain organisms, for example, mammals.

The occurrence of pathological growth in an organism, which *ex hypothesi* requires and is being subjected to a bombardment of cosmic rays, may be explained by a peculiar and pathological shielding or absorbing effect of parts or the whole of that organism.

Preliminary experiments indicate that γ-rays of such an intensity as will inhibit pathological growth, that is, as emitted from a radium needle, have little or no effect on adults or developing eggs of the few invertebrates which we have so far examined, though many more experiments are needed to provide a satisfactory basis for such an important statement. The failure of γ-rays of low intensity to affect tissues is perhaps to be expected if these rays are not markedly different from the normally incident cosmic rays. On the other hand, the simple experiment of shielding animals normally subjected to cosmic rays from these rays has not yet been tried. The occurrence, however, of animals on the sea-bottom at depths which are possibly too great to be affected by such rays [2] gives us either a natural negative experiment or an instance of adaptation to the absence of these rays comparable with that of animals living in darkness. The variation of these rays in intensity with depth may very well provide an important environmental factor in the life of aquatic animals.

Research on this new and recondite biological factor will be expensive and will require close collaboration between the biologist and physicist, but there can be little doubt that it is worth undertaking, even if it should happen that only negative results are obtained.

J. H. ORTON,
S. T. BURFIELD.

Zoology Department,
Liverpool University.
June 28.

[1] NATURE, 128, Supplement, July 18, 1931.
[2] NATURE, 126, p. 29, July 5, 1930.

Mineral Content of Eyes.

IN the course of an investigation into the mineral content of vertebrate tissues, mostly human, by the spectrographic method of analysis already described in NATURE,[1] the choroids of an ox's eyes were found to contain a notable quantity of barium, the percentage in the tissue dried at 100° being estimated at nearly 1·5; a trace of strontium was also present. The choroids of a sheep's eyes analysed at the same time gave no indication of barium, though a trace of strontium was present.

Many analyses of parts of vertebrates' eyes have since been made and certain facts have been ascertained; it is evident, however, that much remains to be done on these lines in extension of the work. The chief facts so far ascertained are as follows:

Human choroids and the choroids of sheep, pigs, horses, dogs, and the common commercial varieties of sea fish gave no indication of barium, neither did the choroids of calves contain the minimum amount detected by this method of analysis. Traces of strontium were nearly always present, the fishes' choroids containing more than those of the land animals.

The choroids of all the cattle, 13 in number, of three years old and upwards, so far analysed contain barium, and the quantity increased with the age of the animals; it is present in oxen, cows, and bulls.

The barium is present in largest quantity in the choroid, but it has been detected in irises and in the dark pigment separated from the choroid by rubbing. The retinas (minus the back pigmented layer, which adheres to the choroid) contain none; they contain more phosphorus than the choroids, similar proportions of magnesium, sodium, and potassium, but less calcium and iron.

Comparing the choroids of cattle of different ages from about three to seven years, the barium, as stated above, increases with the age, and, generally, as the barium increases the quantities of sodium, potassium, magnesium, calcium, iron, and copper appear to decrease: further work on this point is necessary and we hope to obtain eyes from much older animals. The first choroids analysed came from an ox of unknown age, and they contained the largest proportion of barium so far found and the smallest quantities of the other elements named.

Zbinden [2] did not find barium in cow's milk, but the strongest barium lines do not lie in the region of the spectrum in which he worked. Messrs. Adam Hilger, Ltd., in a recent letter to one of us on another subject, state that barium has been detected in cow's milk which had turned sour in glass bottles but not in fresh milk. Barium, to our knowledge, has not previously been detected in animal tissues, and its occurrence in quantity in the choroids, etc., of cattle is all the more remarkable. We are hopeful that the work described and projected may give information bearing on the mechanism of colour vision.

Hugh Ramage.
J. H. Sheldon.

Carrow Hill, Norwich.
Regis Road, Wolverhampton,
July 30.

[1] Nature, April 20, 1929, p. 601.
[2] *Le Lait*, **11**, No. 102, pp. 113-124; 1931.

The Double Lateral Line of *Lepidosiren*.

A few days ago when examining a small male specimen of *Lepidosiren*, one of three which I brought alive on May 1 from the island of Marajo at the mouth of the Amazon River, and which are now living in the Zoological Society's Aquarium, I noticed that it had two lateral lines on each side, one slightly dorsal to the middle of the side, the other near to the mid-ventral line. Since then I have examined more thoroughly a much larger female specimen, and have observed a few more details. The course of the sensory tubes is marked by lines of intense black, contrasting sharply with the light brown of the rest of the skin when the colour is in its pale phase. The principal lateral line, which may be described as dorso-lateral, branches out over the head into the usual three tracts, one above the eye, one between the eye and the mouth, and one below the mouth, or supra-ocular, maxillary, and mandibular. The ventro-lateral line at its anterior end anastomoses with the mandibular branches of the dorso-lateral. Each of the lateral lines is associated with short branches which are obliquely transverse to its course, but these short streaks are slightly separated from the main dorso-lateral line and dorsal to it; in the case of the ventro-lateral line, they are ventral to the line, and arise directly from it. A series of similar short oblique streaks occur on either side of the mid-dorsal line of the fish, but not a continuous line.

The description of Paraguay specimens by Sir Ray Lankester, published in 1898,[1] does not mention the lateral line, but the large figure of the entire fish which illustrates the description shows only one lateral line without branches. This is surprising, because in Lankester's paper special attention is given to a paper by E. Ehlers, published in 1894,[2] and Ehlers' paper contains a detailed description of the double lateral line in specimens from Paraguay. This description agrees very closely with that which I have given above, except that he does not mention the short streaks on either side of the mid-dorsal line of the fish, which suggest a third line of the dermal sensory system. Ehlers believed that *L. paradoxa* was a distinct species, to which some of the Paraguay specimens belonged, and in these the system of lateral lines was not distinctly recognisable. My own observations appear to constitute the first recognition of the multiple lateral line system in specimens of *Lepidosiren* from the Amazon region, and tend to confirm the opinion that there is no specific difference between the *Lepidosiren* of that region and those of the swamps of Paraguay. I am much indebted to Mr. R. H. Burne of the Royal College of Surgeons Museum for his kind help in investigating the literature of the subject.

J. T. Cunningham.

35 Wavendon Avenue,
Chiswick, W.4,
July 22.

[1] *Trans. Zool. Soc.*, vol. 14, p. 11.
[2] *Ann. and Mag. Nat. Hist.*, Ser. 6, vol. 14, 1894, p. 6.

Age of Certain Gravels in the New Forest Area.

While I rejoice to learn that Mr. Burkitt and his pupils are studying the Hampshire gravels,[1] I hope he will forgive me if I question whether his letter adds materially to our knowledge of the sequence of events in this difficult area.

The separation of the gravel into two layers, with or without a sandy layer between, is of frequent occurrence throughout the district, from Stoney Cross to the coast; and often, but by no means always, the upper layer is the coarser and less stratified. Since the lower has a fluviatile aspect through a considerable range of level above the existing rivers, I infer that it belongs to a period of depression of the land, with consequent aggradation: and we can date this period by the fact that unrolled Acheulean implements have been found under the gravel. Implements found in the gravel itself are usually more or less rolled, especially perhaps those from the upper layer, but we can seldom say definitely (and certainly not at Stoney Cross or Pickets Post) from which horizon the tools come. Mousterian specimens are extremely rare, but not, I think, entirely absent.

Facts have been published [2] pointing to the erosion of the main valleys down to about 50 ft. above the present rivers in, or before, Acheulean times; but Mr. Burkitt appears to go further, and to imply that the sea on the south coast of England (and even in the Solent River as far as Hordle) had reached its present level in late Chellean times; in which case the main valleys, in such soft strata, must inevitably have followed suit. But I do not see that he offers any evidence for this, or for his second postulate of a submergence "to a depth of at least 100 ft." before Acheulean times.

Finally, his correlation of the layer of sand (c) at Hordle with the 100 ft. raised beach at Brighton must be received with caution, (1) because a similar layer is found in neighbouring gravels (Setley, Beaulieu Heath, etc.) up to 140 ft. O.D.; and (2) because, unless there is clear proof that the sand is marine, we must make allowance for a possible gradient of the Solent River, the mouth of which was many miles farther east.

Henry Bury.

The Gate House,
Bournemouth West.

[1] Nature, **128**, 222, Aug. 8, 1931.
[2] *Proc. Prehist. Soc. E. Anglia*, pp. 23 et seq., 1923.

I was much interested in reading Mr. Burkitt's letter under the above heading,[1] since some of his conclusions coincide with those that I had formed after a study of similar deposits in the basins of the Thames and Kennet in Berkshire.[2] He suggests that implements of St. Acheul type were deposited in the gravels when the coast-line stood about 100 ft. above its present level. It is reasonable to suppose that at that time our rivers were flowing about the same height above their present beds. Gravels about 100 ft. above the present rivers occur in the Upper Thames basin and beside the Kennet, but have produced no implements. East of the Goring Gap, however, where the terrace is usually 80 ft. above the river, and is known as the Boyn Hill terrace, they are numerous.

It may be open to doubt whether these spreads are of exactly the same age, since there appears to be a slight difference in level between some of the Maidenhead gravels, and the implements that they produce vary in type. It is possible that in this region we should distinguish two distinct layers, much intermixed, at 100 ft. and 80 ft. respectively above the river. Both of these terraces, if there are two, have produced implements in large numbers, mostly of St. Acheul type, but also some that have been described as Chelles, though these are more probably ruder implements of the later industry.

In the Kennet valley a few St. Acheul implements have been found in gravel beds lying 140 ft. above the river; unfortunately it is not known at what depth these were found. It is, however, possible that they were left in hollows in a gravel bench, then 40 ft.–50 ft. above the river-level, and afterwards covered by rain-wash. A similar implement, from a corresponding level, found in a gravel-pit at Boldre in the New Forest, is in the Newbury Museum.

Harold J. E. Peake.

Westbrook House, Boxford,
Nr. Newbury, Berks,
Aug. 8.

[1] Nature, 128, 222, Aug. 8, 1931.
[2] See "Arch. Berks", Chaps. 1 and 2.

Unusual Lightning.

In Nature for Aug. 1, p. 189, Messrs. H. E. Beckett and A. F. Dufton describe "Unusual Lightning". From their description it appears that what they saw was the illumination of a cloud by lightning taking place inside it; the discharges were probably very high up, and went from one part of the cloud to another. Such discharges, which may perhaps be in the nature of a series of discharges through the clouds, often last a second or more and are sometimes many miles long. Lightning may take place very high up in the clouds, sometimes in the hybrid cirrus. In the 'Guildford storm' of Aug. 2, 1906, the lightning, at the time the storm crossed the South Downs, was almost entirely in the hybrid cirrus about two miles above the surface, and the thunder was quite faint even when the discharges were vertically overhead.

Another storm which occurred in the summer of 1917 seems to have resembled somewhat that seen by Beckett and Dufton. Seen from high ground near London, flames seemed to shoot up from the horizon, and a soldier on leave told a member of the staff of the Meteorological Office that it was "Haig blowing up the whole . . . line". At Bedford they thought that a violent air raid was in progress over London; and it was seen from all over the south-east of England. The actual storm was tracked down to a region about five miles to the east of the Kentish coast; the lightning was high up and the thunder faint even on the coast. The farthest points from which records came were Winchester, and Benson, Oxon, each about 130 miles away, and Husbands Bosworth, Leicestershire, about 140 miles away. Even at these distant places the lightning was noticed as something unusual; and so in a way it was—the lightning high up in the clouds lit up the hybrid cirrus plumes, which looked like flames. Most of the places from which the storm was visible were much too far off for the thunder to be audible. Beckett and Dufton seem to have seen something of the same kind, though on a smaller scale. The flame colour described by them may have been due to the distance of the storm and to the state of the atmosphere through which the light had to pass.

I am afraid that 'Flachtenblitz' is new to me, but the light of an electric discharge inside a cloud can produce all the appearances noticed by Beckett and Dufton, namely, glows which extend over the whole cloud or only over a portion of it; flashes starting at one end of the cloud and moving to the other; the flashes may occur at regular intervals of time, and may last a second or more. There is no need to suppose anything more than cloud to cloud lightning.

C. J. P. Cave.

Stoner Hill,
Petersfield, Hants,
Aug. 16.

Conservation of Rainfall as Carbohydrates.

When a good rain falls on arid country of high temperature, the growth of plant life is truly remarkable. But in a short time this verdure loses its moisture to dry winds and hot sunshine and becomes well desiccated. A point I have not seen mentioned is that a fraction of the rainfall (which I hope to determine approximately) is locked up in carbohydrate molecules, safe from sun and wind and available for animal life. Thus, anhydrous glucose when oxidised in the body will furnish 60 per cent of its weight as water and cellulose 56 per cent. Unless this is taken into account, animal life in the desert remote from water-holes is inexplicable.

W. A. Osborne.

Faculty of Medicine,
University, Melbourne,
July 8.

Occurrence of Dulcitol in a Red Seaweed.

The occurrence of mannitol has long been recorded in seaweeds, but, so far as the literature reveals, its distribution is confined to the brown algæ, and hitherto it has been the only representative of the sugar alcohols known to occur in the algæ. We have recently had occasion to examine extracts of the red seaweed *Bostrychia scorpioides*, which grows on the salt marsh at Blakeney Point; from this material we were able to isolate, in crystalline form, the isomeric alcohol dulcitol. As this is the first recorded observation of this substance in algæ, we are proposing to examine a number of other red algæ, with the view of determining whether they also contain dulcitol, or whether we were dealing with an exceptional case. A fuller account of the experimental work will, it is hoped, appear before long in the *Biochemical Journal*.

P. Haas.
T. G. Hill.

Botanical Department,
University College, London,
July 30.

Research Items.

The Hadzapi or Watindega of Tanganyika.—In *Africa*, vol. 4, pt. 3, Miss D. F. Bleek describes a tribe of hunters living in the northern part of the central province of Tanganyika, near Lake Eyazi, who speak a clicking language related to the Bushman and Hottentot tongues. In physique, colouring, and physiognomy the Hadzapi are entirely different from the Bushman, for they are tall, black, and very prognathous. They live by hunting. Arrow heads are made by the men themselves from bits of iron bartered with neighbouring Bantu tribes. Paint is not worn by the men, but many showed on their faces and bodies an elementary kind of tattooing used to cure illness. For cooking their food, which consists of roots, bulbs, and fruits collected by the women, the Hadzapi use clay pots which are bought from neighbouring tribes. The sun is their god, but he is not addressed, and is feared. He makes the people well and ill as he desires. If an invalid's relatives bother the sun with prayers, he will certainly die. Most men own two wives. Girls marry at sixteen, the men a little older. There does not appear to be any initiation ceremony for young people or any marriage ceremony. Dancing and singing is part of the daily life of the men, especially when there is plenty of meat. Their dancing and singing resemble that of the Bantu more than that of the Bushmen. The sounds of the language are less difficult than those of the Hottentot and Bushmen.

Shoshonean Linguistics.—Dr. Edward Sapir has published in the *Proceedings of the American Academy of Science and Arts*, vol. 65, pts. 1-3, a sketch of the Southern Paiute language, a number of Kaibab Paiute and Uintah Ute texts, and a Southern Paiute dictionary. The Shoshonean languages, to which Paiute belongs, comprise four groups—the Plateau Shoshonean languages; Tübatulabal of south-central California; Hopi; and a group of southern Californian languages comprising the Serrano dialects, the dialects of the San Luiseño-Cahuilla branch, and the Gabrielino dialects. The differences between the groups are considerable. All these languages, taken as a whole, comprise the northernmost representatives of the Uto-Aztekan stock, which includes, besides Shoshonean, Nahuatl or Aztekan and the Sonoran or Piman languages spoken in the long stretch of country between the Mexican State of Jalisco and the Rio Gila. So far as is at present known, the Uto-Aztekan languages are not generically related to any other American group. The dialect with which Dr. Sapir deals chiefly is Kaibab Paiute of south-west Utah and north-western Arizona, Kaibab being an anglicised form of an Indian expression signifying 'mountain-lying plateau'. They belong to a number of tribes loosely grouped as Southern Paiute, Paiute belonging to the Ute-Chemehuevi branch of Plateau Shoshonean. Southern Paiute and Northern Paiute must be carefully distinguished as distinct and mutually unintelligible languages.

Breeding from Colour Varieties.—Two examples of breeding from colour varieties, of interest to students of genetics, are given in the *Avicultural Magazine* for August. On p. 209, Mr. J. C. Laidlay records breeding, from hen-pheasants that had been bred white for four generations, and a cock which was white but for some red on the breast, three, among about twenty chicks, marked like the melanistic variety, a form which has come much into notice of late years. In it the chicks are very dark in the down; if males, they assume a dark purple-and-green glossed plumage with no red, and, if females, most strikingly resemble red grouse in colour. The production of this dark form from white parents reminds one of the occasional occurrence of the proverbial black sheep among our white flocks; in neither bird nor beast is the new colour ancestral, though less abnormal than white. The other instance is in Mr. D. Seth-Smith's editorial notes (p. 235) and concerns the breeding from birds reared at the zoological gardens from a blue mutant of the Masked Love-bird (*Agapornis personata*) paired to a normal specimen. One pair have had a brood of two blues and one green, while another had four greens and one blue—rather too many recessives for Mendelian expectation, but future broods may restore the balance, though it may be mentioned that two nests last year, respectively gave two greens and one blue, and one of each colour.

Growth of the Cockle.—A. C. Stephen (*Jour. Mar. Biol. Assoc.*, 17, No. 2, 1931) records observations on the growth of the cockle on the Scottish coast. He found on the Ayrshire coast that small cockles appear about the beginning of August, a fact which points to the breeding season being in summer and not in spring, as is usually stated. Further evidence on this point is afforded by examination of the reproductive organs, which, at Millport, appear to be ripe from about the end of July. Spawning was observed only once; cockles collected on July 1, 1930, spawned on the following day in the laboratory, but the eggs did not develop. By the end of the first autumn a few of the young cockles in the sand are 10 mm. in length, but most are less than 6 mm. The first winter ring on the shells is faint and easily overlooked; the first of the several well-defined rings is therefore not the first but the second winter ring. The first ring is seen in young specimens up to one or two years of age, but in older shells, especially if there has been any erosion, is often obliterated. The size of cockles increases regularly from high-water mark to low-water mark, due to an increased rate of growth. The scattered cockles living in the *Tellina* ground, that is, seawards of the cockle-beds proper, grow very fast.

Insect Vectors and Virus Diseases of Plants.—The first virus disease to be detected was mosaic disease of tobacco. It was discovered by Iwanowsky in 1892, and in 1901 Takami provided the earliest evidence of the insect transmission of such diseases when he showed that the mosaic disease of rice was carried from plant to plant by the leafhopper, *Nephotettix apicalis*. Since these discoveries a large and increasing number of virus diseases of plants have been made known, and, in many cases, insects have been shown to be the vectors responsible for their spread. In *Biological Reviews* of the Cambridge Philosophical Society, Vol. 6, July 1931, Dr. K. M. Smith gives a comprehensive survey of knowledge respecting these various plant viruses and the insect carriers with which they are associated. With few exceptions these vectors are sucking insects belonging to the order Hemiptera, and, among the latter, the Aphididæ are by far the most important. The single species, *Myzus persicae*, is an aphid that is now known to be associated with the spread of fourteen different viruses. The data collected together by Dr. K. M. Smith seems to point to the conclusion that a relationship, other than a merely mechanical connexion, exists between plant virus and insect vector in certain cases. Thus, there is evidence that points to the conclusion that the virus is capable of multiplying within the body of the insect. The whole subject of the nature of plant viruses, and the factors governing their transmission by means of insects, is one of great difficulty. The problem is further complicated by the fact that, in two cases, different symptoms are known to be produced in the plant by the same virus when the latter is inoculated by needle and insect respectively. This carefully prepared review of the subject, which is provided with an extensive bibliography, should be read by all interested in plant pathology.

Crust-Movements after the Tango Earthquake of 1927.—In 1929, a fourth series of levellings was carried out across the central area of the Tango (Japan) earthquake of Mar. 7, 1927. The results of this and the preceding series have been studied by Prof. C. Tsuboi (Nature, vol. 126, pp. 923-924). Nearly a year later, June-Sept. 1930, a fifth series along the same route was made and the results again examined by Prof. Tsuboi (*Tokyo Imp. Acad. Proc.*, vol. 7, pp. 234-237; 1931). Generally speaking, after the lapse of three years, the ground seems to have become nearly stable, the greatest change during the preceding year amounting to only two-thirds of an inch. Prof. Tsuboi gives two curves, one showing the changes along the route before and immediately after the earthquake, the other the total change during the three years since the earthquake. When the vertical scale in the latter curve is taken ten times that for the other, the two curves are very similar in form. The principal difference between them is in the neighbourhood of the two faults produced at the time of the earthquake. Instead of the discontinuities along the faults in the earlier curve, the later shows a sensible drag upwards along the faults, suggesting that, after the earthquake, the land-blocks on opposite sides of the faults have adhered to one another.

Articulation of Isolated Sounds.—The issue of the *Zeitschrift für Experimentalphonetik* for July 1 contains an account by Messrs C. E. Parmenter, S. N. Trevino, and C. A. Bevans, of the Phonetics Laboratory of the University of Chicago, of the methods they have adopted to determine the motions of the median outline of the mouth and throat during the articulation of isolated sounds. The head of the speaker is clamped to a board between the X-ray tube and the photographic plate, the median section of the head and the plate being at right angles to the axis of the X-ray beam. The outline of the median section of the face is secured by means of a streak of powdered barium in vaseline on the nose and lips, that of the hard palate by a strip of lead foil $\frac{1}{8}$ in. broad pasted on it from the front teeth to the uvula. The outline of the tongue is secured by means of a fine gold-plated locket chain, one end of which is fastened to the lip and the other end swallowed by the speaker. The chain is long enough to allow about three inches of it to be tucked under the tongue. Six examples of photographs obtained are reproduced.

Mechanism of Drying.—Owing to the large number of variables concerned in the process and to the variability in condition of the material as the process advances, analytical treatment of the drying of a solid substance involves considerable difficulty. Two communications on this subject by Dr. G. Bozza are published in the issue of the *Rendiconti della Reale Istituto Lombardo di Scienze e Lettere* for the current year (parts 6-10). The errors into which previous authors dealing with this question have fallen are indicated, and complete differential equations for the process, and also those corresponding with the surrounding conditions, are deduced. For the simplest case, when the substance does not suffer deformation, and when the coefficient of diffusion remains invariable during the drying, the differential equations are integrated for non-hygroscopic materials for the two periods when the surface moisture is respectively above and below the critical proportion. In this way, quantitative relationships between the moisture content of each point of a strip or parallelepiped and the time are obtained. Methods are given for the experimental determination of the necessary coefficients, as also are the results of a large number of experiments, made in conjunction with I. Secchi, to establish the relation between the coefficient of evaporation and the air velocity, knowledge of this being necessary for the further development of the investigation.

Krypton and Xenon.—A method of extraction of krypton and xenon from liquid air residues and determinations of some physical constants of these elements are described by F. J. Allen and R. B. Moore in the July *Journal of the American Chemical Society.* The method of separation avoided the use of large gasholders and the elements were obtained in a very pure condition. Preliminary density determinations indicated that the atomic weights at present assigned to krypton and xenon are too low, in agreement with Aston's mass spectrograph results. The average density of krypton was 3·733 gm./lit., that of xenon 5·887 gm./lit., and these give, with Watson's compressibility values, the atomic weights, Kr = 83·6 and Xe = 131·4. The possible errors are ± 0·2 and ± 0·3 respectively. The boiling points were found to be: Kr, − 152·9°, and Xe, − 107·1°, in each case ± 0·3°; and the triple points were Kr (− 156·6°; 557 mm.) and Xe (− 111·5°; 600 mm.). The values for the boiling points differ from the accepted values. It is clear that a revision of the properties of these two elements is indicated.

Molecular Weight of Insulin.—Sjögren and Svedberg, in the July issue of the *Journal of the American Chemical Society*, describe a determination of the molecular weight of insulin by the ultracentrifuge method. The crystalline insulin was supplied by Dr. Jensen, of Johns Hopkins University, and had been prepared from commercial beef pancreas insulin by crystallisation. Previous studies have shown that insulin is of protein nature, giving several protein reactions, having an empirical composition resembling that of proteins, being an amphoteric electrolyte and possessing an isoelectric point and ultra-violet absorption spectrum in the same region as most of the proteins. It is now shown that insulin is stable from *p*H 4·5 to about *p*H 7, and possesses a molecular weight of 35,100; at lower and higher *p*H values its molecule disintegrates into smaller units, the process being reversible near the borders of the stability region. The constants of insulin are, within the limits of error, identical with those of egg albumin and Bence Jones protein. It is very probable that insulin is a well-defined protein, and that its physiological activity is a property of the insulin molecule itself or some special group within it.

Utilisation of Atmospheric Electric Fields.—The *Zeit. für Physik* for June 20 contains a report by A. Brasch and F. Lange of their work upon the production of high potentials. Part of this has been done in the laboratory by the method in which a battery of condensers is charged in parallel, and the connexions rapidly changed to the series arrangement. A study has already been made in this way of the most suitable forms of discharge tubes for use with high voltages, and X-rays have been produced with an exciting potential of two million volts, and hydrogen positive rays with an accelerating potential of almost a million volts. A generator is now being built which it is hoped will give a potential of seven million volts. An even more interesting part of their work has, however, been carried out on Monte Generoso, in northern Italy. The district is very liable to thunderstorms, and use has been made of the large vertical fields which then occur in the atmosphere. To do this, a collector consisting of a large number of points suitably mounted was suspended in a small valley between two peaks. The whole had to be heavily insulated, as potential differences of more than ten million volts were encountered, and at the same time, as is evident from the photographs of the installation, its construction must have called for considerable mountaineering experience. The exact magnitude of the high potentials which were obtained from the apparatus is not certain, but sparks twenty-five feet in length were measured, and the corresponding potential difference estimated to be eighteen million volts.

Radio Observations during a Solar Eclipse.—In the *New Zealand Journal of Science and Technology* for June, Dr. M. A. F. Barnett gives a summary of the results obtained by the Radio Research Committee in New Zealand during the total solar eclipse of Oct. 21 and 22, 1930, by means of radio observations. As the path of totality passed across the Pacific Ocean, the observing stations near it were necessarily limited. The results agree well with those obtained during other eclipses. Observations were made on long waves (11,500 metres), on medium waves (850 and 800 metres), and on short waves (52 to 16 metres). In most cases the transmission path crossed the line of totality. The signal strength was estimated by aural methods. The strength of the long waves between Rugby and New Zealand was increased during the eclipse period, but nothing definite was obtained from the other long wave observations. On the medium wave transmissions, an effect equivalent to a partial return to night time conditions was observed. With short waves the only eclipse effect observed was a partial return to night time conditions in a few cases of the 52-metre transmission. Test records were made of the strength and persistence of atmospherics during the eclipse, but only in a few cases was a slight increase in their strength observed. It is concluded that in general the effect of the eclipse was to produce a partial return to night-time conditions. The resultant changes in signal strength follow fairly closely the equivalent changes in the amount of solar radiation reaching the atmosphere. There are indications, however, of a slight time-lag between the effects produced and the amount of solar radiation between the transmitter and the receiver.

Astronomical Topics.

Comet Ryves, 1931 *c*.—This comet was first seen by Mr. Ryves at Zaragoza on Aug. 10; he observed it almost daily up to Aug. 17, and noted that it was growing brighter. The only observation of position made elsewhere, so far as we know, was on Aug. 14 by Prof. G. van Biesbroeck, at Yerkes, who saw a tail one degree in length.

A telegram from the U.A.I. Bureau at Copenhagen has circulated the following parabolic orbit, computed by Mr. F. E. Cunningham, which indicates that it approached the sun within seven million miles on Aug. 25; it is quite likely that it would be visible in daylight about the time of perihelion:

$$\begin{array}{ll} T & \text{Aug. } 25{\cdot}900 \text{ U.T.} \\ \omega & 168^\circ\ 26' \\ \Omega & 101\ \ \ 4 \\ i & 169\ \ 11 \\ \log q & 8{\cdot}8633 \end{array} \left.\begin{array}{l} \\ \\ \\ \end{array}\right\} 1931{\cdot}0$$

Ephemeris for 0 h. U.T.

	R.A.	N. Decl.	log *r*.	log Δ.
Aug. 27	10h 37m 49s	7° 47′	8·9987	0·0150
„ 31	10 44 22	5 36	9·4339	0·1028
Sept. 4	10 45 56	4 54	9·6070	0·1489
„ 8	10 45 30	4 32	9·7388	0·1895
„ 12	10 46 14	4 13	9·8228	0·2172

It will be seen that the comet remains near the sun in the sky, and observation in a dark sky will not be possible until it has become much fainter. If the above value of the perihelion distance is correct, this comet approached the sun more closely than any other comet observed in the present century, but less closely than the great comets of 1843, 1880, 1882, 1887.

Harvard Card No. 169 gives the following observed position of Nagata's comet by Prof. G. van Biesbroeck at Yerkes Observatory:

	R.A. 1931·0.	N. Decl.	Mag.
Aug. 12 10313 U.T.	12h 17m 57·25s	10° 8′ 18·4″	7·5

He noted that " A sharp nucleus is visible; the round coma is followed by a broad tail visible for 25′ in position angle 110° ": as the comet is moving south more slowly than the sun, the conditions for observation are improving slightly.

John Harrison's Third Time-keeper.—The *Observatory* for August contains an article on this interesting old time-piece, on which Harrison was engaged from 1740 until 1757. It has been cleaned and repaired by Commander Gould, and was restarted in March last. All the four time-pieces of Harrison will shortly be in going order; the last to be undertaken is No. 1, on which Commander Gould is now at work. Harrison evidently bestowed more care and thought on No. 3 than on No. 4, which is much smaller. Yet it was the latter that won the Government award of £20,000. No. 3 was the first time-piece that contained a bimetallic compensation; it also anticipated the modern idea of a master clock and a slave one; it consists of an inner clock that is wound every thirty seconds by an outer clock. Being intended for use at sea (though it seems never to have actually been tried there), it is controlled by two large slowly-moving balances, instead of a pendulum. All Harrison's time-pieces will live in history, from the important part they played in solving the ancient problem of finding the longitude at sea.

Another Large Reflector in America.—A Science Service *Bulletin* from Washington, D.C., dated Aug. 10, announces the successful completion of the 69-inch mirror for the Perkins Observatory of Ohio Wesleyan Observatory, Delaware. It is stated to be the first very large mirror made entirely in America; in other cases the glass had been obtained from Europe. The mirror has been figured in the works of J. W. Fecker, at Pittsburgh. The tests of figure are stated to have been satisfactory; nearly 16,000 hours of work have been spent upon it. It has a central aperture, and will be used as a Cassegrain. The mirror is 10·3 inches thick and weighs 3790 pounds.

Stainless Metals.

THE economic and mechanical advantages which result from the use of the steels and cast irons are so important that, despite their low resistance to corrosion, they are used more extensively than all other metals put together. The inevitable result of this is an enormous wastage, resulting in the expenses of replacements and, even more, of the necessity of their protection by greasing, painting, etc. Sir Robert Hadfield has estimated that the annual cost throughout the world due to corrosion amounts to more than £500,000,000. Sir Harold Carpenter, in a lecture delivered before the Royal Society of Arts (*Jour. Roy. Soc. Arts*, May 8, 1931), reviewed the whole question of stainless metals, mainly ferrous ones, both from a fundamental and from the technical points of view.

Passivity and corrosion resistance appear to be due to the formation of invisible films of oxide, and it is to Evans that the credit is due of actually isolating such films. Most of the common metals have the property of forming protective oxide skins within certain ranges of temperature, and the production of a blue oxide coat on iron is one of the ways of protecting it. Unfortunately, however, the skin thus formed on iron at ordinary temperatures is not continuous and does not, therefore, constitute adequate protection. Where, on the other hand, the film is automatically repaired, efficient protection is provided, and in some cases this condition is realised in certain alloys used at high temperatures. Passivity resulting from immersion in concentrated nitric acid, potassium chromate solution, concentrated solutions of sodium carbonate, etc., is in all cases due to the formation of such skins, which, however, afford only a temporary protection. The films produced on chromium, on the other hand, are continuous and adherent, and the addition of that metal to iron greatly increases the tendency to passivity already possessed by it. The corrosion-resisting properties of the high chromium steels are due to this fact.

Various types of stainless steel have been developed with different degrees of resistance and mechanical properties. In general, the resistance increases with the chromium content and with the homogeneity of the material. The ordinary material is least attacked in the quenched condition, and if the same degree of resistance is to be obtained in the softer, tempered state the carbon content must be reduced or the chromium increased. Unlike the normal stainless steel, the alloy with 0·1 per cent of carbon and some fourteen per cent of chromium is stainless even in the annealed condition, and may be cold-worked to a considerable extent without serious diminution of its resistance.

The addition of nickel is, for many purposes, a further improvement. Such austenitic nickel-chromium steels are, in general, more resistant to corrosion, may be cold-worked without ceasing to be stainless, have remarkable ductility and resistance to shock stresses, and possess great resistance to oxidation at high temperatures. They are used, to choose one or two typical examples, in bridge construction, in refrigerating plant, for superheated steam valves, in acid mixing tanks, bathroom and stove fittings, etc. It has not yet been found possible to produce wire of the same strength as that of the strongest carbon steel wire, or to devise a steel which will withstand hot hydrochloric acid. Resistance to acids, other than nitric, appears to be associated with nickel; and nickel-chromium steels of one kind or another can be prepared which will resist attack by cold dilute hydrochloric acid, and by both hot and cold dilute sulphuric acid.

Apart from cost, however, such materials are available for almost all ordinary, and many quite special, purposes. F. C. T.

Death and Development.*

THE paper before us embodies a rather novel theory of growth. The author tries to show that in both animals and plants, as the germ grows up into the adult, there are periods of rapid growth separated by intervals of slow growth or, especially in plants, of complete quiescence. He maintains that there are corresponding periods of mortality—a very high death-rate being correlated with each period of rapid growth—except at the end of life when old age degeneration sets in.

A priori, there is no inherent improbability in this hypothesis, but we have a right to criticise severely the kind of evidence which is brought forward in support of it. The author himself experimented with the snail *Agriolimax*, which he reared in captivity: he cites results by numerous other workers in confirmation of his own results, such as those of Pearl on *Drosophila*, Ford on the mollusc *Spisula*, Putter on the herring, Gates on the white mouse, Quetelet and Donaldson on man. Now, the obvious objection to the manner in which these results are utilised is that the author fails entirely to discriminate between natural and accidental death. Of course it may be retorted that in the last resort every death is accidental; but there is a wide difference between death as a failure of metabolism in old age and death due to the seizure of an individual by an enemy. Pearl's experiments on *Drosophila*, the author's on *Agriolimax*, and those of Gates on the white mouse, were performed on animals kept in captivity under what appeared to the experimenters to be a close approximation to natural conditions, but in which the experimental animals were carefully guarded from the assaults of their natural enemies, and in which they were supplied with their natural food. The calculations of the death-rates in the herring, on the other hand, were based on statistical studies of the number of herring larvæ in a given area. Now, as Dr. Lebour has shown in her studies at Plymouth, the herring whilst a larva is devoured by a large number of foes to which it is immune in later periods of its life. Thus, ctenophores, medusæ, and *Sagitta* have been found gorged with herring larvæ, and at a later period haddock have been found full of post-larval herring. Death from these causes bears no analogy to the death of mice from old age after about two years of life.

Death from old age, indeed, appears to be an event unknown amongst teleostean fish. When a new fishing area such as the White Sea is opened up, fish belonging to well-known species are found which have reached a remarkable size. It is obvious that when one of the principal causes of death is the attentions of one's fellow-tribesmen, the expectation of life will increase rather than diminish with the

* "Absterben und Entwicklung". By István Szabó (Kaposvár). From "Biologia Generalis," Bd. 7, Lief. 2. (Wien und Leipzig: Emil Haim and Co.)

attainment of a great age and a correspondingly great size.

Pearl's conclusions about the natural term of life in *Drosophila* are probably broadly correct, but as he had perforce to keep his insects in confined spaces, there are certain factors incident to overcrowding which he apparently overlooked. For five or six years a skilled experimenter in my laboratory has been rearing the tadpoles of the common frog with the view of testing their reactions to certain changes in the environment. Rearing tadpoles has been a schoolboy sport since time immemorial, but the average experimenter finds that he begins with a large amount of spawn from half of which tadpoles hatch out; these steadily diminish in number as they grow older, until in the end the triumphant schoolboy points to a dozen or half a dozen young frogs as the outcome of the experiments. But in my laboratory it is now possible to start with a culture dish containing 50 tadpoles and to bring 48 successfully through the metamorphosis. Sometimes extensive mortality occurs in a particular dish; when this case is investigated it is found to be due to some chemical contamination of the water. There is no inherent reason why tadpoles should die at any stage in their growth.

It is noteworthy that marine mammals, in spite of the fact that some of them such as the fin whale attain the largest dimensions (100 ft. in length with corresponding girth) ever attained by any animal living or extinct, nevertheless have a definite limit to their growth and presumably to their lives. For it has been shown (1) that when fin whales are born they are 20 ft. in length, (2) that they attain a length of 50 ft. in about a year, (3) that the union of the epiphyses with the bodies of the vertebræ, which sets a definite limit to growth and ultimately to life, occurs when the animal is eight years old.

In conclusion, we may say that Mr. Szabó's paper is interesting and suggestive of further experiments, but that his thought needs clarifying. The probable truth contained in it is that at various stages in the life history the coming into action of new powers of development, involving very active metabolism and often a resorption of old tissues, impose such a strain on the whole of the animal economy as temporarily to weaken the constitution, and that at such periods the weaker individuals succumb to adverse environmental influences. Szabó mentions such a period of weakness in the human race at the end of the first year. Apart from the strain involved in weaning and the adaptation to a new diet, there is the strain involved in cutting the teeth. Once we ourselves had startling light thrown on this subject. When resident in Canada, we met with an American Indian woman who was the mother of numerous offspring, all of whom she nursed for the full period. But as she pathetically explained to us, "she lost them all". Further investigation revealed the fact that the infants died when one year old or thereabouts, and that the cause of death was the strain of cutting a large number of teeth at one time. The simultaneous cutting of the teeth was due to the fact that when nursing one child she was in her sixth month of pregnancy with another, and Nature could not supply sufficient food to nourish the child in the womb and at the same time develop the teeth of the suckling child: these were held back in development, with catastrophic results to the child.

As to why some germs are more vigorous than others is a question too large to be discussed in this article, but it is, in our opinion, a subject of transcendent importance both for animal and human life, and is certainly not to be explained by 'chance'.

E. W. MacBride.

Pharmacology of Thallium.

THALLIUM salts have been used chiefly as a depilatory in ringworm of the scalp in children and as a poison for the extermination of rodents. Munch and Silver have recently reviewed the literature on the use of thallium, reporting at the same time some personal experiments on its toxicity and use as a rodent poison.* The salts most usually employed have been thallous acetate or sulphate.

Thallium is extremely toxic to animals but has less action on bacteria. In acute poisoning in man and animals, there is marked interference with locomotion, paresis or paralysis of the lower limbs, loss of appetite, decreased gastric activity, emesis, diarrhœa changing to obstinate constipation, a blue line on the gums, albuminuria, nephritis, and marked respiratory depression. Death occurs from respiratory failure, the heart and circulation not being involved. Post-mortem hæmorrhages into the lungs and marked irritation of the gastro-intestinal tract have been recorded. In chronic poisoning, the kidneys and central and sympathetic nervous systems are affected, leading to pains in the muscles and nerves, changes in the endocrine organs, and loss of hair: disturbances of calcium metabolism have also been reported. The action of thallium is cumulative: elimination is slow, two to three months being required for complete removal from the body of medicinal doses.

Thallium has been abandoned for treatment of night sweats in phthisis owing to its toxicity. It is still used as a depilatory in the treatment of ringworm in children: the maximum permissible as well as minimum effective dose is 8 mgm. per kgm. body weight, but even with this dose, toxic reactions frequently occur.

The lethal dose for rats and mice by oral administration and for rabbits by intravenous injection is about 25 mgm. per kgm. body weight: dogs are more sensitive, 10–15 mgm. per kgm. causing death. Rats usually die in three days after eating poisoned food: increasing the dose does not accelerate the fatal issue. Thallium is therefore a comparatively slow poison.

Poisoned bait was readily consumed by laboratory rats, but when tested in the field, prairie dogs did not consume different samples with equal avidity. The reason for the difference between different samples was not determined: presumably prairie dogs are more susceptible to foreign tastes or odours than rats; both the thallium salt and the nature of the food material with which it is mixed probably play a part in making the bait attractive.

Although thallium is as toxic to rodents as strychnine and several times more toxic than arsenious oxide or redsquill powder, Munch and Silver advise that it should not be used indiscriminately as a rat poison, owing to its extreme toxicity to human beings. Where its use is found necessary for the control of highly resistant species of rodents, such as prairie dogs or ground squirrels, which refuse strychnine bait, it should be entrusted only to those who will exercise appropriate care in handling it.

* "The Pharmacology of Thallium and its Use in Rodent Control." By James C. Munch and James Silver. *Technical Bulletin*, No. 238. United States Department of Agriculture, Washington, D.C., 1931.

Swedish Ironfields.

TWO important monographs recently published by the Geological Survey of Sweden* describe the geology of two interesting Swedish ironfields. Both contain excellent English summaries.

Dr. Per Geijer in "Gällivare Malmfält" gives an excellent account of the field and its rocks and ore deposits, accompanied by a detailed map, three plates of mine plans and bore-hole sections, and 71 figures in the text. This field consists mainly of sheets of leptite and gneiss with large masses of intrusive granite, dykes from which are associated with the ores. The leptite is shown by Dr. Geijer to be highly metamorphosed lavas or shallow intrusions; the silica percentage in the leptites varies, as shown by the series of analyses, from 70 to 47 per cent. The ores are non-titaniferous magnetite, with some hæmatite. The ore is often well banded and interlaminated with apatite and granite.

Dr. Geijer again advocates the view that the ores are eruptive, and interprets the field as similar to that of Kiruna, but more highly metamorphosed. The differences between the two fields are obvious and striking, and several features are difficult to reconcile with the eruptive origin of the ores. Several of the photographs of the mines, for example, Fig. 39, p. 56, Fig. 52, p. 69, and Fig. 59, p. 87, show ore resting on a footwall fault. The 'ore breccia' consists of blocks of the country rock isolated by confluent veins of ore; and as the blocks appear in their original position, as in those exposed in the open-cut of the Hermelins mine in 1907, the ore was apparently introduced in solution and not as a molten intrusion. The low percentage of titanium and the regular banding of the ore, which occurs in places in thick bands parallel to the stratification and elsewhere interleaved with such thin layers of granite that Dr. Geijer compares them to *lit-à-lit* injection, also agree with the metasomatic formation of the ore.

That origin is established by Nils H. Magnusson for the very complex ores of the Långban mining field, which is west of Stockholm and north-east of Lake Wener. The ores, like those at Gällivare, are Pre-Cambrian. The field consists of a series of leptites, dolomites, and limestones, followed by an upper series of slates, graywackes, halleflintas, and spilites. The leptitites are altered lavas and tuffs, which have been metamorphosed by the older series of granites: a later series of granites was followed by the intrusion of sheets of diabase.

The field is famous for its very complex mineral composition and the occurrence of many rare and some endemic species. The author gives a list of 110 mineral species, to summarise their paragenesis. The minerals include a great variety of manganese silicates, with lead silicates, species containing arsenic, antimony, beryllium, boron, fluorine, etc., and native metals; sulphides are of minor importance. A new manganese amphibole, tibergite, is founded. The ores are associated with skarn, which passes through a transitional layer, the skol, into the leptite. The author shows that the primary ores are metasomatic: after their formation the country was subject to thermometamorphism by the intrusions of older granites; the skol was formed metasomatically, and at the same time as the fissure veins and subsequent filling of the vugs.

* Sveriges Geologiska Undersökning. Ser. Ca, No. 22: Gällivare malmfält geologisk beskrivning. Av Per Geijer. With a Summary: Geology of the Gällivare Iron Ore Field. Pp. 115+4 tavlor. 10.00 kr. Ser. Ca, No. 23: Långbans malmträkt geologisk beskrivning. Av Nils H. Magnusson. Summary: The Iron and Manganese Ores of the Långban District. Pp 111+5 tablor. 8.00 kr. (Stockholm: Sveriges Geologiska Undersökning, 1930.)

Weather Foreshadowing.

THERE is an increasing number of people nowadays who have not specialised in physics, yet possess enough knowledge of the subject to be able to understand the broad principles underlying the forecasting or —to use a more suitable word that is coming into use— the 'foreshadowing' of future weather by means of synoptic weather charts. Those who are prepared to take the trouble to do this will probably find that the value to them of the official forecasts is greatly increased.

The official forecaster's many difficulties include one which arises from the large variety and extent of country to which his necessarily brief statements must refer. The intelligent recipient of these forecasts, with some knowledge of local peculiarities of weather, can often make the adjustment to the general statement that may be necessary in order to make it apply to his own neighbourhood. If he possesses, in addition, a barograph, showing the variations of barometric pressure as a continuous curve, something can also be done to correct the forecast so as to meet unforeseen movements of anticyclones or depressions. If a depression fails to advance in the expected manner, or begins to fill up, a fall of the barometer may be checked, or even be replaced by a rise. The barograph is extremely effective in showing such changes of barometric tendency.

To meet the needs of this class of person, the Meteorological Office of the Air Ministry has issued a number of pamphlets in recent years. Two that should assist in the same direction have been added this year. They are entitled "The Fishery Barograph" (2*d.*) and "Examples of Weather Maps showing Typical Distributions of Pressure" (3*d.*) (London: H.M. Stationery Office). The "Fishery Barograph", though primarily designed to help seamen to anticipate gales, contains much information that is of general interest, for it includes notes about the behaviour of the wind and the barometer on the approach of stormy weather, and certain important but not generally known facts about the nation's wireless weather forecasts. The "Examples of Weather Maps" are taken from the larger official work entitled "The Weather Map". There is little that appears to call for criticism in either pamphlet; both fulfil their task of explaining in simple language various mysteries of meteorological method and terminology.

University and Educational Intelligence.

From the University of Colorado we have received a bulletin containing abstracts (of 500-1500 words each) of 108 theses for higher degrees conferred in 1930. A noteworthy feature of these abstracts is the evidence they afford of the predilection of advanced students of this university for regional studies, a circumstance attributable in part, perhaps, to the publication in 1927 of a series of university studies of local geology, botany, zoology, and social history. Of the 1930 theses, more than one-fifth were regional surveys: for example, "Colorado in the Civil War", "History of a County", "Vegetation of a Mountain in Arkansas National Park", "Microzoology of Boulder Creek", and so on.

Dr. K. T. Compton, president of the Massachusetts Institute of Technology, has announced that the Rockefeller Foundation has appropriated the sum of 170,000 dollars for research work in physics, chemistry, geology, and biology, to be spread over a period of six years. The number of students at the Institute is the greatest in its history, with the exception of the two abnormal post-War years. It is significant that of the total number (3209), 17 per cent are post-graduate students drawn from other engineering schools and State universities. This tendency has been very marked of late years. The establishment of the loan fund of 4,250,000 dollars, by which assistance is afforded to deserving students, has been of great value; during the past year 226 students have benefited by it. The establishment of special honours courses has been so successful in such departments as have tried them, that it is permissible now for any department to establish them, leading up to a severe comprehensive examination at the end of the course. A new physics and chemistry building and a spectroscopic laboratory are now in course of erection. The main laboratory will be 300 ft. × 60 ft. and will have four stories and a basement, and the spectroscopic laboratory will be 100 ft. × 60 ft. The foundations are exceptionally heavy, more than 3000 piles having been driven for the two buildings. The spectroscopic laboratory is placed upon a mat composed of alternate layers of sand, felt, transite board, ground cork, and reinforced concrete, and it is so well insulated against changes of temperature that if the outside temperature were suddenly to change 100°, it would take the interior of the building about a month to change one degree. Plans have also been drawn for a naval tank combined with a hydraulic laboratory. This has been made possible by the generosity of Mr. J. E. Aldred.

The "Purpose of a University" is discussed in an article contributed by Prof. S. Alexander to the July-September number of *The Political Quarterly*. The work of a university cannot be divorced from its practical issues in life and it would be misleading therefore to define its purpose as the acquisition, communication, and advancement of knowledge without adding that it pursues the sciences not for their own sake alone, but also, so far as the larger part of its members are concerned, in preparation for the professions or higher occupations of life. The distinguishing mark of university studies is the pursuit in each subject, not only the older and well-established aspects but also the newer, more obviously professional —of the 'science' of the subject—meaning thereby its underlying rational principles and its relations with other subjects. In England much of the work done in universities lacks this characteristic, being such as in France or Germany is done in the lycées or the gymnasia: the student is still too much of a schoolboy or schoolgirl to entertain the true spirit of academic life and needs more than mere guidance. Admitting this immaturity of undergraduates in the early part of their university course, Prof. Alexander nevertheless inveighs against the overteaching of students as a glaring defect of our universities in general and of Oxford in particular. This sins against the ideal of a university not only by incompatibility with training the student in intellectual independence and with the cultivation of the scientific spirit, but also by engrossing time which ought to be devoted by the teacher to scientific research. The Oxford tutorial system, which has so often been held up for admiration as a model of university teaching, has, in his eyes, become a positive evil, and he holds that the new studies of the natural sciences are fortunate in that the system has not taken root strongly in them. To it he ascribes Oxford's failure to keep its place in the front rank of the advancement of science: nor is there, he says, any sufficient evidence that the overtaught undergraduates of Oxford are better fitted for the work of life than those of Cambridge who have not been so tutored.

Birthdays and Research Centres.

Aug. 30, 1871.—The Right Hon. Lord Rutherford of Nelson, O.M., F.R.S., past president of the Royal Society; Cavendish professor of experimental physics, University of Cambridge; and chairman of the Advisory Council of the Department of Scientific and Industrial Research.

For many years, I have been engaged in researches to throw light on the structure of atomic nuclei. Several lines of attack on this problem are being actively pursued by different workers in the Cavendish Laboratory, including the determination of isotopes, the artificial disintegration of elements by α-particles, measurement of the wave-length of γ-rays, and the effect of high frequency γ-rays on the nucleus. At the moment my co-workers and I are studying in detail with the aid of new counting methods the groups of long range α-particles—about one in a million of the main group—expelled from certain radioactive substances. There is strong evidence that these rare groups of particles are closely connected with the emission of γ-rays. In an excited nucleus it is supposed that some of the α-particles are raised to a high level of energy. The majority fall back to a lower level, emitting γ-rays in the process, but in the short time before this happens a few of the α-particles are able to escape through the potential barrier and issue as long range α-particles. By a study of these particles, it is hoped to account for the origin of the γ-rays and their complicated spectrum.

In order to increase our knowledge of artificial disintegration of atoms and for other investigations, it is desirable to have available for laboratory purposes sources of high speed atoms and electrons. It is of first importance that the best method of generation of very high voltages for this end and their application to produce swift particles should be actively investigated.

Sept. 1, 1877.—Dr. F. W. Aston, F.R.S., fellow of Trinity College, Cambridge, and Nobel laureate for chemistry (1922).

One of the problems I have been attacking with my mass-spectrograph is the photometrical determination of the relative abundances of the isotopes of complex elements. During this investigation atomic weights have been checked and many new species of atoms discovered. Work has advanced sufficiently far to show that there is little hope of discovering any simple laws connecting these ratios of abundance. I am also making experiments on possible improvements to the apparatus to increase the accuracy of its determination of atomic masses even further. Theoretical investigators of the structure of nuclei ask for an accuracy of 10^5 and I have every hope that in the near future this will be approached.

The crying need in this work is a means of obtaining and controlling really intense beams of high speed positive ions. I hope that all engaged in research in this field will bear this in mind and neglect no byway likely to lead towards this end.

Sept. 2, 1877.—Prof. F. Soddy, F.R.S., professor of chemistry in the University of Oxford and Nobel laureate for chemistry (1921).

I have this year re-determined the rate of growth of radium from uranium. The attempts directly to prove that radium is a product of uranium began simultaneously with those, immediately successful, to detect the production of helium from radium. But, owing to ionium intervening, the growth proceeds according to the square of the time and is infinitesimal for the first few years. Four uranium preparations, purified from radium and ionium a quarter of a century ago, now have from 10^{-9} gm. to 10^{-10} gm. of radium, as much as it is convenient to measure accurately, and they give a very consistent value for the product of the periods of the average lives of ionium and radium, namely, $2 \cdot 44 \times 10^8$ (years)^2.

"Money *versus* Man", published this year, gives a popular account of my theory of virtual wealth—a slight but upsetting modification of the quantity theory of money—and of the problems which confront civilisation owing to the growth of the physical sciences.

I have also applied for a patent for a form of centrifugal reversing and reducing mechanism which I am hopeful will one day find application to turbine-propelled vessels.

Sept. 3, 1882.—Dr. W. L. BALLS, F.R.S., chief botanist of the Egyptian Ministry of Agriculture, and formerly chief of the Experimental Department, Fine Cotton Spinners' and Doublers' Association, Bollington, Cheshire.

A slow development of technological research on spinning quality is taking place concurrently with the isolation, testing, propagation, renewal, and bulk control of pure lines of Egyptian cotton, which occupies much of the time of my staff at Cairo, but my chief personal interest is subterranean, developed from my pre-War studies of the root and its environment. In the Templeton observation-pits we have watched sequences of events and then found them in the open field; roots growing a metre a month and remaining alive for months after the plants had been uprooted; colour changes in soil round the roots demonstrating chemical stages of deterioration through water-logging and re-aeration. We now use the crops as indicators of soil structure, and are interested in the development of aerial survey repeated through a full rotation of crops, with reference to drainage projects. At the moment I am writing up water-table observations which have accumulated on our experimental farm at Giza since 1909.

Societies and Academies.

PARIS.

Academy of Sciences, June 29.—The president announced the death of Friedrich Becke, *Correspondant* for the Section of Mineralogy.—**A. Lacroix**: New observations on the tectites of Indo-China. Discussion of their origin. From the examination of a large number of fresh specimens it is concluded that the tectites result from the vertical fall of fused material possessing a high temperature. This agrees with the hypothesis of a meteoric origin of the tectites.—**Emm. de Margerie**: The last sheets of the *Carte Générale Bathymétrique des Océans* (*Panneau du Pôle Nord*).—**Paul Montel**: Functions of several linearly dependent variables.—**E. Kogbetliantz**: New observations on the orthogonal system of Hermite polynomials.—**Lucien Féraud**: Completely stable systems in the neighbourhood of an equilibrium point.—**H. Guillemet**: The evolution of the wake behind an obstacle for small values of Reynolds's number.—**Mme. V. Popovitch-Schneider**: The extension of Hele-Shaw's method to cyclic movements. The results of the experiments, in spite of the wall effect due to the small dimensions of the apparatus, show good agreement with theory. Four reproductions of photographs accompany the paper.—**Emile Bélot**: The double origin of the small planets and their emission by the rings and vortices of the large planets.—**Louis Gérard**: Reflection on a moving mirror and relativity.—**A. Damiens** and **L. Domange**: An electric furnace made of fluorspar. Details of construction of an electric tube furnace in which the inner tube is made of fluorspar. It permits of working with fluorine or hydrofluoric acid at a temperature of 1000° C.—**B. Decoux**: A piezoelectric quartz frequency meter with synchronous modulation. The meter described is transportable and is capable of high accuracy. It can also be used as a stable receiver by using the apparatus as a heterodyne.—**P. Fleury**: A precision luxmeter with homochrome regions.—**Léon** and **Eugène Bloch**, **F. Esclangon**, and **P. Lacroute**: The observation of the Zeeman effect with high frequency. High frequency discharges in rarefied gases, already proved to be of great service for the production and separation of higher order spectra, can also be utilised with advantage for the study of the Zeeman effect. The results of experiments with neon and with mercury (field 26,250 gauss) are given.—**D. Malan**: The absorption spectrum of oxygen at high temperatures. This work was undertaken with the view of detecting the formation of ozone in oxygen at a high temperature. At 1400° C. no ozone could be detected by the absorption method, and it is concluded that unless the absorption of ozone is diminished at the high temperature, the quantity of ozone produced, if any, must be very small.—**P. Daure** and **A. Kastler**: The Raman effect in some gases. The gases studied were hydrogen, acetylene, cyanogen, and steam.—**François Reymond** and **Tcheng da tchang**. The separation of polonium and of protactinium fixed on tantalum oxide. To the tantalic acid gel in solution in hydrofluoric acid some selenious acid is added, followed by sulphuric acid and sodium bisulphite. The reduced selenium produced by boiling carries down with it the whole of the polonium present.—**F. Bourion** and **E. Rouyer**: The cryoscopic study of paraldehyde in solutions of lithium chloride and magnesium chloride.—**Francis Perrin**: Molecular association and the optimum for fluorescence of solutions. The influence of salts.—**Maurice Curie** and **M. Prost**: The radiation accompanying the hydration of quinine sulphate. In water vapour at the pressure of 1 mm. the path of the radiation is about 1 mm.; at atmospheric pressure the path would be of the order of 0·001 mm.—**Mlle. Sabine Filitti**: The determination of the charge of the micelle. It is possible to determine the granular charge of a non-ionised colloid of known micellary weight by measuring the fall of *p*H produced in the dispersing medium by a given mass of dissolved substance.—**P. Mougnaud**: The estimation of fluorine. A detailed examination of the methods of Rose and of Carrière and Rouanet. The latter is rejected as inaccurate; the former is capable of improvement.—**Mlle. M. L. Delwaulle**: The action of hydrogen upon potassium permanganate.—**P. Carré** and **P. Mauclère**: The chloride of acid ethyl sulphite and the neutral mixed alkyl sulphites. The observation of Michaelis and Wagner on the production of $(C_2H_5O)SO.Cl$ by the interaction of neutral ethyl sulphite and phosphorus pentachloride, with subsequent separation by distillation, is shown to be inaccurate. This compound is formed by treating thionyl chloride with alcohol in the presence of pyridine, but commences to decompose at 18° C. and cannot be distilled.—**Paul Jodot**: The diffusion of silica during the formation of Corsican jaspers.—**Conrad Kilian**: The age of the Harlania grits, and the extension of the Silurian in the eastern Sahara.—**Couvreur**: Comparison of the testa of lamellibranchs and gastropods.—**Louis Dangeard**: The presence of coccolith and coccosphere beds in the laguno-lacustral Oligocene of Limagne.—**H. Colin** and **P. Billon**: Potash in the sugar beet.—**Émile Saillard**: Sugar beets and molasses (nitrogen and raffinose).—L. Bordas: The comparative anatomy of the ovaries of some Hymenoptera.—Charles Pérez: The successive replacement of the visceral sacs in *Chlorogaster*.—Jules Amar: Vital capacity and pulmonary ventilation.—Léon Binet and M. V. Strumza: The hæmatopoietic power of carotene. In anæmic dogs the administration of carotene by the digestive tract has a marked influence in increasing the proportion of hæmoglobin.—Jean Saidman, Jean Meyer, and Roger Cahen: The local effects in the rat due to electric fields of very high frequency. Regional irradiation causes a relatively slight rise in the general temperature, but causes a sharp rise in the temperature of the irradiated region. Abdominal irradiation produces death when the temperature reaches 43·5° C.—Boris Ephrussi: The factors limiting the increase of cultures of tissues *in vitro*. Meaning of the residual energy.—Delherm and Laquerrière: A new electrotherapeutic apparatus for the production of long period alternating waves and undulatory currents.—C. Levaditi, A. Vaisman, Mlles. R. Schoen and Y. Manin: The calcifying action of bismuth.

LENINGRAD.

Academy of Sciences (*Comptes rendus*, No. 26, 1930).—E. Voronovskaja: The transformation of a series of functions by the differences of its terms.—K. Nikolskii: The geometry of the Dirac equation.—G. Laemmlein: The regular formation of twins in porphyro-quartz of Samshvildo. The author believes that the orientation of the composite parts of a twin is not accidental but occurs according to some definite laws of crystallisation.—L. Kamanin and V. Slokevitch: A discovery of *Spaniodontella* strata and of deposits of the first Mediterranean stratum in the Nikopol area of manganese deposits.

Comptes rendus, No. 27.—V. Chlopin and A. Ratner: The distribution of a dissolved substance between the crystalline and the fluid phase. An experimental study of the distribution of radium between crystals of lead nitrate and their solution at 0° and at 25°. The distribution occurs strictly according to the Berthelot-Nernst law.—N. Gutkova: A new titanosilicate, the murmanite of the Lovozero tundras. Physico-chemical, optical, and crystallographical characteristics of the mineral are given.—M. Korsakova and E. Nikitina: The influence of the associated bacteria on the nitrogen régime of *Granulobacter pectinovorum*. When *Granulobacter* is associated with various ærobic bacteria, the latter not only create the anærobic conditions required by *Granulobacter*, but also alter the conditions of its nutrition by providing it with the necessary organic nitrogenous compounds.—M. P. Korsakova: The mechanism of the reduction of nitrates (3). A species of bacterium, not identified exactly, was found by the author to be able to reduce nitrates, but the reduction does not reach the stage of free nitrogen.—T. Ščegoleva-Barovskaja: New Mordellidæ (Coleoptera) in the collections of the Zoological Museum of the Academy of Sciences. Descriptions of *Mordella fallaciosa* and *M. curvipalpis*, spp. nn., from Turkestan, *Mordellistena similis*, sp. n., from European Russia, and *Silaria antennalis*, sp. n., from Yakutsk province.

SYDNEY.

Linnean Society of New South Wales, June 24.—C. Deane: Trichopterygidæ of Australia and adjacent islands. Descriptions of twenty new species of this family under ten genera, five of which are new.—J. W. Evans: Notes on the biology and morphology of the Eurymelinæ (Cicadelloidea, Homoptera). The Eurymelinæ are found principally on Eucalyptus trees, the eggs being laid in incisions made by the females in the bark of these trees. There are five nymphal instars, the nymphs being gregarious, as are the adults of many species. Both nymphs and adults are attended by ants; the latter feed on the 'honey-dew' or excreta of their charges. In spite of the ubiquity of their food-plants, their distribution is localised, due to the control effected by their many parasites and predators.—F. A. Craft: The physiography of the Shoalhaven River valley. (2) Nerrimunga Creek. Nerrimunga Creek and its tributaries drain an area of tableland to the west of the Shoalhaven River, into which they flow. The western divide between the Wollondilly and Shoalhaven waters is a level ridge varied in places by monadnocks. This falls to an extensive plain of the order of 2000 feet above sea-level, across which the streams flow in shallow valleys. Tertiary deposits are found extensively on this surface, and towards the east of the area stream channels filled with Tertiary drift are found down to 300 feet below the plain, which has been partly dissected by the deep gorges of Nerrimunga Creek and the Shoalhaven River.—(3) Bulee Ridge. Bulee Ridge, to the east of the Shoalhaven River at the head of the coastal fall, consists of horizontal sandstones, and rises from 2000 feet above the Shoalhaven south of Tallong to 2600 feet in its highest portion. On the west it falls away to the Shoalhaven Plain at 2000 feet, but the western slopes have been considerably dissected. The ridge is of considerable age, and protects the tableland from the destructive erosion of the coastal slopes.—E. Le G. Troughton: Three new bats, of the genera *Pteropus*, *Nyctimene*, and *Chearephon*, from Melanesia. The genus *Pteropus* is recorded for the first time from Ongtong Java, Lord Howe's Group. The range of the genus *Nyctimene*, not hitherto recorded southward of Guadalcanar in the Solomons, is extended some 350 miles to the Santa Cruz Group, while the third species, an insectivorous bat of the wrinkle-lipped genus *Chaerephon*, from the island of Ysabel, records the first known occurrence of the family Molossidæ in the Solomons.

Official Publications Received.

BRITISH.

Ceylon. Part 4: Education, Science and Art (G). Administration Report of the Marine Biologist for the Year 1930. Pp. G10. (Colombo: Government Record Office.) 10 cents.

Proceedings of the Royal Society. Series A, Vol. 132, No. A 820, August 1. Pp. 353-706. (London: Harrison and Sons, Ltd.) 18s.

Annual Report of the Auckland Institute and Museum, 1930-31, adopted at the Annual General Meeting held on 27th May 1931. Pp. 45. (Auckland, N.Z.)

Ontario Research Foundation. Report for the Year 1930, presented by the Chairman to the Lieutenant-Governor in Council, December 1930. Pp. 31. (Toronto: Herbert H. Ball.)

Transactions of the Mining and Geological Institute of India. Vol. 25, Part 4, May. Pp. 307-382+xiii. 2.8 rupees. Vol. 26, Part 1, July. Pp. 68+viii. 2.8 rupees. Member List. Pp. 26. (Calcutta.)

Indian Lac Association for Research. Reports of the Committee and of the Director, Indian Lac Research Institute, Nankum, Ranchi, for the Year 1st April 1930 to 31st March 1931. Pp. ii+50. (Nankum.)

Bulletin of the Department of Zoology, Panjab University, Vol. 1. Fauna of Lahore. 1: Butterflies of Lahore. By D. R. Puri. Pp. 61+4 plates. (Lahore.) 3.8 rupees.

Committee on National Expenditure. Report. (Cmd. 3920.) Pp. 282. (London: H.M. Stationery Office.) 4s. net.

Proceedings of the Cambridge Philosophical Society. Vol. 27, Part 3, 31 July. Pp. 291-489. (Cambridge: At the University Press.) 7s. 6d. net.

FOREIGN.

Comptes rendus de la cinquième séance de la Commission Géodésique Baltique réunie à Copenhague du 13 au 18 octobre 1930. Redigés par Ilmari Bonsdorff. Pp. 275. (Helsinki.)

Field Museum of Natural History. Botanical Series, Vol. 11, No. 1: Spermatophytes, mostly Peruvian—III. By J. Francis Macbride. (Publication 288.) Pp. 35. Zoological Series, Vol. 18, No. 3: Birds of the Kelley-Roosevelts Expedition to French Indo-China. By Outram Bangs and Josselyn Von Tyne. (Publication 290.) Pp. 31-119+3 plates. Botanical Series, Vol. 7, No. 3: The Rubiaceae of Bolivia. By Paul C. Standley. (Publication 292.) Pp. 253-339. Zoological Series, Vol. 18, No. 4: The Painted Turtles of the Genus Chrysemys. By Sherman C. Bishop and F. J. W. Schmidt. (Publication 293.) Pp. 121-139. Botanical Series, Vol. 8, No. 5: Studies of American Plants. By Paul C. Standley. (Publication 294.) Pp. 293-398. (Chicago.)

Proceedings of the Imperial Academy. Vol. 7, No. 6, June. Pp. xvii-xviii+211-240. (Tokyo.)

Mitteilungen der Naturforschenden Gesellschaft Bern aus dem Jahre 1930. Pp. lxx+211+11 Tafeln. (Bern: Paul Haupt.)

CATALOGUES.

Askania Vibrograph with Photographic Record. (Pamphlet Geo 105E.) Pp. 12. The Prismatic Derivator designed by v. Harbou for graphically determining Tangents and Normals to Mathematical Curves. (Pamphlet Geo 106E.) Pp. 2. (London: O. G. Karlowa; Berlin-Friedenau: Askania-Werke A.G.)

Diary of Societies.

CONGRESSES.

SEPTEMBER 1 TO 19.

INTERNATIONAL ILLUMINATION CONGRESS.

Friday, Sept. 4 (at Glasgow).—O. Höpcke: Über die Brauchbarkeit von Modellen bei lichttechnischen Vorführungen.
C. A. Atherton: Organisation for the Development of Electric Lighting.
C. Clerici: Progress and Teaching of Illumination in Italy.
A. M. Baidaff: Lighting Progress in Argentina.
C. Zwikker and Collaborators: L'exactitude de la photométrie.
L. Simek: Some Observations on Errors in Photometric Measurements.
E. Ferencz and J. Urbanek: Sur la précision de la photométrie.
R. Kövesligethy and P. Selényi: Über die Genauigkeit der subjektiven Photometrie von Glühlampen stark verschiedener Lichtfarbe.
P. J. Waldram: The Provision of Adequate Daylight in Building Regulations.
C. G. Möller: Daylight Illumination and Town-Planning.
H. G. Frühling: Über Leitsätze für Tagesbeleuchtung.
K. Y. Tang: Visual Performance of Various Levels of Daylight Illumination.
T. Hirayama: Daylight Illumination of Art Galleries with Overhead Lighting.
A. Angström: On the Influence of the Surface of the Ground on the Illumination from the Sky.
C. Haslett and N. E. Miller: Home Lighting.
C. W. Sully: Lighting Activities of Supply Undertakings.
G. H. Stickney: Adequate Wiring—A Problem of the Illuminating Engineer.
G. S. Merrill: Voltage and Incandescent Electric Lighting.
A. K. Taylor: Accuracy of Portable Photometers.
J. Hrdlička: Contribution à l'étude de la précision en photométrie.
W. F. Little: Precision of Photometry.
B. P. Dudding and G. T. Winch: Accuracy of Commercial Photometry. Comparison of Visual and Photo-electric Measurements.
J. Wetzel and A. Gouffé: Sur la précision des photomètres portatifs.
Z. Yamauti and K. Hisano: Photo-electric Measurements of Daylight Illumination by the Use of a Model Room.
H. F. Meacock and G. E. V. Lambert: Efficiency of Light Wells.
A. C. Stevenson: On the Mathematical and Graphical Determination of Direct Daylight Factors.
H. H. Higbie and A. D. Moore: Prediction of Natural Illumination in Interiors and on Walls of Buildings.

Monday, Sept. 7 (at Edinburgh).—A. P. Allan and J. M. Campbell: The Lighting of Seaside Resorts.
A. Gouffé: Calcul de l'éclairement moyen des espaces circulaires et elliptiques.
W. S. Stiles: Mass Experiments in Street Lighting.
Sir Francis Goodenough: Notes on Recent Developments in Gas for Street Lighting in Great Britain as Illustrated by the facts relating thereto in the Cities to be visited by Delegates to the International Illumination Congress, 1931.
W. J. Jeffery: Modern Public Lighting by Electricity.
J. S. Preston: The Properties of Diffusing Glasses, with Special Reference to Surface Effects.
J. W. Ryde and B. S. Cooper: (*a*) The Theory of Diffusion of Light by Opal Glasses; (*b*) Practical Applications of the Theory of Opal Glasses.
L. Bloch: Durchsichtigkeit und Durchlässigkeit lichtzerstreuender Gläser.
S. Schönborn: Klasseneinteilung für Beleuchtungsgläser.
M. Cohu: Rapport sur quelques propriétés de certains matériaux diffusants.
F. Born: Zur Frage der Vertikallichtverteilung von Flugstreckenfeuern.
v. Goler and M. Pirani: Über die Anwendung von Leuchtröhren.
H. N. Green: The Light Distribution of Navigation Lamps.
British National Committee: Ground Lighting Equipment for Aviation.
M. M. Exelmans: Appareils pour l'éclairage des routes terrestres et le balisage des routes aériennes.
M. Franck: Feux de position des avions.
F. C. Breckenridge: Transmission of Light through Fog.
C. C. Paterson: The British Standard Specification for Street Lighting.
E. J. Stewart: British Street Lighting in the Lower Classes of the Standard Specification.
W. S. Stiles and J. F. Colquhoun: The Street Lighting Requirements of Different Types of Street.
Public Lighting Department, South Metropolitan Gas Co.: Street Lighting by Gas in South London.
L. A. S. Wood: American Street Lighting Practice.
J. Wetzel: Sur l'établissement d'un projet d'éclairage de voie publique.
R. Kurosawa: (*a*) A Simple Method for Testing Diffusing Material; (*b*) A Study on the Light Distribution of Diffusing Globes.
S. Seki: Distribution of Reflected Light from Test Plate of Macbeth Illuminometer and Proper Direction of Measurement.
M. M. Exelmans: Les glaces moulées diffusantes comparées aux glaces claires.
H. Eguchi: (*a*) Course of Improvement of Visual Acuity during Light Adaptation: (*b*) Über die Sehscharfe unter starker Helligkeit.
H. Klein: Beschreibung eines neuen Sehleistungs-Prüfapparates.
V. Pospisil: L'origine des sensations visuelles.
J. Dourgnon and P. Waguet: Remarques sur la non-réciprocité de certains phénomènes optiques: conséquences pratiques relatives à l'art de l'éclairage.
S. Maisel: Uber die Grundbegriffe der Lichttechnik.

Thursday, Sept. 10 (at Buxton).—H. Lux: Die Leitsätze fur die Beleuchtung mit künstlichen Licht.
M. Luckiesh and F. K. Moss: Humanitarian Footcandles.
N. Goldstern and F. Putnocki: Webstuhlbeleuchtung.
Society of British Gas Industries: The Lighting of Factories and Large Buildings.
K. Norden: Schatten und Halbschatten.
R. W. Maitland and H. Robertson: Electric Light as related to Architecture.
H. Maisonneuve and J. Wetzel: L'éclairage artistique en France de 1928 à 1931.
Comité de Direction des Grandes réseaux de Chemins de Fer Français: Éclairage des gares de triage.
A. Cunnington: Railway Lighting in Great Britain.
L. Schneider: Bergwerksleuchtung.
W. Maurice: A Standard of Illumination for Mines.
W. A. Villiers: Incandescent Lighting in British Cinema Studios.
Z. Yamauti: Construction and A.C. Luminous Intensity of Standard Vacuum Tungsten Filament Lamps.
E. Lax and M. Pirani: Künstliches Tageslicht und Sonnenlicht.
E. Chelioti and B. P. Dudding: Precision in Incandescent Lamp Manufacture.
A. Blondel: Sur un photomètre binoculaire à coins et ses applications aux phares et projecteurs.
L. Kalff: Illumination and Architecture.
W. J. Jones: Engineering Aspects of Architectural Lighting.
J. Dourgnon and P. Waguet: (*a*) Note sur la détermination des dimensions des corniches des volets ou des ailettes à masquer la vue directe des sources ou des appareils; (*b*) Remarques sur les surfaces réfléchissantes mates de brillance uniforme.
B. Matthews: Electric Light on the Farm.
K. Vogl: Künstliches Beleuchtung im Gewächshaus.
S. Odén, G. Köhler, and G. Nilsson: Plant Cultivation with the aid of Electric Light.

Friday, Sept. 11 (at Birmingham).—Z. Ishii and T. Takeshita: Some Fundamental Experiments on Signal Glasses.
T. Abe: An Improved Optical System for Japanese Railway Coloured Light Signals.
K. Fuwa: On the Selenium Ruby Glass.
I. Inaba: Tests of Coloured Signal Glasses.
T. Abe and T. Takegami: Apparatus for Obtaining the Light Distribution Curve and the Rousseau Diagram.
L. Schneider: Ein Beitrag zur Kennzlichnung der Lichtstromverteilung.
J. Wetzel: Sur une nouvelle méthode de calcul des coefficients d'utilisation.
W. Arndt: Über den Stand der Arbeiten-Beleuchtung räumlich zu bewerten.
Report of Committee on Motor Vehicle Headlights: An Experiment on the R.A.C. Disc.
F. Born: Zur Frage der internationalen Regelung der Automobilbeleuchtung.
A. Monnier: Les lampes électriques françaises employées dans les projecteurs d'automobiles.
J. D. Morgan: Motor Vehicle Lamps.
M. Roge: Les derniers perfectionnements apportés sur les projecteurs électriques d'automobiles.
A. V. Blake and W. M. Hampton: The Development of Traffic Control by Light Signals in Great Britain.
E. Schuppan: Lichtsignalregelung.
J. P. Bowen: Lighthouses.
A. Blondel: Brilliance apparente des surfaces de sortie des appareils optiques éclairés par des sources le lumière.
Z. Yamauti: Notes sur la mesure de lumière à couleurs différentes.
B. P. Dudding and G. T. Winch: Photometric and Spectrophotometric Comparison of White and Coloured Light Sources.
J. Escher-Desrivières: La colorimétrie des sources lumineuses ponctuelles.

AUGUST 31 TO SEPTEMBER 4.

INTERNATIONAL CONGRESS OF NEUROLOGY (at Berne).

SEPTEMBER 7 TO 10.

INTERNATIONAL PSYCHO-ANALYTICAL ASSOCIATION (at Interlaken).

SEPTEMBER 7 TO 10.

INTERNATIONAL CONGRESS FOR STUDIES REGARDING POPULATION (at Rome).

SEPTEMBER 7 TO 12.

INTERNATIONAL CONGRESS OF ORIENTALISTS (at Leyden).

SEPTEMBER 9 TO 12.

INTERNATIONAL PROFESSIONAL ASSOCIATION OF MEDICAL PRACTITIONERS (at Budapest).