JUBILEE NUMBER.

NATURE

A WEEKLY ILLUSTRATED JOURNAL OF SCIENCE.

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Of Nature trusts the mind which builds for aye."*—WORDSWORTH.

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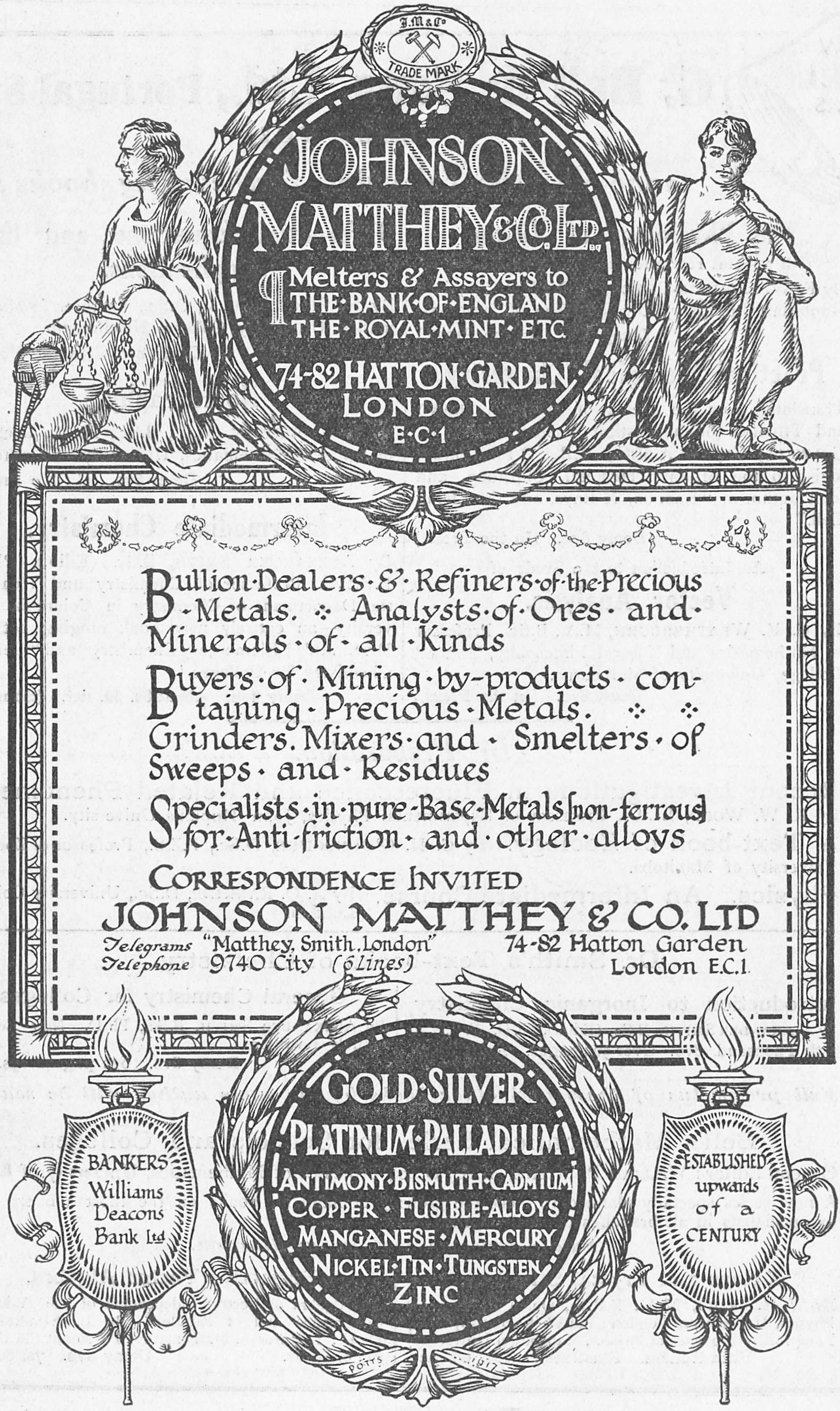
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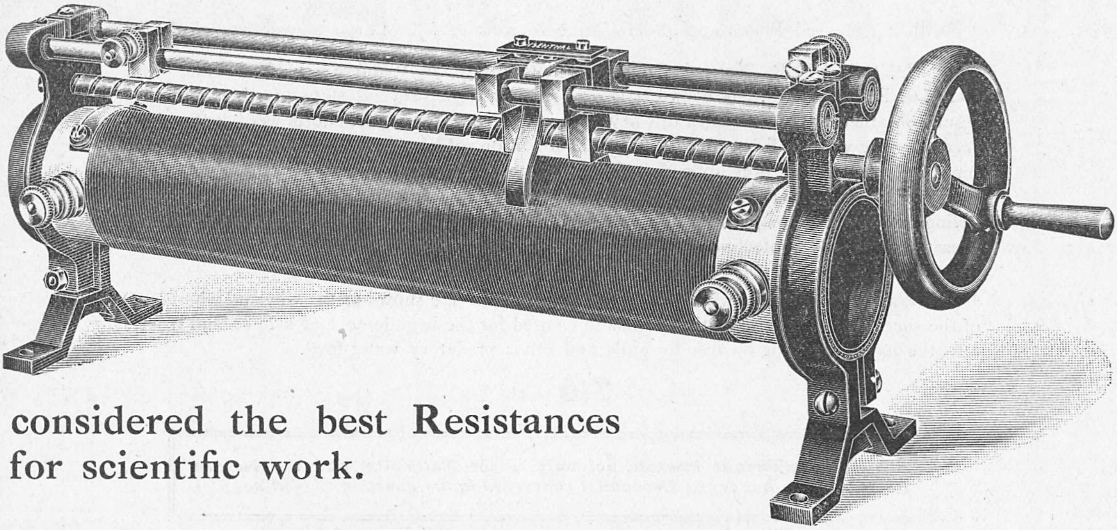

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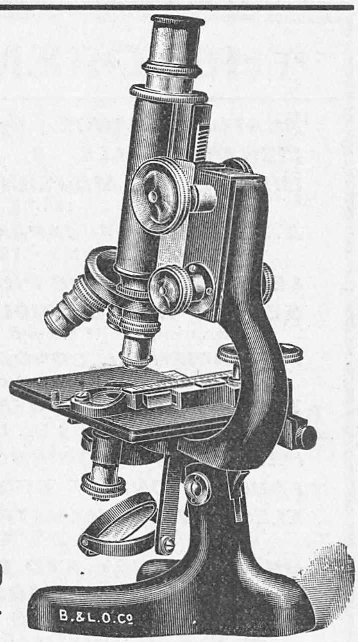

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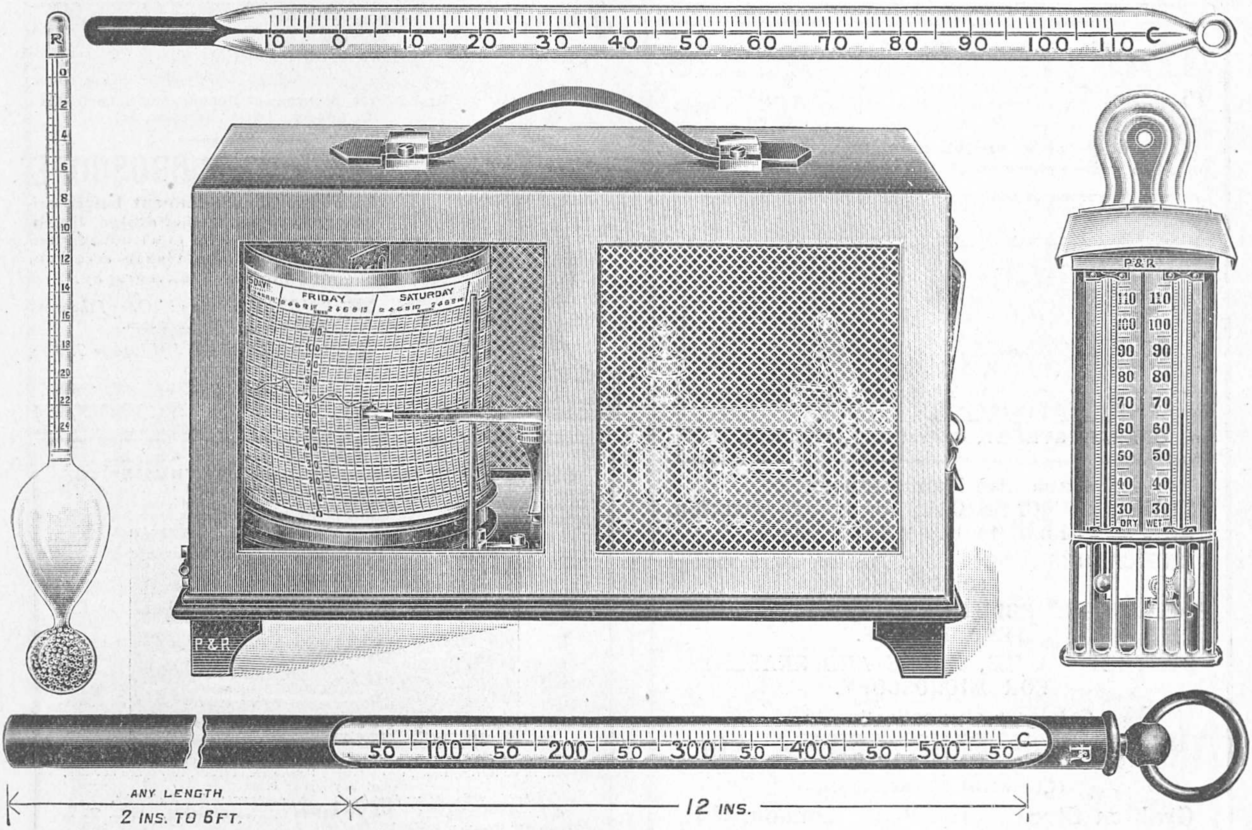

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See Page cxxxviii of the Present Number.

NATURE

1869–1919.

JUBILEE ISSUE.

THURSDAY, NOVEMBER 6, 1919.

VALEDICTORY MEMORIES.

By Sir Norman Lockyer, K.C.B., F.R.S.

IT has been suggested to me that some reminiscences relating to the circumstances which led to the establishment of Nature would be of interest, and I am glad to be able to contribute them to this jubilee issue. It is a great satisfaction to me again to have the opportunity of expressing my best thanks to the many friends whose knowledge has always been placed freely at my disposal, and to know that the vitality of the journal is now as strong as ever it was.

At the time when Nature first made its appearance, just fifty years ago, scientific progress was commanding increased attention from the public mind, and British workers were experiencing the need for an organ devoted to their common activities and interests. In 1858 a fortnightly column of scientific notes was started in the *Saturday Review*, and two years later Huxley became the chief editor of the *Natural History Review*, with the intention of providing a quarterly which would deal with scientific matters systematically and thoroughly. He ceased to contribute to that magazine, however, in 1863, and became associated with the *Reader*, a weekly journal of which I was the science editor.

My first literary work arose from observations of a transit of the shadow of Titan across Saturn's disc. I sent an account of these observations to the *London Review*, and it appeared in the issue of May 10, 1862. This communication brought me two letters—one from Mr. W. R. Dawes, who was at that time recognised as one of the keenest astronomical observers in England, and the other from Mr. W. Little asking me to send astronomical notes from time to time to the *London Review*, together with an article each month on the "face of the sky."

I was then living at Wimbledon, and was honorary secretary of the Wimbledon Village Club, on the committee of which were Thomas Hughes, J. M. Ludlow, and George Pollock. It was this connection that led to my appointment as science editor of the *Reader*, when it was established with Hughes and Ludlow among the proprietors. My astronomical work thus led me into literature, and the subject with which I was particularly concerned—astronomy—was also the product of my Wimbledon environment.

When the *Reader* ceased publication the idea occurred to me of starting a general scientific journal of a more comprehensive scope than the *Natural History Review*, which, like other specialised scientific periodicals, had failed for want of circulation. On discussing the matter with my friends, I found that they were favourable to the idea; and one of them, Mr. Alexander Macmillan, greatly encouraged me to develop it. It was in consequence of his sympathy and enthusiastic assistance that the journal was started. He was unwavering in his support of the belief that British science would be advanced by a periodical devoted to its interests—a point on which I had always laid stress as the result of experience up to that time. It was the hope that a more favourable condition for the advancement of science might be thereby secured that led Mr. Alexander Macmillan to enter warmly into the establishment of Nature in 1869. He enlisted the interest of Sir Joseph Hooker and other of his scientific friends, and before the journal had started I was assured of the support of Huxley, Tyndall, and practically all the other leading workers in science of the time.

It may be of interest to reprint here the following circular which was issued broadcast to bring the aims and intentions of the journal before scientific readers and others :—

The object which it is proposed to attain by this periodical may be broadly stated as follows. It is intended :

First, to place before the general public the grand results of Scientific Work and Scientific Discovery, and to urge the claims of Science to a more general recognition in Education and in Daily Life; and

Secondly, to aid Scientific men themselves, by giving early information of all advances made in any branch of Natural Knowledge throughout the world, and by affording them an opportunity of discussing the various Scientific questions which arise from time to time.

To accomplish this twofold object, the following plan is followed as closely as possible.

Those portions of the paper more especially devoted to the discussion of matters interesting to the public at large contain :

I. Articles written by men eminent in Science on subjects connected with the various points of contact of Natural Knowledge with practical affairs, the public health, and material progress; and on the advancement of Science, and its educational and civilising functions.

II. Full accounts, illustrated when necessary, of Scientific Discoveries of general interest.

III. Records of all efforts made for the encouragement of Natural Knowledge in our Colleges and Schools, and notices of aids to Science-teaching.

IV. Full Reviews of Scientific Works, especially directed to the exact Scientific ground gone over, and the contributions to knowledge, whether in the shape of new facts, maps, illustrations, tables, and the like, which they may contain.

In those portions of NATURE more especially interesting to Scientific men are given :

V. Abstracts of important papers communicated to British, American, and Continental Scientific societies and periodicals.

VI. Reports of the meetings of Scientific bodies at home and abroad.

In addition to the above, there are columns devoted to Correspondence.

From the first I was helped by the free kindness of most of the men of science in the country, by their permitting me to appeal to them for assistance and advice, and my election into the Royal Astronomical Society, and afterwards into the Royal Society, in 1869, brought me into closer correspondence and contact with many of the active workers in scientific fields. I am very grateful for what they did, and for what men of science are still ready to do to ensure that NATURE shall represent scientific claims justly and scientific fact and thought in correct proportion. While this common interest in the journal exists among men of science, not only in the United Kingdom, but also in Europe and America, there will be no falling off from the high standard maintained in its pages from the commencement of its existence.

PROGRESS AND PROMISE.

IN the career of a journal, as in the life of a man, stages are met from which it is appropriate to take a glance backward at the road traversed and to contemplate the outlook of the future. Such an epoch has been reached in the history of NATURE, the first number of which was published fifty years ago—on November 4, 1869. The circumstances which led to the establishment of this journal are described briefly by Sir Norman Lockyer in the preceding article. Men of science had felt the need for an organ devoted to their interests in common, and several attempts had been made to meet it, but unsuccessfully. It required the rare combination of scientific authority, untiring energy, wise judgment, and business aptitude to construct a platform on which investigators of the many and diverse fields of natural knowledge could put their trust, and from which descriptions of their work would command attention.

How fully these attributes are possessed by the founder of this journal, and how consistently they have been made manifest in its pages, is shown by numerous appreciative messages received from scientific societies and distinguished workers. Thanks to the sound and comprehensive programme laid down by Sir Norman Lockyer at the beginning, and followed ever since, NATURE now occupies a high place in scientific life. It would be disingenuous to pretend that we are not proud of the testimonies which have been sent by many leading representatives of progressive knowledge as to services rendered by the journal in various ways. Among those who have expressed their congratulations upon the attainment of the jubilee are readers who have never missed a number since the first issue, while others of a new generation equally acknowledge the stimulus they derive from a wide view in these days of minute specialisation.

The intellectual background is different now from what it was in 1869, and the outlook, as well as the conceptions, of science has changed. Specialised work is necessary to acquire new knowledge, but for the great generalisations which provide an impulse to wide inquiry attention must be given to results achieved in the whole sphere of related investigations. It is the particular function of NATURE to present this comprehensive view, and to bring to a focus upon its pages the living picture of scientific advance as a whole, so that workers in separate fields may see the growth of the grand edifice of natural knowledge, and the place their own contributions take in it.

At one time—as, for example, in the early days of the Royal Society—it was possible for every member of a general scientific society to take an intelligent interest in every paper presented. Since then, however, science has passed from the stage of a simple organism to that of a body made up of parts with highly differentiated functions. Numerous specialised scientific societies have been formed, as may be seen by the list published in this issue of those established since 1869, and many periodicals similarly devoted to distinct branches of pure and applied science have come into existence. The common factor is interest in the advancement of knowledge; and a society or a journal concerned with this as a whole can best assist the aim in general by providing the segregated groups of investigators with intelligible accounts of activities in other fields, which may or may not be on the borders of their own.

The remarkable collection of articles published in this issue represents the highest type of contributions of this kind. Each article is by an eminent authority upon the subject with which it deals, and each can be comprehended by everyone who has had a scientific training. It is scarcely too much to say that no such authoritative epitome of fifty years of scientific progress, as viewed by pioneers in particular fields, has ever been brought together in any one periodical. Contributions of such high distinction are rendered possible largely because the writers know that in these pages they are addressing themselves to fellow-workers throughout the world, as well as to other readers having an intelligent interest in the march of scientific knowledge.

Four of the writers—Sir Archibald Geikie, Sir E. Ray Lankester, Prof. Bonney, and Canon Wilson—were contributors to the earliest issues of this journal; and every reader will be grateful for the enlightening descriptions of stepping-stones of scientific progress which we are now privileged to publish. NATURE could not have maintained its original standard for so long but for the active support which these and many other leading men of science have been ready to give it since its foundation. This is as true of the new generation as it was when the journal was founded; and the value of the association is most highly appreciated. While NATURE is honoured by the active co-operation of the men of genius who are traversing the royal roads of science, its functions will extend, and its influence increase, with the expansion of knowledge. With this assurance, and the encouragement which the past has given, we look with confidence and strength at the prospect of the future.

SCIENTIFIC WORTHIES.

XLI.—SIR NORMAN LOCKYER, K.C.B., F.R.S.

THE simple title NATURE, embracing all in a single word, was most appropriately chosen by Sir Norman Lockyer when, exactly fifty years ago, he founded this weekly journal, which is devoted to all the sciences, and has had so successful a career. The first article in the journal reproduced profound aphorisms of Goethe on the intimate relations of man with Nature, of which he is a part. The poet-philosopher set forth in striking language, which was rendered into English by Huxley, the innate feebleness of man before the immutable forces and the great mysteries which everywhere surround him, and at the same time the incessant human desire, never completely satisfied, of comprehending and penetrating them. The contribution is a stimulating preface to a scientific periodical; it well exhibits the high character of the journal at the outset, and the spirit in which it has always been conducted.

Indeed, NATURE is, of all scientific journals, the most comprehensive in the world; it includes articles of the highest scientific standard, as well as those of a more popular kind; it has open columns for the discussion of current subjects, and it provides summaries of most of the papers presented to the chief academies and learned societies; it gives the latest events of the scientific world, news about men of science, and accounts of the most recent discoveries in scientific fields. It has rendered inestimable services to the cause of science in general.

Since the first issue the journal has maintained the form and character which we see to-day. A comparison of a number issued in the year 1869 with one of 1919 shows the same general arrangement, the same sequence of subject-matter; moreover, the pages and the style of type are nearly identical in appearance. The founder, who in 1869 was only thirty-three years of age, has proved himself a publicist and an organiser of the first rank. During its existence the journal has ably recorded the magnificent discoveries which have distinguished the last fifty years in every branch of science; it has had to deal with subjects beyond one's dreams; and it has been the better able to present them to the public because the founder has himself been one of the foremost builders of this noble edifice.

Sir Norman Lockyer is distinguished not only by his eminent public work, but also as one of the greatest men of science of our time. In the three years which preceded the foundation of this journal he made discoveries relating to the sun which will permanently preserve his memory among men. He was one of the pioneers of astrophysics, the new branch of astronomy which is now of such importance. For fifty years, with untiring activity, he has carried on a multitude of researches in the three observatories established by him and in the physical laboratories associated with them; and, like a true philosopher, he has presented a general synthesis of celestial phenomena. The title "Nature" might be justly given to the record of his personal achievements, to which the remarks which follow are particularly devoted.

Sir Norman Lockyer is not the product of a university; he may be termed a self-made man of science. He was at first employed in a Government Department, where he remained for more than ten years; but he was irresistibly drawn towards science, and especially to astronomy, the wonder of which exercises a powerful attraction. All his leisure and all his personal resources were devoted to scientific pursuits. Spectrum analysis had come into being, and its application to celestial bodies opened up the widest horizons. Sir Norman Lockyer attached a small spectroscope to a modest equatorial telescope of 6-in. aperture, which constituted his private observatory, and he studied the light emanating from the solar spots. The first results were summarised in a note presented to the Royal Society in 1866, where the author discussed the bearing of his observations on the two rival theories which were then to the front as to the nature of sun-spots. He foresaw the possible daily observation of the red flames, or prominences, which up to that time had only been observed on the outer edges of the sun during total eclipses. He conceived the idea that the spectroscope might be able to reveal them at ordinary times under the same conditions as those which caused the appearance of bright lines in the new star in Corona Borealis. This star had appeared a few months previously, and, as observed by Huggins, had presented a stellar nucleus surrounded by a relatively feeble nebulosity; but in the spectroscope the light of the nucleus was spread out in a continuous spectrum and thereby enfeebled, while the atmosphere showed the bright lines of hydrogen with great brilliance.

This idea was really a flash of genius, because it contained the germ, or the principle, of the method which, for fifty years, has revealed to us at all hours of the day the gaseous atmosphere of the sun. The first application of the method to the sun's edge, however, gave no result; the spectroscope employed was not sufficiently powerful. Two years later the observations in India of the total eclipse of the sun of August, 1868, gave valuable information—the solar prominences were gaseous, and showed the red and green lines of hydrogen with very great intensity.

On October 20, 1868, Sir Norman Lockyer, at last provided with a powerful spectroscope, for which he had waited two years, discovered, at Hampstead, a prominence on the sun's edge, and made a drawing of it two days later. The discovery was communicated to the Royal Society on October 20 and to the Academy of Sciences at Paris on October 26. By a striking coincidence, at the same meeting of the Academy, a letter sent from India by the French astronomer Janssen announced the same result. During the eclipse Janssen had recognised in the spectroscope the nature of the prominences, and was able to see them again on the following day with the same instrument. Janssen continued to observe them daily during three weeks, and found that they were composed principally of hydrogen, and were subject to remarkable variations of form which were often very rapid. The astronomer Faye then pointed out that the first idea of the method was certainly due to Lockyer, but that the first application had been realised by Janssen, and since then the two names have been justly united in connection with the discovery.

During the weeks and months which followed, Sir Norman, with praiseworthy activity, continued the study of the sun by the new method without intermission, and he successively recognised several new facts of the first importance, namely:—

1. The prominences emanate from a gaseous layer of the same composition, which envelops the entire sun, and reaches a height of 8–10 secs. of arc. This layer is of a rose colour, like that of the prominences themselves, and Sir Norman Lockyer gave it the name of the *chromosphere*; it had already been glimpsed in preceding eclipses, but its existence was not generally acknowledged.

2. The yellow radiation of the prominences, which had been attributed to sodium by the eclipse observers, proclaimed in reality the existence of a new gas, to which Sir Norman gave the name of *helium*. It was the first recognition of the famous gas which was afterwards obtained from terrestrial sources by Ramsay in 1898; it is emitted by radio-active bodies, and now can be used for the inflation of dirigibles.

3. The green line of hydrogen becomes broader in passing from the summit to the base of a prominence. From a series of experiments on hydrogen at low pressures, carried on in the chemical laboratory of his friend, Frankland, Sir Norman concluded that this widening is simply due

to an increase of pressure. Spectrum analysis disclosed not only the chemical composition of the prominences, but also to a certain extent their physical state.

4. The lines of the prominences are often displaced and distorted. This phenomenon was correctly attributed to the movements of the vapour in the direction of the observer; it was the first real verification of the velocity displacements which have since become of such great importance in astronomy.

This first series of investigations is set forth in some detail, because it represents magnificent work; it is an example for all, and has its place marked out in the history of science, especially as it was carried out with simple means. The greatest discoveries, as one knows, have not been made in the largest laboratories, and the capacity of the man is always of more consequence in research than that of his instruments. In his investigations Sir Norman Lockyer has shown a power, an acuteness of mind, and a creative imagination which are truly exceptional. These are the qualities of men who, like him, have overcome all difficulties placed in their way in order to pursue fixed ideas and follow vocations which they have fully resolved to adopt.

In the succeeding years Sir Norman organised several eclipse expeditions under Government auspices; all the important solar eclipses since 1868 have been observed by him or by his assistants, with programmes laid down by the Solar Physics Committee, of which he was a member. At the same time, he undertook extensive work which may be summarised in the words: "Comparative study of terrestrial spectra and the spectrum of the sun, extended afterwards to stars, nebulæ, and comets. Special and general consequences drawn from them." After fifty years of continuous labour the work has certainly been advanced, but it is not yet completed. It was carried on at first in his own observatory, then from 1879 in the establishment at South Kensington which the Government had created for the development of the new methods and placed under his direction.

The astrophysical observatory at South Kensington was a model of its kind; it consisted of two parts, quite distinct but closely related, namely, an observatory properly so called and a physical laboratory. The astrophysicist must pass constantly from one to the other, and, in fact, the number of publications issued from South Kensington has been nearly the same in the two sections. It has been said that an astrophysical observatory is merely a physical laboratory oriented towards astronomy, the astronomical instruments being in reality nothing more than physical apparatus of large dimensions; and it is therefore necessary to attach to them men who have been trained by the study of physics and capable of immediately applying to the celestial bodies the most recent discoveries made in the laboratory.

In this connection Sir Norman has trained at South Kensington several investigators, including Prof. Fowler, Dr. Lockyer, and Messrs. Shackleton, Baxandall, and Butler, at once physicists and astronomers, and well known by their publications. Prof. Fowler, now president of the Royal Astronomical Society, is already distinguished; we owe to him important discoveries and some fine series of precise measurements.

In 1912 the land occupied by the observatory at South Kensington was required for the extension of the Science Museum, and the observatory, with all its instruments, was transferred to Cambridge. Sir Norman, having passed the age-limit, was obliged to retire from the directorship, but, feeling that his work was not yet accomplished, and still vigorous in body and mind, he forthwith set up another observatory—the Hill Observatory—with the aid of several friends of science. The site chosen, at Sidmouth, is very favourable for astronomical observations, and as the first buildings were erected very quickly and provided immediately with some fine instruments, the researches commenced at South Kensington, especially those on stellar spectra, have been continued with but little interruption. It is hoped to establish there an astrophysical observatory comparable with the American observatories and worthy of the United Kingdom.

The new facts gathered together in the course of these fifty years are extremely numerous; they are set forth with the inferences drawn from them in 200 memoirs, and it is impossible to give any detailed analysis of them here. Fortunately, the author, who has an affection for great generalisations, has always sought to connect the facts in a few leading ideas which are for him "working hypotheses," and he has expounded each hypothesis in a special book. The volume on "The Chemistry of the Sun" (1887) deals with the differences of spectrum emitted by different parts of the sun, and explains them by the dissociation hypothesis, according to which the molecules and atoms are grouped in different ways or are split up into simpler elements. In his book on "The Meteoritic Hypothesis" (1890) the author explains all the celestial bodies by collisions of meteorites; it is a simple and fertile idea, which has been adopted by several astronomers. The last volume, entitled "Inorganic Evolution" (1900), develops the final methods and ideas of the author, and presents a general classification of all the stars. It is only necessary to add one remark: Sir Norman is one of those who publish the observed facts immediately, and also the interpretations which present themselves at once to his mind. This method inevitably involves imperfect detail, or over-sanguine conclusions, which have been freely criticised. Pruning and revision have become necessary, and this work has recently been taken in hand by the author himself. The main body of facts and ideas remains unaffected, and is always worthy of being retained.

It will suffice to mention here very briefly on one part some of the more important results on the sun and the effects of its radiation, and, on the other, the great classification of the stars.

Sir Norman was the first to recognise the presence in the solar spectrum of lines due to a band spectrum, attributed at first to cyanogen, and now assigned to nitrogen alone. He observed the widening of the dark lines in the spectra of sun-spots, a phenomenon which has since been so brilliantly explained by Prof. Hale, of the Mount Wilson Observatory.

With the simple arrangement of the objective prism, he was the first to photograph in an eclipse the spectrum of bright lines given by the reversing layer, situated at the base of the chromosphere, thus obtaining a verification of the general accordance of these bright lines with the ordinary dark lines, and confirming the simple explanation of the dark lines given by Kirchhoff.

He discovered in the fluctuations of the solar prominences a period of 3·8 years, which is superposed on the great eleven-yearly period, and he showed later, in collaboration with Dr. Lockyer, that this same period of 3·8 years reveals itself in variations of pressure of the terrestrial atmosphere. This last result has a practical importance because it renders possible the forecasting of the variations of the monsoons in the Indian Ocean. In addition, the schematic chart of the law of the winds in the southern hemisphere, drawn up in this case by Dr. Lockyer, has been verified by all later observations; it has been reannounced in 1919 by Prof. Hildebrandson, one of the founders of meteorology, in a note on the general movements of the atmosphere presented to the Paris Academy of Sciences.

One of the questions which have most occupied Sir Norman is that of the variation of laboratory spectra with the energy of the excitation. He has from the first distinguished the long and short lines in the same spectrum, and the employment of a very powerful induction spark has given him new lines which he has called "enhanced lines." The three types of lines—long, short, and enhanced—correspond with increasing temperature, and constitute valuable tests which serve to differentiate the stars. Sir Norman has observed the presence of these lines in the spectra of stars, and at the same time the different behaviour of the lines of hydrogen, of helium, and of the metals, which has led to a new classification of the stars. The labour involved in this investigation was considerable, because it became necessary to photograph stellar spectra under the unfavourable conditions of London and with a high dispersion. Its success was secured by the use of an objective prism of large angle and by great patience.

At the same time, the great American astronomer Pickering, with much more powerful means, had entered upon the observation and classification of stellar spectra over the entire sky, and was content to use a small dispersion which enabled him to reach the fainter stars. But as the study of enhanced lines demanded a high dispersion, Sir Norman confined himself to the stars visible to the naked eye.

The classification adopted differs essentially from all previous classifications, which had considered only the actual temperatures of the stars and supposed a continuous cooling. Sir Norman went much further, and in the year 1888 established a distinction between the stars in which the temperature was rising, and those in which the temperature was diminishing. Beginning with a primitive nebula, the body which forms by condensation will at first become hotter, then attain a stationary temperature, and will finally cool. Its natural evolution, expressed by temperature as a function of time, ought to comprise an ascending branch, a steady state corresponding with the maximum, and a descending branch. In the ascending phase the lines of hydrogen are narrow and the chromosphere is of low density; at the time of maximum the enhanced lines predominate and the maximum intensity of the spectrum is far in the ultra-violet; in the later phase the lines of hydrogen are broad and diffuse, and the chromosphere is of greater density. It is certain that one thus penetrates more deeply into the nature of things. Further, Sir Norman does not explain the variable number of metallic lines by a different distribution of the chemical elements in the stellar atmosphere. When the star is very hot the metallic lines are wanting, and he has attributed this to a dissociation of the elements analogous to that of radio-active bodies. On this view the heavier elements are split up into lighter and even into new and simpler elements which he has called "proto-elements." The evolution of the stars is accompanied by a simultaneous evolution of the simple elements of Nature.

The great chemist, Ramsay, who was a pioneer in many directions, gave the greatest attention to these new ideas and to the numerous observations which appeared to support them. The classification of the stars in accordance with the foregoing tests has been fully confirmed by optical measurements of their absolute temperatures.

To sum up, in his latest researches, as well as in the first, Sir Norman Lockyer has exhibited an aptitude for experiment, a creative faculty, a penetration, and a breadth of view which are truly remarkable; and the results obtained on the sole basis of experiment are of the first importance. He is one of the great men of science of England and one of the greatest astronomers of all time. Finally, let us hope that, bearing the weight of years in comfort, he may continue his services to science and his association with this journal, and witness for himself the increasing success of his ideas and his methods.

H. DESLANDRES.
(Vice-President of the Academy of Sciences of Paris, Director of the Astrophysical Observatory of Meudon.)

RETROSPECT AND PROSPECT.

By SIR ARCHIBALD GEIKIE, O.M., K.C.B., F.R.S.

FIFTY years have passed since the publication of the first number of NATURE on November 4, 1869. To start successfully a weekly journal entirely devoted to chronicling the onward march of science was an experiment that could not but involve some financial risk, and certainly required no small editorial ability. To maintain such a journal for half a century on a high level of excellence, and to gain for it a place admittedly of importance in the periodical literature of our time, is a feat of which Editor and publishers have good reason to be proud. The weekly contributions of this journal to current scientific literature now amount altogether to more than a hundred volumes, which contain a contemporary record of the progress made by every department of natural knowledge, often contributed by the men to whom the progress was due. It may be appropriate, as we take note of this achievement, to cast an eye back upon the condition of science among us fifty years ago, to survey our present position, and to look forward into the vista that is opening out for the future.

In taking such a retrospect one of the most conspicuous and satisfactory features to attract attention is the remarkable increase and steady growth of fresh centres of higher education all over Britain, where not only is the time-honoured literary side cherished, but ample room and full equipment are found for the theoretical and practical teaching of science. These centres, beginning perhaps as modest colleges, have attracted a constantly increasing number of students, and each of them has become a nursery in which the men of science of the future are being bred. A convincing proof of their vitality is furnished by their successful claim for recognition as universities. They have already added half a dozen new universities to our educational strength, and this year one of the youngest yet most important of them, the Imperial College of Science and Technology, is now in turn demanding the status and powers of a university. There has never been a time in our history when the opportunities for obtaining a thorough scientific training have been thrown open so widely and attractively, and when advantage has been taken of them in so large a measure.

That one of the great duties of a nation is to promote the cultivation of science by appropriating funds not only in aid of education in theory and practice, but also in support of research and experiment, never began to be realised until within living memory. British science has attained its greatness without State aid. There are, indeed, a few directions in which public money has been disbursed for scientific objects, such, for instance, as Greenwich Observatory, the British Museum, and the various geographical expeditions and geological surveys. But not until the middle of last century did it dawn upon the attention of the Ministry of the day, awakened possibly by the portents of the coming Great Exhibition of 1851, that men of science are not as a rule wealthy, that they must often be involved in considerable expense in carrying on their researches, that they cannot always look to the universities, colleges, or learned societies for financial support, and therefore that it might be of public advantage to come to their help from the public purse. Accordingly, in November, 1849, Lord John Russell, then Prime Minister, sent a confidential communication on the subject to the president of the Royal Society (Earl of Rosse), who remitted to a committee to report how a financial grant, if made by Government, could best be employed.

After deliberate Governmental consideration for the space of nearly a year it was decided at the beginning of 1851 to make an annual grant of one thousand pounds to be administered by the Royal

Society, chiefly in aid of private individual scientific investigation. At the end of four years the Treasury declined to continue the grant of this sum (trifling as it was, compared with the revenue of the country), on the ground that the fund from which it was taken would no longer admit of "an annual grant to the Royal Society." The council replied with spirit that it was not a grant to the Royal Society, but "a contribution on the part of the nation towards the promotion of science generally in the United Kingdom," the council being only trustees for the due administration of the fund. The grant was then placed on the Parliamentary Estimates, and the 1000*l.* continued to be paid annually for nearly twenty years. In 1877 the vote was increased to 4000*l.*, but the council had still some difficulty in preventing the grant from being regarded as one to the Royal Society, which was in no way benefited by it, but, on the contrary, had an onerous and difficult task in looking after its proper administration. In 1894 application was made for an increase in the amount of the grant, but without success.

Meanwhile the German Government, looking keenly to the future and thoroughly impressed with the importance of stimulating the cultivation of science, was spending large sums to equip laboratories and otherwise further education in science, and to stimulate discovery and invention. The example of that country was often cited here, and contrasted with the unsympathetic attitude and stingy support of our authorities, much to the surprise and annoyance of the permanent officials of the Treasury, who rather seemed to think that their grants to science were remarkably liberal. I remember an occasion when I had to go to the Treasury about a matter connected with the Geological Survey. The official on whom I called was one of the heads of the Department, with whom I had long been on terms of friendly intimacy. He began the interview by saying that he would be glad to hear me, but begged that the example of Germany might not be mentioned.

Happily these times of indifference belong to the past. Twenty years ago an appeal was made to Government for the creation of a National Physical Laboratory for the purpose of standardising and verifying instruments, testing materials, and for the determination of physical constants. After some effort and with the persistent support of Lord Rayleigh, the appeal was eventually successful. The institution began on a modest scale with a staff of only twenty-six, no more than two departments, and a small grant annually voted by Parliament. But under the able supervision of Sir Richard Glazebrook it rapidly increased the scope of its work, the extent of its buildings, and the size of its staff, until the burden of responsibility for its administration was becoming too heavy for the Royal Society. In April of last year it was transferred to the newly established Department of Scientific and Industrial Research, the number of its departments of investigation having now grown to seven, and that of the staff to more than 600. In this enlarged sphere of public utility it will no doubt achieve still greater success, while at the same time research in all directions and its practical applications will be greatly quickened. The day of parsimony in regard to the prosecution of scientific inquiry and its applications is now gone beyond the power of any Government to revive.

Obviously it is not zeal for the advance of pure science that has led to the augmented general interest in research. The appreciation of the practical value of many discoveries in relation to the daily life of mankind has naturally been the main stimulus. The philosophers might have experimented until doomsday upon æther and its undulations without awaking more than a languid interest in their work, or receiving any pecuniary help in their expenses; but when they showed that by means of these undulations messages could be flashed across the ocean without any wires, the public imagination was at once excited, and millions of money were ready for investment in any company that would undertake to fit up the necessary apparatus for sending such messages. In like manner, there might have been but a feeble appreciation of the phenomena of radioactivity, but when it was shown that by means of Röntgen rays the surgeon could see the bones inside a human body and detect there the existence and exact place of any bullet or other dense substance, a wide interest in the discovery was awakened, and little difficulty was found in supplying every hospital with the requisite apparatus.

The War has brought the economic value of science before the world on a colossal scale of demonstration. While scientific inventions have enormously augmented the offensive powers of the belligerents, it is pleasing to know that the applications of science have not been all on the destructive side, but that at the same time the greatest stimulus in the history of mankind has been given to medicine and surgery, and that each of these great divisions of the healing art has made notable advances and gained fresh powers for dealing with diseases and wounds.

Exactly ten years had elapsed after the publication of Darwin's "Origin of Species" when the first number of NATURE was issued. The doctrine of Evolution had long been before the world. Laplace had introduced it into the history of the solar system; Lamarck, after Buffon, had proposed an ingenious ætiology in the history of organised life upon the earth; while towards the middle of last century came the cruder efforts of the author of the "Vestiges of the Natural History of Creation," which so perturbed the minds of his generation. But it was not until after the appearance of Darwin's book, and in consequence of that book, that Evolution came slowly to be regarded as the great law of the whole cosmos. If we consider broadly the relation of the community to scientific progress during the last fifty years, its most outstanding feature will probably be recognised in the general acceptance of this great generalisation.

The views of Darwin made their way with

more speed on the Continent than in his own country. Probably not many survivors are left to recall the astonishment and indignation with which some of the older geologists of the day read his two chapters "On the Imperfection of the Geological Record" and "On the Geological Succession of Organic Beings." To the younger men, on the other hand, these chapters were a luminous revelation. I shall never forget their influence on myself. They gave me a new key to unlock the history recorded in the rocky crust of the globe. They linked together Stratigraphy and Palæontology in the most masterly way, making each of them explanatory of the other, and confirming the doctrine of Evolution more clearly than ever.

The bearing of the "Origin of Species" on social questions was more promptly recognised abroad than at home. Thus, in the first number of NATURE, it was stated that when the Austrian Reichsrath, after the disastrous war with Prussia, assembled in December, 1866, to deliberate on the best means of re-consolidating the prostrate empire, a distinguished member of the Upper Chamber, Prof. Rokitansky, began a great speech with this sentence: "The question we have first to consider is, 'Is Charles Darwin right or no?'" Such phrases as "the struggle for existence" and "the survival of the fittest" have not only become household words, but they have been brought into the domain of social relations and of the physical improvement of mankind. Foremost among those who have insisted on the vital importance of these subjects to human society was Darwin's cousin, Sir Francis Galton, to whose writings and persistent advocacy the new study of Eugenics owes its existence.

In one important branch of research Britain has always taken a foremost place. Geographical exploration, where it can be undertaken by the Navy, has long been a favourite task with our Admiralty. The earlier expeditions were mainly intended for geographical discovery. Those of the last fifty years have been in increasing measure devoted to scientific observations in magnetism, meteorology, oceanography, and natural history. A new type of equipment has thus arisen, in which each vessel becomes a kind of floating workshop of laboratories, microscope rooms, photographic chambers, and all the other requirements of physical and biological science. It was the naturalists who asked for State assistance in the exploration of the ocean, its temperature, currents, depths, and living things. In 1868 they succeeded in obtaining from the Admiralty the services of the *Lightning*, and two years later of the *Porcupine*. These tentative missions brought to light so much fresh information and raised so many new problems that, in response to a loud appeal from the scientific world, the *Challenger* was prepared on a more complete and elaborated scale, fitted with every kind of appliance, and furnished with a company of skilled investigators, under the leading of a distinguished naturalist. For the first time in the history of exploration the globe was circumnavigated during four years (1872–76), not for the discovery of new lands, but for an investigation of the oceans from their surface waters to their utmost depths. Splendid in its conception and admirable in its achievement, this great expedition laid a solid foundation for the new department of science which has now been named Oceanography. And the fifty quarto volumes in which its labours and results are recorded form a noble monument of successful research.

Since that time the problems of the Antarctic regions have been attacked by several expeditions. The two brave adventures of Capt. Scott and his associates in 1901 and 1910, amply supported by the Admiralty, were meant not merely for the increase of geographical knowledge, but were fitted out with all the needful appliances for observations of the magnetism, meteorology, geology, and zoology of the area around the South Pole. They have added much to our knowledge of Nature in that region of the globe.

If, now, we cast our eyes towards the future, the prospect for British science is eminently encouraging. The opportunities for research and experiment were never before so ample, the co-operation of the State never so cordial, the ranks of the investigators never so full, and the joy and enthusiasm for investigation never more ardent. For years to come this prosperity ought to continue and increase. But unquestionably in the distance a cloud may be discerned, which has long been in sight, but is now much nearer. Our present great source of power is coal, but at a not very remote date our coal-fields will be exhausted. If before that time some other source is not discovered, our position as a great manufacturing country will be seriously affected. Hopes have been raised on the possibility of finding large supplies of mineral oil in our islands. It is well known that in one or two places oil has long been coming to the surface in small quantities. It is possible that these indications may point to larger supplies below. But we are still so ignorant of the distribution of the oil within the earth that no confident prognostications are warranted. Much misunderstanding still exists on this subject. There can be now no doubt that the oil found so abundantly in some regions has no connection with coal-fields or with any deposits of organic origin, but comes from a depth probably below all the stratified part of the terrestrial crust. The most probable explanation of its origin is that it results from the decomposition of carbides forming part of the original constitution of the globe. These carbides, or compounds of carbon with some metal, such as iron, are decomposable by water and then give rise to the production of hydrocarbons, such as mineral oil and marsh gas. If water descending from the surface through the upper crust should reach those deeper-seated compounds, this decomposition would take place, and the pressure of the generated gas might force the oil up the fissured crust to the surface. Only where it makes its appearance do we know for certain that there must be some oil below, but whether in quantity sufficient even to repay the cost of boring for it cannot be predicted.

But before our coal supplies are worked out, and whether or not we discover subterranean supplies of oil, we may surely hope that some of the sources of power which are now unused will be harnessed to the service of man. To the waterfalls, tides, and winds, which have long been considered, Sir Charles Parsons in 1904 suggested another possible source of power in the internal heat of the globe, and in his recent presidential address to the British Association he has returned to the subject. His proposal is to sink a bore-hole 12 miles deep, which would cost five million pounds and require about eighty-five years for its completion. With the use of a fresh source of power and an extended development of electricity, we should doubtless be able to hold our own in the competition of the nations.

It may be allowed to me to end this article on a more personal note. To the foresight, energy, and constant attention bestowed on NATURE by its founder, Sir Norman Lockyer, the world of science has been indebted during half a century for the possession of a journal which with persistent force has sustained the cause of science in this country, has been an invaluable medium for recording the progress of research and discovery, and has played a most useful part as a medium for the discussion of questions of general interest and for public intercommunication between the cultivators of science, to whom it has become indispensable. I contributed to its first number, and have often sent communications since then, and now I am proud to be asked to write a preface to this jubilee issue and to wish continued life and prosperity to my old and valued friend, the founder of the journal.

THE FOUNDATION OF BIOLOGICAL SCIENCES.

BY SIR E. RAY LANKESTER, K.C.B., F.R.S.

WHEN the first number of NATURE was published in November, 1869, the word "biology" had not the currency now given to it. The word had been adopted by Whewell, and was used by Treviranus and philosophical writers of the early half of last century. What is now called hypnotism was termed "electro-biology," but the extent of the great field of exploration signified by "biology" was little understood. The great event in the history of biological science occurred ten years before the appearance of the first issue of NATURE, namely, in 1859, when Darwin published his book "On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life."

The new conception of organic phenomena brought about by Darwin's work took deep root in the ten years from 1859 to 1869, and the main lines of study necessitated by it had been boldly laid by the pioneers, chief of whom were Huxley and Hooker. One main line of work set going, and ever since continued, was the production of further evidence of the kind brought forward by Darwin and Wallace. The period was one of intense activity and movement. The Darwinian theory spread in every direction, and new evidence in its favour was accumulated by naturalists, collectors, and explorers. By a remarkable coincidence, the year 1859 was marked not alone by the publication of the "Origin of Species," but—owing to the work of Joseph Prestwich and a small group of English geologists—it is definitely distinguished as the date when the occurrence of flint implements in the gravels of the Somme was recognised as proving (as had been maintained since 1847 by M. Boucher de Perthes and denied by the French *savants*) the existence of man as a contemporary of the mammoth and the woolly rhinoceros.

When this journal started its career we had already Darwin's additional volume on the "Variation of Animals and Plants under Domestication," which was followed in 1871 by the "Descent of Man." Practically the whole scientific world (and much of the thinking world outside it) had been convinced of the truth of the doctrine of organic evolution and also of the vast antiquity of man. The evolution of man from animal ancestry, with all its consequences as to the development of the human mind, became an inevitable inference.

Elementary Biology.

By the year 1869 the triumph of the Darwinian theory was assured. In that year Huxley began his course of lectures and laboratory work on elementary biology. The class numbered about a hundred, and Huxley's three assistants were (Sir) Michael Foster, Rutherford (then professor at King's College, London, afterwards professor at Edinburgh), and myself. This course of lectures to teachers, which was given also in the following year, largely emphasised the unity of animals and plants, and it aroused great enthusiasm. Each lecture by Huxley was followed by demonstrations by his assistants in the laboratory, which lasted all day. This became the model for the courses in biology in all English-speaking countries, and formed the basis of the examinations in the University of London.

Huxley by no means sought to put forward zoology at the expense of physiology and botany. In the new laboratories at South Kensington the first course of botany dealing with the vegetable kingdom as a whole, and not, as heretofore, merely with flowering plants, was given at Huxley's invitation by Thiselton-Dyer. It included the very complete study of lower as well as higher plants. This and the publication of the translation of Sach's "Text-book of Botany," in which Dyer was chiefly concerned, were the starting points of the rapid and remarkable development in botany in the English-speaking universities, which has continued very actively ever since. Profs. Vines and Marshall Ward and others who became leaders in botany were pupils of Dyer at that time.

About the same date, and as part of the same general movement, the development of "physiology" began, so far as this country is concerned. This name has been curiously, by sheer chance, assigned to a study which would more properly be called "organology." Originally physiology meant the study of Nature, but it has been whittled down until now it means essentially the activities of organisms. Burdon Sanderson, together with Michael Foster and Rutherford, were especially active in the introduction of the laboratory study of physiology in connection with physical measuring apparatus, such as the kymograph and other devices already in use in German and French universities. This has resulted during these fifty years in great progress in both the teaching and the understanding of physiology in every university in Great Britain and America.

In 1868 our greatest teacher of physiology in London—Prof. Sharpey, of University College—used to exhibit the mode of record by means of a kymograph by fitting a piece of paper round his tall hat and slowly rotating it on the lecture-table! There was no physiological laboratory in the place at that time.

Methods of Research.

Another great development connected with the new outburst of biology was the improvement both of the microscope itself and of methods of microscopical research. In 1870 all biological workers and teachers became convinced that the long tube and immensely complicated brass-work of English microscopes were superfluous, and that the smaller microscopes of the Continent were better suited to ordinary work. Moreover, the high powers made by Hartnack, of Paris, especially the No. 10 immersion, were found to be more suitable for work upon living and biological material generally than the equivalent powers of English makers. In Vienna in 1869 I worked with Stricker in his laboratory, and learnt from him the method of embedding in waxy materials for the purpose of section-cutting, of which he was the actual inventor. I also studied the methods which he had devised for the investigation of living protoplasm—the out-wandering of white corpuscles in inflammation, movements of the large connective tissue-cells of the cornea, etc.

In 1870, owing to the connection thus established, Dr. Emmanuel Klein came to London as assistant to Burdon Sanderson, and was afterwards, by his appointment at Bartholomew's Hospital, the chief teacher of Continental methods of staining, section-cutting, and refined histology, which at once took firm root in English schools of medicine. Previous to this it was not realised in England that it was easy to watch the movements of the white corpuscles of the blood and other living cells of the animal body.

Also previous to 1870 a few individuals, such as Lockhart Clark, had in this country used the method of carmine staining for the study of such tissues as the spinal cord. But the method of hardening in various fluids, passing the sections from absolute alcohol to chloroform and ultimately to Canada balsam or Damma varnish, and so rendering them transparent, was practically unknown. But since 1870 the methods of staining and section-cutting have enormously developed in this country. English workers are especially responsible for the development of the microtome and the methods of producing long ribbons of consecutive sections, which has had an immense effect on the study of the microscopic structure of all organisms.

Embryology.

Obviously, a line of research the importance of which was greatly accentuated by the Darwinian point of view was embryology. The discovery in 1866, by Kowalevsky, of the identity in the early stages of cell arrangement in embryos of the Ascidians and Amphioxus gave an enormous impulse to the study of embryology, and raised the hope that secrets of organic relationship in plants and animals might be revealed in other cases. Indeed, Kowalevsky's great discovery may be considered to rank in biology with that of his fellow-countryman Mendeléeff in chemistry. For he showed that the study of cell development could be carried further, and laid the foundation of cellular embryology, which culminated in what is called the ascertainment of "cell-lineage." That remarkably accurate pursuit had its inception in a paper by Whitman published in the *Quarterly Journal of Microscopical Science* in 1878, and has been largely continued by Conklin and others in America.

The actual study of embryology took a new departure in this country under the influence of Frank Balfour, who published papers on the development of the Elasmobranchs, and established the origin of the notochord and the cœlomic cavity in Vertebrates as identical with that shown in Amphioxus and Ascidians by Kowalevsky. My own part in this embryological work was chiefly in regard to the Mollusca, but general conceptions were, I think, facilitated by the introduction by me of the terms "archenteron," "blastopore" (orifice of invagination by which the two-cell-layered sac, called by Haeckel the gastrula, is formed), "stomodæum," and "proctodæum" (the in-pushing of the outer layer relating respectively to the mouth and anus). The German terms "Vorderdarm" and "Hinterdarm," referring merely to the anterior and posterior ends of the alimentary canal, were not identical with my terms, which apply only to portions of ectodermal origin. The doctrine that the cœlom throughout the animal kingdom is actually or implicitly an out-growth or a series of out-growths of the archenteron was maintained by me in opposition to the views of Haeckel and Gegenbaur and others, and was finally established by the observations of Sedgwick on Peripatus. It was further proved by me that the vascular system was an organic unit entirely independent of the cœlom, and my conception of "phlebœdesis" made an end of the German misinterpretations of the body-cavities of Arthropods and Molluscs. The abundant cumulative study of embryology during these years has led to most important conceptions with regard to the relationship of various animals—*e.g.* the origin of vertebrate limbs. Present conclusions are really based on inquiries into embryological beginnings, and the whole interpretation of morphology in its embryological aspect is still in progress.

The Cell.

The study of the structure of the cell itself, and of the processes of cell division, shortly after 1869 made a very great advance. Chromosomes and their importance, and the whole subject of mitosis, became a part of our fundamental knowledge. This very naturally, in view of the importance of heredity with regard to the whole theory of organic evolution, led to the minute study of the structural facts connected with the egg- and sperm-cells, as well as fertilisation and the earliest divisions of the fertilised egg-cell to form the embryo. This study, beginning about the commencement of the period under consideration, is still actively proceeding. Whilst it seems that in the chromosome we have got very much closer to an understanding of the actual visible features relating to the phenomena of heredity, yet there are important facts in course of discovery.

Oceanic Research.

Another line which also suddenly came into activity and has been a prominent feature since 1869 is deep-sea exploration, which began with the voyage of the *Challenger*. When the first number of NATURE was published, this was having its initiation under Dr. W. B. Carpenter and Prof. Wyville Thompson, who, led by the discoveries made by those who laid the first deep-sea cables, had conceived the notion of exploring great depths of the ocean by means of the dredge. They obtained the brief loan of a warship from the Government for the purpose of their explorations. This led to the three years' voyage of the specially fitted ship *Challenger* and its staff of scientific experts, and the publication afterwards of a magnificent series of reports. This example of the *Challenger* has been followed by every country, and valuable explorations of the ocean—oceanographical research as it is called—has become an established branch of scientific inquiry.

A complement of the pursuit of oceanography by means of ships and apparatus for deep-sea dredging has been the establishment of zoological laboratories in specially suitable localities on the seashore. The one organised on an international basis by Dr. Anton Dohrn was the first to become widely known and useful, although the French naturalists had some years before this founded marine laboratories—Coste at Concarneau and Lacaze-Duthiers at Roscoff. Now they are established everywhere.

Palaeontology.

Beginning with our starting point, and more especially connected with the founders of the Darwinian theory, there has been an immensely important and productive activity in palæontology. A large part of Huxley's scientific work consists of the thirty or more valuable memoirs on the remains of extinct fishes and reptiles published by him as naturalist of the Geological Survey. By his palæontological studies he was led to views as to the genealogical history and connection of the birds and reptiles, and also as to the special development of certain mammalian forms, such as the horse. Also at this period there developed in America an enormous activity in palæontological discovery. Up to 1869 we knew some few of the extinct animals of America through the work of Leidy. Marsh and Cope then burst upon the scene with most astonishing and valuable accounts of extinct dinosaurs, birds, and mammals. These have been followed ever since by a stream of important discoveries in which Henry Fairfield Osborn is now the leader. The stimulus of this work for the Darwinian theory and its vast importance in relation to that theory are obvious.

Pathology.

A study which has greatly developed, and has had an effect on Darwinism and been reacted upon in turn by Darwinism, is that of the whole field of pathology. Before 1869 the germ theory and the importance of bacteria in disease had begun through Pasteur's work to be appreciated. Since then knowledge has accumulated, and the work of Lister has fundamentally altered views as to the effective nature of asepsis in the treatment of wounds. The outcome of this is an immensely increased study and knowledge of bacteria and other parasitic organisms, and also of the means of resistance to their attack.

Special importance attaches to the recognition by Metchnikoff of the function of the colourless corpuscles as scavengers in the blood and tissues—his doctrine of phagocytosis and the *rôle* of phagocytes in immunity. Perhaps most strikingly significant is his explanation of inflammation, which is now seen in the light of the Darwinian theory to be a life-preserving property of the higher organisms in which, by local arrest or slackening of the circulation, the access of phagocytes to injured and diseased tissues is facilitated.

General Retrospect.

All these developments will be found recorded in successive volumes of NATURE, in reviews of books, correspondence, and articles. In this way greater perfection of record and comprehensiveness of treatment have been attained than in any other scientific journal.

Whilst all these studies were going on, the more direct observations by the Darwinian method have been accumulating enormously. Classification and general views on morphology have been affected accordingly. Various serious attempts have been made to improve upon or to add to Darwinian theory, perhaps to its detriment. One example of this is Romanes's notion of physiological selection. Another is the attention given to the experiments and conclusions as to hybrid breeding of the Abbé Mendel. Mendel's conclusions differ but little from those contained in Darwin's own work, as was pointed out in a letter to NATURE for August 14 last, p. 463. No doubt the breeding experiments which are now carried out in the name of Mendel might equally well be performed in the name of Darwin. The importance of this work was little assisted by those interested in Mendelism, when in the early days they called it a "new science."

Within the limits of a short survey it is impossible to measure the heights of more than a few peaks of biological science, or to describe the boundaries of even a few fields of work. Others will deal with particular branches of biology, including psychology, which will be developed in the near future as the basis of anthropology, and should be to education what physiology is to medicine. Physiology itself has yet to come under the full influence of the Darwinian doctrine—"the preservation of favoured races in the struggle for life." As yet there has been no investigation of the *development* and survival of functions. It is necessary to study their evolution from simpler types and to analyse by experiment the progressive series of chemical activities involved in digestion, secretion, excretion, and so on. At present physiology is as incomplete as morphology would be if no forms below terrestrial vertebrates had been studied.

In concluding this sketch I desire to bear testimony to the valuable services in the promotion of scientific progress which NATURE has rendered throughout its existence. In the hundred and three volumes which have been published since 1869 the names of all the most active workers in the realm of natural knowledge will be found in their pages, not only in papers and books recorded and epitomised, but also as the authors of articles, letters, and other contributions. Every man of science knows the useful function performed by NATURE, and appreciates its essential importance to the vitality of the scientific organism. I am particularly glad that my friend, Sir Norman Lockyer, has lived to see the completion of the fiftieth year of the journal established by him. The high and secure position which NATURE occupies is due to the sympathetic, impartial, and honourable editorial traditions gained for it by him and still maintained. As a personal friend I cherish the recollection of association with the founder of the journal throughout the long period of its existence, and with all other scientific workers I tender him grateful congratulations for what he has done through it to stimulate the increase and application of knowledge.

SCIENCE AND THE CHURCH.

BY THE VEN. JAMES M. WILSON, D.D., CANON AND VICE-DEAN OF WORCESTER.

THE Editor of NATURE reminds me that in its first year of publication I was one of its contributors, and he asks me to write something for its jubilee issue. He goes on, further, to assign me a subject—"The General Attitude of the Church and the Religious Laity towards Science now compared with what it was fifty years ago"—and he limits me to "about a thousand words." It is a sufficiently large subject for, say, ten or twenty thousand, and yet I am going to double that subject by adding the words "and that of the scientific world towards the Church." I think there has been an equal change in both, and I take the latter half first.

About fifty years ago I was more at home in the scientific than in the clerical world. I was a fair mathematician; an enthusiastic, though ill-equipped, teacher of science; an observer in astronomy; on the council of the Royal Astronomical Society; and associated with Huxley and Tyndall in a small British Association Committee on teaching science in schools. They were among my friends. I had also many friends among the rank and file of men of science. Such are my credentials to speak of the attitude at that time of men of the scientific world to the Church.

That world, impressed and dazzled as it was by the vast extension of the sphere of the natural—that is, of what was sure to recur in like physical circumstances—felt, speaking generally, that "the Church," which insisted on the supernatural, was *ipso facto* an upholder of error and superstition, an enemy to truth. They were out to sweep the Christian faith away. It might hold out, they thought, for a few decades in obscure circles, but its time had come. They were as cocksure and contemptuous of believers in the supernatural as were the Germans of the English in 1914. I am speaking generally, and chiefly of the smaller fry and hangers-on. But some of the leaders occasionally showed the same tone.

The attitude of men like Huxley, Adams, Stokes, H. J. S. Smith, Asa Gray, Salmon, Maxwell, and others was very different. They never wavered in their sense of the duty of setting truth first, and of the value of knowledge. They saw and welcomed the setting far back the traditional boundary between the natural and the supernatural. But they stopped there. They felt the presence of the unknown, and humbly suspended their judgment, conscious of limitations. Tyndall and his admiring school seemed to feel no such limitations. I remember talking with him at his house on the Bel Alp one glorious evening. He gave some two or three of us a brilliant monologue on his doorstep. But that universe of stars and snow-peaks was to him a magnificent field of exercise of atomic forces. Further knowledge, he doubted not, would establish the fact that we also, with our mental faculties, were only items in the same field, products of the same forces.

Such was the impression given of their beliefs by the dominant and aggressive school of men of science of that time—that freedom in spiritual life, and therefore responsibility, were illusions, though goodness was no illusion.

Insensibly a change has occurred which is not easy to define. Perhaps it may be described broadly as the discovery by that scientific world that the sphere of religion is not inherently anti-rational; that faith, like knowledge, rests ultimately on experience; that science has its sphere in the world of matter leading up to forces of unknown origin and nature; and that faith has its sphere in a world of personality leading up to a similarly unknown goal of personality: that their methods are not inconsistent; and that their goals may be identical.

There is a pregnant saying of Augustin: "Interrogate thyself, O man, and make of thyself a step to the things which are above thee." Science has of late begun to do this. Previously it had turned its face to things which are below us. Faith has ever turned its eyes to that which is above us, dim though it is, proofs of the existence of which it finds in its own mental and spiritual faculties—in the sphere of the good, the beautiful, and the true. Through that experience faith is led up to the conviction of a Personal origin of Nature, with whom it is possible for us to be in some communion.

Miss Jane E. Harrison, in her recent "Conway Memorial Lecture on Rationalism and Religious Reaction" (Watts and Co.), has laid us all under a debt by her characteristic frankness on this subject. "If you will pardon," she says, "a personal reminiscence, I should like to acknowledge my debt as a rationalist to a reviewer. Mr. Clutton-Brock, in reviewing a review of mine—I do not think he has read my book—noted, truly enough, that I always implied that religion was obsolete, and only to be examined as a curious survival of man's past. 'And,' he ended, 'it is hardly scientific to lecture on the corpse of religion when all the while religion is alive and laughing at you'! It is a staggering experience to learn anything from a reviewer. That sentence made me reel for a moment. When I recovered I determined that religion anyhow should not go on laughing at me any longer. So I turned to the study of modern developments, and I confess the result has in some ways surprised me."

This is an illuminating statement.

There has been also, during the last fifty years, a corresponding change in the attitude of religious faith towards science. The following points strike me as the most obvious.

First, the clergy and the educated laity have lost their fear that the predictions of the science of fifty years ago would be verified, and that we should find ourselves in a world of determinism and materialism.

Secondly, the younger generation of both clergy and laity take it as a matter of course that science has helped faith to extricate itself from many crude mythological forms in which its exponents in pre-scientific days expressed their beliefs. Science has shattered some of our idols, and we are grateful, and shall be more grateful as the years pass.

Thirdly, all Christians value highly the enormous extension of knowledge of the works of God due to scientific labour and genius. Moreover, not a few would like to say emphatically that the disinterested search after truth, which is the very soul of science, is in itself a worship of the God of truth. It is faith. It is a religion. It is a consecration.

Lastly, the ordered reason and method which have won such conquests in the physical world, and revealed fresh sources of power, have helped religious thinkers to see an inexhaustible source of spiritual power in that conception of the divine indwelling life which leads, not to the quietism and the static passivity of Pantheism, or to a selfish individualism, but to ever-hopeful and ever-fruitful activities for the common good of men.

May we not in conclusion say that the human and spiritual energies which in the past have created religion and science have now begun to see that they can work as independent allies, urged by a common motive, which one of the two would describe as the elevation of humanity in the scale of being, and the other would call seeking the kingdom of God?

THE EXPANSION OF GEOLOGY.

By Prof. T. G. Bonney, F.R.S.

In the fifty years since this journal began, the progress in geology has kept pace with that of the other natural sciences. In regard to them, in an article contributed to the first volume, I wrote of what had been done and what yet required to be done for their study in Cambridge, where I was then resident, and whither I have since returned. The changes may almost be called a transformation. The museums and laboratories, though the supply is not yet quite equal to the demand, far surpass what we desired in those early days, and the class-list of the Natural Sciences Tripos, instead of containing about a dozen names, had risen before the war to fully 130. The same is true of the other older universities, while more than as many, non-existent fifty years ago, are now busily engaged in educating natural science students.

But to refer to geology only. In 1869 even the geography of considerable regions on the earth's surface was unknown. There were large areas in Africa, away from the coasts, where only here and there had a traveller passed. Hundreds of square miles about the North and South Poles were blanks upon the maps. With the exception of Western Europe, North America east of the Rocky Mountains, some portions of Asia, and a little of Australia, geological knowledge was very limited. Now careful surveys have been made far beyond the original boundaries, and it is not too much to say that a general idea has been obtained of the geology of the earth as a whole, for, in addition to exploration of its surface, deep-sea sounding has revealed the nature of the deposits now forming on the ocean floor.

The advances in stratigraphical knowledge have told on every branch of geology, but especially on palæontology. Much valuable work had no doubt been done by 1869 on the Corals, the Echinoderms, the Crustaceans, the Brachiopods, the Molluscs, and the Vertebrates, but great discoveries have been made, particularly in regard to the last. The work on them, begun by Cuvier and carried on by Owen, has now been extended to most parts of the globe. Even so near as Belgium, the buried ravines of Bernissart have yielded up whole skeletons of the Iguanodon; the more central parts of North America show that, when the Rocky Mountains had partly begun to rise, reptiles, stranger in form and vaster in bulk than the founders of palæontology had imagined, haunted their swamps, and lakes, and rivers. Cope and Marsh, fifty years ago, were only beginning their work. Such giant reptiles as Brontosaurus; Atlantosaurus; Diplodocus, with its inordinately long neck and tail; Stegosaurus, with its strangely serrate back; and Triceratops, with its horned and armoured head, have all been reconstructed. Some century and a half ago a forerunner of the sea-serpent had been discovered at Maestricht, but the list of Mosasauroid reptiles has been much augmented from the inhabitants of the inland seas of late Cretaceous age near the Rocky Mountains of the present day. Dentigerous birds, and the Archæopteryx, half-bird, half-reptile, have been discovered, and some of the earliest Tertiary mammals, again more especially in Central North America, are no less weird in shape than the above-mentioned reptiles.

Since the publication of the "Origin of Species," which antedated that of NATURE by ten years, scientific palæontology may almost be said to have been born. Missing links in the chain of living creatures have been found, gaps in knowledge have been filled in, difficulties which raised opposition from not a few good naturalists have been removed; evolution has passed from the stage of hypothesis to that of theory, and extended from natural history to other branches of science and into yet wider fields. The pedigree of not a few forms of life has been constructed, so that "zoning" by fossils has greatly aided the stratigrapher, and the zoologist finds it possible in many cases to retrace the steps of that pedigree until, in this tree of life, the twigs are followed down into the branches, and the branches to the primary stems, though, notwithstanding recent discoveries in regard to the fauna of early Cambrian times, not a few pages have disappeared from the history of life, especially in its opening chapter. Discovery is now proceeding with quickened pace in the history of plant life, so that when NATURE celebrates its centenary the zoology and botany of the world will undoubtedly be understood far more completely than they are at the present day.

In 1869 petrology was at a low ebb. Macculloch and De la Beche had done what was possible without the microscope, but the great majority of field-workers remained well contented if they could recognise the commoner igneous rocks and vaguely identify the metamorphic. Clifton Sorby, by applying the microscope to petrological study, had pointed out, nearly twenty years before 1869, the way to success, but had attracted very few followers, so that even our official surveyors did more to retard than to advance this branch of geology, while in regard to metamorphism the wildest ideas were not seldom proclaimed. Light gradually dawned, misconception after misconception was dispelled, until in 1883 Prof. Lapworth made the great forward step in this branch of the subject by discovering the "Secret of the Highlands." Petrology now claims dozens of students, busily engaged in clearing up the difficulties and solving the puzzles of this or that region, and the study of rocks has become as truly scientific as that of palæontology.

The value of geology for economic purposes has been increasingly recognised during the last fifty years, though for no small part of that time the so-called "practical man" was accustomed to make light of it. By the middle of last century the importance of some knowledge of stratigraphy was beginning to be generally realised in regard to coal-mining; yet cases sometimes occurred such as making boreholes in search of that material in hopeless places, or carrying a shaft down into the Wenlock Limestone in the hope of striking a valuable seam, which, as the result of an unconformity, had never been deposited. Much information, however, has been obtained about underground stratigraphy by some of these borings for minerals or for water, even when they proved fruitless in themselves. Shafts also for coal and for metals have been carried to much greater depths than formerly, one or two even going down to as much as 5000 ft. below the surface. But the late war repeatedly proved the practical value of a good knowledge of geology, in the cutting of deep trenches, in driving tunnels, mines, and counter-mines, and in constructing underground shell-proof shelters, so that we may now reasonably hope that our military and political authorities will recognise the importance of geology as a subject of education.

This increase of knowledge is not without its attendant drawbacks. The microscopic study of rocks and minerals, the minute observance of the variations in closely allied species, the distinction of geological areas, tend to foster specialism. In the present age the emergence of men like Darwin, Hooker, and Huxley, men with far-reaching views and wide outlook, who make great forward steps, has become increasingly difficult, while the literature of all the subjects, though it aids, also lays a heavy burden on the student. Much time has often to be spent in searching through many volumes, for fear of overlooking some fact which may have an important bearing on a special investigation; in short, there is sometimes a great danger in being unable to "see the wood for the trees." But we may hope that these obstacles will in due time be overcome, and details be regarded in their right relation to principles.

THE NEW BIRTH OF MEDICINE.[1]

By SIR T. CLIFFORD ALLBUTT, K.C.B., F.R.S.

WITHIN the period of fifty years during which NATURE has been published, medicine has undergone a revolution. It has become enlarged from an art of observation and empiricism to an applied science founded upon research; from a craft of tradition and sagacity to an applied science of analysis and law; from a descriptive code of surface phenomena to the discovery of deeper affinities; from a set of rules and axioms of quality to measurements of quantity. When I turn back to the medical text-books of my pupilage, to the wise and scholarly Watson or the respectable Alison, and contrast them with the text-books of to-day, I marvel that a change so vast, so profound, so revolutionary, should have come about in one lifetime! Many a generation had to pass before Harvey's researches established animal mechanics; many again before the half-lights on animal heat of Willis, Mayow, and Boyle were brought to quantitative verifications.

In medicine, observation cannot carry very far —not so far, let us say, as in astronomy; while skill and sagacity, if they do not die with the individual, keep in the axioms and exercises of the school but a transitory life. No observation of a thunderstorm could unravel its affinities to the action of a loadstone on a scrap of iron; no observation on diet could reveal the relation of food protein, by way of the amino-acids, to the tissues; no observation bestowed on scurvy or beri-beri could detect the occult and elusive but all-potent influence of the vitamines; no observation of secretory and muscular action could reveal the play of surface-tension in muscular contraction, or its relations to lactic acid and oxygen. By what sagacity could the shrewdest observer, let us say of heart disease, perceive the likeness of the formations of a soap bubble, or a raindrop, to the contraction of a muscle-fibre in terms of its length; or that muscular contraction is not so much a chemical as a physical system with a negative temperature coefficient? Again, the relation of sexual hormones to the development of men and women, and to the phases of their respective organs of reproduction, is an issue of the academic laboratory. The prodigious harvest medicine has reaped in the recent operations of war was derived from the original researches of a chemist into the occult causes and laws of fermentation by microbes, and from a field apparently so alien as of the silkworm disease.

One of the main lessons of our history has been that, in neglect of research into truths below the surface, medicine, for lack of a deeper anchorage, has always sunk back into empiricism and routine.

Research is the salt of the most practical training; it cannot begin too soon; it is the light of the wisdom of the man, of the mind of the boy, of the heart of the child. Education has lingered on Hellenistic and scholastic ways, on the systems of abstract notions unvexed by verification, so long that the hard-shell practical man is still occupied by the notions of antiquated theory and the phrases of a dead or moribund nosology. The

[1] Abstracted from an address by the author to the Scientific Meeting of the British Medical Association in April, 1919.

majority of medical men have to work upon the store of scientific ideas and facts with which they set out in practice; onwards they may gain in adaptiveness and technical facility, but can dig little deeper into the strata of knowledge; but for the modern academic spirit this would spell, as in our history it has spelled, stagnation.

Physics and Medicine.

Let us glance, however hastily, towards some of the fields in which new knowledge has been gained. In the venerable study of anatomy in its static aspects the student has long been taught the value of precision; but the recent tide of anatomical study towards its dynamic aspects, as by the work of Sherrington and Head, is bringing in new currents, not of theory only, but also of practice. Of other casements opening upon new visions of medicine that from the chambers of physics is perhaps the most arresting, at any rate at present. How fascinating, in their application to pathology, are the principles of osmosis with its curious reversals, of surface action and adsorption, of electrolytic differentials and electric methods of taking quantitative measurements, of mechanical pressures in the circulation of body fluids and, in the heart, as measured and graphically delineated by Hales, Ludwig, Gaskell, and Mackenzie, of the behaviour of fluid veins, and of the relative diameters, normal or variable, of the cardiac chambers and their main outlets. I need not do more than allude to the recent work on the CO_2 tension in the pulmonary alveoli, and to its immediately practical bearing on so-called acidosis, on the treatment of persons gassed in military or civil operations, and so forth.

By physics again we are shown, especially in plants, how in life the less complex molecules, working not only in planes below those in which the higher functions are developed, but also upwards by pacific penetration, moderate where they do not command. How instantly such researches as these must govern the practice of medicine we perceive, for example, in the gum-saline treatment of surgical shock. It would seem indeed that some of the most mysterious phases of immunity and anaphylaxis, of phagocytosis, as also of narcotism, may depend, at any rate in great part, on surface action; and that the behaviour of lipoids released from disintegrating proteins may lower surface energy, as in the retention of water in renal dropsy; or again in a different field may determine the touch or the permeability of synaptic neurons. These, and such physical laws, as they are revealed to us, teach that the multiplication and co-ordination of surfaces, let alone their chemistry, are operations which do not arise in mere mixtures of the same ingredients. So far it seems as if all biological reactions were determined by physico-chemical laws—that is, by molecular structure. The laws of selective absorption, as revealed in incandescent vapours, might throw some light upon those of biology; for in both fields we have to study vibration of molecular systems in unison, harmony, or discord.

When we rise from physics into systems of biological activity two conceptions especially strike us as new and marvellous; namely, those of the colloids and the cell. But throughout these systems we shall find the physical phases, if no longer constructively dominant, yet still active and effectual. We cannot even guess at the links of these chains where physics recedes and biochemistry takes the lead. The mere size of the molecules now concerned alters their relation to the spaces in or about which they move; not only so, but in organic compounds a mere change of position of a radical profoundly alters the properties of the compound and leads to manifold changes of function.

Often, moreover, these changes, as in the cases of immunity and susceptibility, do not vary gradually, but by leaps and bounds, as flames respond to musical scales of vibration. Thus great diversities, contrasts, and strange conjunctions of morbid phenomena do not necessarily signify great divergence of nature in the morbific agents; so that again we cannot get very far by grouping phenomena by direct observation. Processes outwardly disparate may be alike at the core. A small and latent change of chemical constitution may turn a benignant into a virulent substance, and conversely; as we may see in such substances as cacodylic acid and the cyanides, or as saliva, serpent's poison, and trypsin; and so forth. On a small deviation in a secretion we may be destroyed by those of our own household.

How far are hormones a particular category, how far universals? Do they differ in nature from other secretions, enzymes, antisubstances, and so on? Do they by their interactions, compensations, and inhibitions cover the ground of concerted chemical action in kind, as the nervous system does in time; or are they few and peculiar to certain limited needs? Whether inhibitory or stimulatory may often depend rather upon the term of the series to which the hormone is applied than to a difference in quality. Merely to glance at such questions as these reveals to us how vast is the realm of knowledge yet unconquered, nay undiscovered—

. . . mazes intricate,
Eccentric, intervolved, yet regular
Then most when most irregular they seem.

A very interesting transition from physics to chemical biology is found in the phenomena of catalysis. By some elusive property certain inorganic substances—spongy platinum, for example, or manganese dioxide—themselves unaltered, exercise an accelerating influence upon chemical change; properties which are utilised to-day on an enormous scale in industrial processes. Now by our increasing knowledge of biochemistry we perceive that the function of which the inorganic catalyst is a simple case is manifested also in more complex orders by certain enzymes, or colloidal catalysts, upon which depends in great part the sweep of our health and of our diseases. In these enzymes which accelerate metabolism we may admire again, as in the simpler catalysts, the exquisite economy of energy in vital processes; how small the energy transactions may be, and these often reversible, which may compass great ends. A striking example of such economy is now being demonstrated to us in the calculated balances of voluntary muscular activity. The minute quantities of vitamine suggest that they, too, are catalysts, and function without much waste.

Diet and Nutrition.

During the last half-century the subject of dietetics has been strictly analysed on quantitative lines, and its energies calculated in caloric and other units. Yet even herein our attainment is far from complete. About this well-worn, almost hackneyed subject a breeze of new and far-reaching ideas is gathering. Our balances, as in the children's milk, and in the analysis of the diseases of deficiency, are eluded by imponderables, by the infinitely little; our quantities are set at naught. For health and disease the new vitamines to which I have alluded, like some other hormonic and enzymic imponderables, are as potent as they are intangible. Hormones work in infinitesimal ranks; and I believe no antibody has as yet been isolated. Once more we find that Nature laughs at our formal categories, at our several compartments of protein as such, of carbohydrates as such; a straitlaced reckoning. No one class of foods, it appears, will build or burn without another; carbohydrate metabolism leans on that of protein, the protein on carbohydrates, and all these on the fats, in mutual function; each of these is engaged in the totality of the chemical changes. For instance, deficient carbohydrate means deficient oxygenation of fats, and imperfect protein distribution.

Nor is this all; some of our great ancestors, likewise having penetrating ideas of the infinitely little, supposed that the sources of nutrition must contain a supply to each and every living tissue of its own form of minute identical elements; be they of bone, of muscle, of blood, of "nerve," and so forth, each being proper to its particular tissue, to which it attaches itself (Homœomerism). This crude notion, it is true, made no great way; still until lately we have all of us supposed some, if a more general, congruity of form between the nutritive elements and the qualities of their various destinations. But the study of the reduction of foods to amino-acids, and issues of like researches, are telling us to-day that there is no necessity even for the food proteins to be of similar constitution to the tissues which they subserve. To the almost magical part played by certain elements, such as calcium, as stabilisers, or of the alkali-metals as labilisers of equilibrium I need but allude. The bearings of these dietetic researches upon practice, for example in the treatment of diabetes, are too obvious for reiteration.

If we turn now to the cell, as described to us by Virchow, we realise that our knowledge of this tiny microcosm is as yet only beginning. The infinity of extension is not strange to us, for some of it we can see; but the infinity of the universe of the little, which far escapes even our microscopes, does not so strike the imagination. Still, even of this inward universe and its intense activities, as by present research they emerge into the field of the mathematical physicist, of the spectroscopist, of the radiologist, of the physical chemist, we are beginning to conceive something. The microcosm is no longer Man, but the cell of which he is built. To our wonder we see that, even within such tiny spheres, some of them filtrable, are multiple systems moving in relative independence of each other. The cell membrane is formed chiefly perhaps by the physical processes we have considered. Yet puzzling and intricate as these reactions are, they are all-important to the physician; as, for instance, in the relations of the glomerular epithelium to sugars; its unerring discrimination between substances, even isomeric, in the blood, as between glucose and lactose; or again in the constant and subtle opposition of the normal intestinal epithelium to the entrance of poisonous elements, or foreign proteins, into the vessels and tissues.

For the Future?

This rapid glance over a small part of the field of the medical sciences may serve to reinforce the lesson of their profound and instant bearing upon practice, and the need for linking up the laboratory with the wards. Only by disinterested research on the large patient and prophetic lines of the pure sciences can progress be made. The isolated academic worker, as well as the practitioner, loses by this isolation; he loses the spontaneous outcrops of problems and crucial instances which so often spring up in practice, but fail to show themselves in the laboratory. So complete and mischievous, however, has been the barrier between research and the industry of medicine that a reaction from "laboratorism" to symptomatology has set in, because there are no intermediary workers—no engineers—between the knowledge getters and the knowledge dealers. Thus we have laboratory investigators completely out of touch with practice, and practitioners faithless of theoretical principles—just "Philistines."

As the engineer is something of a mathematician, something of a physicist, so the professor of medicine must be something of a physicist, something of a biochemist. Through these middlemen the man of science and the practitioner should mutually feed each other. In every adequate clinical school, then, there must be a *professoriate*; whole time—or nearly whole time—professors, each with his technical laboratory, biochemical and pathological, who with their assistant staffs shall be engaged continually in irrigating our profession from the springs of the pure sciences.

DEVELOPMENTS OF PHYSIOLOGY.

By Sir Edward Sharpey Schafer, F.R.S.

MOST of the fundamental facts of physiology had been discovered before 1869, but nearly all the progress in the nineteenth century up to that time was made in France and Germany; and those who wished to learn the subject properly had perforce to seek instruction abroad—a condition of affairs which is fortunately in great measure now reversed. During the sixties of last century physiology had ceased to exist as an active science in this country. There were no laboratories, and no systematic investigations of a physiological character were carried on. The men who professed the subject in our medical schools were physicians or surgeons who were switched on to it as it came to their turn, and imparted to their hearers such knowledge as they might have acquired from books, but were themselves ignorant of the methods and aims of the science they were appointed to teach.

There was, however, one notable exception in William Sharpey, who was called from Edinburgh to fill the newly-constituted chair of general anatomy and physiology in University College, London, in 1836, and retained it until 1874. Sharpey, although a great teacher, was not really a physiologist. His training was wholly that of an anatomist, and his teaching was largely anatomical. Of the physiology he taught very little was acquired as the result of personal investigations, and his knowledge of the methods employed in modern physiology was nil. But he had clear ideas regarding the principles of the science, and an extraordinary facility for imparting his ideas and for interesting his hearers in them, so that when the opportunity came for learning the methods they were in an advantageous position to pursue the subject.

It was a pupil of Sharpey—Michael Foster—who founded the famous school of physiology at Cambridge, and it was through Sharpey's influence that Burdon Sanderson was induced to give up the practice of medicine in order to install the practical teaching of physiology in London. These were the pioneers, and their influence gradually spread, so that before very long England succeeded in again taking a foremost place in a science which may be said to have had its birth in our country, for before the immortal discovery of Harvey no true physiology was possible.

The development of the science during the last fifty years has occurred partly along the old lines, which have been thrust forward far in advance of the position they occupied half a century ago, partly on new lines which were at that time not only untraced, but even unthought of. The immense progress on the old lines of investigation is evident whatever be the branch of the science to which we may turn our attention. This progress is actively correlated with the parallel development of the sciences upon which physiology is based—physics and chemistry. More than all, perhaps, has physical chemistry—a branch of science which, if already born fifty years ago, had at any rate not been baptised—enabled the physiologist to see—if still very dimly—into the processes which make up life itself further than could ever have been dreamed of in those distant days.

To give an account of the progress which has been made on the old lines of investigation would occupy a large volume; the shortest description would take many pages. Fifty years ago nothing was known of the constitution of the proteins or of the manner in which they are built up into the tissues. The mode of action of the heart and the factors which regulate circulation and respiration were still obscure. The localisation of functions in the brain had not been discovered. The important changes which cells undergo in the performance of their functions and in multiplication were unknown. The relation of the sympathetic to the rest of the nervous system was in no way understood. But perhaps the most striking fact which has come out as the result of modern investigation is the dominant action of the central nervous system upon all physiological processes. Not that this is entirely new; it was undoubtedly indicated before the period with which we are dealing. But the paths and manner of its action have been so thoroughly studied, and the accumulation of evidence regarding it has become so great, that one may fairly look upon this as the most important development of physiology along the lines it was pursuing some fifty years since. That this advance has been assisted by the remarkable conception of the structure of the nervous system, which we owe in the first instance to an anatomist—Golgi—is willingly conceded, for it must be admitted that our understanding of the mode of action of the nervous system has become vastly simplified thereby.

The new lines on which the science has undergone development within the period with which we are dealing relate to the influence of chemical agencies in regulating the functions of the body. New lines, do I say? Nothing under the sun is ever entirely new. From the earliest times with which history deals, and doubtless even in prehistoric days, it was known that the functions of the body are affected by chemical agencies. For have not drugs, many of them of a potent, not to say poisonous, nature, been administered from time immemorial? Was it not known that the chemical condition of the circulating fluid influences the functions of some organs; that an excess of CO_2 in the blood affects respiration, an excess of sugar the kidneys; whilst any alteration in its constitution or reaction is liable to have a deleterious action on the body, and may produce fatal effects? For all that, fifty years ago no one suspected that the body itself produces drugs destined to influence its own functions, that certain organs pass chemical substances (chemical messengers, as they have appropriately been termed) into the blood to affect distant parts, and that many functions of the organism are regulated by these chemical agents and self-formed drugs, sometimes in conjunction with the nervous system, sometimes to the exclusion of its action.

The discovery of these internally formed drugs has led to the development of a new branch of physiology to which the term "endocrinology," or physiology of the internally secreting glands, has been applied. Fifty years ago the pituitary body, the thyroid gland, and the suprarenal capsules were mere names. Little was known of their structure, nothing of their functions. The account which we are now able to give of these organs reads like a fairy-tale. That one of the smallest should by its secretion be able to influence the growth and stature of the body, rendering this man a giant, that man a dwarf; that another should produce a material without which the nervous system is not in a condition to perform its functions; that yet others should elaborate materials which when discharged into the blood exercise a profound influence upon the activity of totally distinct and distant organs of the body, are secrets of Nature which were unrevealed fifty years ago, although now amongst the commonplaces of physiological instruction.

The individuals who have been responsible for these advances—whether on the old or on the new lines—are too numerous even to be mentioned here; those who most deserve such mention would indeed be the last to desire it. But History will carve their names on the monument they have joined in erecting, and Science, no less mindful of her votaries than Religion of hers, will not fail to reward their services with the grateful encomium: Εὖ, δοῦλε ἀγαθὲ καὶ πιστὲ.

THE MODERN SCIENCE OF PSYCHOLOGY.

THE progress made by psychology since 1869 may be justly described as unparalleled. In that year the subject had no laboratories, and it was regarded as a matter of philosophical study. To-day a psychological laboratory exists in nearly every important university, and psychology has become recognised as the youngest recruit to the natural sciences—the natural science of mental processes.

The modern science of psychology, while admitting the great value of the older purely introspective psychology of the philosophers (represented in this country by the writings of Ward and Stout), realises its dangers and its inadequacy, and seeks to remove it from all metaphysical implications and to study mental processes under known variable conditions. From experimental psychology, thus established, have arisen the sub-sciences of (i) physiological psychology, in which the relation of mental to nervous processes is investigated, (ii) animal psychology, which studies the relation of animal to human mentality and behaviour, and (iii) individual and racial psychology, which determines the mental differences between different individuals and races of mankind.

There have also developed various "applied" psychological sub-sciences—*e.g.* (iv) educational psychology, the results of research in which are now taught to teachers in their period of training; (v) social psychology, which includes the psychology of religion and other social institutions and characteristics; (vi) abnormal psychology, which forms a subject of examination for the post-graduate diploma in psychological medicine now established in the Universities of Cambridge, Edinburgh, Manchester, and elsewhere; (vii) industrial psychology, which is concerned in discovering the best conditions for the highest mental efficiency of the workers, in connection with which applications for the services of psychologically trained investigators are now coming from pioneer industrial and commercial firms; (viii) the psychology of æsthetics, in which laboratory investigations of importance for art have been published in this country and elsewhere. Particularly in America, but also in Germany, many special journals have arisen devoted respectively to the psychology of education, abnormal psychology, individual psychology, animal psychology, industrial psychology, the psychology of evidence, etc. In this country we have the British Psychological Society, consisting of about 500 members, and publishing the *British Journal of Psychology*.

Fechner, who worked at Göttingen, and Wundt, of Leipzig, who in the 'seventies established the first psychological laboratory, may be reckoned the fathers of experimental psychology. Fechner was the first to formulate the psychophysical methods, a thorough grounding in which is indispensable for the avoidance of the many pitfalls of psychological experiment. To Wundt or to his pupils (especially Külpe) flocked students from other parts of Europe, and notably from America, who sought to be trained in the principles of the science. But in Italy, Austria, and Russia experimental psychology has attracted few workers. In Switzerland it has followed the

French guidance of Ribot and Janet, who laid the foundations of our modern conceptions of the disorders of memory and personality, and of Binet, who was among the first systematically to study individual mental differences and to devise tests of mental ability.

In the United States, under the influence of Stanley Hall and Titchener, and in Scandinavia, the German tradition was at first faithfully upheld. Most American, like most German, psychologists had their earlier training in philosophy, and the work published generally followed along German lines, consisting often in "maiden" papers written by candidates for the doctorate of philosophy. In this country, especially through the influence of Rivers, who went to Cambridge in the early 'nineties at the invitation of Michael Foster as lecturer in the physiology of the sense-organs, experimental psychology has developed on rather different lines. It has seldom received more than lukewarm support from philosophy, and it has been taken up by maturer workers, fewer in number, who in several instances came to it from physiology and medicine. Thus, Rivers and MacDougall began their psychological work on vision, and Myers on hearing, while later Spearman, who had graduated under Wundt, specialised in the correlation of mental abilities. In this country scientific psychology has never suffered, as in America, from the dangers of excessive popularity. Here stress came to be laid on one or other of the aspects of comparative psychology, rather than on the pure experimental psychology of the German laboratory. For it was quickly recognised that the mental differences found under different experimental conditions in any given individual are generally less in degree and less in significance than those observed under the same conditions in different individuals. True, both in England and in Germany there have been important investigations carried out upon the effects of alcohol and other drugs on the mental processes of a given individual. But even here, as also in the striking researches of Ebbinghaus and G. E. Müller on memory, the special interest has been found to lie in the study of the behaviour of different individuals. The Cambridge Anthropological Expedition to the Torres Straits, under the leadership of Haddon, which included in its *personnel* three psychologists, and the later rapid growth of the applied sciences of educational, industrial, and medical psychology, have likewise helped to stimulate the study of comparative psychology in this country.

But in Germany and in America there have also been signs of a breaking away from the initial, less fruitful (though fundamental) themes of research. Stern's work on individual psychology, following the pioneer investigations of Francis Galton in this country, and the work on animal behaviour by Jennings, Thorndike, and Yerkes in America, based on the foundations laid here by Romanes and by Lloyd Morgan, are examples in point.

The insufficiency of the older introspective psychology, whether studied in the laboratory or outside it, has since been growing more and more obvious. Watson and others have vainly sought to establish a psychology expressed merely in terms of behaviour, Loeb and Pawlow in terms of purely mechanical or physiological processes. Head and his collaborators have shown the impossibility of analysing and tracing the evolution of sensory and higher processes save by studying the effects of lesions in the peripheral nerves and the central nervous system. Freud and his foremost pupils and critics have indicated the enormous importance of the study of the emotional, instinctive, and sub-conscious processes which are inaccessible to introspective examination. Whether or not we accept Freud's views in their entirety, his work has given an enormous impetus to psychology by laying stress on the conflicts arising from rival incompatible mental (especially emotional) processes, and by indicating the different principles which Nature and the physician may employ to combat such conflicts. The published experiences of MacCurdy and others of the American Army, and of Brown, Hart, MacDougall, Myers, Pear, Rivers, Rows, and other psychologists engaged in the treatment of functional nervous and mental disorders in the British Army during the recent war, have also shown how much can be done by the early application of appropriate psycho-therapeutic methods to the cure of such disorders.

The war has likewise emphasised, both in this country and especially in America, the great value of psychological tests in the selection of candidates for the work to which they are best fitted. The importance of psychological experiment is now becoming recognised not only in regard to vocational guidance, but also in regard to industrial fatigue, the effects of different lengths and distributions of periods of work and rest, etc.

There was a time now past when in the popular view psychological research was supposed to be limited to reaction time experiments, or was confused with "psychical research" into spiritualistic phenomena. It is true that the enormous amount of labour spent in Germany on reaction time experiments promises at length useful results in the study of emotional complexes and of vocational selection. And only by the narrow-minded can psychical research be excluded from psychological science provided that it be conducted by workers systematically trained in experimental methods and freed from personal bias and prejudice. But the most promising future developments of psychology may be looked for along quite other lines, which have been already briefly indicated in the foregoing account of its present position, more especially in the study of the effects of nervous lesions and of mental and nervous disorders, and in the examination and recognition of individual mental differences.

PREVENTIVE MEDICINE SINCE 1869.

By Dr. C. J. Martin, F.R.S.

PREVENTIVE medicine is concerned with the application of knowledge to the prevention of disease. To this end all the sciences have been laid under tribute, but physiology, pathology, bacteriology, and epidemiology to the greatest extent, as these have the more immediate bearing.

The rapid progress of preventive medicine during the last half-century is due primarily to the increase of physiological and pathological knowledge, and pre-eminently to the completer understanding of the process of infection which has been acquired during this period. So long as defective development and disease were regarded as wholly constitutional or inherent in the individual, the only prospect of improvement lay in the weeding out of the unfit by the ruthless process of natural selection. A greater hopefulness has, however, arisen as the part played by prejudicial environmental conditions, such as improper feeding and housing, undue fatigue, the abuse of alcohol, and, above all, the invasion of pathogenic agents, was realised.

By the end of the 'sixties the necessity of supposing a *contagium vivum* as the cause of many diseases was fairly generally recognised. Pasteur's researches on fermentation and putrefaction had led him to the opinion that infectious diseases might be interpreted as the result of particular fermentations due to specific microbes, and it was the ambition of his life to substantiate this conception. Lister had launched his antiseptic methods on the basis of Pasteur's work, and these were already beginning to revolutionise surgical practice. Villemin had just demonstrated that tuberculous diseases, hitherto regarded as "constitutional," were due to a common infective agent capable of multiplying indefinitely in the bodies of animals and of being handed on from one animal to another by inoculation. Hitherto, however, although various microscopic organisms had been found to be associated with disease, and indications had been obtained of their ætiological significance, not one of them had been isolated. The causal relationships claimed were thus unproven and much of their life-history unknown.

The first isolation and propagation in pure culture of a pathogenic organism took place in 1876, and was accomplished by Koch in the case of a bacillus derived from cases of splenic fever or anthrax. Inoculations of cultures made *in vitro* into animals reproduced the disease. Progress in bacteriological discovery remained slow until in 1880 more appropriate methods for the isolation of bacteria were derived by Koch. Then followed a period of extraordinary fertility. Within fifteen years the causal agents of cholera, typhoid fever, diphtheria, tuberculosis, various types of suppurative processes, gas gangrene and erysipelas, glanders, gonorrhœa, pneumonia, food poisoning, meningitis, Malta fever, leprosy, and plague, as well as of a larger number of diseases of animals, were discovered.

The discovery of pathogenic agents of another kind soon followed. The association of relapsing fever with the presence of a minute motile spiral organism in the blood was observed by Obermeier in 1873. Later, a number of diseases of man and animals were found to be caused by various spirochætes, most important among them being relapsing fevers, syphilis, yaws, and infective jaundice.

In 1881 Laveran described the parasite of quartan malaria. This observation was followed by the discovery of more than a hundred microparasites belonging to the protozoa which are responsible for diseases in higher animals. The most important human diseases due to protozoan parasites are the three types of malaria, sleeping sickness, and kala azar.

Another class of pathogenic agents which is already known to be responsible for upwards of thirty separate diseases of man and animals remains to be mentioned. These viruses are either on the margin of visibility or invisible with the microscope. They are so small as to pass through biscuit porcelain. The causal agents of infantile paralysis, yellow fever, *molluscum contagiosum,* dengue fever, the three-day fever of the Mediterranean, and typhus fever belong to this category, as well as those of many important animal diseases, as rinderpest, horse sickness, and foot-and-mouth disease, and there are a number of indications that the infective agents of the common exanthemata—measles, scarlet fever, smallpox—are at some period of their life-history so small as to be included amongst the "filter-passers."

Since 1880 the ætiological factor of most human maladies has been brought to light. A correct ætiology is fundamentally necessary, but for preventive measures mere identification of the cause of a disease is not sufficient. The life-history of the parasite within and without its host, and particularly the channels and method of entrance and exit, must be known if a successful attack is to be made upon it. Indeed, some of the most striking triumphs of preventive medicine have been gained in the case of diseases in which the virus had not been seen or isolated (such as hydrophobia, yellow fever, and trench fever), but in which, nevertheless, many properties of the virus and the method whereby it effected entrance and exit had been revealed by experiment.

In the first half of the period under review researches were more particularly directed to the discovery and isolation of the causative factors of disease; the latter half, for the reasons outlined above, has been characterised by the amount of knowledge gained regarding the details of the life-history of various parasitic agencies, the maintenance of the infection in the absence of obvious cases of the malady, and the transmission of the infective agent from one individual to another.

If the infective agent is present in a superficial lesion, as in smallpox, syphilis, diphtheria, or pneumonia, or passes out with the excreta, as in cholera and typhoid fever, more or less direct transmission can occur, but in the case of a parasite situated only in the blood or internal organs it was for long a mystery how the disease was transmitted. The secret was revealed by the discoveries of Manson, Smith, and Bruce on filariasis, red-water fever, and Nagana, showing that in these diseases mosquitoes, ticks, and tsetse-flies respectively acted as transmitters. These observations were soon followed by those of Ross on the transmission by mosquitoes of malaria, and afterwards it was shown by the American Commission that yellow fever also was transmitted by a particular species of mosquito.

Relapsing fever, sleeping sickness, and bubonic plague were also found to be spread by the agency of insects; ticks or lice in the first case, a tsetse-fly in the second, and fleas in the last, and the most recent addition to the list is trench fever, which has been proved to be louse-borne.

The dependence of these maladies for their dissemination upon particular species of insects has afforded a long-looked-for explanation of their distribution—*e.g.* sleeping sickness, yellow fever, and dengue—and the very extensive investigations into the life-history of the parasites and their insect hosts has enabled the sanitarian to choose the stage in the cycle most convenient for attack. He could strike at the enemy whilst it was resident in either host or indirectly by preventing the insect from biting the patient and other individuals until in course of time the infection died out. By netting-in patients suffering from yellow fever so that mosquitoes could not attack them, and at the same time insisting on the removal of all small collections of water in the neighbourhood of habitations in which these insects were wont to lay their eggs, Gorgas rid the city of Havana of yellow fever. By a campaign on similar lines against malaria-bearing species of mosquitoes, the Isthmus of Panama was converted into a health resort. Equally satisfactory results have followed elsewhere when it has been possible to institute equally thorough measures.

Before leaving the subject of infection, I must not omit to mention that biological discoveries regarding the life-history of the parasitic worms —*e.g.* the hookworms and Bilharzia—have shown how diseases caused by this class of parasites could be successfully controlled.

It has not often been found possible to eliminate the cause of a disease. In some cases knowledge has not been sufficiently complete. In others its application has been too difficult, and it has been found impracticable sufficiently to control the lives of the population. In many such cases, however, preventive medicine has another arrow in her quiver. This is aimed at reducing the susceptibility of a population to a particular infection by protective inoculation. The earliest effort of preventive medicine along these lines was that of inoculation against smallpox practised in Asia for some centuries and introduced into England in 1721 by Lady Mary Montagu. Cutaneous inoculation of smallpox usually produces a local and comparatively mild illness, but the method suffers from the disadvantage that it propagates the virus of the disease. Jenner's vaccination with cow-pox—a modified virus—obviated this disadvantage.

With the discovery of the microbial origin of disease, Pasteur saw that the principle of Jennerian vaccination might be further exploited, and in 1881 successfully employed attenuated cultures of the microbes of splenic fever and chicken cholera to protect flocks and poultry against the depredations of these diseases.

In the case of man, the possible danger from the employment of living cultures of the germs of fatal diseases led to researches to determine whether the injection of the microbes which had been killed by heat or chemical agents also induced some measure of protection against a subsequent inoculation with living virulent organisms. By experiments on animals this was found to be the case, and the use of such bacterial "vaccines" was employed by Haffkine to protect man against cholera and plague. Shortly afterwards Wright and Semple elaborated a similar method of protective inoculation against typhoid fever. Anti-typhoid inoculation has been extensively used. The experience in the British and American Armies during the last fifteen years has been that a material reduction in the incidence of the disease has occurred amongst inoculated troops.

The greatest triumph of preventive medicine during the late war was the comparative rarity of typhoid fever amongst our troops. This was the case not only in France, but also in military operations in other areas, where the conditions were such that satisfactory hygienic measures could not be carried out. No other explanation of this freedom from enteric is forthcoming other than the periodic prophylactic inoculations to which our armies were subjected.

So far I have dealt exclusively with infection by living pathogenic agents. I make no apology for so doing, for the great developments in preventive medicine throughout the world which are characteristic of this period have been due to the impetus given by the conceptions of Pasteur and the methods of Koch.

At the same time, knowledge in all departments of physiology and pathology has steadily, though less dramatically, progressed. The increased understanding of animal nutrition must, owing to its important bearing upon the maintenance of the health of the peoples, be briefly referred to.

Before the period under review Pettenkofer and Voit had been able to strike a balance-sheet of the net in-goings and output of matter by the animal body. Within the last fifty years the applicability of the principle of conservation of energy to animals has been established by Rubner. The energy-value of the important foodstuffs has been ascertained, and the requirements of the human body under various conditions of age, climate, and occupation have been determined.

This knowledge has been inadequately exploited because everyone prefers to be a law unto himself in the matter of food intake. It has served as a basis for the rationing of armies and for the construction of institutional dietaries. During recent years, however, it has become increasingly apparent that man cannot live on protein, fat, and carbohydrate alone, but that a diet must contain in addition small quantities of what, until they can be isolated and identified, have been designated "accessory food factors." The best example of these is the for long recognised anti-scorbutic substance in fresh vegetables and fruits. The existence of at least three accessory food substances has been since established. For all of these the animal is dependent directly or indirectly upon the vegetable kingdom. An insufficient supply of any one of these leads to trouble. If one of them is inadequate, scurvy results; deficiency of another leads to the disease beri-beri; and if deprived of the third an animal fails to grow. There appears also to be no doubt that rickets in children is due to a similar cause.

This knowledge has for long been utilised to prevent scurvy. Where it has been intelligently applied it has eliminated beri-beri from coolie-camps, the population of jails, and industrial communities of the Far East, and if it is utilised in the efforts to feed the famished population of the unfortunate countries of Eastern Europe it will be the means of saving thousands of young lives during the ensuing winter.

Science has also been successfully applied in recent years to the diminution of the dangers incident upon certain industrial occupations, such as mining, caisson working, and deep-sea diving. During the last ten years, too, the influence of industrial fatigue, alcohol, improper atmospheric conditions in workshops, etc., upon the health and efficiency of the worker has been seriously studied. In these inquiries America has shown the greatest energy, but in Britain the subject is beginning to receive the attention its importance demands.

It is impossible to assess the effect of preventive medicine and improved hygienic surroundings upon the health and happiness of mankind; but the influence upon longevity can, in the case of civilised communities, be determined. During the last fifty years upwards of ten years have been added to the mean expectation of life of a child born in Britain or in the United States of America. An increase of 25 per cent. in so short a time is cause for congratulation, but, on the other hand, the fact that a million young men were found unfit for active service indicates that all is not well with Britain.

We are still far from the possession of sufficient knowledge to regulate satisfactorily our environment or to avoid all noxious influences, but owing to lack of power, money, or sometimes sense, we apply far less than we possess.

THE ANTIQUITY OF MAN.

By Dr. A. Smith Woodward, F.R.S.

At the beginning of the Tertiary period, when mammals began to spread widely over the world, they were all very small and so uniform in character that it is scarcely possible to classify them into groups or orders. They all had a comparatively small brain of a simple kind, and as in course of time they became gradually subdivided into the groups with which we are now familiar, the brain increased both in size and effectiveness, while many of the animals themselves grew larger. In the middle and towards the end of the earliest Tertiary (Eocene) epoch some of the low-brained hoofed mammals attained their greatest size and then became extinct. Next in the Oligocene another group with somewhat improved brain grew even larger just before extermination.

In the following Miocene epoch several groups that had by that time acquired a still more efficient brain, such as rhinoceroses, horses, certain carnivores, and primitive elephants, attained a comparatively large size and soon reached their maximum in the Pliocene. About the middle and towards the end of the Miocene epoch true apes, with a higher development of brain than any mammal up to that time had acquired, also began to grow to as large a size as most of the apes of the present day. It may therefore be predicted that the earliest remains of the largest members of the ape-series, with a truly overgrown brain—the great ground-apes which were the immediate forerunners of man—will not be found in rocks of older date than the Pliocene, and probably not in any but the latest of this epoch. For other reasons Sir William Boyd Dawkins came to the same conclusion so long ago as 1880, and as discoveries progress it becomes increasingly clear that true man, of the family Hominidæ, cannot be earlier than late Pliocene or the dawn of the Pleistocene.

So few fragments of apes and man have hitherto been met with that it is difficult to decide upon the region of the world that may be most hopefully searched. If, however, conclusions may be drawn merely from teeth, the most promising field at present seems to be south-central Asia. By the discovery of such teeth, Dr. Pilgrim has shown that a varied assemblage of apes lived in the forests of northern India in the Miocene epoch. At that time the Himalayan Mountains did not exist, and the late Joseph Barrell ingeniously suggested that it may have been during the uplift of this mountain range at the end of the Miocene and beginning of the Pliocene that primitive man originated. As the land rose, the temperature would be lowered, and some of the apes which had hitherto lived in the warm forest would be trapped to the north of the raised area. As comparatively dry plains would there take the place of forests, and as the apes could no longer migrate southwards, those that survived must have become adapted for living on the ground, and acquired carnivorous instead of frugivorous habits. By continued development of the brain and increase in bodily size, such ground-apes would tend to become man.

Unfortunately, we are still ignorant of fossils to test this hypothesis. We know from fragments of jaws, isolated teeth, and one limb bone that generalised apes as large as chimpanzees existed in Europe so far north as the latitude of Darmstadt until the end of Miocene times, but the only giant ground-ape, which many have claimed to be an ancestral man, was found by Dubois in Java in deposits of much later age which may even be Pleistocene. *Pithecanthropus erectus*, as the Javan species is named, is still known only by a cranial roof, two molar teeth, and a diseased thigh-bone, which bear many resemblances to the corresponding parts of the existing gibbon, and are tantalising in their imperfection.

It is, however, curious that almost the only traces of true man hitherto found with distinctively ape-like characteristics are from Western Europe. The imperfect skull and mandible of *Eoanthropus dawsoni* discovered by the late Charles Dawson at Piltdown, Sussex, represents a man with the lowest of all known human brains, and with an ape-like jaw in which typically human molar teeth are accompanied by large canines as completely interlocking as in any ape. The massive lower jaw of *Homo heidelbergensis* from Mauer, near Heidelberg, still retains much reminiscence of an ape in its retreating chin. The fine skeleton of Neanderthal or Mousterian man described by Prof. Marcellin Boule from La-Chapelle-aux-Saints, France, combines more apelike features in a single individual than are known in any existing man. The Piltdown and Heidelberg fossils are shown by associated mammalian remains to date back at least to the beginning of the Pleistocene, perhaps even to the end of the Pliocene epoch. Neanderthal man is later, and is very soon followed by typical modern man.

As to the actual age of these various remains in years or centuries there has been much discussion, but it must be confessed that on present evidence only vague guesses are possible. It is true that Penck and Brückner have made some plausible suggestions as to the length of Pleistocene time based on their studies of the glaciation of the Alps. Baron de Geer has also been able to date more precisely the retreat of the Pleistocene ice-sheet in Scandinavia by counting the annual layers in the mud which its flood-waters left behind. It is impossible, however, with our present knowledge, to correlate the isolated patches of Piltdown gravel, Mauer sands, or cavern deposits with the surface phenomena of distant areas; and it is doubtful whether this difficulty will ever be overcome.

Our knowledge of the ancestry of man has, indeed, progressed much during recent years, but unfortunately it is necessary to depend on accidental discoveries. Systematic exploration seems to meet with little or no result. Mrs. Selenka made great and prolonged excavations in Java in the river-deposits whence Pithecanthropus was obtained, without any success. The great sandpit at Mauer has been continuously worked and most carefully watched since the famous jaw was discovered, but without recovering any further traces of man. I have worked hard in the Piltdown gravel, but for the last three seasons I have not found a fragment of either bone or tooth. The research needs much patience, but we may hope that as interest in the subject is more widely spread a larger proportion of the accidental finds relating to it will escape destruction.

THE PRESENT POSITION OF THE MUTATION THEORY.

By Prof. Hugo de Vries.

DARWIN assumed that species originate by the gradual accumulation of infinitesimal, ordinarily invisible variations on account of their utility in the struggle for life. The difficulties inherent in this conception have led to the theory of mutation, which supposes that the production of species and varieties proceeds by small but distinct steps, each step corresponding to one or more unit-characters. It is only after their appearance that the environment can decide about their utility.

The new theory reduced the time necessary for the evolution of organic life on earth to the limits deduced by Lord Kelvin and others from physical and astronomical data. It explained the appearance of the numerous useless qualities of animals and plants, and eliminated the objection that the first almost imperceptible changes could scarcely have any beneficial significance for their bearers. It developed the doctrine of two essential types of variability, which are now called fluctuating variability and mutability. The first of these describes the small but always present differences among individuals of the same stock, whereas the second is the way in which varieties are known to arise in horticulture and arboriculture.

Since the publication of my book on the mutation theory (1901–3) numerous instances of mutation have been observed by different investigators among animals as well as among plants. Half a dozen species of Œnothera, some types of Primula, the walnut, the sunflower, Narcissus, Antirrhinum, Ligustrum, and many other instances might be cited. Among insects Morgan and his pupils have described more than a hundred mutations from the fruit-fly, Drosophila. Other cases have been studied by Tower for Leptinotarsa, etc.

The production of new races of agricultural crops by means of continual selection constituted for Darwin one of his strongest arguments. He showed conclusively that new species and varieties are produced in Nature in the same way as agricultural novelties. But at that time the practical method was far from being clearly understood. The work of Hjalmar Nilsson and Hays has since shown that selection may be conducted according to the principle of the mutation theory, only one choice being necessary to start the whole new variety.

It is now generally conceded by mutationists that the initial change takes place in the production of the sexual cells before fecundation. From this conception it follows that the chance of two similarly mutated cells to meet one another in this process must be very small, whereas ordinarily the mutated cells will combine with normal ones. This must produce half-mutants, and these may, in ordinary cases at least, split off the full mutants after the same rules which Mendel discovered for his hybrids. Sometimes the half-mutants will be distinct from their ancestors, as in *Oenothera Lamarckiana rubrinervis* and *erythrina*, and, therefore, will easily be discovered. In other instances external differences may be absent, and only the unexpected production of a new type in about 20–25 per cent. or more of the individuals will betray the internal change. This explains the mass-mutations discovered by Bartlett. Such an indirect way of producing mutations by means of two successive steps seems to be very common in Nature, and will probably afterwards prove to be the general rule.

Willis has made an elaborate statistical study of the appearance of endemic species, which he considers to be the youngest of their region. He finds that utility of the new characters cannot have had any part in their production, since it cannot be shown to have any influence either on their first local extension or on their subsequent spreading over larger regions. Wide spreading is mainly the result of age, the oldest species having, as a rule, the largest areas. Moreover, in comparing the diagnoses of endemic species with the differences among the mutated forms of such a group as the evening primroses one finds a close parallelism, showing that our experimental mutations are quite analogous to the species-producing steps of Nature.

Objections against the mutation theory have been made by different investigators. Some systematists and palæontologists still adhere to the old view either wholly or only for special cases. Biologists rarely attack the theory in a direct way, but mainly discuss the question whether the observed mutations are really the representatives of the species producing changes in Nature, as is claimed. They assume that the splittings seen in our experiments are due to hybridism, and that every mutating species is a hybrid between supposed ancestors which possessed the mutative characters as specific marks. This idea can scarcely aid in simplifying the question, since it puts the origin of the characters involved on to unknown parents. Sterile varieties cannot produce hybrids, and therefore cannot originate in this way. This fact seems sufficient to disprove the hypothesis. In the case of the evening primroses this view has led to fantastic diagnoses of hypothetical ancestors, but even these fail to explain the facts observed in our cultures. Morgan's hypothesis of crossing over, which goes far to explain the splitting phenomena of the fruit-fly, fails in its application to the evening primroses, since here half-mutants are the rule. These must evidently be produced without the aid of that process. Moreover, the heterogamous mutants have dominant characters which are handed down by the egg-cells, and not by the pollen, instances of which are given by the mutations called *lata, scintillans, cana, liquida,* and others of *Oenothera Lamarckiana*. Evidently these can never be explained by the assumption of a hybrid condition of the parent species.

Thus we see that the broad arguments for the mutation theory are continually increasing in number, whereas the criticisms are more and more directed against special cases. They are concerned with the possibility of experimental proof and with the fitness of our material for further studies, but are not expected to invalidate the theory as such.

THE PROGRESS OF MENDELISM.

By Prof. W. Bateson, F.R.S.

FROM the discoveries to which the Mendelian clue immediately led, many lines of research and speculation are diverging. These enterprises have still aims in common, a fact which we recognise by including all under the one name, genetics; for, though various in their methods, all relate to the physiology of breeding, a department of science the growth of which is a feature of the period surveyed on this occasion.

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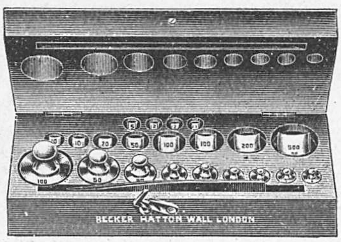

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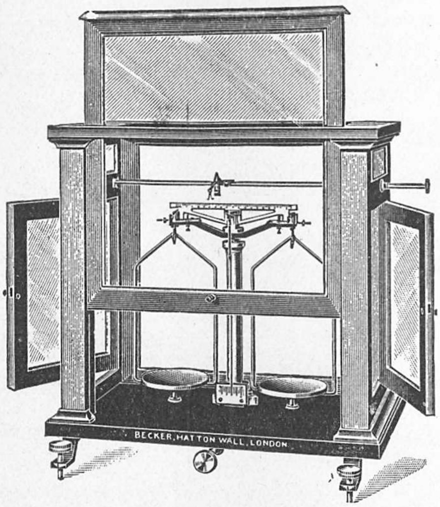

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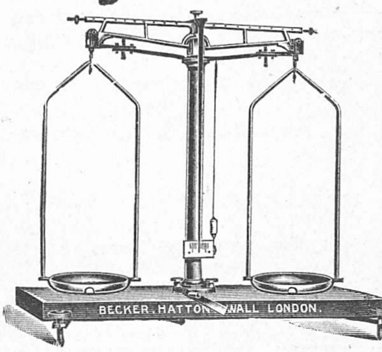

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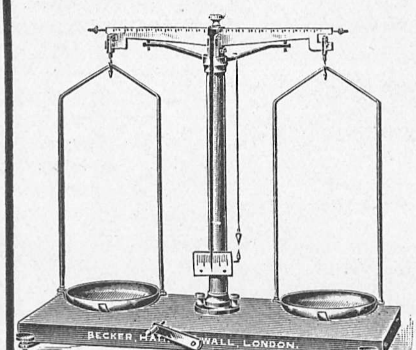

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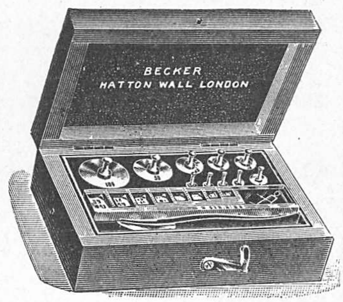

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not easy. Much of the new work is in an incipient stage, and that which is the most attractive of all—namely, Morgan's effort to establish a close connection between cytological appearances and the results of experimental breeding—promising though it is, must be tried by tests on a scale far wider than experience of Drosophila provides before we are able to assess its value with confidence. Whether the theory that the factors are arranged in the chromosomes, like beads on a thread, stand or fall, it has already served the purpose of a good theory. It has fired the minds of many workers, and has directed their inquiries with manifest success. Its weakness lies first in the narrowness of the field studied, but besides this it is not yet wholly free from the objection that the subordinate and incidental hypotheses are not altogether independent of each other.

Various as are the methods of attack, the objects before us are sufficiently clear. Among them the most important is a determination of the moment or moments at which segregation may occur. To the solution of this problem most of the investigations contribute. On one hand, we have the large body of facts consistent with Morgan's view that synapsis is the critical moment. Were our outlook confined to animals, we should scarcely hesitate to accept that hypothesis as satisfying the conditions, but the plants give no such clear answer. Not only is an obvious somatic segregation leading to genetic diversity of the parts not rare, as in many variegated plants and plants which give dissimilar forms from adventitious buds, but there is now a large group in which the male and female organs of the same plant differ in the factors which they carry. Miss Saunders's stocks are the classical example, where the male side carries doubleness and cream plastid colour, whereas the ovules are mixed in these potentialities. Similar sex-linkage, as, following Miss Pellew's use, it may provisionally be called, has been shown to exist in Petunia, *Campanula carpatica, Begonia Davisii,* and in certain forms of Œnothera.

In all such examples segregation cannot be supposed to occur later than the constitution of the sexual organs. Collins's experiment, showing that in Funaria the scales surrounding the male organs by their vegetative growth give rise exclusively to male mosses, is another and very striking indication to the same effect. The genetics of "rogue" peas point to a similar conclusion in regard to the distinction between the rogues and the type from which they come. In some way not yet clear, the type-elements are wholly or partially excluded from the germ-lineage of the heterozygotes, being apparently relegated to the lower parts of the stem. Such facts raise a suspicion that, considered as genetic machines, plants may be fundamentally distinct from animals, an idea already suggested by the contrast between their modes of growth. In the animal the rudiments of the gametes are often visibly separated at an early embryonic stage, whereas in the plant they are given off from persistent growing points. Indeed, since Baur's work with variegated chimæras, which led to his brilliant interpretation of Winkler's "graft-hybrids," this possibility has inevitably been present to our minds.

In knowledge of the nature of sexual difference many very substantial advances have been made, which have much extended the original discovery that sex depends on a segregating Mendelian factor, in some forms the male, in others the female being the heterozygous member. In the fowl femaleness is dominant, and the hen is heterozygous in sex, from which Morgan drew the interesting corollary that the "henny" character of the Sebright cock is also a dominant. Not only has this been proved experimentally, but he has lately shown that after castration the Sebright cock acquires ordinary cock's plumage, much as hens do in ovarian disease. Perhaps we may regard the henny male as containing part of the large compound factor which normally constitutes femaleness. Conversely, we may interpret the spurs frequently present in normal Leghorn hens as indicating that they have lost that part of the female factor which inhibits the growth of the spur. Whether such transference involves actual detachment of chromosome material, as Morgan's theory would demand, is uncertain. Nevertheless, an approach to such evidence is provided by the extraordinarily interesting observation of Bridges of a condition which he calls non-disjunction. Certain crosses in Drosophila failed to exhibit the normal sex-limitation, and unexpected terms appeared. Bridges was able to show that in the families which behaved in this way an extra sex-chromosome sometimes occurred, carried over, as he imagines, by some error of division. Not improbably Doncaster's female-producing strains of *Abraxas grossulariata,* in which evidence of an extra chromosome was found, are an analogous case. Patterson with great probability proposes a similar explanation for the curious phenomenon which he has investigated in Copidosoma, where, by polyembryonic division of a single egg (almost certainly), males, females, and inter-sexes may result. The inter-sexes seen by Kuttner in Daphnia, and those produced by J. W. Harrison with considerable regularity in some hybrid combinations of species of Geometers, are obviously to be considered in this connection, and doubtless the sterile males, accompanied by fertile females, which Detlefsen found as the normal produce of a species cross in Cavia, will be investigated with such possibilities in view.

But though sex behaves in so many ways as a Mendelian allelomorph, showing, of course, frequent phenomena of linkage, it begins to be remarkable that no case of crossing-over in respect of these linkages has yet been established. Were the sex-chromosome always mateless, this fact would fit admirably with Morgan's views, but since the *x*-chromosome not rarely has a mate, a distinct problem is created. As bearing on the same question, we have also to remember Tanaka's observation that a certain linkage found in the male silkworm is absent in the female.

Another far-reaching discovery has been made by F. Lillie. When in horned cattle twins of opposite sexes occur, the female is sometimes sterile, being called a free-martin. We were inclined to interpret these twins as arising by division of one fertilised ovum, but Lillie, in a study of material from the Chicago stockyards, found that an ovum had dehisced from each ovary, and the twins were therefore originally distinct. Moreover, he showed that in some instances the twins have an actual anastomosis in the fœtal circulation. We are thus driven to believe that the presence of a male embryo may influence—in cattle—the development of a female embryo, poisoning it, in so far that the development of the generative organs is partially inhibited.

Many complex cases of interaction between factors have been successfully analysed. Punnett's elaborate experiments on the colours of rabbits and sweet peas, Emerson's studies in Phaseolus, and several more such investigations are gradually laying a solid foundation from which the mechanism of factorial determination may be deduced. The discovery made by Nilsson-Ehle, and independently by East, that in some forms there are several factors with identical powers, is another notable advance.

Controversy is proceeding respecting the divisibility of factors. When on segregation, either in the gametes of F_1 or in later generations, instead of two or three sharply differentiated classes of zygotes, much intergradation occurs, or when one of the parental types fails to reappear, the result may be interpreted either as showing imperfect segregation, or as an indication that the number of factors involved is very large. The balance of evidence perhaps suggests that many factors can, and on occasion do, break up (as the sex-factor almost certainly does), some commonly, others exceptionally, while others, again, seem to maintain their individuality indefinitely unimpaired.

As bearing on evolutionary theory, the new work leaves us much where we were. Progress in genetic physiology has been rather a restraining influence. The notion that Mendelian segregation applies to varieties and not to species has been often refuted. One of the most useful contributions to this subject is Heribert-Nilsson's evidence respecting Salix hybrids. Wichura believed himself to have proved that they and their derivatives are simple intermediates between the parental forms, and this statement, which has passed current for fifty years, is now shown to be a mistake due to insufficient material. Interest also attaches to Castle's recent withdrawal of his conclusion that by continued selection certain Mendelian characters in rats could be modified, an opinion which, though consistent with his own experimental work, has not stood a crucial test. We are still without any uncontrovertible example of co-derivatives from a single ancestral origin producing sterile offspring when intercrossed. This, one of the most serious obstacles to all evolutionary theories, remains. The late R. P. Gregory's evidence that tetraploid Primulas, derived from ordinary diploid plants, cannot breed with them, though fertile with each other, is the nearest approach to that phenomenon, but the case, though exceptionally interesting, does not, of course, touch this outstanding difficulty in any way.

Space does not suffice to enumerate the practical applications of genetic science to economic breeding, of which some have already matured and many are well advanced.

TELEGONY.

BY PROF. J. COSSAR EWART, F.R.S.

THE belief in telegony is probably as old as the belief in maternal impressions, so intimately associated with Jacob's breeding experiments, recorded in the thirtieth chapter of the Book of Genesis. In prehistoric times, when breeds of sheep and cattle brought from the East by the Alpine race were crossed with the more recently formed European breeds striking new varieties would now and again appear. The ancient shepherds would doubtless endeavour to account for the differences between the cross-bred offspring and their pure-pred ancestors, and later biologists would be called upon to decide which of the views of the ancient breeders were most worthy of support.

The doctrine of the infection of the germ now known as telegony was more or less firmly believed in by men of science as well as by breeders up to the end of the nineteenth century. Beecher, writing at the close of the seventeenth century, says: "When a mare has had a mule by an ass and afterwards a foal by a horse there are evidently marks on the foal of the mother having retained some ideas of her former paramour, the ass." Agassiz held that the ovary was so modified by the first act of fecundation that "later impregnations do not efface that first impression." Similar views were entertained by Haller, Darwin, Herbert Spencer, Carpenter, Sir Everard Home, and others, and up to 1895, when I started my experiments, physiologists as a rule either admitted the possibility of the blood of a mare imbibing from that of the fœtus some of the attributes which it had derived from its male parent and thereafter handing them on to offspring by a different sire, or believed that some of the unused germ plasm of the first mate penetrated the immature ova and eventually took part in controlling the development of offspring by subsequent mates.

Up to the end of last century Lord Morton's experiments with a male quagga and a young chestnut seven-eighths Arabian mare were regarded as affording strong evidence of telegony. Hence at the outset I decided to repeat as accurately as possible Lord Morton's experiment. The quagga being extinct, a Burchell zebra was mated with Arab and other mares belonging to different breeds and strains. The mares, after producing one or more hybrids, were mated with Arab and other stallions.

In an account of my experiments, illustrated by numerous figures, published in the Transactions of the Highland and Agricultural Society of Scotland for 1902, it is pointed out that, though, to start with, I believed there was such a thing as telegony, I eventually came to the conclusion that "there never has been an undoubted instance of infection in either dogs, rabbits, or horses." Though a full account of my investigations, by Mr. Hermon C. Bumpus, appeared in the *American Naturalist* (December, 1899), and an abstract was published in the 1910 Report of the United States Bureau of Animal Industry, it is related in a recent American work on evolution[1] that the idea of telegony "rests mainly upon what are known as the Penycuik experiments (Ewart, 1899), the initial one of which was the impregnation of a mare, 'Mulatto,' by a quagga, a species of zebra which is now extinct. The offspring of this union was the foal 'Romulus,' which showed the quagga-stripes of his father very distinctly. Later, 'Mulatto' was bred to a pure Arab stallion and her second foal also showed traces of stripes, although by no means as distinctly as his half-brother 'Romulus.' . . . Definite instances are neither numerous nor well authenticated with the exception of the one in question, and even this may be due to some other cause."

It is scarcely necessary to say that I am not responsible for the idea of telegony—without going far afield, Lull might have discovered that the doctrine of "infection" had been dealt with by Agassiz and was especially associated with a mare belonging to Lord Morton—but it may be as well to point out that I used a Burchell zebra (the quagga had been extinct for nearly a quarter of a century); that the hybrid "Romulus," instead of being striped like his sire, approached in his markings the very richly striped zebra of Somaliland; and that the two subsequent foals of "Mulatto" were decidedly less suggestive of zebras than pure-bred foals of a near relative of "Mulatto" who had never even seen a zebra.

In 1910, when giving a course of lectures in Iowa, I gathered that the doctrine of telegony had few adherents in America. This view is supported by a statement in the recent work by Jordan and Kellogg, who "think it probable that the phenomena called telegony have no real existence."

[1] Lull, "Organic Evolution." (New York: The Macmillan Co.)

PROGRESS OF CHEMISTRY.

By Sir Edward Thorpe, C.B., F.R.S.

THE half-century which has elapsed since the first issue of NATURE has witnessed an extraordinary development of science in general, but in no department has it been more marked, or the changes more profound, than in chemistry. Before dealing with the period over which the existence of this journal extends, it may not be uninteresting to indicate, in the broadest possible outline, the main features of progress in chemical science to which the growth we have witnessed during the last fifty years is in reality due.

The opening years of the nineteenth century constituted a new era in the history of chemical science. The revolution initiated by Lavoisier and his associates—Morveau, Laplace, Monge, Berthollet, and Fourcroy—was by this time accomplished, and its influence had extended throughout Europe. The French chemists, who emancipated chemistry from the thraldom of a false German doctrine, swept phlogistonism into the *limbus fatuorum* of extinct heresies. The early years of that century saw the passing of the more prominent adherents of Stahl's philosophy; of the English chemists, Priestley died in 1804, and Cavendish, who for some years previously had ceased to pursue chemical inquiry, followed him six years later.

Within the first quarter of the century appeared some of the most eminent of those who were destined to consolidate the principles upon which the New Chemistry was founded. Dumas and Wöhler were born in 1800, Liebig in 1803, Graham in 1805, Laurent in 1807, Gerhardt in 1816, Wurtz, Kopp, and Marignac in 1817, Kolbe and Hofmann in 1818, Pasteur in 1822, Alexander Williamson in 1824, and Edward Frankland in 1825. But there was already a generation at work the members of which, although not specially distinguished for their direct contributions to speculative chemistry, yet served by their labours to strengthen the foundations upon which it is based; among them were Wollaston and Davy, born in 1766, and Gay-Lussac, born in 1778. Berzelius, who was born in 1779, first published his electro-chemical theory in 1827. A revolution scarcely less momentous than that of Lavoisier had, moreover, by this time been effected by John Dalton; the enunciation of the atomic theory in 1807–8 wholly altered the aspect of chemistry; henceforth it was brought within the domain of mathematics, and its laws and processes were established on a quantitative basis. It consummated a change which Cavendish may be said to have originated. It can be proved that Cavendish was cognisant of the principles underlying what we term the "law of constant proportion" and the "law of reciprocal proportion"; that he foresaw that the facts embodied in these laws are at the foundation of all quantitative analytical work, and that in his practice he implicitly recognised their truth.

In spite of the widespread political and social disturbance which marked the early years of the last century, a tide in the affairs of chemistry then set in, which, with periods of ebb and flow, reached a high-water mark at the time this journal was founded.

The first two decades of the century not only witnessed the establishment of the fundamental laws of chemical combination and their rational explanation by means of the atomic theory; they also saw the enunciation of the gaseous laws; the discovery and application of voltaic electricity as an analytic agent; the isolation of the metals of the alkalis and alkaline earths; the determination of the nature of the halogens; and the discovery of many new metallic elements. In 1802 these were only twenty-three in number, as against sixty-three at the present time. They saw, too, the discovery of fulminating mercury and fulminating silver, acetylene, carbonic oxide, phosgene—some of which have played a large part in the Great War, but which when first made known were regarded as mere chemical curiosities, incapable of application. This period also saw the invention of the miner's safety lamp and the creation of the gas-lighting industry—two new departures of which it is impossible to exaggerate the consequences, immediate and remote. It witnessed also the discovery of isomorphism, the enunciation of the law of Dulong and Petit, and the first synthesis, by Wöhler, of an organic product.

The third decade brought us Faraday and the discovery by him of tetrachlorethylene and perchlorethane; the liquefaction of the gases; the isolation of benzene; the preparation of naphthalene sulphonic acids; and the formulation of the laws of electro-chemical decomposition. It witnessed also the activity of Graham; the promulgation of the law of gaseous diffusion; the recognition of the basicity of acids and the constitution of salts; the establishment of the doctrine of compound radicals by Liebig and Wöhler; the discovery by Dumas of chlorine substitution and the publication of his theory of types. It saw also the death of Wollaston and Davy, and the birth of Cannizzaro, Berthelot, Kekulé, and Lothar Meyer. The early 'thirties are memorable, too, for the attempts made to regularise chemical notation and for the gradual adoption of the system of Berzelius.

But, with the exception of the work of Graham and Faraday, the decade 1830–40 is not particularly remarkable for British contributions to chemical science. Although the volume of published work was no doubt considerable, it was not of the epoch-making order. As Edward Turner wrote, "the era of brilliant discovery in chemistry appeared to have terminated for the present." Thoughtful men deplored the condition of British science at this period, and they were concerned at the general apathy of the public with respect to it. One result of their action was the foundation, in 1831, of the British Association for the Advancement of Science. At the same time, it cannot be said that Continental workers were much more active. Apart from those already referred to, we find no noteworthy contribution to the theory of chemistry. The extent of the retrogression in this country may be judged from the fact that at this time the number of communications to the various societies, and to scientific periodicals dealing with chemistry, was not much more than half of what it was in 1802.

With the advent of the fourth decade there was a great awakening. It was signalised by the discovery of the first of the organo-metalloid radicals by Bunsen in 1841; the recognition of homology by Schiel in 1842; the early work of Pasteur on racemic acid; the synthesis of acetic acid by Kolbe; the dissociation of water by heat by Grove; the work of Frankland on ethyl and zinc-ethyl; the discovery by Wurtz of the compound ammonias and their synthetical formation by Hofmann; and the elucidation of the constitution of ether and the theory of etherification by Williamson. This decade was further made memorable by the creation, in 1841, of the Chemical Society of London, and by the foundation, in 1845, of the Royal College of Chemistry. At that time organic chemistry was scarcely studied in this country, and schools of practical chemistry were very few in number here. English chemists who sought instruction in operative chemistry and in the methods of original investigation for the most part resorted to Liebig at Giessen or to Wöhler at Göttingen. Liebig soon made his influence felt abroad, and his memorable English tour in 1842 gave a strong stimulus to the study of chemical science in this country. One of its immediate effects was the foundation of the Royal College of Chemistry, with Hofmann, one of Liebig's most brilliant pupils, as its director.

This was the first institution of its kind in Great Britain in which chemistry was studied for its own sake, and not merely as subordinate to other professional training. Space does not permit of any detailed account of its activities, or of the circumstances which led to its absorption into the School of Mines. It is only necessary to recall the names of Warren de la Rue, Abel, E. C. Nicholson, How, Bloxam, Blyth, Price, Rowney, Muspratt, Mansfield, Field, Noad, Brazier, Medlock, Crookes, Spiller, Tookey, Church, Perkin, Groves, Valentin, Vacher, O'Sullivan, Duppa, McLeod, Reynolds, Griess, Holzmann, Martius, Geyger—among the most distinguished of Hofmann's pupils and coadjutors—to indicate the influence he exercised on the development of chemistry in Great Britain during the twenty years of his residence amongst us. That he should have been allowed to depart was nothing short of a national calamity.

As regards British contributions to chemistry during this and the succeeding decade, the most noteworthy may be said to have emanated from the Oxford Street institution. Williamson, however, was still active at University College, and to this period belongs Frankland's recognition, in 1851, of the principle of valency. The synthetic colour industry originated in 1856 from Perkin's discovery of mauve, and Hofmann himself, with other of his pupils, contributed greatly to its development. As regards other workers, notable contributions to chemical theory at about this time were Clausius's work on electrolysis, Deville's studies on dissociation, Couper's conception of atomic linkage, and the resuscitation by Cannizzaro of Avogadro's hypothesis and his demonstration of its sufficiency at the memorable Congress of Karlsruhe in 1860. The introduction of spectrum analysis by Bunsen and Kirchhoff belongs also to this epoch.

NATURE was founded at a time of extraordinary development in chemistry. Kekulé had made known his fruitful conception of the constitution of benzene, and a host of workers, more particularly in Germany, were exploiting with feverish activity the chemistry of the so-called aromatic compounds. The synthetic colour industry received a remarkable impetus by the synthesis of alizarin. Newlands had already adumbrated Mendeléeff's great generalisation, of which the validity seemed to be established by the dramatic discovery, in quick succession, of the new elements it had predicted.

During the fifty years of its subsequent existence this journal has recorded and made intelligible to the general public every notable advance in chemistry. It has witnessed great and fundamental changes in the science. New conceptions have arisen and time-honoured doctrines have been modified or altogether supplanted. Chemical knowledge has been augmented by the inclusion of the theories of stereo-isomerism, desmotropy, the gaseous theory of solutions and free ions, and the Walden inversion. It has had to note and describe the methods of liquefaction of all the so-called permanent gases, and it has seen the universal recognition of the principles, first indicated by Andrews, on which the change of physical state depends. It has chronicled the discovery of argon by Rayleigh, and that of terrestrial helium, krypton, neon, and xenon by Ramsay. It has seen the rise and progress of radio-activity, the isolation of radium and its associates, and the discovery of isotopic elements. Lastly, it has seen a profound change in our conception of the Daltonian atom as an indivisible entity, and a strengthening of our belief in the intimate connection between matter and energy.

Throughout the whole of its existence NATURE has been true to the ideals which it established at its birth, and has been consistently faithful to the traditions it created. It has insisted from the outset that national progress must be based upon new ideas, and that the main source of new ideas is original research. It has shown that the greatest practical realities of our time have originated from the search for truth; that invention waits upon discovery—the most powerful of all agents of civilisation; and that new knowledge means new power. Hence it has with a uniform insistence pointed out that it is the duty of the State, in its own interest, to encourage and foster research and to remove the hindrances which beset the pursuit of science and impede its progress. Nor has its advocacy been based solely on the lower ground of material advantage, or on the fact that original research has proved to be the source of new industries and of wealth—that it creates employment and alleviates labour. It has striven to show that mental and moral progress have a scientific basis—that our knowledge of Nature and the universe, our modes of thought, our criteria of truth, our detection and avoidance of fallacies, are dependent upon that habit of mind we call "scientific"—a habit which can be cultivated and strengthened only by the study and pursuit of science.

It has a record of which it may justly be proud. By the manner in which it has discharged its functions and fulfilled its obligations, it has earned the gratitude of all men of science, and it now celebrates its jubilee with the knowledge that it has merited, and will receive, the unstinted appreciation of all true lovers of science.

CHEMISTRY IN THE MAKING.

BY PROF. HENRY E. ARMSTRONG, F.R.S.

THE period covered by NATURE happens to be that which just comes within my ken. In chemistry, both pure and applied, it has been one of astounding progress and fulfilment. Frankland and I published our new method of water analysis—involving combustion *in vacuo* with the aid of the Sprengel pump—in the year of its birth: people then ran their sewage into a cesspit and drank the water from an adjoining well. Typhoid fever was rife throughout the land. Bacteriology was an unknown science. Frankland's work on the Rivers Commission gave the nation a pure-water supply and contributed greatly to a complete sanitary system, in this respect placing us ahead of the world. The systematic use of the Sprengel pump dates from our inquiry; Crookes afterwards used it in constructing his radiometers.

It is noteworthy that sulphuric anhydride was a laboratory curiosity at that time: when I prepared several pounds of it, in Leipzig, in the autumn of 1868, I was regarded with wonder: Squire and Messel began its manufacture here at Silvertown in 1873: it soon came into vogue, especially in the alizarin industry. During the war, many thousands of tons have been used in the production of propellants and high explosives. I then also made the chlorhydrol, SO_3HCl, in quantity, and suggested to my student friend, Karl Knapp, Liebig's nephew, that he should test its value as a sulphonating agent. He sulphonated benzene. I took up the work afterwards and first applied it to toluene, so laying the foundation of the method now preferred in manufacturing saccharin.

In 1868 chemists were waxing enthusiastic over Mendeléeff's great generalisation, brought home to us not only in his paper in the *Annalen* but also by Lothar Meyer's well-known book, then recently published, especially by Meyer's justly famed atomic volume curve. At that date those of us who could think in terms of systematic organic chemistry were possessed by the view that the "elements" must be compounds: the "periodic" inter-relationships were so similar to those manifest in homologous and isologous series. Soddy's "isotopes"—the word is unnecessary—are simply the chemist's homologues. That the two leads should be as like as the two Dromios—recent observation shows that they are perceptibly different—is in no way surprising: methane and ethane are all but indistinguishable chemically; we can also foresee isomeric as well as homologous primaries. Now that the "primaries" have been robbed of their position as "atomic" materials, by the appearance on the scene of radium, this view is proved to have been justified; but none of us ever dreamt that they would come to be regarded as made of lumps of electricity—still less that we should ever dare to think of energy in terms of quanta or to discard the doctrine of the other in favour of one of relativity.

All my life, I have regretted the aloofness of chemistry from physics: that the physicist shows so little real interest in chemistry. It is a welcome finish to find him at last entering upon the fringe of our domain and taking up our work, though it is a pity he cannot become one of us instead of a mere extrapolation; probably it cannot well be otherwise, as the mathematical habit of mind is required for the new work and chemist and mathematician are different natures. Ours must be the task of digesting the material to the point at which our mental enzymic machinery no longer suffices and that of the mathematician and physicist comes into play. The two recent lectures to the Chemical Society by Nicholson and Jeans—both astounding displays of eloquence and imaginative power—are demonstrative of the new departure. If fifty years hence the new field be as fully grasped as that has now been which I saw opening up in 1868, NATURE at its centenary will indeed have cause to congratulate its readers.

In 1868, we were only beginning to write $C=12$; our symbolic system was barely stabilised; the importance of Avogadro's theorem was but coming home to us, mainly through Cannizzaro's insistence. Structural constitutional chemistry was in its infancy. Frankland's theory of valency—it is now clear that he included carbon in his scheme—and Kekule's benzene symbol were new weapons; we were only beginning to interpret isomerism in terms of structure; we scarcely thought of position as its cause. A vast edifice has been erected in the interval but the foundations are simple: Frankland's postulates have but been supplemented by van't Hoff's extension of Pasteur's geometric conceptions. What is most noteworthy is the surprising simplicity and sufficiency of the system.

Latterly we have begun to think in terms of solid structure: it is already clear that the next advance will come from the geometric, crystallographic side: and having learnt to see through a brick wall, we are now beginning to peer directly into the molecular structure of crystalline solids. Low temperature phenomena have been probed to their depths, especially in this country; indeed, we have seen a series of important industries grow out of the work.

The growth of our knowledge of method, of our analytic and synthetic powers, has been marvellous—full use has been made of this development by the manufacturer, so that we can now not only reproduce natural colouring matters but match the rainbow in every tint. Although British chemists cannot claim the credit of much of the matching, they can at least rejoice in the fact that the foundations were laid in London—by Faraday's discovery of benzene in 1825, in Albemarle Street; and by Perkin's discovery of mauve, in Oxford Street and at Sudbury in 1856.

It is noteworthy that mauve was made in attempting to synthesise quinine: as we are not yet certain as to the structure of this alkaloid and in no way near to a method of producing it artificially, it is clear that even now our powers of interrogating and copying Nature are but limited: remarkable as our progress has been, she yet defies us in many directions. We stand ashamed before the unassuming ease with which she fabricates starch from glucose underground in the dark; indeed, cane-sugar, starch, cellulose and not a few other compounds of primary importance are still to be ranged with the Delphic mysteries.

But whilst, on the organic side, we have secured a wonderful mastery and the odds in favour of our structural conceptions are many thousands to one—because we have been able to ring the changes so often with success; on the inorganic side, almost complete ignorance prevails—because we have not been able to ring the changes. Thus we cannot say, with any approach to certainty, what is the structure of so simple a substance as sulphuric acid. In this and similar cases probably the clue will come through X-rays.

On the biological side the advance has been very great and it can no longer be said with truth that "Thierchemie ist Schmierchemie"—Emil

Fischer's expression; but physiologists are still far from being sufficiently schooled in our science and progress has been chiefly due to men such as Emil Fischer, who have had sympathy with biological problems and been alive to the fact that it is desirable to walk before running. It is strange that few chemists have biological leanings—but the biological is still further removed than the chemical from the mathematical habit of mind.

The chief feature of progress in later years has been the ongrowth of the physical school. This has had both its advantages and its disadvantages—for whilst we have been led to widen our vision and increase our grip on the philosophy of our subject, we have lost in manipulative skill, as we have given inadequate attention to the development of method and technique. This probably is one of the chief causes of our comparative failure on the industrial side. Though based on analysis, chemistry is mainly a constructive, practical science: our success has been in proportion to the extent to which we have been able to confirm analytic by synthetic results. The man who does always gets ahead of the man who doesn't—of the man who merely seeks to explain; though the latter is often more useful than is supposed in controlling practice. Still it is because fingers and artistry come first in the practice of chemistry, that the chemist proper is not and cannot often be a mathematician. The superior value of the preparative side has been so brought home to us during the war, that it is to be hoped that full attention will now be given to its development.

Our ill-balanced bookish system of examinations is one of the main causes of the incomplete practical training chemists have received of late years; we have yet to teach the real value of books, that they are meant for constant reference; to force students to memorise them is the worst of policies: thoughtful, dextrous fingers and knowledge of materials are the chemist's chief needs.

Much progress has been made, on the physical side, in correlating properties with structure. Also great attention has been paid to the problems of solutions: unfortunately the men who have dealt with this latter side of chemistry have not been working chemists—in fact, scarcely chemists at all—and the pseudo-mathematical treatment they have introduced has often savoured far too much of dogma. The result has been to introduce an unscientific, partial habit of mind into our subject. We are strangely behind in having no proper, accepted theory of chemical change in general. Our elementary text-books too are behind the times—full of half-truths and superficial when not inaccurate: there is no lack of detail but little philosophy and still less logic. Chemistry is the most fundamental of the sciences, the one by means of which it is alone possible to teach the principles and practice of scientific method in their entirety—and yet chemists are rarely trained to be masters of method.

To make chemistry a truly philosophical science, for the guidance of students, we need a man of giant mind, well versed in practice, who will survey and weigh the facts and give sympathetic consideration to all hypotheses, then summarise the situation in broad and simple terms which all can understand. Fitzgerald was a man of the type I have in mind.

Certainly the progress made during the fifty years is astounding—the extent of our collective knowledge is extraordinary. But we must be on our guard—there are too many "bits of chemist" about: the most pretentious member of the species is of modern invention—the "research chemist." No chemist is a chemist who is not fully imbued with the spirit of inquiry. Not a little of the work that is now called research is of a trivial character; the majority are incapable of original effort and far more careful direction of advanced work is required. If care be not taken, "research" will become a word of reproach. The effort of the future must be to produce the whole chemist—the man who will know his subject and be ever careful and modest, both in word and deed, being possessed by scientific method.

THE DISCOVERY OF CHEMICAL ELEMENTS SINCE 1869.

BY PROF. H. B. DIXON, F.R.S., AND H. STEPHEN, M.Sc.

A GLANCE at the history of the chemical elements reveals the fact that no fewer than fifty-three of them were recognised so early as 1818, and since that time some thirty more have been discovered. The search for new elements between 1818 and 1869 represents an empirical programme without considerations of marked theoretical interest, and the investigations were directed more particularly to an examination of minerals. The chief results were the isolation of new metallic elements, and the work of the great master, Berzelius, stands out pre-eminently during this period, and his quantitative work surely paved the way for future investigations.

The later period extending over the past fifty years marks out a new era in the history of the chemical elements, inasmuch as it opened with the discovery of the periodicity of the elements in connection with their atomic weights. The elaboration of the system in its final form was due to Mendeléeff in 1869, although Newlands had foreshadowed such a system in his law of octaves (1863).

Mendeléeff's system had a profound effect in bringing about radical changes in respect of the atomic weights of certain elements, notably beryllium, uranium, and indium; and in affording predictions of the existence and properties of new elements, which were confirmed with astonishing exactitude in the cases of scandium, gallium, and germanium.

Another factor which played an important *rôle* in the development of the chemistry of the elements in the early years of this period was the application of the spectroscope by Bunsen and Kirchhoff to chemical analysis, when, by a comparison of the bright lines in the spectra of the vapours of metallic elements with the dark lines in the solar spectrum, they showed that many terrestrial elements exist in the sun. During the last two decades the interest in spectroscopy has revived, and much of the valuable information which we now possess of the intra-atomic structures of the elements is due to the remarkable developments in the construction of diffraction gratings, and in particular the concave gratings of Rowland.

Notwithstanding the great possibilities for research opened up by Mendeléeff's periodic table, the latter remained only slightly modified until 1893, when a period of rapid development and continual progress began. The later discoveries with regard to the chemical elements fall in a remarkable way into three distinct groups: the rare earths, the inactive gases, and the radioactive elements, and it is to be lamented that the pioneers in the two first-named groups have passed away.

Much of our knowledge of the rare earths is due to the late Sir William Crookes, who was the first to advance the conception of the meta-elements—*i.e.* elements which show great resemblance to each other, and have many physical and chemical properties in common, and, in consequence, are not easy to separate. Such in a few words sums up the chief characteristics of the rare earths, which have found so far only a temporary resting place in the periodic table. Apart from their purely academic interest and the high degree of accuracy attained in their separation, the rare earths have found important technical application as catalytic agents and in the manufacture of the modern incandescent mantle. Our knowledge of them, however, remains in many respects incomplete.

Of the second group, the inactive gases, we possess a more complete history of their chemistry, due in no small measure to the brilliant achievements of Lord Rayleigh and Sir William Ramsay, who were the first (1894) to characterise the inert gas argon in the atmosphere, and so confirmed the almost forgotten work of Cavendish more than a century before. The discovery of helium in cleveite by Ramsay followed shortly after that of argon; his attention had been directed by Miers to Hillebrand's discovery of nitrogen in the mineral uraninite—and gas-containing minerals seemed to be a possible storehouse of condensed argon. He sought for argon and found helium, the presence of which in the sun's atmosphere had been detected by Lockyer twenty-five years before.

The proof that helium was an inert monatomic gas like argon led to many speculations as to the position of these new elements in the periodic system. Ramsay predicted the existence of another inert gas between, and forming a "triad" with, helium and argon, having an atomic weight between that of fluorine (19) and that of sodium (23), and he and his fellow-workers deliberately hunted for the missing element. They found it in the atmosphere, but besides the gas they sought—neon (20)—they also isolated the heavier elements krypton and xenon. All the inactive gases are colourless; they form no chemical compounds, and are monatomic. They have definite boiling points, give characteristic Geissler-tube spectra, and occupy a unique position in the periodic table—the neutral points in Crookes's descending figure of eight.

The last group of elements to be discovered include the remarkable and interesting series of radioactive elements, which originated in the discovery of radium by Mme. Curie in 1898. The development of this field of research has produced a profound effect upon chemical theory and given us entirely new conceptions of the structure and nature of the atom, foremost among which is the nuclear atom proposed by Sir E. Rutherford, and recently modified by Prof. Bohr.

The chief interest of the radioactive elements centres round two elements of highest atomic weights, uranium and thorium, which are continually decomposing into a series of other elements at definite rates over which we have at present no control. These new elements in a similar way undergo spontaneous changes into still another series of elements. Accompanying these changes in both cases there is a high-speed emission of three distinct kinds of rays, now designated the α-, β-, and γ-rays respectively. The first-mentioned have been identified as electrically charged atoms of helium, and it is now believed that all radio-elements are built up of lead and helium, a conclusion reached by Rutherford and others, and thus after the lapse of a century the hypothesis advanced by Prout (1815), concerning the existence of a primordial substance, makes a reappearance in modern guise.

The majority of the elements formed in the transformations associated with uranium and thorium (which are the progenitors of a long line of descendants) have not as yet been obtained in a pure condition, and are characterised at the present time solely in connection with radioactive properties. Two substances, radium and niton—the gaseous emanation from radium—have been definitely described, and their atomic weights and positions in the periodic table fixed. Niton belongs also to the group of inactive gases; its existence is transitory, since the gas disappears after a few days, during the course of which radioactive disintegration takes place. Its atomic weight being 222, four units less than radium, the difference is attributed to the loss of a helium atom from radium.

Based on a consideration of their researches, Rutherford and Soddy have formulated a theory of atomic disintegration (1902) in connection with which Soddy has recently introduced the term *isotope*, by which he defines very closely related elements which are chemically inseparable but have different atomic weights. The non-separability of isotopes by chemical methods has recently been confirmed by Richards and his co-workers, who found that the atomic weight of lead obtained from Australian carnotite (containing uranium-lead) was unaltered even after the nitrate into which the lead was converted had been subjected to more than a thousand fractional crystallisations. Furthermore, Richards has determined the atomic weight of uranium-lead, and the number found (206·08) is less by as much as 0·25 per cent. than that of ordinary lead, which differs from it in other physical properties involving weight. It is possible that lead descended from thorium (208) and lead descended from uranium (206) have enough in common to be each called lead, but are varieties or isotopes of the same element, common lead (207·2) being a mixture of the two.

We may conclude, therefore, that in radioactive substances there is a continual transformation of one element into another of lower atomic weight, such transformation (apparently quite independent of temperature and external electrical conditions) being accompanied by the liberation of enormous amounts of energy, compared with which the magnitudes of energy of chemical reactions fade to insignificance. Has the earth passed through its element-building epoch? Instead of spinning "for ever down the ringing grooves of change," are we mounting backwards up the spiral as our larger empires of matter disintegrate into smaller and perhaps more stable states?

Just as the beginning of the last half-century was marked by the epoch-making discovery of the periodic system of the elements, so in effect is the close of it marked with another—namely, Moseley's discovery of the atomic numbers of the elements, the importance of which we have as yet scarcely realised.

The atomic number of an element as suggested by van der Broek defines the place-number occupied by the element in the periodic table, and at the same time is the number of electrons in the atom or nuclear charge of it. Moseley showed from a spectroscopic examination of the frequencies of characteristic X-rays emitted when X-rays bombard anticathodes of various metals, that the square roots of the frequencies are proportional to the atomic numbers. The latter are known for all elements up to uranium—thus, hydrogen one, helium two, lithium three, and so on until finally uranium 92, and the anomalies which appear in Mendeléeff's table disappear, as in all cases the correct chemical order is maintained. The atomic numbers appear to be even more fundamental than the atomic weights.

PHYSICAL CHEMISTRY—PAST AND PRESENT.

By Prof. J. C. Philip, F.R.S.

THE cultivation of the border-lands between the various sciences, so actively prosecuted in the last few decades, has nowhere led to more notable results than on the frontiers of physics and chemistry. This particular field of investigation, covering phenomena in some measure common to both these sciences, has gradually taken shape, and has attracted crowds of workers, keen to apply the exact methods of physics to the wealth of problems and material presented by chemistry. With the passing of the years physical chemistry has ultimately emerged as a definite branch of natural knowledge, full of intrinsic interest, but comprising also much that is of value for other sciences.

Fifty years ago the foundations of physical chemistry had to some extent been already laid. Faraday's experiments on electrolysis and the liquefaction of gases, Graham's observations on gaseous and liquid diffusion, and Hittorf's investigations of electrolytic migration had been put on record, although in some cases, notably the last-mentioned, the full significance of the work was not to be realised for many years to come. Avogadro's hypothesis and the kinetic theory were also before the scientific world, and the Brownian movement of minute particles suspended in water, destined ultimately to figure so prominently in the physical chemistry of recent years, had been not only recorded but, for the time, forgotten.

During the period in which NATURE first appeared, new methods of investigating chemical change, and new conceptions of chemistry as a quantitative science were being developed. The work of Harcourt and Esson, of Guldberg and Waage, on the action of mass as a factor in equilibrium and velocity, as well as Horstmann's application of thermodynamics to chemistry, inaugurated a new epoch, with which, in both directions, the name of van't Hoff was afterwards so brilliantly associated. It was van't Hoff who put the science of chemical dynamics on a secure experimental basis, and thus prepared the way for a rational study of catalysis, a particular development of vital significance for the growth of important chemical industries. It represents part of the contribution which physical chemistry has made to the advance of chemical knowledge from the purely descriptive to the rational and quantitative stage.

Appreciable progress towards the recognition of physical chemistry as a distinct branch of knowledge resulted, at a somewhat later date, from van't Hoff's study of osmotic pressure, and his extension of the gas laws to solutions. This remarkable work was followed, at a short interval, by Arrhenius's hypothesis of electrolytic dissociation, a conception that has left its mark deep on the physico-chemical research records of the past thirty years. This hypothesis has been the guiding principle in countless investigations, and although it presents difficulties not yet satisfactorily solved, and appears to require modification in some respects, notably in regard to the *rôle* of hydration, it holds the ground to-day as the most acceptable and intelligible interpretation of the properties of electrolyte solutions. The history of the electrolytic dissociation theory may be fairly described in Larmor's words: "In the case of every successful scientific theory the time must come when its first easy triumphs become exhausted, and what prominently confronts the investigator are its outstanding defects and difficulties." Such is the present position in regard to the ionisation theory, and during recent years there has been a concentration of effort on such outstanding problems as the application of the mass action law to strong electrolytes, the catalytic action of ions, and the differences existing between the values of the ionisation ratio deduced for one and the same electrolyte by the osmotic and conductivity methods respectively.

The decade in which the theories of van't Hoff and Arrhenius were propounded saw also the establishment of the first journal exclusively devoted to the record of physico-chemical research. The first number of the *Zeitschrift für physikalische Chemie* appeared in 1887, and an inspection of the early volumes reveals the extraordinary variety and attractiveness of the problems that were being attacked under the ægis of the new science, and on the more definitely quantitative lines for which this branch of chemistry stands. It was not long before the influence of physical chemistry began to be apparent beyond its own borders in a renascence of inorganic chemistry which continues to the present day. Important reactions between well-known substances, regarded as completely worked out, have been explored afresh in the light of physico-chemical principles, and have yielded an extraordinary amount of valuable quantitative data. In this connection one might refer to the phase rule and its practical utility in connection with the conditions of existence of salt hydrates, the constitution of alloys, and various technical problems.

Prominent among the later developments of physical chemistry has been the examination of matter in a condition coarser than that corresponding with the molecular state. The study of mechanical suspensions, and the investigation of colloidal solutions with the aid of the ultramicroscope, have opened up a whole new world of fascinating phenomena, and bridged the gap between the visible particle and the molecule. Perrin's epoch-making count of the particles at different levels in a vertical column of a mechanical suspension, and the evaluation of the Avogadro constant which follows therefrom, have notably extended the validity of the gas laws, and supplied at the same time definite quantitative proof of the molecular movements postulated by the kinetic gas theory. Of extraordinary interest also in this connection is the fact that purely physical evidence, based on the atomic character of electricity and depending on measurements of the elementary electric charge, gives strong support to the Avogadro conception.

At the present moment fresh means of attacking the still unsolved problems of the physico-chemical field are being developed. Planck's quantum theory, for example, coupled with such experimental work as that on the heat capacity of solids at low temperatures, and on the origin and relationship of spectral lines, appears likely to have a notable influence on the future of physical chemistry. The thorough investigation of colloids along physico-chemical lines, which is actively proceeding to-day, promises to throw light on many problems which are of interest not only from the purely scientific point of view, but also to the industrial chemist. The sister sciences, too, are vitally concerned in the exploitation of this field, and, indeed, the physical chemist of to-day may point with legitimate pride to the fact that the principles of his science are welcomed by the metallurgist, the physiologist, the geologist, and others, as valuable aids in the elucidation of their respective problems. This ever-widening influence is the guarantee of the future vitality of physical chemistry.

THE INFLUENCE OF INVESTIGATIONS ON THE ELECTRICAL PROPERTIES OF GASES ON OUR CONCEPTIONS OF THE STRUCTURE OF MATTER.

BY SIR J. J. THOMSON, O.M., PRES. R.S.

ALL workers in science owe much to NATURE, and so I am glad to comply with the request of its Editor to write a few words on the progress of some branch of physics in the fifty years since NATURE was started. I shall confine myself to the effect which results obtained by investigations on the electrical properties of gases have had on our conceptions of the structure of matter and the potentiality of further applications of these results to increase our knowledge of physical and chemical problems. In these investigations we study atoms and molecules when they are charged with electricity, and the success which has been obtained is due in the main to the fact that the methods by which we can detect the existence and follow the behaviour of these charged particles are almost infinitely more powerful than those which are available when the particles are uncharged. We can by the aid of their charges detect the presence of a few thousand atoms, while the most delicate methods of chemical analysis will scarcely detect a million million. Again, when an atom or molecule is charged we can by acting upon it by electrical forces increase its energy a million-fold, and thus enable it to produce effects by which its presence can be detected. We obtain in this way very powerful and accurate methods for measuring some of the fundamental constants associated with atoms and molecules. We know now, for example, with great precision the masses of the molecules of the different gases; we owe this to the study of their electrical properties.

Again, the study of the positive rays has shown that all the atoms of an element have to a very high degree of approximation the same mass, and has disposed of the idea that the atomic weight only represented an average value taken over a considerable range. The positive rays, too, have demonstrated the existence in most gases of both atoms and molecules; not only have they shown that atoms exist, they have also proved the independent existence of the radicles of organic chemistry such as CH, CH_2, CH_3. These rays will, I think, in the future play a considerable part in the determination of the atomic weight of those elements which can exist in the gaseous form, as they furnish a method which is independent of impurities, and can distinguish between "isotopes," should such exist. The rays provide a powerful method for detecting new elements and compounds, as they demand only an infinitesimal amount of material and the atomic weight of the new body can be calculated at once from the position of its line in the positive ray spectrum. As a side issue the rays show the complexity of the conditions when electricity passes through compound gases. I have found cases in which there were as many as thirty-seven different types of positive carriers at work simultaneously.

The convection of negative electricity presents a remarkable contrast, for one of the most striking results of the study of the electrical properties of gases is that at very low pressures the carriers of negative electricity are not atoms or molecules, but electrons, the mass of which is only about 1/1700 of that of the smallest known atom, that of hydrogen; these carriers are unaltered in character whatever changes may take place in the nature of the gas through which the electricity is passing. These electrons can be obtained from atoms of every kind, so that they form an integral part of the normal atom. The number of electrons in an atom which are not fixed too rigidly to be shaken when struck by Röntgen rays has been determined, and it has been found that the number of such electrons in an atom of any element is equal to the atomic number of the element. The positive rays show that the atoms of elements other than hydrogen which occur in these rays must contain more than one electron, for atoms which have lost two or more electrons are a common feature in these rays; mercury atoms have been observed which have lost as many as eight electrons. The speed which the electrons may attain is very great; some of the electrons emitted by radio-active substances (the β-rays) travel at a speed only a few per cent. less than that of light.

The source of the mass of the electrons is interesting; it was known before they were discovered that a charged body had in virtue of its charge a larger mass than an uncharged one, the difference increasing as the size of the body diminished. The result at that time looked very academic, as even molecules were far too large for the effect to be appreciable; the result became of practical importance when electrons (the linear dimensions of which are only about one-hundred-thousandth part of those of atoms) were discovered; and the experiments indicate that the whole of the mass of an electron is due to its charge. Mass of this kind depends upon the velocity and becomes infinite when the velocity is that of light. The mass of the electrons accounts, however, for only a minute fraction of that of the atom of which they form a part.

Since we know the number of electrons in an atom, the problem of finding the structure of the atom is that of finding the configuration of these electrons when they are in equilibrium under their mutual repulsions and whatever forces may be exerted upon them by the positive charges. The solution of this problem would give representations of the structure of the atoms of the various elements. The consideration of the positions of equilibrium when two such atoms of the same or different kinds are brought near together would lead to clear views as to what constitutes chemical combination and the conditions under which it is possible. This is one of the problems which call most urgently for solution. It must be noticed, however, that we cannot explain the properties of the atoms of the elements by a system of positive and negative point charges exciting forces varying inversely as the square of the distance. These would not give rise to systems of atoms sharply limited to definite and distinct types, but to systems passing continuously from one type to another. To get the requisite definiteness in the model atom we must introduce some other condition, such, for example, as that the force between the positive and negative forces is not always an attraction varying inversely as the square of the distance, but that it changes from attraction to repulsion at definite distances (such distances giving a length to measure the size of the atom), or we may assume some condition such as is imposed by the quantum theory, which rules out all but a small fraction of the solutions otherwise possible.

RADIUM AND THE ELECTRON.

By Sir Ernest Rutherford, F.R.S.

WHEN we view in perspective the extraordinarily rapid progress of physics during the last twenty-five years, we cannot fail to be impressed with the great significance to be attached to the discovery of X-rays by Röntgen in 1895, not only from its intrinsic interest and importance, but also from the marked stimulus it gave to investigations in several directions. In fact, this discovery marks the beginning of a new and fruitful epoch in physical science, in which discoveries of fundamental importance have followed one another in almost unbroken sequence.

It does not fall within my province to discuss the great advances in our knowledge that have followed the close study of this penetrating type of radiation, but to indicate, I am afraid very inadequately, the progress in two other directions of advance which were opened up by the discovery of X-rays, and have revolutionised our ideas of the nature of electricity and the constitution of matter.

Following Röntgen's discovery, attention was concentrated on two aspects of the problem. On the one side it was thought that the excitation of the X-rays might be connected with the phosphorescence set up in the glass of the discharge tube by the impact of cathode rays, and experiments were consequently made by several observers to test whether substances which phosphoresced under ordinary light emitted a type of penetrating X-rays. By a fortunate combination of circumstances, H. Becquerel in 1896 tried the effect of a phosphorescent uranium salt, and this led to the discovery of the emission of a penetrating type of radiation, and thus laid the foundation of the new science of radioactivity, the further development of which has been attended by such momentous consequences.

On the other side, the problem of the nature and origin of the X-rays led to a much closer study of the cathode rays and to the definite proof, as Sir William Crookes had long before surmised, that the cathode rays consisted of swift charged particles of mass small compared with that of the hydrogen atom. It was soon shown that these corpuscles of small mass or negative electrons, as they are now termed, could be set free by a variety of agencies, by the action of ultra-violet light on metals and copiously from glowing bodies, while they were ejected with high speed spontaneously from the radioactive bodies.

The interpretation by Lorentz of the Zeeman effect in which the spectrum lines were displaced by placing the source of light in a magnetic field showed that electrons of the same small mass were present in all atoms, and that their vibrations constituted visible light. Sir J. J. Thomson early pointed out the significance of the electron as one of the units of atomic structure and its importance in the mechanism of ionisation in gases, and the rapid growth and acceptance of electronic ideas owes much to his work and teaching. An important stage in advance was the proof by Kaufmann that the mass of the electron was entirely electrical in origin. Sir J. J. Thomson had shown in 1881 that a charged particle acquired additional or electrical mass in virtue of its motion. The variation of mass with speed has been shown to be in accord with general theory, but is in best agreement with the formula based on the theory of relativity. It would be of great interest to compare theory with experiment for the highest attainable speed of the electron from radium which is so near to the velocity of light that the variation of mass with velocity is very rapid.

The proof that the electron was a disembodied atom of negative electricity was a great step in advance in electrical ideas. Information as to the nature of positive electricity is far less precise and definite, for no positive electron, the counterpart in mass of the negative electron, has ever been observed. In all experiments with positive rays and with radioactive transformations where the processes are very fundamental in character, no positive charge has ever been found associated with a mass less than that of the atom of hydrogen. While it is well to keep an open mind on this fundamental question, the evidence as a whole suggests that there is an essential difference in mass between the carriers of positive and negative electricity. In fact, such a difference seems to be essential to fit in with our knowledge of the structure of atoms. The nucleus of the lightest atom hydrogen may prove to be the positive electron and its much greater mass than that of the negative electron would then be ascribed to the greater concentration of the electrical charge in the former.

From consideration of the passage of electricity through gases, it had long been surmised that electricity, like matter, was atomic in character. The study of the deflection of the cathode rays and α-rays in magnetic and electric fields showed that the carriers of each type had all the same charge, and the atomic nature of electricity was implicitly assumed by all workers. Townsend showed that the charge carried by the ions in gases was equal to the charge carried by the hydrogen atom in the electrolysis of water and made the first measurements of this fundamental unit. Other methods of attack were developed by Sir J. J. Thomson and H. A. Wilson, and by a skilful adaptation of methods Millikan was able to demonstrate in a very direct way the unitary nature of electricity and to measure the value of the unit charge, probably the most important and fundamental constant in physics, with an accuracy, it is believed, of one in a thousand. By combining the value of this constant with electrochemical data, the number of molecules in a cubic centimetre of gas and the mass of the atoms can be deduced with equal accuracy. The convincing proof of the atomic nature of electricity and the accurate measure of the fundamental atomic and molecular magnitudes are two of the greatest triumphs of the new era.

One of the most important properties of X-rays is their power of making gases a temporary conductor of electricity. The study of this small conductivity led to a clear idea of the transfer of electricity through gases by means of charged ions, and the nature and difference of the positive and negative ions have been closely studied. The proof by Townsend of the production of ions by collision in electric fields opened up a new field of investigation and gave us for the first time a clear idea of the processes leading up to an electric spark. The ionisation theory was found to explain the conductivity produced by radium rays and the conductivity of flames. The laws controlling the escape of electricity from glowing bodies were closely examined by H. A. Wilson and O. W. Richardson.

It is a striking fact that these purely scientific researches on the conductivity of gases, which had their inception in the Cavendish Laboratory, and appeared at first to have only an academic interest, should so soon have resulted in important practical applications. We may instance the use of a hot filament in a low vacuum as a rectifier of alternating currents and a detector of electrical waves. The supply of electrons from a glowing filament coupled with the generation of ions by collision has led to the production of powerful electric oscillators and amplifiers for magnifying minute currents to any desired degree. These amplifiers have not only been of great service in war, but have also rendered possible radiotelephony across the Atlantic. Last, but not least, we have the invention of the Coolidge X-ray tube, which has played such an important part in research and in radiography.

While the mechanism of ionisation of gases by X-rays and radium rays and the transfer of electricity in ordinary electric fields is in the main well understood, it is a striking fact that the passage of the disruptive discharge through a vacuum tube, which was the starting point of so many discoveries, is still almost a mystery. While no doubt some of the main factors involved in the discharge are known, the phenomena in gases at low pressure are so complex that we are still far from a complete elucidation of the problem. This complexity is well instanced, for example, by the sign and magnitude of the charges communicated to atoms and molecules in the positive rays, which have been so closely studied by Wien and Sir J. J. Thomson, and in the hands of the latter have given us a very delicate method of chemical analysis of gases in a discharge tube.

The discovery of the electron as a mobile constituent of the atom of matter has exercised a wide influence on electrical theory, and has been the starting-point of attack on numerous electrical problems. In these theories the electron may be considered as a point charge with an appropriate mass associated with it, and in many cases no assumptions as to the nature and constitution of the electron itself are involved. One of the first problems to be attacked was the passage of electricity through metals where it was supposed that the negative electrons are continuously liberated from the atoms, and are in temperature equilibrium with the matter. While the theories as initially developed by Drude and Sir J. J. Thomson have been instrumental in accounting for a number of relationships, they are unsatisfactory on the quantitative side. These difficulties have been enhanced by the recent discoveries of Kamerlingh Onnes of the supra-conductivity of certain pure metals at very low temperatures and the marked departure from the law of Ohm under certain conditions. As in the case of the theory of radiation, it may be necessary for an ultimate explanation to introduce the ideas of quanta as recently proposed by Keesom. Langevin has applied the electron theory to the explanation of magnetism and diamagnetism, but there are still many difficulties. The suggestion, first proposed by Weiss, that there exists a natural unit of magnetism called the magneton, analogous in some respects to the atom of electricity, still lacks definite confirmation.

In this brief review reference can be made only to the apparently insoluble difficulties in the explanation of the facts of radiation brought to light in recent years, and to the application of the theory of quanta which has had such a large measure of success in many directions.

Radioactivity.

The rapid growth of the subject of radioactivity after the discovery by Becquerel of the radiating power of uranium was greatly influenced by the discovery and isolation of radium in 1899 by Mme. Curie, for the radioactive properties of this element were on such a scale of magnitude that they were difficult to explain and still more difficult to explain away. The systematic chemical analysis of uranium ores disclosed the presence of new radioactive substances like polonium and actinium, while the study of thorium, radium, and actinium disclosed the emission of radioactive emanations or gases and their apparently remarkable power of conferring temporary activity on all bodies in their neighbourhood. The changes in activity of these substances with time and the different types of radiation emitted at first gave an appearance of great complexity and confusion to the rapidly accumulating mass of facts, but the whole subject took on an orderly and systematic development after the transformation theory was put forward by Rutherford and Soddy in 1903 as an explanation of radioactivity. On this view radioactive matter is undergoing spontaneous transformation of its atoms with the appearance of a succession of new radioactive bodies, each marked by characteristic chemical and radioactive properties. The radiations accompany the transformation of atoms and are a measure of the rate of transformation. Guided by this theory, the whole sequence of changes in the uranium-radium series, the thorium and actinium series, were investigated in detail, and in a remarkably brief space of time more than thirty new radioactive elements were brought to light and their position in the scheme of radioactive changes determined. Special interest attaches to the discovery by Boltwood of the substance called ionium, which is directly transformed into radium. This afforded a direct experimental method of determining the average life of radium with a result that is in close accord with the value calculated from the rate of emission of α-particles. The position of actinium in the main scheme of changes has occupied much attention. The constancy of the relative amount of actinium and uranium in uranium minerals showed that it must be derived ultimately from uranium, but the activity of actinium is too small to be in the direct line of succession. This has led to the view that actinium is a branch product at some point of the uranium series where about 6 per cent. is transformed into the actinium branch and 94 per cent. into the main line of descent. The general evidence indicates that this branching occurs near to uranium, and possibly the branch product called uranium-Y by Antonoff is the first member of the family. Recently the intermediate parent substance of actinium itself has been discovered.

While in the majority of cases the atoms of a radioactive product break up in a very definite fashion and in only one way, certain cases are known where one substance breaks into two chemically distinct substances. Examples of this are: radium C, thorium C, and actinium C. Usually the transformation is mainly in one direction with a small fraction in the side branch. It is quite probable that further study may lead to the discovery of a number of such dual transformations. In the violent cataclysm that must accompany the transformation of an atom, it is not unexpected that the constituents of the residual atom may arrange themselves in more than one configuration of temporary equilibrium.

Much attention has been directed to the properties of the radium emanation—the radioactive gas constantly produced by the transformation of radium atoms. The equilibrium volume of this gas from one gram of pure radium is only six-tenths of a cubic millimetre, but contributes more than three-fourths of the total activity of radium. By concentration of purified emanation into fine glass tubes, very powerful sources of radiation have been obtained, which have proved of great utility both in the laboratory and for therapeutic purposes. Although only about one-tenth of a cubic millimetre of purified radium emanation has ordinarily been available for experiments, methods have been devised to determine its spectrum, molecular weight, freezing and boiling points.

We owe to Hahn the discovery of two fairly long-lived products of thorium called mesothorium and radiothorium. The mesothorium, which is separated with the radium from ores containing both thorium and uranium, is transformed into radiothorium. These products can be obtained of activity greater than radium for equal weights, and give us another source of powerful radiation.

The discovery of the production of helium from radium by Ramsay and Soddy was of great importance in emphasising the reality of the transformations occurring in radium. Rutherford showed that the α-rays which are shot out from radium consist of positively charged atoms of helium so that all radioactive substances which emit α-rays give rise to helium. The production of helium by radioactive substances explains the occurrence of large quantities of helium in uranium and thorium minerals, and indeed the prediction by Rutherford and Soddy that helium would prove to be a product of radioactive transformation was based in part on this fact.

The great majority of radioactive substances are transformed with the expulsion of helium atoms with great velocity, but in a few cases swift electrons appear. The appearance of helium in so many changes, coupled with the observation that many of the atomic weights of many known elements differ by four units—the atomic weight of helium—indicates that helium must be one of the secondary units of which many of the ordinary elements are built up. It is noteworthy that so far no definite evidence has been obtained that hydrogen is a direct product of radioactive transformation, although its complete absence would be very surprising.

The proof by the Curies of the rapid and continuous emission of heat from radium showed clearly the vast amount of energy that must be stored up in radioactive matter and released by its transformation. This heat emission has been shown to be a secondary effect of radioactivity, for it is a measure of the energy of the expelled radiations, the greater part being due to the energy of the expelled α-particles.

The transformation of an atom is the result of an explosion of intense violence in which a part of the atom, whether a helium atom or an electron, is shot out with great speed. In order to produce α-, β-, or γ-rays of equal energy to those emitted by radioactive substances, potential differences of about two million volts applied to a vacuum tube would be necessary. These spontaneous radiations have been of great utility in studying the ionisation, scattering, and other properties of particles moving at high speed, while in the very penetrating γ-rays we have a type of X-rays of much shorter wave-length than can be produced at present or is likely to be produced by laboratory methods.

The properties of the α-rays have been very closely studied and their speed and mass have been determined accurately. The definiteness of the range of α-particles, to which Bragg first directed attention, is a matter of remark, and so far the apparent disappearance of the α-particle while still moving with a high velocity has not been adequately explained. The analysis of the β-rays has disclosed the presence of groups of electrons emitted at a definite velocity, so that the pencil of β-rays deflected in a magnetic field shows a veritable magnetic spectrum. The presence of these groups of β-rays appears to be connected with the emission of characteristic X-radiation from the atom, and the evidence as a whole strongly supports the view that the γ-rays from radioactive substances, like the X-rays from a vacuum tube, contain rays of a wide range of frequency in which the characteristic rays from the atom predominate.

Space does not allow me to do more than mention the extraordinary delicacy and definiteness of the electrical methods devised for measuring minute quantities of radioactive matter. By their aid the chemical properties of the numerous radioactive elements have been studied and their position in the periodic table established. The orderly sequence of changes in the chemical properties of successive elements in the radioactive series has been shown to be intimately connected with the type of radiation, whether α- or β-ray, emitted by the preceding element. One of the most important fruits of these chemical investigations has been the proof of the existence of non-separable elements, named isotopes by Soddy, which are identical in ordinary physical and chemical properties, but have different atomic weights. In the case of lead, six isotopes are already known which differ from one another either in atomic or radioactive properties. On the nucleus theory of the atom, this indicates that the charges on the nuclei are the same, but that the masses differ. The proof of the presence of isotopes promises to open up a new and very fundamental field of chemical inquiry which must inevitably exercise a great influence on atomic weight determinations and also on our ideas of atomic constitution. In a recent letter to this journal Merton has indicated that the minute change in the wave-length of spectrum lines of isotopes may give us a simple method of attack on this problem.

While the subject of radioactivity belongs in essence to the border-line of physics and chemistry, with affiliations to both sciences, it has had numerous connections with other fields of work. The examination of the earth's crust has shown that radioactive matter is very widely distributed, and has disclosed, notably through the work of Strutt and Joly, that the heating effect due to this matter vitiates to a large extent the old arguments of the duration of the earth's heat. While showing that the old views are not tenable, radioactivity has at the same time supplied new methods of estimating the age of minerals and the duration of geological epochs. The minimum age of minerals can be deduced from the helium accumulated from the transformation of radioactive matter, and the maximum age from the accumulated lead which is the product of both uranium and thorium. Now that the atomic weights of the lead isotopes are well established, the atomic weight of the lead in a uranium mineral should serve as a definite guide to the fraction of lead present which is due to the transformation of uranium and thus give a trustworthy estimate of the age of the mineral. Joly has demonstrated in a striking way that the pleochroic haloes observed in mica are of radioactive origin, and he has also estimated their age. The presence of radioactive matter in the atmosphere has been shown to account for its electrical conductivity. Just before the war, evidence was obtained indicating the presence of a very penetrating type of γ-radiation in the upper atmosphere. It is to be hoped that soon a further study will be made to determine the nature and origin of this interesting radiation. Finally, numerous investigations have been carried out to determine the effects of the radioactive rays on living tissue and on the growth of plants and organisms. With the increased use of radium for therapeutic purposes, it is likely that our knowledge of this important field of inquiry will grow rapidly.

It is a matter of remark that while the study of radioactivity has disclosed in a striking way the transformation of heavy atoms through a long series of stages, it has at the same time provided us with indubitable proof of the correctness of the old atomic theory of matter. The electric method devised by Rutherford and Geiger of counting single α-particles allows us to count the total number of α-particles projected from one gram of radium per second. By determining the volume of helium produced by the collected α-particles, we have a simple and direct method of determining also the number of molecules in a cubic centimetre of helium at standard pressure and temperature. This number is in good agreement with the number found by Millikan by measuring the charge on the atom of electricity. On account of the great energy of motion, a single α-particle can be detected in a variety of ways, by the electrical method, by the scintillations produced in zinc sulphide or the diamond, and by its action on a photographic plate.

The most striking proof of the individuality of the electron, the α-particle, and the ion has been given by C. T. R. Wilson by his beautiful photographs showing the trails of α- and β-particles through gases. By a sudden expansion, each charged ion produced by the flying particle is rendered visible by becoming the centre of a visible drop of water. In the case of the swift electron, the number of ions per centimetre of path is so small that the number may be directly counted. These photographs bring out in a vivid and concrete way the phenomena accompanying the passage of ionising types of radiation through gases, and are, in a sense, the ultimate court of appeal of the accuracy of theories of the properties of these rays.

The discovery of the electron and of the property of radioactivity has given a great stimulus to attempts to deduce the structure of the atom itself, and numerous types of model atoms have been proposed. The great difficulty in these attempts is the uncertainty of the relative importance of the *rôle* played by positive and negative electricity. In the model atom proposed by Sir J. J. Thomson the electrons were supposed to be embedded in a sphere of positive electricity of about the dimension of the atom as ordinarily understood. Experiments on the scattering of α-particles through large angles as the result of a single collision with a heavy atom showed that this type of atom was not capable of accounting for the facts unless the positive sphere was much concentrated. This led to the nucleus atom of Rutherford, where the positive charge and also the mass of the atom are supposed to be concentrated on a nucleus of minute dimensions. The nucleus is surrounded at a distance by a distribution of negative electrons to make it electrically neutral. The distribution of the external electrons on which the ordinary physical and chemical properties of the atom depend is almost entirely governed by the magnitude of the positive charge. The experiments by Marsden and Geiger on the scattering of the α-particles, and also on the scattering of X-rays by Barkla, show that the resultant units of charge on the nucleus of an element is about equal to its atomic number when arranged in order of increasing atomic weight. Strong proof of the correctness of this point of view has been given by the work of Moseley on the X-ray spectra of the elements, for he has shown that the properties of an element are defined by a whole number which changes by unity in passing from one element to the next. It is believed that the lightest element, hydrogen, has a nuclear charge of one, helium of two, lithium of three, up to the heaviest element, uranium, of charge 92.

Radioactive evidence indicates that the nucleus contains both positively charged masses and negative electrons, the positive charge being in excess. Apart from the difficulty on the ordinary laws of electric forces of explaining why the nucleus holds together, there is a fundamental difficulty of accounting for the stability of the external electrons on the ordinary laws of dynamics. To overcome this difficulty, Bohr has applied the quantum theory to define the position of the electrons and to account for the spectra of the lighter atoms and has made suggestions of the structure of the simpler atoms and molecules. Space does not allow me to discuss the important developments that have followed from Bohr's theory by the work of Sommerfeld, Epstein, and others. The generalised theory has proved very fruitful in accounting in a formal way for many of the finer details of spectra, notably the doubling of the lines in the hydrogen spectrum and the explanation of the complex details of the Stark and Zeeman effects. In these theories of Bohr and his followers it is assumed that the electrons are in periodic orbital motion round the nucleus, and that radiation only arises when the orbit of the electron is disturbed in a certain way. Recently Langmuir, from a consideration of the general physical and chemical properties of the elements, has devised types of atom in which the electrons are more or less fixed in position relatively to the nucleus like the atoms of matter in a crystal. It appears necessary, in Langmuir's theory, to suppose that electrons, in addition to their electrical charges, are endowed with the properties of a magnetic doublet, so that at a certain distance the forces of attraction and repulsion between two electrons counterbalance one another.

The whole question of the possible arrangements and motion of the external electrons in an atom or molecule still remains a matter of much doubt and speculation. While there are strong indications that the conception of the nucleus atom is in the main correct, we are still very uncertain of the laws controlling the position of the external electrons on which the ordinary physical and chemical properties depend. The study of the light spectra and also of the X-ray spectra already promise to throw new light on this very difficult but fundamental problem.

From the above hurried survey of the progress of atomic physics, it will be seen that the investigations of the past twenty-five years have dealt mainly with three great outstanding problems, viz., the nature of electricity, the structure of the atom, and the nature of radiation. While great additions have been made to our knowledge of these questions leading to a much wider outlook, we cannot but recognise that much still remains to be done before we are certain that we are building on a firm foundation for the future. Notwithstanding the prolonged halt during the war, the scientific outlook is one of good augury for the immediate future, and there is every prospect that the vigorous attack on these outstanding problems will be continued.

ATOMS AND MOLECULES.

BY PROF. FREDERICK SODDY, F.R.S.

IT may be doubted whether, fifty years ago, chemists and physicists believed very deeply in the actual reality of the molecules and atoms, which they used as convenient and simplifying conceptions to interpret the behaviour of matter. The half-century, indeed, has not passed without strong protest from the thermodynamical school of physical chemistry that the science should be so wedded to pure hypotheses and unverifiable assumptions, then, apparently, for ever beyond the power of being actually apprehended and demonstrated. That the modern student of physical science believes in the reality of the existence of his atoms and molecules, as much as he does in that of chairs, tables, and lamp-posts, probably sufficiently epitomises one of the most striking features of the change of outlook since NATURE made its first appearance in 1869. Vague ideas of their actual individual mass, size, shape, and constitution have been or are being replaced more and more by exact quantitative knowledge, which invites our literal acceptance and grows in fruitfulness the more implicitly it is used as the basis for further investigations.

But the latter half of the period under review witnessed an even greater change of outlook. The atom, since the discovery of radio-activity in 1896, has ceased to be the smallest coin of the realm of material change. The farthings of 1869 have proved to resemble 1000*l*. notes, and the potentialities of the world in consequence have been multiplied a million times. The change of the single atom of matter is well within the range of direct perception by the senses, and, stranger still, the change reveals that, under the image and superscription of the same Cæsar, coins of different mass and mintage have been circulating unsuspected in the chemist's currency.

As regards the physical reality of molecules, by no means the least important factor contributing to the result has been the recognition that, if the molecules were not the smallest parts of matter capable of free independent existence and motion, heat would not be the final permanent form which all kinetic energy liberated in the world assumes. The limit that fixes the physical sub-division of matter limits also the sub-division of motion. Though in the real world of matter in bulk, as contrasted with the ideal fictions of mathematics, friction and imperfect elasticity quickly reduce all moving masses to apparent rest, that "rest" is the perpetual heat motion of the molecules, which, literally and necessarily, must be perfectly frictionless and elastic because they are the smallest particles capable of free independent motion, and no smaller particles exist among which their motion can be further distributed.

Moreover, in accordance with the law of equipartition of energy, all molecules at the same temperature, whatever their mass, become, in consequence of their ceaseless mutual collisions, possessed of the same average amount of kinetic energy, and, therefore, of a velocity of translation inversely proportional to the square-root of their mass. This serves to clarify the conception of the real molecule from misnomers still unthinkingly retained.

For example, it is a pure survival of past confusion to speak of the molecule of a crystalline solid, if not of any solid, for in such the smallest parts are not free to move, but are anchored in fixed, unchanging positions in the crystal space-lattice, as the resolution of X-rays by the crystal structure has shown. It is, similarly, always a pure misnomer to give the name "molecule" to the least number of atoms which represent the chemical composition and properties of a substance, in the absence of experimental knowledge of the molecular magnitude, and therefore of any knowledge as to whether such a particle really exists in a form capable of free independent movement.

Cleared of these ambiguities, the conception of the individual molecule has become very real. We have been led by Perrin, and the mathematical physicists who paved the way for his experimental work, to recognise the Brownian movement as but one aspect of the perpetual motion of the molecules, which, though invisible to the naked eye, becomes swift and ceaseless for particles even of the scale of minuteness resolved by the microscope, and we can extrapolate with assurance to the minuter world which science had long before visualised by faith.

Or, again, we may follow Langmuir, with none of the feeling of hesitancy and diffidence that would have held back an earlier generation, into the explanation of catalysis, adsorption, and allied phenomena, as caused by surface layers of molecules "one molecule thick." Nor do we consider it fanciful to explain the spreading of animal and vegetable oils upon water and the non-spreading of mineral oils, as due to the attempt, in the first case, of the one end, the soluble glycerine ester end, of the rod-like molecule to dissolve in the water, and the refusal of the other end, the insoluble, hydro-carbon, or oily end, to do so. Wherefore the molecules of such oils stand up on end and cover the surface with a one-molecule thick layer of the oily ends of the molecules, whereas the mineral oils, with molecules oily at both ends, do not spread! Real in one sense as the structural formulæ of organic compounds have been for many decades, an earlier generation would scarcely have thought of this.

The discovery that the X-rays are of a character identical with light, but of wave-length of the order of one ten-thousandth of that of light of the visible spectrum, has made the structure of crystalline solids as open to direct examination as the ten-thousand-fold coarser structure of the Rowland grating, ruled by the dividing engine, is by means of ordinary light. In this way many of the space-lattices hitherto arrived at only by the aid of the second-sight of the mathematical crystallographer have been tested and found real.

Since the explanation by Le Bel and van't Hoff of optical isomerism as due to structural differences of the arrangement of the atoms in the molecule, of the kind that exist between an asymmetrical object and its mirror-image, and therefore only capable of representation in space of three dimensions, chemists have, not without reproach, used model carbon atoms in building up the structure of organic compounds, and have found them capable of accounting, for example, in cyclic structures, for many of the properties of these compounds far removed from the field of optical activity. That the real carbon atom should possess any resemblance to these little wooden balls bearing four spokes radiating symmetrically from the centre may have appeared to many too crude a conception for literal belief. Yet when the character of the space-lattice of the diamond crystal was elucidated by means of the X-rays, these very models were used to represent it—a striking proof, surely, of the basis of physical reality underlying the conceptions of stereo-chemistry.

But these triumphant vindications of what only a generation ago were described as purely hypothetical and unverifiable conceptions have been to some extent overshadowed and eclipsed by the startling progress made since the discovery of radio-activity in 1896 and its almost immediate interpretation as due to the explosive disintegration of the atoms of the radio-elements. This subject is being treated by Sir Ernest Rutherford in another article, and need be only briefly alluded to here. The change is attended by the liberation of energy a million times greater than is liberated in any previously known change of matter, and so it has come about, as for example in the spinthariscope, that the effect of each individual atom disintegrating can be perceived by the senses. The counting of the number of atoms disintegrating per minute has become one of the regularly used methods of investigation, whereas it requires, at least, some 25,000 times as many atoms as there are people alive in the world before an element can be detected by the spectroscope. The condensation of moisture on the columns of ions, lying in the tracks of the fragments of the atom after its explosion—both of the α- and β-particles, which may be likened to projectiles fired from a gun, and of the recoiling residue of the atom or gun itself—has in the hands of C. T. R. Wilson enabled the individual atomic explosions to be photographed. These permanent records, of extraordinary interest and value as they are as confirmatory evidence, yet revealed nothing new. Every detail of the whole phenomenon had been correctly comprehended and established without such direct aid. In particular, the photographs show well the almost rectilinear flight of the α-particle through the myriads of gas atoms in their path, and their rare and occasional wide-angle deviation when perchance they pass near enough to the heart of the atoms penetrated, which is the experimental basis for the present provisional representation of the internal structure of atoms.

The atom is regarded now as a solar system, but the massive central sun, comprising all but a negligible fraction of the whole mass, is an exceedingly minute positively charged nucleus, attended by numerous rings or shells of the almost mass-less electrons. In spite of its relatively great mass, the nucleus is so minute that the chance of an α-particle—which itself is the nucleus of a helium atom—in its passage through the atom approaching or colliding with the central nucleus, is exceedingly small. Mass and radio-activity alone seem to depend directly upon this hitherto unsuspected and all-important nucleus. The chemical and physical properties, including the light spectrum, are governed probably by the outermost shell or ring of valency electrons, which alone are variable in number. The coming and going of these seem to constitute chemical change and to give rise to ordinary light radiation. Barkla's various series of X-rays characteristic of each element probably originate in the successive completed rings or shells of electrons surrounding the nucleus.

All the properties of the atom, practically, save mass and radio-activity, depend solely upon the numerical value of the positive charge of the nucleus, which is equal to the number of the surrounding negative electrons. This number, which is known as the atomic number, increases unit by unit in passing from one place of the periodic table to the next. From numerical relationships between the wave-lengths of the characteristic X-rays, Moseley was able to determine or infer this atomic number for all the elements. So he called the roll of the elements for the first time and found between hydrogen, the first, and uranium, the last and ninety-second element in the table, only five still missing.

In the course of successive radio-active changes the radio-element expels from its nucleus an α- or β-particle, so losing two positive charges, or, relatively, gaining one, and shifting back two places or moving forward one in the periodic table. The expulsion of one α- and two β-particles produces an isotope of the parent, chemically and spectroscopically identical with it, but of atomic mass four units less. The ultimate products of uranium and thorium have been identified as isotopes of lead of atomic mass 206 and 208 respectively, and this has been confirmed by an examination of the atomic weight of the lead derived from uranium and thorium minerals. Of all strange consequences of the atom changing, this is perhaps the most subtle and hitherto unsuspected, for now nothing is more certain than that the analysis of matter into chemical elements depends on a superficial identity of the outer shell of the atom, and that the same type of outer shell may contain internal nuclei of different mass and different constitution.

Naturally, the many, at first separate and independent, lines of evidence which have led to the present results cannot all be even mentioned in an article of this length. The significant fact is that all the new and powerful methods of attack developed by physics and chemistry during the last quarter of a century are converging successfully on the problem of the internal constitution of the atoms. The prospects of successful accomplishment of artificial transmutation brighten almost daily. The ancients seem to have had something more than an inkling that the accomplishment of transmutation would confer upon men powers hitherto the prerogative of the gods. But now we know definitely that the material aspect of transmutation would be of small importance in comparison with the control over the inexhaustible stores of internal atomic energy to which its successful accomplishment would inevitably lead. It has become a problem, no longer redolent of the evil associations of the age of alchemy, but one big with the promise of a veritable physical renaissance of the whole world.

Even in the present year a further significant advance in this direction has been made. For it appears, from the latest results of Sir Ernest Rutherford on the passage of α-particles through nitrogen, as though the nuclei of an exceedingly minute proportion of the nitrogen atoms struck by the α-particle were shattered by the collision. If this is so, artificial transmutation on an infinitesimal scale has already been accomplished, though, it is true, only by the aid of a previous natural transmutation, still impossible artificially to imitate.

IONISATION OF GASES.

BY PROF. J. S. TOWNSEND, F.R.S.

DURING the last fifty years many physicists have been occupied in studying problems connected with electric currents in gases. The earlier work was principally confined to experimental investigations of the general outlines of the phenomena which occur in discharges obtained with high potentials. The large number of complicated and surprising properties of gases which were thus discovered naturally attracted much attention, and it is very interesting to read the accounts of the first experiments of the discharges in air and through vacuum tubes which were written before any special investigations of the theory of the conductivity were undertaken.

It would clearly have been extremely difficult to obtain from these experiments any general theory of electricity to explain what was taking place, as such a large number of different phenomena seemed to occur simultaneously. From the first, some physicists maintained that the currents through gases were carried by means of ions, as in liquids, although there were peculiar differences between the two cases, and it was not evident why under a given force a gas might act either as an insulator or as a conductor.

The greatest success in advancing the theory of electricity was obtained from careful studies of the discharges at very low pressures. In this direction some remarkable experiments on the cathode rays were made by Hittorf in 1869. He found that the rays travelled in straight lines from the cathode; when they fell on glass they caused the surface to fluoresce, and an obstacle in the path of the rays cast a shadow on the glass. He also found that the rays were deflected by a magnet into circles, or more generally into spirals, which were described in the direction which would be taken by negatively charged particles moving from the cathode. Notwithstanding these results, and further experiments made by Crookes, the projected particle theory of the rays was not at first universally accepted, and some physicists maintained that the rays were an undulatory motion of the ether. This question was decided by Perrin in 1895. He showed by direct experiment that the rays carried a negative charge, but thus far the origin of the rays, their velocity, and the mass and charge of each particle were unknown.

The question of the ratio of the charge to the mass was studied by Schuster in 1890, and he concluded that in gases it was of the same order as in liquids, but for negative ions it was larger than for positive. This was the first indication of the characteristic difference between positive and negative ions in gases.

A direct method of finding the ratio of the charge e to the mass m of the cathode particles, and the velocity of the particles, was devised by Wiechert, and in 1897 he described the experiments which showed that in some cases the velocity of the rays was about one-tenth of the velocity of light, and that the ratio e/m for the cathode rays was between 4000 and 2000 times as great as the corresponding quantity for a hydrogen atom. Thus, assuming the charges to be the same in the two cases, the experiments showed that the mass of a cathode particle is very small compared with the mass of an atom of hydrogen. This small cathode particle has been called the electron. Further experiments show that currents of negative electricity obtained from metal surfaces by other methods also consist of streams of electrons. Thus Sir J. J. Thomson investigated the charged particles set free from hot wires or from a metallic surface by the action of ultraviolet light, and found that in both cases the ratio e/m was the same as for cathode rays. The values of e/m afterwards found by various methods show that the ratio of the mass of the electron to the mass of an atom of hydrogen is 1 : 1830. This value of e/m is constant provided the velocity is small compared with the velocity of light, but with velocities of this order the effective mass of the electron increases, and Kaufmann found that the value of e/m diminishes in accordance with Lorentz's theory as the velocity approaches the velocity of light.

During the earlier part of this period some investigations were made of the currents that can be obtained with forces smaller than those required to produce discharges. The positive and negative ions produced in air at atmospheric pressure at the surface of incandescent metals, the conductivity of flames, and the charges obtained in newly prepared gases, or by bubbling air through water, were examined. In these cases the mass associated with the ions is comparatively large, and varies rather irregularly over wide ranges, so that it was difficult to formulate precise theories from the results of the experiments. These large ions have the property of condensing water vapour, and in a moist atmosphere small drops are easily obtained which form a visible cloud. This phenomenon led to the method of estimating the charge on each particle. The number of particles in a given volume was found by dividing the weight of the cloud by the weight of each particle estimated from the rate of fall of the cloud. The charge on each particle was then obtained by dividing the total charge by this number. Various corrections and improvements were later introduced by Millikan, and the charge on an ion in a gas has been found to be $4{\cdot}7 \times 10^{-10}$ electrostatic unit.

The remarkable discoveries made by Röntgen and Becquerel, which have led to so many advances in the knowledge of molecular physics, were of invaluable assistance in providing means of studying the properties of ions in gases. It was found that X-rays and the rays from radioactive substances made gases conduct, and it was possible to obtain ionisation at a uniform rate in gases under various conditions, with the advantage that the mass associated with the ions was not liable to irregular change.

Special experiments were devised to determine the rate of recombination of positive and negative ions, the velocity of the ions under electric forces and their rate of diffusion; and various properties of ions in gases were discovered.

The experiments on diffusion, for instance, led to a method of finding the number of molecules per cubic centimetre of a gas and of comparing the charges on ions in liquids and in gases. If N be the number of molecules per cubic centimetre of a gas at atmospheric pressure and 15° C., and e the charge on an ion in a gas, a direct determination of the product $N \times e$ is given by observing the lateral diffusion of a narrow stream of ions. The value of $N \times e$ thus found is $1{\cdot}23 \times 10^{10}$, and as the charge e was also found by other experiments, the value of N is seen to be $2{\cdot}6 \times 10^{19}$.

If E be the charge on a hydrogen ion in a liquid, the total charge $2N \times E$ carried by all the atoms in a cubic centimetre of the gas is equal to the quantity of electricity required to evolve that volume. When expressed in electrostatic units, the latter quantity is $2{\cdot}46 \times 10^{10}$. Thus the two charges E and e are the same.

Another line of investigation was undertaken in order to discover how ions are generated in large numbers, as when small changes of force convert a gas from an insulator to a conductor. It was found that when ions are generated by Röntgen rays or by ultra-violet light a maximum current composed of ions generated by the rays was obtained with small forces, but as the force increased beyond a certain point new ions are generated in the gas by the motion of those produced initially by the rays. At first the new ions are produced by the collisions of negative ions, or electrons, with molecules of the gas, and as the force increases and approaches the value required to produce a discharge, the positive ions also acquire the property of generating others by collision.

The theory of ionisation by collision was found to be in accurate agreement with the experimental determinations of the forces required to produce spark discharges, brush discharges, and the corona discharge which is accompanied by a glow over the surface of a wire or cylinder.

Thus the various properties of ions which have been discovered in the last fifty years have already explained many phenomena connected with electric currents.

SPECTROSCOPIC ASTRONOMY.

By PROF. A. FOWLER, F.R.S.

THE science of celestial chemistry and physics was brought into existence in 1859, when Kirchhoff's famous experiment on the reversal of spectral lines furnished the key to the interpretation of the dark lines of the solar spectrum, and thence to the determination of the composition of the sun and stars. The new science developed with extraordinary rapidity, and within ten years the spectra of all the different classes of celestial bodies had been carefully observed. The gaseous nature of some of the nebulæ had been discovered by Huggins, and a spectroscopic classification of stars had been made on such sure foundations by Secchi that it still survives as one of the most convenient modes of describing the main features of stellar spectra. The memorable discovery by Lockyer and Janssen of the method of observing solar prominences without waiting for an eclipse of the sun was also made during this fruitful period, and the possible determination of the radial motions of stars by displacements of the spectral lines had been put to a practical test by Huggins. The demonstration that the immensely distant celestial bodies were composed, in part at least, of the same kinds of matter as the earth may well take rank among the greatest triumphs of science.

The half-century which has elapsed since the first issue of this journal has witnessed a progress which must far exceed the highest hopes of the earlier workers. Some of the advances have followed from the increased apertures of the telescopes which collect the light for spectroscopic examination, but many more are to be attributed to the substitution of photographic for visual methods of observation which was made practicable by the introduction of the gelatine dry plate.

Great observatories dedicated to astrophysics have been erected, notably in America, and observational methods have reached a high degree of refinement. In solar investigations, where the great intensity of the light allows of the use of instruments of high resolving power, velocities on the sun's surface can now be measured with a probable error of only a few metres per second; and even more remarkable is Hale's determination of the general magnetic field of the sun by observations of Zeeman effects involving displacements usually amounting to less than one-thousandth of an Ångström unit. Stellar spectroscopes have been improved by the provision of temperature control and other aids to efficiency, so that radial velocities are now measurable in the case of the brighter stars to within a quarter of a kilometre per second. With the exceptional resources of the Mount Wilson observatory, stellar spectra have even been photographed on a scale comparable with that of Rowland's great map of the solar spectrum, providing data for deductions, among other things, on such a delicate matter as that of the pressure in the atmosphere of a star.

Not less important has been the development of experimental researches bearing upon the interpretation of celestial spectra. The study of enhanced lines initiated by Lockyer has been especially productive, not only in relation to stellar temperatures, but also in leading to a satisfactory explanation of most of the lines which are met with in the spectra of the hotter stars, where we might well have expected that the reproduction of the conditions would be outside the range of our laboratory resources. The application to sun-spots of Zeeman's discovery of the effect upon spectrum lines of a strong magnetic field, and Ramsay's discovery of terrestrial helium following its previous detection in the sun's chromosphere, are familiar examples of the close bonds which unite astronomy with other sciences to their mutual advantage.

The spectrum of the sun has naturally been the subject of an immense amount of detailed study, and as the work has progressed it has become less and less probable that there are any substances in the sun which do not also exist on the earth. The spectra of sun-spots and of the chromosphere have also been minutely recorded, and most of their peculiarities have been satisfactorily accounted for. The bright lines of the coronal spectrum, however, have not yet been matched in any terrestrial source, but the precise knowledge of this spectrum which has been obtained during total eclipses has stimulated theoretical investigations, and some extremely suggestive relations have been deduced by Nicholson in his calculations of the spectra of atoms of assumed simple structure. Similar considerations have also been extended to the unidentified lines which occur in nebulæ.

As regards the stars, many of them have been photographed in great detail for minute analysis, and a multitude more for purposes of classification. Secchi's classification, at first merely empirical, soon came to be regarded as indicating the actual sequence of forms assumed by a star in the process of cooling, and the same idea is embodied in the Harvard system of classification, which has been most widely adopted by astronomers in recent years. Lockyer, however, has based a classification on the supposition that there must be stars which are becoming hotter as well as stars which are cooling down, in accordance with the theory of condensing masses of gas or meteorites, and this view has lately been greatly strengthened by the work of H. N. Russell on the densities of stars. In either case the impressive result is that the different types of stars are not to be looked upon as arising from fundamental differences of composition, but as representing successive stages in an orderly evolutionary progression.

The spectroscopic determination of the velocities of stars in the line-of-sight, irrespective of distance, has united the old and the new astronomy in the great task of deciphering the intricacies of structure of the sidereal universe. Besides contributing the velocities and spectral classes of individual stars, the spectroscope has revealed the existence of a large number of close binary systems, and has provided the most trustworthy means of investigating the sun's motion in space, the effect of which is to be eliminated in deducing the movements of the stars themselves.

An entirely new field for the spectroscope has been opened up by the remarkable discovery by Adams of a method of estimating the absolute brightnesses, and thence the distances, of the stars by mere inspection of photographs of their spectra. This novel method is full of promise, and encourages the hope that other equally unexpected applications of the spectroscope may yet be discovered.

Lack of space forbids even the enumeration of many other remarkable achievements, but sufficient may have been said to convey some impression of the enormous extension of the scope of astronomical research which has been brought about by the introduction of the spectroscope. It cannot be doubted that the spectroscope will continue to play a leading part in the advancement of our knowledge of the universe of which we form a part.

X-RAYS IN PHYSICAL SCIENCE.

BY PROF. W. H. BRAGG, F.R.S.

IT is twenty-four years since Röntgen made the famous discovery which at once excited such immense and widespread interest. Everyone felt the fascination of the photograph which actually showed the bones of a living human hand. Surgeons seized on its obvious application to their craft; students of physical science realised that a new and most powerful means of investigation had been placed in their hands. And at the present day we see that the first expectations have been more than realised. We stand only at the beginning of what the Röntgen rays promise to accomplish for us.

Knowledge of the main properties of the X-rays grew rapidly under the labours of Röntgen himself and the many investigators who were attracted to the new field. Much was discovered respecting the power of penetrating various substances, the existence of different qualities, hard or penetrating, soft or less penetrating, the dependence of quality on the degree of evacuation, the construction and the applied potential of the X-ray bulb, the action on the photographic plate and on the fluorescent screen, and the power of producing ions in a gas. At the same time, the technique improved rapidly; bulbs, plates and screens, coils and interruptors were all designed afresh to meet the demands of an experiment which grew into an industry.

Notable advances were made by Barkla when he proved the existence of a polarisation which was to be expected on the hypothesis that the rays were ethereal waves or pulses, and when he showed that every element emitted its own special and characteristic X-rays under proper stimulus. The properties of characteristic radiation are most remarkable and instructive. The radiation of any element can excite the corresponding characteristic radiation in elements lighter than itself, but never in any element which is heavier. For example, "zinc rays" can excite the characteristic radiation of magnesium, potassium, or nickel, but not the characteristic radiation of bromine or silver, nor, indeed, of zinc itself. Since energy is necessarily spent in the excitation of radiations, the absorption coefficients of zinc rays by the various elements show a marked discontinuity; they increase steadily from magnesium upwards, but there is a sudden drop at zinc, the coefficient falling to about one-eighth of its previous value. After that the coefficient increases steadily with the atomic weight as before.

X-rays can excite an electron radiation in any substance on which they fall, and this effect has also been the subject of much investigation. The more penetrating the X-rays, the higher the velocity of the electron which it can cause to be emitted. This effect is carried to an extreme in the corresponding emission of very high-speed electrons under the stimulus of the γ-rays of radium, for the parallelism between all the properties of X-rays and γ-rays is an obvious indication of the similarity of their nature. There is a striking correspondence in the two processes—that of the excitation of X-rays by the moving electrons of the X-ray bulb, and that of the emission of electrons under the stimulus of X-rays. The quality of an X-ray depends on the velocity of the electron that excited it, and not at all on the number of electrons in the exciting stream; conversely, the velocity of an electron due to X-rays depends only on the quality of the rays, and not at all on their intensity. Some kind of matter is required to bring about either of the energy transformations, but the atomic weight of it has no influence on the principle just stated. Anomalies may appear when characteristic radiations are excited, but they can be explained as apparent only.

Many other remarkable properties, which cannot be described in so brief a notice as this, were discovered in the first period of X-ray investigation. All of them were examined with the greatest interest, because it was recognised that if X- and γ-rays were essentially of the same nature as light, their study must contribute to any true theory of light radiation, and, indeed, must be necessary thereto.

A new period of investigation began when von Laue and his collaborators demonstrated in 1912 that X-rays could be diffracted by the ordered array of the atoms of a crystal. From a simple interpretation of von Laue's principle, and from the results of its application to the study of crystals of sodium and potassium chloride, W. Laurence Bragg was able to discover the actual arrangement of the atoms of those crystals and the distances separating the atom-bearing planes. It thus became possible to find the actual length of an X-ray. The older and vaguer methods of defining the quality of an X-ray were at once replaced by a method of great precision. Previous work can now be revised under infinitely better conditions, and much has already been accomplished in that direction.

Moseley, making a careful survey of the wave-lengths of the radiations of all the elements available, showed that the wave-length of the characteristic radiation marched in perfectly even step with the increase of the atomic number, and, therefore, that the atomic number of an element defined it more fundamentally than its atomic weight. So all the elements were drawn together by a common tie as they had never been before; anomalies of position in the periodic table were explained, and the number and places of missing elements were made clear.

The examination of the interchange of energy between X-radiation and electron movement can now be made so effectively that it has been possible to use the experimental results for one of the best determinations of Planck's constant.

In another direction the new discoveries have opened out a wide road of advance into crystallography. In the first place, it is possible to determine the crystal lattice—that is to say, to measure the sides and angles of the rhomboid cell which contains the unit pattern of atomic assemblage and is repeated throughout the crystal without change of form or orientation. This is a comparatively easy task. It is a second and more difficult task to determine the arrangement of the atoms within the cell; it has been accomplished in a few single cases only. Lastly, the new researches will give us information concerning the position of the electrons or the diffracting centres within the atoms and about their normal movements. Something has already been done in this direction also.

Moreover, the new knowledge reacts on older information, shaping it for interpretation and making it more valuable. From a knowledge, for example, of the elastic constants of crystals, the forces between the atoms themselves may be calculated as soon as the architecture of the crystal is known. It will be possible to make use of facts concerning cleavage planes, occurrence of certain natural faces and not of others, etching figures, and the like. Light will be thrown on the meaning of valency and on all that lies at the root of chemical action. If the atomic forces can be calculated, an explanation of the form of the wave-surface of light within a crystal will be at hand.

X-rays have been applied with ever-increasing success to medicine and surgery; their extraordinary power of revealing the interior of a body without disturbing its exterior are beginning to be recognised as a trustworthy aid to industry, as, for example, in the detection of flaws of construction otherwise invisible; and their use in observing the crystalline state is already being considered as a probable and welcome aid to metallurgical problems. But still the richest mode of their employment is by the indirect methods of pure science. Their unique properties help as nothing else can to a knowledge of the relations between radiation and matter, ether-waves and electrons, atoms and the forces that bind them together, which are among the greatest of the fundamental problems of physics.

X-RAYS IN MEDICAL SCIENCE.

By A. C. JORDAN, M.D., M.R.C.P.

THE discovery of X-rays in 1895 was justly hailed as one of the greatest scientific marvels of any age. Medical men eagerly grasped the possibilities of these rays, which enabled them to see the internal organs of their patients actually at work, hitherto impossible even to surgeons, who in the course of their operations had the organs exposed to view, but only under conditions of anæsthesia.

The first practical uses to which X-rays were applied were: (1) In the detection and localisation of metallic foreign bodies, such as needles and bullets; (2) in the detection and localisation of metallic or other foreign bodies that had been swallowed; (3) in the diagnosis of fractures of bones: this branch of radiology has made enormous strides during the war, and has led to a vast improvement in the treatment of fractures and to the saving of countless limbs; (4) in the diagnosis of calculi in the urinary tract and elsewhere: these foreign bodies throw shadows which have to be distinguished from concretions in the bowel and calcareous deposits: many pitfalls lie in wait for the unwary observer, and the right interpretation of these shadows, even at the present time, calls for skill, patience, and discrimination; (5) in the diagnosis of diseases of the chest: the appearance of the normal movements of respiration and of the beating heart was closely observed, and as a result of these observations upon healthy subjects this branch of physiology has had, to a large extent, to be re-written. The position of the heart and vessels in the chest—in the midst of the air-filled lungs—rendered accurate diagnosis difficult by the older methods of physical examination, but by means of X-ray examinations with the fluorescent screen the mechanism of the heart has been closely studied and its diseases accurately diagnosed.

In regard to diseases of the lungs, pneumonia, pleurisy, abscess of the lung, tumours, enlarged glands in the chest, and many other conditions produce characteristic shadows on the fluorescent screen, and enable the site, nature, and extent of the disease to be determined. In pulmonary tuberculosis the aid which X-rays have brought to its early diagnosis, and in defining its extent, has proved of such value that this means of diagnosing phthisis is playing an essential part in the campaign in progress for dealing with this scourge. X-ray study has shown that the first changes which occur in the lung in this disease lie so deeply buried in the chest—under cover of a thick layer of healthy lung—that they are quite beyond the reach of the older methods of detection by percussion and auscultation. By the time the stethoscope is able to discover the signs of consumption, the disease is probably so far advanced that the prospects of a cure are remote. The diagnostic utility of X-rays has increased steadily with the continued improvement in the apparatus and the increased skill and experience of those engaged in this branch of science.

The correct estimation of fractures and other injuries to bone and joints necessitated an accurate study of the form and texture of normal bones, as well as the individual variations that occur in the conformation of bones and their joint surfaces. This knowledge led at once to a most important extension of the diagnostic powers of X-rays—the recognition of disease in bone and the differential diagnosis of many diseases of bones and joints.

So far we have considered radio-diagnosis as dependent on differences of density among the tissues. Bone, with its lime salts, is far more opaque to X-rays than muscle: consolidated lung is more opaque than healthy, air-filled lung. At first sight this precludes from the range of radio-diagnosis a very important part of the body—the hollow viscera constituting the digestive tract. Very little information is to be gained from an ordinary X-ray inspection of the stomach and bowels, but the introduction of opaque substances into hollow organs with the object of determining their outlines and of observing abnormalities of size, shape, or function has opened up an entirely new extension of the science of radio-diagnosis.

An "opaque meal" consisting of a heavy insoluble salt, such as carbonate of bismuth, is given in a dose of 2–4 oz. Its progress is observed through the œsophagus into the stomach and duodenum, and observations are continued at intervals to note the position and behaviour of each part of the small and large intestine as the bismuth passes through. By this means much new information is being gained concerning the physiology and the diseases of the alimentary tract. Our views regarding the causation and nature of many of the affections of the digestive system have had to be reconsidered and modified.

Medical and surgical text-books of a few years ago contained separate chapters devoted to individual diseases, such as gastric ulcer, duodenal ulcer, gall-stones, and appendicitis, but when radiologists were called upon to aid in the diagnosis of these various diseases they tendered evidence that showed conclusively that these diseases were not isolated morbid affections of the organs concerned, but "end-results" of a more general derangement of the digestive system. In other words, the stomach or appendix does not "go wrong" by reason of any intrinsic vice, but because it is in an environment which has become vitiated or unhealthy.

An entirely different aspect of our subject is the application of X-rays to the treatment of disease. From observations upon the far-reaching consequences of undue exposure to the action of X-rays, radiologists were led to explore their possibilities for therapeutic purposes.

It is well known that the first workers in the field of radiology were destined to pay a heavy price for their devotion. The repeated exposure of the skin to the action of the new rays set up a disease in skin known as X-ray dermatitis. Gradually the skin and even the deeper tissues of the hands and other parts that had been exposed to the action of the rays were destroyed. Extensive and painful sores appeared which penetrated deeply and resisted all attempts to induce healing, and in some cases cancerous change set in, necessitating the loss of a limb, and unfortunately, in a few cases, leading to a fatal termination. It was natural to surmise that an agent with such terrible powers for evil as X-rays possess might, in suitable small doses, be converted into a means of salvation, in the same way as many deadly poisons—strychnine, opium, digitalis, and mercury—have become the physician's most potent and useful remedies when rightly administered.

It was found that certain diseases of the skin yielded very readily to carefully administered applications of X-rays; and to-day ringworm, so difficult to eradicate by ordinary methods of treatment, is almost universally treated by X-rays. Prior to this treatment primary schools were deprived of numbers of their pupils for long periods, averaging two years for each child, but now the disease is usually eradicated in three months.

Other diseases which have been treated with a large degree of success by irradiation are: Tuberculous glands; other gland enlargements, such as occur in lymphadenoma (Hodgkin's disease); uterine fibroids; exophthalmic goitre (Graves's disease); blood diseases, such as leukæmia; and some forms of gout, rheumatism, and neuritis: in these painful disorders X-ray treatment relieves pain even when it cannot achieve a cure.

In view of the successful application of X-rays in dispelling enlarged glands, the question naturally arose: Have we here a therapeutic agent which can cure that most dreaded of all diseases —cancer? The answer to this important question was sought with diligence, and at first with much promise. But its limitations soon became apparent, and to this day the results of X-ray treatment of cancer have not fulfilled our greatest hopes. True, many cancerous masses can be destroyed and made to disappear by this treatment, yet a genuine cure does not always follow. Other growths may appear in inaccessible places, or general dissemination of cancer may set in. Early removal by operation is still the safest method of dealing with a cancerous growth. The removal may, however, be advantageously followed by the systematic irradiation of the operation area, so as to destroy any cancerous cells that may have been left behind. We must not (nay, we dare not) despair of the successful treatment of cancer. Recent researches, however, lead to the conclusion that the road to salvation is in the prevention rather than in the cure of the disease. In these researches X-ray observations of the digestive system occupy a prominent place. They have taught us that particular sections or points in the gastro-intestinal tract become so altered from their healthy state as to be specially liable to take on a cancerous change. We have learnt that toxic products, absorbed from the intestinal canal into the general circulation, give rise to deterioration of the tissues and render them liable to become cancerous as the result of some slight source of continued irritation such as would do no harm to healthy tissues.

The effects of X-ray exposures on white blood corpuscles are receiving increased attention, and to-day results are being obtained which are of great interest. We know, for instance, that the white cells of the blood play a leading part in the struggle with invading microbes. If particular kinds of white cells can be increased in numbers and in activity, we shall have gained a notable step in treatment. Already there are reports from more than one part of the world of promising results from treatment on these lines in cases of pulmonary consumption.

It will be seen from the foregoing brief account that important developments in the functions of X-rays in the direction both of diagnosis and of therapeutic application can be hopefully awaited.

Every day we are learning more of the nature and properties of the various kinds of X-rays, the soft and hard primary rays, the homogeneous and other secondary rays; and knowledge is increasing regarding their action on the surface and within the body tissues.

It is safe to predict that in the coming years X-rays will play an increasingly important part in attaining the end and aim of all medical study—the prevention of disease and the maintenance of a high standard of health and efficiency in the community.

PROGRESS OF ELECTRICAL INVENTION.

By PROF. J. A. FLEMING, F.R.S.

THE progress of electrical discovery and invention, and especially of electric lighting, telegraphy, and telephony, in the last fifty years is the theme on which the Editor of NATURE has asked me to make a short contribution to this jubilee issue. The chief difficulty, however, is in selecting from the enormous stores of accumulated knowledge the topics most worthy of notice in a space all too brief for any adequate treatment.

Casting our glances backward to 1869, we can, however, say that on the theoretical side electrical science was then beginning to emerge from the stage of a chiefly qualitative study of phenomena into an era of quantitative measurement, on which progress so much depends. The initial attempts to lay deep-sea submarine cables and the engineering aspects of land telegraphy had compelled attention to the exact measurement of electrical quantities. Advanced physicists had already appreciated the advantages of an absolute system of measurement based on the fundamental units of space, time, and mass; but practical electricians still employed vague phrases such as "quantity currents" and "intensity currents," and precise ideas on the subjects of potential, capacity, inductance, electric energy, and power were not widely diffused. Lord Kelvin (then Prof. W. Thomson) had, indeed, started into existence some years previously (in 1861) the famous British Association Committee on Electrical Units, and Maxwell, Balfour Stewart, and Fleeming Jenkin had commenced experiments on the practical determination of the ohm, or British Association unit of electric resistance, for which work Faraday, W. Thomson, and Maxwell in Great Britain, and Gauss, Weber, and Helmholtz in Germany had laid the foundations.

A new era began in 1873 with the publication of Maxwell's stimulating work on electricity and magnetism. Up to that time students of the subject for the most part obtained their knowledge from such descriptive non-mathematical works as de la Rive's great treatise on electricity and magnetism. When Maxwell was appointed professor of experimental physics at Cambridge in 1871, and the Cavendish Laboratory was opened for work about 1873, quantitative researches at once commenced with Hicks, Gordon, Chrystal, Fleming, Schuster, Glazebrook, and Shaw as early workers. After Maxwell's lamented death in 1879, the late Lord Rayleigh accepted the position as his successor and directed his attention and great abilities at once to the exact determination of practical electric units, in which he did magnificent service, a work very ably continued by Glazebrook, J. J. Thomson, Searle, and others. After the introduction of public electric lighting, the measurement of electric quantities became a commercial matter. In 1885 the writer of this article read a paper to the Institution of Electrical Engineers in London advocating "the necessity for a standardising laboratory for electrical testing instruments." Soon after, the Board of Trade established such a laboratory, later on the Germans started their "Reichsanstalt," and at a still later stage the National Physical Laboratory in England was organised and equipped.

The Cambridge physicists have always maintained the high standard of research which marked that of Kelvin, Maxwell, and Rayleigh, and much valuable quantitative electrical work has been done there, too extensive for detailed reference. When Sir J. J. Thomson succeeded Lord Rayleigh at the Cavendish Laboratory he began the epoch-making researches on the nature of electricity and matter which have revolutionised scientific concepts. His identification of the cathode-ray particle with the electron of Larmor and Johnstone Stoney, and his measurement of its charge and mass, are amongst the most brilliant achievements of experimental science, and opened up an entirely new era in electrical research. J. J. Thomson gathered round him a band of experimental investigators whose researches, coupled with his own, threw light on innumerable obscure phenomena. The discovery of X-rays by Röntgen in 1895 and of the Becquerel rays, and the discovery of radium by Mme. and Prof. Curie, stimulated the work of Rutherford, C. T. R. Wilson, Townsend, and others, which has resulted in immense accessions to our knowledge of the nature of electricity and atoms.

Side by side with this progress in pure scientific knowledge fruitful advances were made in electrotechnics. Faraday's great discovery of magneto-electric induction had been long before applied in the construction of machines with permanent magnets for generating, by rotation of coils of wire, an electric current. Henry Wilde had suggested the use of electromagnets for producing the magnetic field, and he, as well as Werner, Siemens, and Wheatstone, had discovered the self-exciting principle and applied it in machines, to which the term "dynamo" was later on applied. In 1870 Z. Gramme, a French electrician, re-invented a special form of armature construction, first suggested by Pacinotti, which enabled a dynamo to give a very uniform direct electric current; and Hefner Alteneck, in Germany in 1873, had patented another type of armature winding, now called the drum winding. The way was then opened for the production of electric currents by mechanical power on a large scale and for the solution of the problem of public electric lighting.

Paul Jablochkov invented in 1876 his "electric candle" and initiated public street electric lighting in Paris. C. F. Brush, in America, invented a simple form of arc lamp adapted for working in series with others and a type of series arc-lamp dynamo. This Brush system soon after 1878 was largely in operation for street lighting.

In the following year Edison, in America, and Swan, in England, solved the problem of the production of a practical carbon filament incandescent electric lamp and thus rendered domestic electric lighting possible on a large scale.

In the same year the writer of this article exhibited some of Edison's early carbon filament lamps in operation in Queen Victoria Street, London, though it was not until the Crystal Palace Electrical Exhibition of 1882 that the public saw the new illuminant used on a large scale. The invention of the metallic filament lamp about 1904 made an immense improvement in economy in electric illumination, and more recently the "half watt" gas-filled lamp threatens to displace arc lighting entirely from streets and buildings.

The utilisation of this lamp, however, required a public electric supply, and Edison was one of the first to work out all the practical details and provide a complete system. This was put into operation in New York and in London in 1882. Improvements in the dynamo rapidly followed, and in the hands of J. Hopkinson, Crompton, Siemens, and others it became a highly efficient machine. About 1883 attention began to be directed to alternating currents, and alternators and transformers were designed by Ferranti, Mordey, and Parker.

In or before 1890 or 1891 polyphase alternators were first produced by Ferraris, Tesla, and C. E. L. Brown. Large electric supply stations were then built, and a lively contest took place on the relative merits of direct and alternating currents. The polyphase alternating system has, however, enabled electric power transmission to be conducted over great distances, and in the last twenty-five years an immense utilisation of natural water-power has taken place by this means, beginning with the Niagara Falls Power Station in 1893. Electrification of urban tram lines and short-distance inter-urban railways has made enormous progress in the last quarter of a century.

Meanwhile, between 1876 and 1879 Graham Bell, Edison, and Elisha Gray, in the United States, had given us the speaking telephone, and D. E. Hughes, in England, had produced the microphone, which is the basis of all modern telephone transmitters. In 1876 Lord Kelvin astonished the British Association at Glasgow by the information that he had heard articulate speech transmitted over a wire by one of Bell's early telephones. In 1879 the first rudimentary telephone exchange was established in London.

When once the commercial possibilities of telephone exchanges and of domestic electric lighting had been realised, progress was assured, although that of the latter was retarded by the unwise Electric Lighting Act of 1882, not repealed until 1888, and telephonic improvements were hindered by the Government control of it established by the legal interpretation of the term "telegraph" to include "telephone," under the Telegraph Purchase Acts.

Limiting consideration, then, to improvements in telegraphy and telephony, we note very briefly the following stages of invention. In 1869 the British Government passed an Act for the acquirement of the electric telegraph companies, and made the transmission of paid messages a public service. This "nationalisation" has, however, put a burden on the taxpayer, although it resulted in great extension of the facilities. Improved methods of transmission, such as the Wheatstone automatic system, capable of sending 400 words a minute, were soon introduced for Press purposes.

So far back as 1855 D. E. Hughes had invented an ingenious printing telegraph, but immense improvements afterwards introduced by Baudot, Creed, and Murray now enable twelve messages to be sent simultaneously on a single wire, each being printed down on paper at the receiving end, the sending being done by a typist on a special typewriter at the rate of thirty to forty words a minute.

Most long telegraph lines are now worked multiplex, meaning that several messages can be sent in the same or opposite directions on the same wire simultaneously.

In submarine cable work Great Britain has always been pre-eminent. The first submarine cable was laid in 1851 by the Brothers Brett across the English Channel, and the first permanently successful Atlantic cable by Sir Charles Bright and Sir James Anderson in 1866 from the s.s. *Great Eastern*. Lord Kelvin, who had previously given to the world his mirror galvanometer, invented also in 1867 the syphon recorder which receives and records the feeble arrival currents, and later improvements have given to it its present form. Very sensitive relays and repeaters have been invented by Muirhead, Heurtley, S. G. Brown, and Axel Orling, which have vastly increased the speed of transmission. Lord Kelvin laid the firm foundations for the theory of the telegraph cable so far back as 1855. There are at present about 300,000 miles of working submarine cable in the world, most of which has been made and laid by British electricians. In connection with telephony, enormous inventive thought has been given since 1880 to perfecting the mechanism of telephone exchanges, and the difficulties of automatic exchanges, which require no telephone girls or operators to effect the connection between subscribers, have now been finally overcome. Another very great advance has been in the "loading" of telephone lines. In 1887 Oliver Heaviside first showed the importance of inductance in the line as a remedy for "distortion" in the wave form of the speech currents, but it was not until Pupin, in the United States in 1899, suggested the insertion of inductance or "loading" coils at certain proper intervals in the line that practical success was obtained. A Danish engineer, Krarup, introduced a system of uniform loading for submarine telephone lines. The Pupin type of loading has made telephony possible over very great distances, such as New York to San Francisco, and Berlin to Rome. The difficulties of loading submarine cables up to 100 miles or so in length have been overcome. The theory of the subject has been treated by Heaviside, Kennelly, and Fleming.

Wireless telegraphy has attracted the attention of electricians since 1842, but no important invention was made until Marconi in 1896 first showed how to employ electromagnetic waves for this purpose, generated by a special form of Hertzian oscillator, and detected by an improved form of Branly metallic filings coherer. Lodge then demonstrated the importance of syntony in connection with the subject, and it soon took very practical shape. Inventors all over the world were attracted to this new field, with the result that in a few years, chiefly by the work of Marconi and his co-workers, electric wave telegraphy between ships and shore became established as an indispensable aid to navigation. The construction of long-distance wireless stations, the first of which was erected at Poldhu, in Cornwall, in 1901, brought to notice many remarkable facts in connection with the propagation of long electric waves round the earth and through the atmosphere.

A very important factor in the recent developments of wireless telegraphy and telephony has been the invention of the thermionic detector and oscillator. The pioneer invention, according to judicial decisions, was made by the writer of this article in 1904 in applying for the first time an incandescent electric lamp with a metal plate sealed into the bulb as a detector of high-frequency electric oscillations. The "Fleming valve" led to the invention of the three-electrode amplifier and thermionic generator of oscillations. This has given us an instrument of marvellous sensibility for detecting electric waves, and made wireless telephony a success and wireless telegraphy half round the world an achievement. The importance of wireless telegraphy and telephony in the European War of 1914–18 has been the cause of wonderful developments of the subject owing to the number of able minds brought to bear upon it.

Turning, then, from the present and the past and directing our gaze upon the future, we can certainly see many achievements looming before us. The world will be covered with long-distance wireless stations which will effect instantaneous communication over thousands of miles. Long-distance wireless telephony will enable speech to be transmitted over great distances, and it is quite within the bounds of possibility that the business man of the near future in London may hold a five-minutes' conversation with a friend in New York or even South Africa with as much ease as we now telephone to Glasgow or Liverpool. Directional wireless telegraphy will be used to steer passenger-carrying aeroplanes through cloud or fog. The steam locomotive and engine will gradually be replaced by the electric motor, and the water-power of the world will be utilised by its means. There are large possibilities still latent in connection with electro-chemistry and electro-metallurgy, and one great problem of the future is to tap the illimitable stores of energy latent in every chemical atom for the use and benefit of man. As coal becomes exhausted or coal power is made too expensive by labour difficulties, the question of new sources of energy becomes pressing. The engine of the future may be an improved form of internal-combustion engine in which the combustible is not coal gas or oil vapour, but some form of explosive compound in which atomic energy is suddenly released and expended in heating air or other gas in a cylinder.

Of one thing we may be perfectly certain, namely, that it is only through the avenue of pure scientific research sedulously and disinterestedly pursued that we shall reach the solution of these technical problems of supreme importance to mankind. The last fifty years has been a period of extraordinary technical applications of ever-increasing electrical knowledge, and no one can see reason to think that we have yet reached finality in the possible utilisation of this physical agent for ameliorating the conditions of human life.

DEVELOPMENTS OF MECHANICAL SCIENCE.

By DR. W. C. UNWIN, F.R.S.

THE attempt here made to give a sketch of the mechanical side of progress in the last fifty years is necessarily slight. The year 1869 was the centenary of that in which Boulton and Watt took out their first patent for the steam engine. It is due to the application of steam-power to industrial operations, more than to anything else, that there has been so great an increase of population, of wealth, and of social prosperity, and indirectly also of scientific knowledge, during the last 150 years. Perhaps a review of some of the earlier advances already slipping out of knowledge, as well as of more recent and familiar discoveries, will be interesting.

Eighty years ago Dr. Lardner said it was due to the steam engine that reason had taken the place of force, the pen had superseded the sword, and that war had almost ceased on the earth. History does not confirm the prescience of this. The last war, largely an engineering war, owes its vast range and frightful devastation to means placed in the hands of armies and navies by mechanical science. To take one point, success in war depends chiefly on the rapidity with which large masses of men can be moved and served with ammunition and food. This must be accomplished by railways and motor trucks. At Verdun sixty million shells containing three million tons of steel were expended in thirty weeks.

During the last fifty years there has been a wide extension of research in mechanical science. Most large engineering works have their laboratory for testing materials, and the problems investigated are largely those suggested by industrial operations. This was specially important during the war, and it is now necessary to make permanent the more intelligent and active spirit thus aroused.

Hydraulics is a very old subject of research. Its problems are generally too complex for purely rational solution. Hence the need of continued experiment. A remarkable series of measurements of flow over weirs of different forms, under different conditions, with varying velocities of approach, and an investigation of the peculiar change of form of the water nappe on the weir crest at low discharges, was communicated by Bazin to the Ann. des Ponts et Chaussées in 1888–98.

In 1885 Froude gave the first direct determination of the frictional resistance of surfaces of different roughness in water (Brit. Assoc. Report). The most novel result was that the average friction per square foot depended on the length of the surface in the direction of motion. The friction of rotating discs was investigated by Unwin in 1880, and by Gibson in 1910. A research by Stanton and Pannell (Trans. R.S., 1914) has shown the conditions of similarity of motion in fluids, and extended the results to water and air and to high velocities. These results have been of service in discussing the resistance of aeroplanes as tested in wind channels. Osborne Reynolds's experiments in 1882 showed that in flow-in pipes there was a critical velocity below which the resistance varied as the velocity, and above nearly as the square of the velocity.

Froude applied his results to the extremely important subject of the calculation of the resistance of ships. The greater part of the resistance is due to skin friction, and can be calculated on the assumption that the wetted surface is equivalent to a plane of equal area and length in the direction of motion and equal roughness. The remainder of the resistance, due to waves and eddies, can be found by model experiments. There is an exact relation between wave and eddy resistance of the model and ship at corresponding speeds. The method of model tests of ships as a guide to design is now fully established. Sir Alfred Yarrow has generously established an admirable ship model tank at the National Physical Laboratory.

Water-power is one of the oldest sources of mechanical energy for industrial purposes. Its importance, looking to the fact of the limitations of coal supply and that in favourable circumstances it is cheaper than steam-power, can scarcely be over-estimated. Its use has greatly helped processes such as the fixation of atmospheric nitrogen, and the production of aluminium, calcic carbide, carborundum, caustic soda, etc., besides being an essential auxiliary in many great electric lighting installations. Thirty years ago no water turbine existed of 1000 h.p.; now turbines up to 20,000 h.p. have been made. The harnessing of Niagara, commenced in 1890, gave rise to a movement for utilising water-power on a great scale. The possibility of transmitting energy electrically to distances up to 200 miles, with little loss and commercial success, has greatly enhanced the availability of water-power. In the U.S.A. some seven million horse-power are utilised, in Norway more than one million, in Canada two millions, and in Italy one million. There are great possibilities in the British Dominions. In Canada and some other countries a Government survey of the water-power resources is in progress.

In 1869 the steam engine differed little from what it was as Watt left it, except in detail, size, and variety of application. One important modification since may be noted. Rankine and Clausius drew up a complete rational theory based on the mechanical equivalent of heat. But it appeared that actual engines used 40 to 60 per cent. more steam than was accounted for by the theory. In the late 'fifties Hirn, of Colmar, traced the discrepancy to the conductivity of the cylinder wall, which was cooled by evaporation to the condenser during exhaust, and then condensed part of the steam on admission. To remedy this he introduced superheated steam, used to some extent in the 'sixties with economical results, but not widely adopted until the 'nineties. Watt aimed at getting a dry, hot cylinder, but only partly succeeded. Superheating is a further step, only second in importance to the separate condenser.

The greatest change in the generation of power is due to the perfecting of the steam turbine by Sir Charles Parsons. The principle of the steam turbine is old, but it involved great scientific tenacity and courage and large, unremunerative expenditure before practical success was achieved. The first condensing turbine of 100 h.p. was made in 1892. Now in the latest cruiser, the *Raleigh*, there are turbines of 70,000 h.p. For large electric installations and for large and speedy ships the steam turbine has superseded the reciprocating engine. Lately Sir Charles Parsons has introduced gear for reducing the necessarily high turbine speed to one more suitable for the propeller, and this will much extend the use of the turbine in marine engineering.

The development of the internal-combustion engine belongs almost entirely to the last half-century. On it has depended all aircraft and submarines, and most mechanical road transport. The first satisfactory gas engine was that of Dr. Otto in 1876. Dowson, in 1878, introduced producer gas, emancipating the engine from dependence on illuminating or town gas; and Benier soon after invented the suction producer. The Germans developed the large-cylinder, high-powered gas engine chiefly for utilising blast-furnace and coke-oven gas—a waste product. Sir Dugald Clerk, who has led the way in this country in developing the gas engine, and especially in studying its theory, estimates that there were gas engines of $5\frac{3}{4}$ million h.p. at work in 1909.

The first paraffin engine was that of Priestman in 1885. The Diesel oil engine, introduced in 1893, has perhaps the greatest thermal efficiency of any heat engine.

The petrol engine, which has made the conquest of the air possible, was greatly improved during the war, and is the lightest of heat motors. An aeroplane engine of 850 h.p. is stated to weigh only 1·63 lb. per h.p.

The future of air transport has very great promise, but it looks as if for commercial purposes the airship has advantages over the aeroplane. In coastal patrol and anti-submarine work naval airships carried out 9000 patrols covering $1\frac{1}{2}$ million miles. Engineers interested believe that an airship capable of carrying 1000 persons at 80 miles an hour is in reach of present practice. Attempts are being made to produce helium to replace hydrogen in the envelope, removing one source of danger.

Mr. Lanchester has reminded us that, with Government help largely withdrawn, the aeronautical industry is in the position of a youth luxuriously brought up who finds himself face to face with the fact that he has to earn his own livelihood.

Structures and machines should be designed with adequate strength and at the same time with the least necessary material. In the old view the strength limit was the statical breaking weight, and the ratio of this to the working stress was termed the factor of safety. Wöhler's research in 1871 proved that, in ordinary conditions of continual variation of stress, fracture occurred with much less than the statical breaking weight, and depended on the range of variation of stress. Bauschinger showed that the position of the elastic limit changed with repetition of straining action, and that the range of elasticity appeared to be the same as the range of stress, which could be sustained indefinitely. Bairstow and Stanton have confirmed this. Osborne Reynolds constructed a machine in which continuous changes of stress in a test bar could be produced by the inertia of reciprocating weights.

In the period under consideration there has been a great extension of public and private mechanical testing laboratories. The National Physical Laboratory and the Bureau of Standards, Washington, are now Government institutions. In the U.S.A. very large testing machines have been constructed, several of 600 tons capacity, and one of 5000 tons at Pittsburgh. For testing full-size members such as bridge ties, reinforced concrete columns, etc., such machines are necessary. Though new tests of materials must be adopted with great caution, tests of hardness and tests of brittleness have been found useful. Guest, Scoble, and others have investigated compound stress, and found that in ductile materials the limit of resistance is the greatest shear stress. A very great advance has been made in the delicacy and accuracy of strain measuring instruments.

THE TREND OF MODERN METALLURGY.

By Prof. H. C. H. Carpenter, F.R.S.

METALLURGY is the art of extracting metals from their ores, refining them, and working them up into finished products for the use of mankind *at a profit*. The inevitable corollary of this is that the economic factor is always decisive as to the applicability or otherwise of any new scientific discovery which bears upon the industry. The art is one of the oldest in the world, but in spite of its highly diversified character and the profound influence that scientific methods have had upon its scope and technique, it does not differ to-day in essence from the ancient art except in the fact that to an ever-increasing extent the applications of science are found to be payable.

In attempting a survey of the present position and tendencies of the great metallurgical industries, only the broadest treatment is possible. Accordingly, no account will be taken of the usual subdivision of the subject into ferrous and non-ferrous metallurgy. Rather does there appear to be an advantage in omitting this distinction which has no scientific basis, but is purely one of custom.

The first stage in the passage from the mineral as mined to the manufactured metal is "ore-dressing," and here a very notable advance, made in the last few years, has to be recorded. The old method of "gravity" concentration, whereby the ore after being crushed was suspended in water and treated in a variety of machines for the concentration of the metallic contents, which, being specifically heavier, tended to sink, while the lighter gangue floated, never, at its best, gave an extraction of more than 82 per cent. In the "flotation" process of to-day the sulphide ore particles are made to float on a froth produced by the agitation of the pulp with the addition of a small amount of oil and acid, while the gangue, although specifically lighter, sinks. The flotative agent is air, the froth being stabilised by the particular oil mixture used. Surface tension and not gravity is the principle utilised in the separation. The method has been principally applied to the concentration of copper sulphide and mixed lead and zinc sulphide ores. Its largest application has been in copper reduction work in America, where many millions of tons of ore are being treated to-day. At Anaconda the total recoveries in the concentration process have been raised from 76 per cent. to as much as about 95 per cent. There can scarcely be any doubt that flotation has a great future as a concentrator of metal values. At the present, however, it is limited to sulphide materials. For that reason it has had no effect on the metallurgy of iron, where the mineral is either an oxide or a carbonate; but it seems likely to have a very wide application to the principal economic minerals of copper, lead, zinc, gold, and silver, especially when the two latter contain base metal values.

Thus far the concentration has been mechanical —*i.e.* there has been no change in the chemical composition of the mineral itself. In the next stage, in the great majority of cases, "smelting" or "reduction" begins, which has for its object the conversion of the ore into a metal, usually unrefined. Hitherto the shaft or blast furnace has held its own, with coke as the fuel. This furnace has had its principal recent development along the lines of better charge distribution, and, in the iron industry, more efficient hot blast stoves and more economical power plants. Fifteen years ago many furnacemen were satisfied with almost any distribution of charge they happened to get from the apparatus installed, but this most important operation cannot be ignored without causing low output and high coke consumption. Distributors are now in use which give the charge a columnar structure with alternate columns of coarse and fine ore, instead of uniform layers produced by most systems of filling. Highly beneficial results are claimed for this improvement.

Hitherto the reverberatory furnace has been markedly inferior to the shaft furnace from the point of view of thermal efficiency. For this reason only the ore which was in too fine a state of division for treatment in a shaft furnace was smelted in a reverberatory. The very extensive application of gravity and flotation concentration, particularly to copper ores, with the fine grinding which these processes involve, has, however, necessitated the smelting concentration of such materials in these furnaces. Until comparatively recently the best practice in the reverberatory furnace concentration of copper ores was about 4·8 tons of charge per ton of coal, against about 8 tons of charge per ton of coke in the blast furnace. Here, too, a remarkable improvement during the last five years has taken place. This is due, in the main, to three factors:—

(1) To the increased efficiency of burning coal in the form of dust as compared with burning it on a grate.

(2) To maintaining a very large mass of the charge piled along each side of the furnace, which increases the speed of heat absorption.

(3) To the augmented size of the hearth, which has now reached a length of about 143 ft. and a width of 30 ft.

For successful practice, the coal, before pulverising, must be dried to a maximum of 1 per cent. of moisture. It must be finely pulverised, since the increased surface thus obtained has a direct bearing on the efficiency. Upwards of 80 per cent. should be capable of passing through a 200-mesh sieve. The delivery of coal and air must be controlled so that the proper proportion between them is maintained, and the coal itself must contain enough volatile combustible matter to give the required combustion. Only a few years ago it used to be reckoned that to smelt from 230 to 270 tons of charge per 24 hours was good work. The current practice to-day in the new furnaces is to smelt between 600 and 700 tons, and the ratio of charge to fuel has been brought up to about 7:1, which raises the reverberatory furnace almost to a level with the blast furnace from the thermal efficiency point of view. Certain of these large reverberatories are fired with oil, and very satisfactory results, as regards both economy in fuel consumption and weight of charge smelted, have been obtained.

Passing next to the refining of the metal, it is here that "electric heat" is tending in some cases to supplement, in others to supplant, fuel heat. An instance is furnished by the refining of steel on a large scale in the so-called triplex process, in the second stage of which fuel heat, in the form of producer gas, is used (the charge being worked first in a converter and afterwards in an open-hearth furnace), while in the third stage an electric resistance furnace is utilised which permits the refining of the steel to a considerably further degree. It is widely held that the quality of steel which can be produced in this way is superior to that obtained in the open-hearth furnace. This is due to the fact that, owing to the high temperature employed, more refractory basic fluxes can be used which permit of a greater removal of sulphur and phosphorus, with a consequent improvement in the properties of the refined steel. Moreover, in the electric furnace the charge is decidedly less contaminated with gases. For high-grade materials, such as high-speed cutting tools, where quality is of paramount importance, the electric furnace seems to have a field all its own, and, owing to the fact that, under special conditions, current for it can be bought from public service companies during "off peak" periods, its installation cost is not necessarily high. This permits of its use in plants smaller than otherwise would be justified in making their own steel. The rapid growth of the electric furnace is shown by the fact that the total number in operation in March, 1910, was 114, and in January, 1917, 471.

As an alternative to flotation concentration and smelting operations, which, as mentioned, are particularly suitable for sulphide ores, the achievements of hydrometallurgy have also to be considered. The cyanide process, which has long been established as the most suitable method of extracting gold and silver from low-grade ores, depends on the fact that the dilute solutions employed exercise a selective solvent action on the precious metals, and is the best-known instance of the application of leaching on a large scale.

Recently the extraction and refining of copper by hydrometallurgical and electrolytic methods direct from the ore has become a commercial process. Many of the low-grade ores of copper, particularly the vast porphyry deposits in the highly mineralised mountainous country in the south-west of U.S.A. and Mexico, are oxidised and not amenable to flotation concentration. For their beneficiation leaching is the most suitable method. A famous example of this kind is the treatment of the ore obtained from the mine of the Chile Exploration Co. situated at Chuquicamata, which, as regards tonnage and contents of valuable metal, is one of the greatest known copper deposits in the world. The high point of the mine lies at an altitude of 9890 ft., while the extraction plant is situated at 9023 ft. on a plateau of the Andes, 160 miles north-east of Antofagasta. Here a plant of 10,000 tons daily capacity has been designed and erected in a desert 5000 miles away from the base of supplies. The ore, which carries about 2 per cent. of copper, is an oxysulphate known as "brochantite."

The process chosen utilises its sulphuric acid ion for the solution of the copper, and allows a percentage discard of the liquid after each operation, thus avoiding its fouling by continual use. The ore is crushed to about half-an-inch mesh and leached with sulphuric acid. The greater part of the chlorine is eliminated in tube mills by treatment with metallic copper. The remaining copper is precipitated from solution by electrolysis and the cathodes are melted and cast into commercial wire bars. In this way a high-grade commercial metal is produced direct from the ore in three operations, in only the last of which is a furnace treatment necessary. Against this the ordinary concentrating, smelting, and refining operations involve no fewer than seven stages. The output of refined copper from this plant is at the rate of 200 tons per day.

The refining of metals by electrolysis, of which the previous process is an illustration, is one of the most important features of the industry of to-day. It derives its importance from two considerations which are inter-related: first, that it permits the production of the commercial metal in a highly purified form; secondly, arising out of this, it allows the complete recovery of the precious metal values from base metal ores, which thus increases their commercial value. To-day, iron, copper, zinc, lead, aluminium, sodium, magnesium, nickel, gold, and silver are obtained in a marketable form by such methods. To take one instance only, upwards of 90 per cent. of the world's annual production of copper, which in 1913 was about a million tons, was refined by electrolysis within 20 miles of New York City. The cathode copper thus produced did not contain more than 2–3 parts of impurities in 10,000. As a by-product of this refining, there was obtained nearly 20 per cent. of the world's entire output of silver, a substantial amount of gold, small amounts of platinum and palladium, together with notable quantities of nickel, selenium, and tellurium.

Viewing the industry to-day, it is manifest that there is a notable trend towards the substitution of furnace- or pyro-metallurgy by hydro- and electro-metallurgy. Even where furnace operations still hold the field, attempts are being continually made towards the substitution of fuel heat by electric heat. Iron is being produced commercially in Sweden, Canada, and the U.S.A. by electric smelting and refining. There is a clear trend of a similar character in the metallurgy of certain ores of copper which are not amenable to direct flotation or leaching. Metals such as aluminium, sodium, and magnesium are produced direct by electrolysis. The great importance of this tendency, as already suggested, is that it permits of a more complete beneficiation of any given ore, and, indeed, brings a far wider range of raw materials within the scope of economic exploitation than otherwise would be the case. How clearly this is so may be seen from the following instances:—

Previous to the introduction of the cyanide process, it did not pay to extract gold from any sulphide ore unless it contained at least 0·5 oz. of this metal. By means of this process, however, the limit of such payable ores has been brought down to about 1 dwt. per ton, and in the case of clean gravel containing native gold to as low as 3 grains—*i.e.* 0·006 of an oz. of gold per ton. Similarly in the case of the sulphide ores of silver, the previous limit of 20 oz. has been lowered to about 2 oz. per ton by the same process. As regards copper, the economic percentage was about 5 per cent. down to the year 1890. By the introduction of leaching processes this figure was quickly reduced to about 2 per cent. Progress has been continuous in lowering the limit, and to-day tailings from concentrating tables containing only 0·5 per cent. of copper are being treated for extraction at Cananea (Mexico) and Anaconda (U.S.A.). In regard to such materials it is more than possible that the flotation process will lower the limit still further.

Limits of space prevent any reference to the trend of current practice in the mechanical and thermal treatment of metals and alloys and the ever-deepening influence of metallography on this great branch of the metallurgical industry.

POSITION AND PROSPECTS OF AVIATION.

By L. Bairstow, F.R.S.

The present phase of scientific development of aviation may be said to date from the period 1890–1900, and to have its most definite form given by the researches of Langley and Maxim. From Langley's book were taken the early data on which pioneer designs were prepared, and a protracted controversy arose between Blériot and Farman as to the relative merits of the biplane or the monoplane as a result of a statement by Langley which has since proved to need considerable modification.

The first notable flight in public appears to have been that of Santos Dumont in 1906, for which he was granted the Deutsch de la Meurthe prize; this was little more than a long hop, and for the next two years it was clear that one of the larger difficulties of flight was the control of aircraft in the air.

Flying with reasonable certainty dates from the exhibition flights of the Wright Brothers in France during 1908, and may fairly be ascribed to the introduction by them of wing warping for the purposes of lateral control. Since then progress, both scientifically and industrially, has been very rapid.

In 1909 the Advisory Committee for Aeronautics was formed by the then Prime Minister, Mr. Asquith, with the late Lord Rayleigh as its president. The Committee controlled the activities of the Aeronautical Research Departments of the National Physical Laboratory, and was closely informed of the full-scale research work carried on at the Royal Aircraft Factory.

The development of the best shape of aeroplane had approached finality somewhat closely in the years 1913–14; on the other hand, owing to the death in an aeroplane accident of Mr. E. Busk, preliminary experiments on the industrial application of the theory of stability came to a premature end. During the war the attention of scientific workers in aeronautics was devoted to the many applications of existing knowledge rather than to its extension, and it was pointed out by them that the performances of aeroplanes could be predicted approximately with little effort, and that these predictions could be made the basis for an appeal for new designs to meet the increasing exigencies connected with fighting in the air.

On the other hand, no such simple generalisation has been found possible for dealing with stability, with the unfortunate result that designs made to give the necessary speed and rate of climb have been put into use before their condition as to stability was fully understood. Defects of stability made themselves felt by a series of accidents peculiar to each type. The analysis of these accidents and suggestions as to remedies came from the existing scientific work on stability. Examination of the categories into which accidents fall gives, perhaps, the clearest idea as to the technical development possible in the next decade. Some 80 per cent. of the total accidents during training are due to loss of speed of the aeroplane and an attempt on the part of the pilot to turn his aeroplane towards suitable alighting ground. The remaining 20 per cent. are in large part accounted for by failure of the engine to continue to develop power and so to compel descent on unsuitable landing ground. The latter point scarcely needs more than passing comment, for the general history of development in machinery shows that many years are necessary after main ideas have been established before details are satisfactory. Progress made in understanding the phenomenon connected with fatigue suggests that a moderate reduction of the power expected from existing aeroplane engine designs would lead to an enormous increase in the length of their life. It may therefore be expected that the ordinary precautions taken in the development of an engine will lead to the practical elimination of accidents under the heading of forced landings; here, again, progress will be accelerated by use of the known scientific data.

The larger group of accidents mentioned above needs a consideration of design intimately associated with the pilot's power of control of the aeroplane and its inherent stability. It should not be forgotten that the relation between these two quantities in an aeroplane designed for fighting in the air may have little or no connection with the corresponding relation of the properties desirable for civil aeroplanes. This field is as yet comparatively unexplored, and there are strong grounds for believing that an aeroplane can be so designed that the dangerous consequences of error of control by the pilot are greatly reduced; it is not improbable that the accidents on the score of loss of flying speed can be reduced to some 5 or 10 per cent. of their present magnitude when the necessary skill in design has been acquired.

The most important of the many difficulties which make it impossible to forecast the future of aviation are not technical, but commercial. Development under the stress of a great war has left an industry capable of producing an enormous number of aircraft. Attention has been given solely to military uses, and aeroplanes are therefore not specifically designed for civil purposes. At the same time, the civil uses are not clear; how far aviation will be good for the purposes of carrying mails, passengers, or merchandise is at present almost wholly a matter for conjecture.

Pre-war experience was gained in the development of aircraft which could be flown with a moderate degree of ease and safety, and no lines of commercial communication had been inaugurated. The main asset of both the aeroplane and the airship is speed, and here the importance of long distances will be evident on little consideration. In a country like England, with well-organised railway trunk lines and journeys of the order of 500 miles, the saving of time in the carriage of mails is small, particularly since the mail trains travel by night, whereas aeroplanes wait for the dawn before commencing the journey.

Where the route includes a sea passage the advantages are much greater, and the enterprise of our two leading transport companies has shown the possibility of a remarkable degree of certainty in the service between London and Paris. It is, however, on much longer journeys than these that the saving of time by aerial transport presents its most attractive possibilities.

On the other hand, the initial outlay and running expenses are roughly proportional to the length of journey, and the inception therefore represents a formidable undertaking. The returns are problematical, and from the nature of the case it will be obvious that until the special facilities have existed for some time no estimate of value can be made as to the charges which will prove remunerative to an operating company and sufficiently attractive to the users of the new form of transport.

Civil aerial transport is therefore still in its infancy as an addition to our industrial life.

THE LIQUEFACTION OF GASES.

BY PROF. C. H. LEES, F.R.S.

IN 1869, when the first number of NATURE appeared, Andrews had just completed his experiments on carbonic acid, and established the fact that for each gas there is a critical temperature above which it is impossible to liquefy the gas by pressure. Faraday, by using low temperatures and considerable pressures, had liquefied chlorine, sulphurous and hydrochloric acids, cyanogen, and ammonia in 1823, by 1844 had added eight other gases to the list, and had solidified sulphuretted hydrogen, ammonia, and nitrous oxide. Cailletet, in 1878, by suddenly reducing the pressure on oxygen, nitrogen, and carbonic oxide compressed to 300 atmospheres, obtained mists which he ascribed to fine drops of the liquefied gas. Pictet, about the same time, by employing greater pressures and cooling his apparatus with other liquefied gases, succeeded in obtaining a small quantity of liquid oxygen which was of a slightly blue colour.

In 1883, at Cracow, Wroblewski and Olszewski succeeded in obtaining small quantities of liquid oxygen, nitrogen, and air, which evaporated in a few seconds. By 1887 Olszewski could obtain a few c.c., and by 1900 100 c.c., of liquid oxygen before an audience of his students. Dewar had been able to produce quantities exceeding 20 c.c. since 1886, and had already made determinations of the properties of substances at the low temperatures thus attainable. In 1892 he introduced the double-walled vacuum vessels with a little mercury within to convert the internal surfaces into mirrors, now known as Dewar flasks. These reduced the rate of evaporation of a liquid gas stored in them to about a thirtieth of the rate for ordinary vessels. The utilisation of the Joule-Kelvin cooling effect by Linde and by Hampson in 1895 enabled each to produce a machine capable of liquefying air, oxygen, and nitrogen on a commercial scale. In 1898 Dewar produced for the first time liquid hydrogen, using the Joule-Kelvin effect in the gas pre-cooled to 68° A. by a bath of liquid air evaporating *in vacuo*. Next year he solidified it, and determined its melting point to be 14° A. In 1908, at Leyden, Kamerlingh Onnes liquefied helium and determined its boiling point to be 4° A. In the meantime, Olszewski had liquefied and solidified argon in 1895, and Ramsay and Travers had by 1900 liquefied krypton and xenon.

The commercial production of liquefied gases gave facilities for the examination of the physical properties of substances at low temperatures, and in this work Dewar and Kamerlingh Onnes and his pupils have played prominent parts. It is to the Leyden professor we owe the discovery of the disappearance of the electrical resistances of many metals at temperatures a few degrees above absolute zero attained by the use of liquid helium.

PROGRESS OF METEOROLOGY.

BY W. H. DINES, F.R.S

THE progress of meteorology during the last fifty years has been very marked, as may be seen by a casual reference to the current meteorological literature of the period 1865–75; to a great extent, it resembles the emergence of astronomy as an exact science from the old astrology, but it must be confessed that the Newton of meteorology has not yet appeared.

Fifty years back the student of meteorology spent much of his time in a vain hunt for weather sequences, and the principle of *post hoc propter hoc* held full sway; the laws of motion and the more recently discovered laws of thermodynamics were in most cases completely ignored, or at least considered as not being applicable to meteorology. This has been largely changed for the better, and one does not now expect to find a cold area explained as being due to the descent of air in an anticyclone from a higher and colder region. Perhaps the pendulum has swung too far the other way, and mathematical analysis may sometimes be used when it is not applicable. On the assumption that air is a perfect fluid, it follows from a strict mathematical analysis that a sphere exposed to a steady current of wind will offer no resistance to that wind—a result obviously inconsistent with the facts. The assumption made cannot be justified, and one cannot help feeling that great caution should be used in making assumptions if the result of a complex mathematical investigation into a meteorological question is to be trustworthy. Mathematics, however, afford a most useful and often indispensable aid to meteorology, and of late years especially, although far from exclusively, by their means many useful deductions have been drawn.

It is impossible in a brief article to give any full statement of the present position of meteorology, but a short account of the great access of knowledge that has come to us in the last fifteen years or so by means of observations in the upper air may be of interest, the more so because the great central problem of meteorologists who live in temperate latitudes has always been the genesis and motion of cyclones and anticyclones which bring us our various types of weather, and this problem is most intimately interwoven with the upper-air observations.

A mass of detail remains to be filled in, but the salient facts of the distribution of temperature in the upper air are well established, and, at least for Europe, where some 1500 observations are available, are beyond dispute. We have also observations from Canada, the United States, and Batavia, and a few from Central Africa and the tropical Atlantic.

It has been found that the atmosphere is divided into two parts: a lower part, the troposphere, in which there is a lapse rate—that is, a fall of temperature with height—of about 6° C. per kilometre (17° F. per mile); and an upper part, the stratosphere, in which there is no appreciable change of temperature with height. The boundary between the two parts is in these latitudes quite sharp and distinct, but is not so well defined in the tropics. Its height varies with the latitude: for the South of England the mean is 10·6 km.; for Scotland it is 9·8 km.; and for the equatorial regions it reaches 16 km. It has also for temperate latitudes an annual variation, rising in the summer, falling in the winter. It should be added that the usual lapse rate is less than 6° per kilometre in the first three or four kilometres, is more than 6° above that height, and in regions of excessive cold, such as Canada or Siberia in the winter, may be absent or reversed in the lower strata. With regard to temperature, over the equator the stratosphere may be as cold as −80° C.; over Europe it has about −54° C. for its mean, but may vary from −40° to −70° C.

Confining, now, our attention to Europe, there is very little or no correlation between the temperature and the barometric pressure of the air at the surface, but a totally different set of conditions is met with as soon as the very lowest stratum—the first 2000 ft., say—is passed. From 1 km. and upwards there is a very high correlation indeed between temperature and pressure; between 4 and 8 km. the correlation coefficients are more than 0·85; they then fall off rapidly, so that there is again no correlation at the boundary between the troposphere and stratosphere. Above this, in the lower part of the stratosphere, the correlation is negative and reaches −0·30, but falls off with increasing height. Also the correlation between the pressure at 9 km. and the temperature at any height excepting the surface and the common boundary is very high, being positive for the troposphere and negative above 12 km. Since a low-pressure area at the surface remains so up to nearly 20 km., the correlation defined above leads to the following rules. In a cyclone the troposphere is relatively cold and the stratosphere warm, and, it may be added, the boundary between the two is much lower than usual. In an anticyclone the troposphere is warm and the stratosphere cold; also the common boundary is raised. The actual differences of temperature between a well-marked cyclone and anticyclone in the British Isles are about 10° C., the cyclone being 10° cooler from 3 to 8 km., and the anticyclone 10° cooler from 12 km. height and upwards. In the cyclone the common boundary is 3 to 4 km. lower than in the anticyclone.

The cause of these differences is still more or less a matter of conjecture and controversy. In my opinion the changes of pressure at heights of 8 or 9 km. are in some way brought about by the accumulated momentum of the general circulation, and the temperature changes that follow are easily explained by the laws of mechanics and thermodynamics. Thus I think that temperature changes in the upper air are the results, and not the causes, of cyclones and anticyclones.

In addition to the results obtained by observations of temperature and humidity by means of registering balloons, much work in the last fifteen years has been done by means of pilot balloons. A large portion of this remains to be worked up. Also a considerable advance has been made from the theoretical side in our knowledge of the motion of the air particles near the centre of a cyclone, and meteorologists have good cause for congratulation in the steady progress that is taking place.

PROGRESS OF GEOGRAPHY.

By SIR JOHN SCOTT KELTIE.

DURING the past half-century marked advances have been made in all the departments now included under the head of Geography, which has to deal with certain problems dependent on the constitution, configuration, and distribution of the surface features of the earth. In attempting to take stock of the results of the exploration of the unknown and little-known regions of the globe during this period, I think it is safe to say that we have to go back to the half-century which followed 1492 (when Columbus stumbled upon a New World) before we find a period so prolific. The two Poles have been reached and large additions made to our knowledge of the deep island-girt ocean which covers the Arctic basin, and to the vast ice-bound, mountainous continent near the centre of which the South Pole is located. The unknown two-thirds of the no longer "Dark Continent" have been more or less provisionally charted, and all but an insignificant fraction partitioned among the Powers of Europe. Great areas of North America have been surveyed, charted, and occupied, while much has been done for the exploration of Central and South America. The map of Asia has, to a large extent, been reconstructed, while the vast unknown interior of Australia has been traversed in all directions. Even much of Europe has been re-surveyed. A new department essentially geographical—oceanography—has been created as the result of the *Challenger* and other oceanic surveys.

Survey work not only in the official surveys, but also among explorers, has become more and more accurate, while methods and instruments have been greatly improved. These improvements, combined with the more thorough training available at the Royal Geographical Society and certain of the universities by would-be explorers, have greatly enhanced the scientific value of the results of exploring expeditions. Many of these in recent years have been accompanied by specialists, not only in strictly geographical subjects, but also in other departments of science—geology, biology, meteorology, anthropology, etc.—certain of the data of which are required in working out some of the problems with which it is the business of geography to deal. For, to quote from the presidential address of Sir Richard Strachey to the Royal Geographical Society in May, 1887:—

There is no greater difficulty in recognising the legitimate place of geography as one of the sciences of observation, because of the close relation that subsists between the matters with which it deals, and those that fall within the scope of other branches of science, such as geology or biology, than there is in assigning the like character to chemistry and electricity, because of the interaction of the forces with which they specially deal, with those that constitute the principal subject of inquiry in other specialised fields of human knowledge.

Of course, apart from the gains to geography as an observational science, the other departments of science represented on these expeditions have greatly profited by the opportunity thus afforded.

The results of all this activity have been vast additions to our knowledge of the great features of the earth's surface, their constitution, their morphology, their distribution, their mutual relations, their influence on the distribution of all that the surface sustains, mineral, vegetable, animal, and, most important of all, man, of whom all the other factors form the environment. If we compare the maps of to-day with those of fifty years ago, they will afford striking evidence of the great additions which have been made to our knowledge of the face of the earth. The entirely unmapped has been enormously decreased, while marked progress towards accuracy has been made on the imperfectly mapped features. Great improvements have been made, especially in the British Islands, in cartography, both in the symbols adopted for indicating the physical features and in execution and workmanship. At the International Geographical Congress of Geneva in 1891, a great scheme was initiated for an international map of the world on the scale of 1/1,000,000. At subsequent conferences a series of regulations was drawn up to be followed by each country in producing a map of its territories, and a certain amount of progress has been made, though it is feared that the war has been a serious interruption. On the other hand, one important result of the war has been the production by the Royal Geographical Society, under the direction of the Geographical Section of the General Staff, of a map of Europe and the Near East on the lines of the international map which not only has proved of great service in connection with the war, but also will be of permanent value as the standard map of the extensive region dealt with. In general, it may be said that the maps and atlases of the present day reflect the marked advance which has been made in geography generally during the past half-century.

In recent years considerable progress has been made in geodesy. In 1899–1902 an arc was measured in Spitsbergen, while under the direction of the late Sir David Gill there was initiated the measurement of a great arc in Africa along the meridian of 30° E. If these arcs are connected through Asia Minor and Europe, a continuous measured arc of 105° would be obtained. The arc of Quito (Peru) has been re-measured under the direction of the French Academy of

Sciences, and it is hoped may be connected with the great arc in 98° W. which has been undertaken by the U.S. Coast and Geodetic Survey. Other arcs of special importance have been measured in Europe and Asia.

One of the great problems with which geography has to deal is that of distribution. It is obvious, on the face of it, that the many types of features which are distributed over the surface of the earth must have a potent influence on the distribution and activities of humanity, which lives and moves and has its being among them. There can be no doubt as to the influence of geographical conditions on history and other human activities, and perhaps even on race; but, as Ellsworth Huntington points out, the claims in this respect are often too vague to convince the sceptical historian. What we want is a more precise statement as to the nature and amount, the quantity and quality, in each case in this environmental influence compared with various other elements. Several attempts have been made to deal with the problem in recent years; definite areas should be selected and the problem worked out in detail on the spot.

In what precedes we have dealt mainly with the geosphere; but the hydrosphere is an important section of geography, both in itself and in its influence on the former. Hydrography is a convenient term to include the various forms in which water is distributed over the face of the earth—rivers, lakes, and the ocean itself. Potamology, or the study of rivers and their *régime*, has attracted much attention in recent years. Limnology, the study of lakes—depth, movement of their waters, distribution of life, physical nature of their basins—initiated by Forel in the 'eighties and 'nineties on the Lake of Geneva, has been continued in the Scottish lochs with voluminous results of high scientific value. But it is in oceanography that the greatest advances have been made during the half-century. A certain amount of work on a limited scale had been done in oceanic research, but it remained for the great *Challenger* Expedition during its 1872–76 cruise over the oceans of the world to create a new department of science under the name of Oceanography. This was followed by other similar expeditions in the *Siboga*, the *Planet*, and the *Michael Sars*, the result being a vast accumulation of data on the ocean in all its aspects—its depths, the nature of its bed, distribution of life at all depths, saltness, temperature, its surface and under-currents, and other features.

As the result of a movement initiated by the Royal Geographical Society in 1884, geography has obtained a place in education in Great Britain which it had never held before, while the standard of the subject has been raised to a much higher level. The subject has at last received ample recognition at Oxford and Cambridge and other universities in the kingdom, while radical reforms have been made in schools of all grades. On the university programme we have such heads as the Principles of Geography; Survey of the Natural Regions of the Globe; Land Forms and Morphology of the Continents; Meteorology, Climatology, and Oceanography; Human Geography in its Various Phases; Geographical Methods of Notation, and so on. This will show how high is the standard and how wide the field of the subject compared with the position even thirty or forty years ago.

Such, briefly, is a review of the progress of geography during the past half-century and its present position in this country. It has made vast advances in all directions and risen far above the lowly position assigned to it fifty years ago. Still it has by no means reached the position claimed for it by the late Sir Joseph Hooker; "it must permeate," he said, "the whole of education to the termination of the university career, every subject taught having a geographical aspect." Notwithstanding all that has been accomplished in the more or less scientific exploration of the face of the earth, much still remains to be done before our knowledge of its features is adequate. The great blanks which disfigured the map of Africa fifty years ago have, no doubt, been filled up, but it is doubtful if more than one-tenth of its surface has been mapped with anything like accuracy. Of Australia, large areas have only been provisionally mapped, and the same may be said of Asia. Even in the case of Canada and the United States much remains to be accomplished before these countries are as thoroughly mapped as the United Kingdom, India, and even Japan. Of South America, only fragments have been adequately mapped, and probably a million square miles are entirely unexplored.

Oceanography has by no means completed its task, though when Amundsen returns in four or five years' time he may be able to tell us all we want to know about the Arctic basin. While there is no need for a network of mapping on the Antarctic continent, still we desire further additions to our knowledge of its great features, its geology, its meteorology, as well as its resources, if there are any of value accessible. There remains ample room for work by trained explorers in many of the islands of the ocean. It is thus evident that plenty of work still remains to be done in exploration, in survey, in mapping, and in collecting the varied material which will enable the trained geographer to work out those problems which bear on the relations between man and his geographical environment. Happily, the marked educational advance during the last thirty years in the status of geography, and the great improvement in geographical education, have resulted in producing an increasing number of young geographers capable of dealing on scientific lines with the problems presented; in this respect we are rapidly approaching the standard which has for long been almost a monopoly of Germany.

PROGRESS OF PHOTOGRAPHY.

By CHAPMAN JONES.

TO most people fifty years ago, photography was represented by the "carte-de-visite" which they exchanged with their friends, and a few "views" which they bought now and then as mementoes. Some who were rather better-to-do preferred the larger "cabinets" which had been fashionable for two or three years. But there were also, as there had been for the previous thirty years or more, an increasing number of those who were really interested in the art and the science of photography. The Royal Photographic Society, then the Photographic Society of London, was sixteen years old, and there had been journals devoted to photography for about as long. The rapid rectilinear lens, which has enjoyed a greater popularity than any other lens, had just been introduced. The carbon process had already been practised commercially, but in that very year it received its final simplification by the elimination of the use of a cement to hold the exposed tissue on to its support during development. Large photographs had been made, one, 12 ft. by 7 ft., having been recorded in 1868. Photography in natural colours had had its history written, the principles of three-colour photography were understood, the nature of the developable image had been much discussed, and an electrical theory had been proposed. Actinometers had been devised. The kinematograph was represented by the zoetrope, or "wheel of life," a mere toy.

Thus it is obvious that when NATURE first saw the light photography had made very considerable progress, but its applications were hampered by its limitations. There was no plate sensitive enough for a photographic zoetrope, and the three-colour method of colour photography was not practical, because the plates available were insensitive to red and nearly insensitive to green. But the keys to the removal of these two great barriers to progress were soon to be found. Vogel's fundamental discovery that silver haloids might be made sensitive to red and to green by treating them with certain colouring matters was made within four years, and within eight years, during which gelatine had been coming to the front as a medium to replace collodion, Bennett found that by keeping gelatine emulsion warm for a few days the general sensitiveness of the plates coated with it was increased very many times. It remained, of course, to develop the possibilities thus demonstrated, and, equally of course, they were developed. During the 'seventies there were other notable matters. Printing in platinum was introduced, the replacement of glass by films received attention, and the photographic zoetrope became an accomplished fact in the work of Mr. Muybridge, of California.

In the 'eighties hand-cameras began to appear, isochromatic plates (that is, plates sensitised for green) were commercially produced, films were made practical, plates and films were coated by machines instead of by hand, and developing agents, which had hitherto been restricted to two or three, began to increase in number.

In the next decade, the 'nineties, Carl Zeiss issued the first anastigmat, which was soon followed by the products of other firms, and the mechanical, photographic, and optical difficulties of kinematography were largely overcome. Many new developing agents were introduced, and the chemical constitution apparently necessary to confer the power of development was elucidated.

In the early years of the present century much superior colour sensitisers for gelatine plates were found, and panchromatic plates became practically a new power in dealing with colour. The autochrome plate provided the first commercially practical method of photography in natural colours on a single plate and by one series of operations.

This brief sketch of some of the chief items of the history of photography for the period under review is necessarily very incomplete, but it gives landmarks that may help to picture the general progress. The applications to scientific and pictorial work, as well as to matters of immediate commercial importance, followed close upon each step that increased the scope of photographic methods, until in many cases these took the first place instead of a very subordinate position. We have examples of this in astronomy, in surveying, and especially in photo-engraving and block-making, for in this last case the hand methods have been rendered commercially obsolete. With the increase of facility the popularity of photography increased until now one regards any person who can say that he has never taken a photograph as something akin to a person who is unable to write.

The Editor asks me to say something as to the "promise of future advance." Photography in its essence is a pictorial method of recording, and may therefore be fitly associated with writing, though photography has the great advantage of being automatic. Besides this it has so many advantages that it will form a necessary part of the training of every well-educated person. Whether it will be a college or a secondary-school subject the educationists must decide, but it will form a necessary adjunct to the study of almost all college subjects. In the professional and commercial world its importance will be increasingly recognised as a means of rapidly getting unbiased records. The kinematograph is a photographic method of recording movement whether slow or rapid, and will therefore be increasingly appreciated both for scientific purposes and as a means of education.

As to pure photography—that is, the study of photography itself—we do not know what change takes place in silver salts when they are rendered developable. Of late this matter seems to have passed into the domain of atomic or molecular physics. We know little enough about gelatine, and want to know a great deal more. Gelatine has proved to be a better medium than collodion, but there seems no reason to suppose that a better than gelatine may not be found. We seem to have realised the maximum aperture (or rapidity) in lenses, but there is no such absolute boundary to the sensitiveness of photographic plates, and here we look for continued progress. One fundamental question: Why should silver occupy such a unique position among all the elements with regard to the sensitiveness of its salts?

REPRODUCTION OF ILLUSTRATIONS, 1869-1919.

By EMERY WALKER.

FIFTY years ago illustrations for books or periodicals were printed either from engraved wood blocks, steel plates, or were lithographs. In the earliest numbers of NATURE examples may be seen of the first method—in that of January 20, 1870, we find a diagram of a section of the tube by which it was proposed to construct the Channel tunnel; and in that of February 17 an illustration of the Newall telescope at Gateshead: these could scarcely be bettered now. The map illustrating the main drainage of London, in the issue of March 31, is an example of the inadequacy of wood for such a purpose.

Two years later Mr. Alfred Dawson patented a method of engraving designed to supersede wood, and though his object was not attained in subjects requiring tone, diagrams and simple maps were found at once to be better and more cheaply engraved by his process.

Dawson's typographic etching, as he named it, is produced thus: A metal plate is coated with a ground of wax composition; the drawing is made upon the plate through the ground down to the surface of the plate with steel points, similar to those used in etching, but they are faceted to different dimensions at the points. If lettering is wanted, as for a map or a diagram, the letters are stamped in the wax with ordinary printer's type. The spaces between the lines and letters are then raised upon the plate by the addition of melted wax, which unites with the ground and runs up to the line, and in the hands of a skilful operator stops there, thus forming a mould. This is then blackleaded, and upon it copper is deposited by a galvanic battery. When the copper is about the thickness of fairly stout brown paper it is taken off the mould and the outer surface tinned and "backed up" with antimonial lead. The leaden surface is turned in a facing lathe and mounted upon wood or metal, which brings the printing surface of the block to the height of type. It is then practically a piece of type and can be "set up" and printed with the text of the page.

This process was a development, with some refinements, of a method patented by Edward Palmer about 1840, and called by him "glyphography"; it was used to a limited extent for book illustration.

Dawson's typographic etching is still in use, and it may be interesting to note that the line blocks for the maps in Fortescue's "History of the British Army," and the greater part of those for the last edition of the "Encyclopædia Britannica," were engraved in this way.

In France a method called, after its inventor, "Gillotage" had been in use a few years earlier than this, by which blocks for the cheaper kinds of newspapers were made by transferring to zinc drawings made in reverse upon lithographic transfer paper, and the "whites" bitten away with dilute nitric acid. This process was introduced into England after the suppression of the Commune in 1871. The application of photography to this process was the beginning of a revolution in book illustration. For though wood-engraving held its own for many years after this for subjects in which chiaroscuro was required, it was gradually disused for drawings made in line, and the art of pen-and-ink drawing for reproduction began.

Artists soon got used to the new method, and there was a general demand for a process which would reproduce not only drawings in line, but also those made in washes or body colour, and would be suitable for the direct reproduction in the printing press of a photograph from nature. This was met simultaneously by F. E. Ives, an American of great photographic distinction, and by a German inventor, Meisenbach. Ives's process, though beautiful results were obtained, was too complicated for general use, and Meisenbach's process, called in English "half-tone," held the field. The negative of the drawing to be reproduced was made by photographing through a screen of parallel lines placed close to, but not touching, the sensitive surface of the photographic plate, and when the exposure was half-completed the lens was covered and the screen turned round so that the lines ran in the opposite direction to that in which the screen was first placed, and the exposure completed.

This was in 1882. The result was rather crude and deficient in variety of tone. The real advance was made by the invention, by Max Levy, of Philadelphia, of a new screen composed of two ruled glasses placed in contact at right angles. Max Levy's screens were imported largely, and from this time England, which had been, in the earlier stages of the invention, dependent upon Vienna, and to a smaller extent upon Paris, for half-tone blocks, went ahead, and now half-tone work made here is not second to that of any country in the world. It is used, not only in books, but also for the illustration of daily papers.

The most important invention since Meisenbach's is the three-colour half-tone process. This was based upon James Clerk Maxwell's researches made so long ago as 1861. The drawing or object is photographed successively through three colour filters: for the red negative a green filter is used; for the blue, a red; and for the yellow, a violet or blue filter.

A half-tone block is made from each colour negative, an operation requiring the utmost accuracy to get register, and the screen is placed at different angles to get white into the interstices of the grain and to prevent an effect like that of "watered silk."

In all these processes intended for the letterpress machine, the metal plate, for rough work of zinc, and for more delicate work of copper, is mounted "type-high" in the manner described above.

A more recent invention obviates the use of the objectionable but necessary shiny coated paper: An impression is made from a half-tone plate upon an india-rubber roller and transferred to the paper, which may have an ordinary or even a slightly rough surface. Excellent work has been done with some subjects by the application of this method to the three-colour process, but so far the average results are not equal to those obtained by the use of blocks upon glossy paper. This is called "Off-set."

A very important photographic process, used until lately more on the Continent than in England, where it was first introduced in 1870, is collotype; or, as it was known in earlier days here, "heliotype." Mungo Ponton, in 1839, used bichromate of potassium, and Fox Talbot, in 1851, discovered the action of this chemical in making a gelatine film sensitive to light. When a negative is printed upon a film of gelatine so sensitised, it absorbs moisture in inverse ratio to the amount of light it has received, and when by means of a roller a greasy ink is applied to it, it takes the ink in the ratio of its dryness, and so gradation in the print is obtained. The advantage of this method of reproduction is that it is not necessary to use the glossy coated paper, which is essential if one is to obtain the best result from either a half-tone block in black or from a set printed in three colours. The disadvantage is that it cannot be printed on a letterpress machine in the same way as a block.

This process is unrivalled for facsimiles of documents and early manuscripts. But for the reproduction of pictures and illustrations requiring a greater depth of tone, photogravure remains without a rival at present. It is interesting to note that Niepce de Saint-Victor, in 1847, had produced a photogravure plate. He coated a copperplate with bitumen of Judea and exposed it to the action of the sun under a line engraving, which acted as a photographic positive, afterwards biting the protected lines into the copper, and etched a plate which could be printed on a copperplate press.

Since that time many modifications have been made, the more important being the process invented by Rousillon based upon a beautiful invention of Walter Bentley Woodbury, patented in 1866, and introduced by Messrs. Goupil, of Paris, early in the 'seventies, which was an electrotype from a gelatine mould in relief; and that by Klic, of Vienna, who invented the method now most generally used: A copperplate is covered with an aquatint ground made by dusting powdered resin or bitumen of Judea on it and then melting it with a gentle heat. This causes the particles to run together in little "hills," leaving minute "valleys" between them. Upon this plate an ordinary carbon positive made from a reversed negative is squeegeed down and developed. When it is dry it is placed in a bath of perchloride of iron. This acid bites through the gelatine of the carbon positive and into the copper, the depth being graduated by the varying thickness of the gelatine of the carbon positive. When the biting is completed the gelatine is cleaned off, the copperplate inked by filling the interstices or pits and the excess of ink wiped off, first with canvas and fine muslin, and, finally, with the printer's hand, and an impression taken upon damped paper in the same way as from a copperplate engraved by hand.

An adaptation of photogravure to machinery was made at Lancaster about twenty years ago. It consists in applying Klic's method to a copper cylinder by the use of a half-tone screen instead of a grain produced by bitumen or resin. After inking the surface of the cylinder it is wiped to remove the superfluous ink and impressions on paper are made by a rotary motion at a great rate. The process is now largely used for illustrations for weekly illustrated newspapers and magazines.

PROGRESS IN SCIENCE TEACHING.

BY SIR WILLIAM A. TILDEN, F.R.S.

A MAN who remembers clearly the first Great International Exhibition in 1851, and was at school through the period of the Crimean War, can no longer claim to be ranked among young men or even the middle-aged. But, with all the disadvantages of age, there is something to be said for the satisfaction and practical use of personal reminiscence. The days of school life which I can recall were practically pre-scientific, for, though one or two schools, such as the Quaker School at Ackworth, included elementary science in their programme, the utmost attempted, as a rule, was a visit from a peripatetic teacher, who came, like the dancing-master and the drawing-master, once a week or a fortnight. This was the practice at a school in Norfolk at which

I was a pupil in 1856. It was kept by a kindly old clergyman, who would, in the occasional absence of the lecturer, quack a bit himself and sometimes show experiments, not always well chosen. I remember seeing the cruel operation of putting a mouse under the receiver of the air-pump and extracting the air. And though Stockhardt's "Experimental Chemistry" was the text-book, the boys made no experiments for themselves, but were required to commit to memory passages from the book, such as "iodine has a violet vapour." There were no school laboratories in those days, even in the great public schools, neither was natural science so much as mentioned in the great majority of the schools in the country.

There can be no doubt that the Great Exhibition in 1851 set many people thinking, for in 1853 the Department of Science and Art was created with the object of assisting in the establishment of local science schools and classes. Many of the first created schools failed, and in 1859 the only classes in actual operation under the Department were at Aberdeen, Birmingham, Bristol, and Wigan.

The difficulty at that time arose chiefly from the scarcity of competent teachers willing to undertake the work, and a system was therefore inaugurated by which persons who passed the examinations held by the Department were considered qualified to teach and to earn payment on results. The system, with modifications, grew to gigantic proportions, and, whatever may have been said in later years in the way of criticism by those who object to all kinds of examinations, there can be no doubt that the existence of these classes served to spread an elementary knowledge of physical and natural science very widely through the country, and especially among the industrial classes, who would otherwise never have found their way into any place of higher instruction.

With regard to the introduction of systematic teaching of science into public schools and others of similar rank, there is the evidence of the Rev. W. Tuckwell, headmaster of Taunton School, who, in a paper contributed to the British Association at Exeter in 1869, stated that science had been taught at Taunton "for the last five years" and at the rate of not less than three hours a week. This was, however, a marked exception, for from the first report of the Duke of Devonshire's Commission it appears that in 1864 science did not exist in the programme of the largest and most famous schools. Very soon after this, however, systematic teaching, associated with practical work, began at Clifton, Rugby, and the Manchester Grammar School, and this example was soon followed elsewhere. Nevertheless, the Commissioners reported that in 1875, of 128 endowed schools examined, not one half had even attempted to introduce it, while only thirteen had a laboratory, and only ten gave so much as four hours a week. It was uphill work. Obstruction was rampant, not only among the headmasters, but also in the old universities to which the schools passed on their boys. The distribution of scholarships at that time was most unfair, and mischief was done by the procedure of the Oxford and Cambridge Schools Examination Board, which sent down examiners, sometimes ill-qualified for their office, who set unsuitable questions from the text-books with very little reference to the teaching.

At the present day all the great schools are provided with spacious laboratories and an equipment generally superior to that which was to be found in many British universities fifty years ago. Moreover, there is now a large body of highly efficient and enthusiastic teachers, not only in the schools for boys, but also in the high schools for girls, which have sprung up since that day. The science masters have formed an association which includes representatives of all the great public schools and many others—in all, upwards of three hundred members. The science mistresses have a separate association of their own, and as the problems they have before them are very nearly the same as those which interest the masters, it seems a pity that the two associations are not amalgamated. The existence of these associations and the position of influence to which the Association of Science Masters has attained show the changed position of physical and natural science as a school subject. There are, however, schools still where the headmaster stands in the way of the development of science teaching; there is the persistent, ignorant demand on the part of the public for those subjects only which are supposed to lead immediately to remunerative business; there is the almost total ignorance in Whitehall, in Parliament, and in the Ministry of the commonplaces of physical science; there are the indifferent methods still employed in classical teaching whereby an enormous waste of time is incurred: all these are circumstances which operate perennially against that kind of recognition of physical science in education which is essential to national progress, and must continue to be the subject of conflict until a state of balance between the advocates of the old and of the new has been established.

From the schools we may now turn to see what has been accomplished at the universities. In the early sixties of the nineteenth century the position of science at Oxford is indicated by the fact that Dr. C. G. B. Daubeny occupied down to 1867 the chair of chemistry simultaneously with that of botany. An undergraduate who chose to "go in for stinks" could attain a degree, but it was B.A. Daubeny's successor, Sir Benjamin Brodie, was a distinguished chemist, and in his evidence before the Royal Commission in 1873 he plainly stated his view that Oxford did nothing to extend scientific knowledge—that is to say, that research was not encouraged. At Cambridge things were in much the same position. There were some distinguished scientific professors, of whom Stokes was one of the most eminent, but there was no university laboratory, though one had been opened at St. John's College. At this time and for many years afterwards serious students of chemistry and some other branches of science resorted to the German universities for the instruction which they could not obtain in their own country in the higher parts of their subjects and in research, usually returning with the Ph.D. degree. In London the only chemical laboratories for the reception of students were at the Pharmaceutical Society (opened in 1844), at the Royal College of Chemistry (opened in 1845), at University College, at King's College, and at the Royal School of Mines in Jermyn Street. But a great step forward was taken when in 1860 the University of London founded for the first time in England a Faculty of Science and began to hold examinations for the degrees of Bachelor and Doctor in that faculty. The effect was immediate and extensive. The programme put forth appeared formidable, but it provided at once a stimulus and a guide to all the numerous casual students scattered throughout the kingdom, some attending classes of the Science and Art Department or mechanics' institutes, some engaged privately in evening study after business. As a simple matter of autobiography, my case was one of the latter kind. I was then a young demonstrator in the laboratory of the Pharmaceutical Society, but I was fairly well up in the physics and chemistry of that day. I also held a Science and Art certificate as a teacher of botany. The matriculation was the chief obstacle, as I had practically learned no Greek at school. This, however, diligence enabled me to surmount, and by 1868 I got my B.Sc. with First Class Honours in chemistry.

My case must have been very similar to that of dozens of young men at that time to whom came the opportunity of getting a stamp or brand without the necessity of throwing up the occupation by which they were getting a living. But it did more than that, for the syllabus of subjects comprised the whole circle of the sciences, including, besides the various departments of natural and experimental science, logic and moral philosophy, so that candidates were required to show at least a rudimentary knowledge of the subject-matter of various branches of human knowledge of which they would otherwise have remained totally ignorant. My own experience leads me to think that this "little knowledge," which, according to Pope's mistaken aphorism, is "a dangerous thing," is of great value even to the specialist. A *Doctor* of Science ought, and is supposed, to be an expert in some direction or other, but not long ago I met a London D.Sc. who had never heard of Bishop Berkeley. This curious fact revealed a state of ignorance of all philosophy and much more which he would have escaped had the old regulations been retained. This is, of course, now past praying for, and research, which implies specialism, is the order of the day. It is only consolatory to reflect that anything which induces concentrated thought has an educative effect on the young mind.

One of the greatest movements for the promotion of education in general, and conspicuously in the encouragement given to scientific teaching and research, was the foundation of the university colleges and new universities distributed over the country. In Manchester the college which became the nucleus of the present Victoria University had been founded by John Owens in 1851, while in London University College (the original University of London), King's College, and Bedford College were already in existence. But in 1871 the first step was taken towards the extension of similar benefits to other parts of the country. In the first instance these institutions subsisted on endowments provided by private benefactors, supplemented by aid from local subscribers or such bodies as the Guilds of London. But in a very few years these were found to be insufficient, and serious financial embarrassment had to be faced. After repeated applications to the Government for assistance, and a long struggle, the battle was won, and in 1889 State aid was granted in the form of the very modest amount of 15,000*l*. per annum, to be divided among the English colleges. Sir William Ramsay was one of the most active promoters of the movement, and the full story is recorded in his "Life" (Macmillan).

As to the future of scientific discovery, who can tell? The wonders which have been successively revealed during the last fifty years should teach us not to be surprised at anything. Co-operation among workers and organisation may do something in the way of gathering up knowledge of Nature, but whatever is done by Governments, institutions, or individuals, one consideration should ever be kept in view, and that is that genius will find its own way, and it would be worse than useless to prescribe subjects, or methods, or opportunities to the man who has been gifted by the gods.

ASPECTS OF SCIENCE AT UNIVERSITIES.

By Dr. Alex Hill.

DOUBTLESS the provision made by the universities of the United Kingdom for the teaching of science and for research is still inadequate. It always will be. The occupation of the field and its extension is a single process, not a process and its result; since the farther man explores, the wider is his vision of the unexplored. The improvement which has marked the past fifty years is roughly proportionate to the growth of knowledge and to the investigator's success in utilising it for the meeting of human needs.

Oxford, Cambridge, the four Scottish universities, Trinity College, Dublin, Durham (with no Newcastle College of Science), and London were the only universities in 1869. To these must be added Owens College, still in the house in Quay Street "to which a chemical laboratory and a large lecture-room had been added." In science Cambridge led the van with, possibly, University College, London, as her nearest rival. It is unsafe to adopt an order of merit. Much depends upon the point of view. Edinburgh, for example, in the biological aspect, might lay claim to precedence. We may take Cambridge and University College as examples of the provision made for science, then and now, seeing that space will not allow of a fuller treatment of the subject.

Science attained to the status of a department of knowledge when the Natural Sciences Tripos was established. The first examination was held in 1851. Yet for many years the various branches of natural science were regarded as possible substitutes for the humanities in the education of a gentleman, rather than as vehicles of a grim and strenuous discipline for the work of life. Science was Whewell's *forte,* omniscience his foible. The Tripos was reminiscent of his influence. All branches of science ranked alike. A candidate's place depended upon his aggregate of marks. To secure a first class he must show that his knowledge, like that of the stupendous Master of Trinity, ranged from zoology to mineralogy.

The institution of the Tripos was a powerful stimulus to scientific study. New buildings were erected in 1864 and 1865, yet the contrast between the accommodation and equipment of the various departments, in 1869 and to-day, is so marked as to be amusing. Salvin's building was a palace as compared with the hovel in the south-east corner of the old Botanic Garden, erected in 1786 by Mr. Bradwell, bricklayer, and Mr. Kaye, carpenter, both of Cambridge, in which, until 1864, all departments, with the exception of geology, had been lodged; a building which for several years after that date was shared by the professor of chemistry and the professor of anatomy (including comparative anatomy and comparative physiology). The lecture-room on the upper floor of this building was well lighted, but the metallurgical laboratory on the ground floor, and the cabinet in which, if possible, a body was dissected every year, were dark and inconvenient in such degree as seemed appropriate to the evil-smelling and repulsive rites to which they were devoted.

Salvin's building, which was enlarged later by the addition of an upper story, provided accommodation for mineralogy, botany, zoology, and natural philosophy. For long the block was known as the "New Museums," since the greater part of its space was given up to the housing of the herbarium and the collections of minerals and of zoological specimens. Museums, be it noted, were considered, in those days, as of far more importance than laboratories for the teaching of science. The geological collection was stored—it would be misleading to write "exhibited"—in Cockerell's building, now given up to the university library.

To-day the whole of the old Botanic Garden, with much surrounding property from which houses have been cleared, together with about six acres on the opposite side of Downing Street, is covered with noble buildings. Fortunately, they are not too noble. For the most part, they look as if they were intended for the purposes for which they are used. Cambridge is happier than some modern universities in this respect. The dignity of science is not enhanced by Gothic or Palladian architecture. Science looks to the future, not to the past. Steel girders and sheets of glass can be rearranged to meet new needs. The cotton-mill style is the only style appropriate to museums and laboratories. Proportion, light, ventilation, and convenience of access of the building as a whole and of its several parts are the only merits for which the man who designs them can lay claim to renown.

Excluding the professors of mathematics and astronomy, the scientific staff of the university comprised the professors of chemistry, anatomy, botany, geology, natural philosophy, and zoology, each of whom received a yearly stipend of 300*l.*, together with a demonstrator of anatomy, who received 100*l.*, and an attendant at the chemical laboratory. These officers alone were paid out of the University Chest. Additional assistants, lecturers, and demonstrators were to be found in some departments, but their employment was the professor's private affair. To the university staff must be added a lecturer in natural science at Trinity, two lecturers at St. John's, a medical lecturer at Caius, the superintendent of the laboratory at Sidney, and two lecturers in medicine and natural science at Downing. To-day we find nineteen professors of natural science and seventy-three readers, lecturers, and demonstrators on the university staff, and forty-three college lecturers.

The lures set in the gates of science were scarce likely to beguile a student from the broader ways. "Three-quarters of all university prizes and more than one-half of all college prizes are awarded for classics and English," the Calendar boasted in 1869. English might as well have been omitted. It could not stand alone. The only prize for natural science was the Sedgwick. Thirteen names appeared in the Natural Sciences Tripos, against 111 in the Mathematical and 73 in the Classical class-lists. In 1914, 153 men and women took honours in the Natural Sciences Tripos, against 121 in the Mathematical, 113 in the Classical, and 352 in the various other Triposes which have come into existence in recent years.

At University College, London, the laboratory accommodation was singularly modest, as, indeed, it remained until quite recent times. The steady flow of discovery which has issued from the cramped, dark, inconvenient chemical laboratory is testimony to the genius of the men who have successively occupied the chair. Students were not expected, in 1869, to do practical work, as understood to-day. The writer recalls sitting in a row of other students, in 1872, pulling petals from flowers and filling his notebook with floral diagrams; attending demonstrations in the physical laboratory; dissecting, when it came to his turn, a rabbit to be inspected by the class, whilst Prof. Grant, in the dress-coat, brocaded vest, and white cravat of the Georgian period, discoursed philosophy, with occasional reference to the rabbit. In the chemical laboratory students worked in relays, but so limited was its space that the lecture-theatre had to be fitted for the examination in practical chemistry by clamping a tray for each student on to the sloping board on which, during lectures, the notebooks rested. A similar description would apply to the laboratories at Edinburgh, Glasgow, Dublin.

Provision for teaching and research has kept step with the uses to which scientific knowledge has been turned. The distinction drawn between pure science and applied science is essentially unsound and wholly mischievous, as if the purity of science were sullied whenever the problem to be solved is suggested by an immediate human need. The discoveries made by an investigator who has a practical application in view are as truly additions to the sum of human knowledge as those which reward a worker who is following a line of research which can never, so far as he is aware, contribute to man's comfort. In most cases the practical man also advances the grasp of pure science by directing attention to gaps in theory, and by asking the professors questions which they cannot answer. The universities have been slow in realising their duty to the crafts and manufactures. It is greatly to be hoped that, in the near future, we shall cease to hear of independent bodies set up for the purpose of carrying out either "scientific" or "industrial" research. There is but one Science, and the universities are the instruments for extending its range.

FIFTY YEARS OF TECHNICAL EDUCATION.

By J. H. REYNOLDS, M.Sc.

JUST fifty years ago there appeared a remarkable book, the fruit of much thought, experience, and wide travel, entitled "Systematic Technical Education for the English People." Its author was Mr. J. Scott Russell, F.R.S., the designer of the *Great Eastern*, the largest vessel of that time, which rendered singular service in the laying of the first Atlantic cable. The volume was dedicated to the Queen, and the purpose of the dedication was declared to be "to entreat her Majesty graciously to consider the case of the uneducated English folk who are now suffering great misfortune in their trade, commerce, and manufactures, as well as in their social, moral, and intellectual condition, through having been neglected and allowed to fall behind other nations better cared for by the men whose duty it was to lead as well as to govern the people." The Queen was urged "to issue her Most Gracious Majesty's commands to her Majesty's Ministers to see to it that for the future the dexterous, energetic, willing working people of England receive at the hands of the Government a practical education for useful life as thorough and systematic as the best-educated nation in Europe."

Mr. Scott Russell declared that the condition of English education, both general and scientific, compared very unfavourably with that prevailing in Continental countries, notably in Prussia, Saxony, Württemberg, and Switzerland, whilst no provision worthy of the name existed for technical education and training, which were abundantly provided for all grades of workers in industry and commerce in all the countries named. He called in evidence the lessons taught by the Great Exhibition of 1851, which owed its origin to the enlightened views of the Prince Consort, and in which the civilised nations of Europe received their first lessons in technical education. Our superiority in machinery and its products was manifest, whilst in articles demanding beauty and grace of design we were plainly lamentably far behind some Continental nations. Mr. J. Scott Russell concludes his book by pleading for the appointment "of a powerful statesman to be Minister of Public Education with a strong will; a complete organised plan of a people's teaching; a determination that, at whatever cost, the English people shall become in one generation the best-educated nation in Europe—and it will be done." We have at last such a man in the present President of the Board of Education, and it is to be hoped that he may so remain and be given the means to carry out the essential reforms embodied in the great Act of 1918.

The enormous progress made by the several important nations as a result of the object-lesson of 1851 was made clearly evident at the exhibition held at Paris in 1855. England was no longer, in consequence of the establishment of schools of design and the circulation of the best models in the areas affected, outstripped in pottery and glass, whilst, on the other hand, foreign nations, such as France and Germany, recognising the advantage which England enjoyed in the possession of abundant raw material, such as coal, iron, and steel, together with skill in adapting them to the purposes of industry, and realising that the only effective way of meeting it was to apply higher science and research in their treatment and application, had already, with this aim in view, established schools for the education and training of both masters and workmen, with the result that their engineering exhibits made a remarkable display.

The International Exhibition of 1862 held in London showed a further striking advance on the part of foreign nations: Switzerland with her aniline colours, Prussia with her ingots of Krupp steel, France with her steam-engines, and the United States with ingenious machinery for economising labour. But it was the Exhibition of 1867, held in Paris, which offered conclusive and disturbing evidence of the successful efforts of foreign nations in the application of organised scientific and technical education to manufactures, especially in the production of well-designed steam-engines, boilers, ships' armour, and artillery.

In the great ironworks at Creusot, in France, there was established a systematic organisation of technical schools such as could be found nowhere in England. It was the considered judgment of skilled observers and of representative workmen in various trades who visited the exhibition that England no longer held the pre-eminence in industry which was surely hers in 1851, due, as was declared, entirely to the absence of sufficient facilities of training in pure and applied science. The Science and Art Department, founded in its entirety in 1853, had encouraged the establishment of evening classes in science and art, but they reached only a fraction of the workers, and except in a few instances they had little bearing upon the technology of industry. It may safely be said that in 1869 out of 1,250,000 youths engaged in industry not more than 5 per cent. were receiving any training in applied science in the day and evening institutions of the kingdom.

The period of trade depression that followed after the year 1869 and the awakening of the nation to the serious industrial competition of certain foreign nations, largely due to better educational provision, notably of scientific education, especially for the leaders of industry, gave rise to earnest efforts to provide the means of scientific and technical training in this country. The Livery Companies of the City of London joined with the City in the creation of the City and Guilds of London Institute in 1879, the purpose of which it was to provide a day and evening technical college at Finsbury (opened in 1883) for boys purposing to enter upon industrial pursuits, together with a central college at South Kensington, opened in 1884, for the training of future industrial leaders and teachers of technology. In addition, the aim of the institute was to encourage the establishment of technological classes throughout the kingdom and to set up a system of examinations in the subjects. Large annual sums were subscribed in support of these objects, and certificates, prizes, and medals were awarded to successful students.

Considerable annual grants were given in aid of the establishment of technical schools in Manchester, Sheffield, and other places, and the Company of Clothworkers made itself responsible for the establishment and support of a textile department at the Yorkshire College, Leeds, whilst the Company of Drapers founded and supported the People's Palace, now the East London College. The interest aroused in the subject of technical education and the rising competition of Continental nations led the Government to appoint in July, 1881, a Royal Commission "to inquire into the instruction of the industrial classes of certain foreign countries in technical and other subjects for the purpose of comparison with that of the corresponding classes in this country, and into the influence of such instruction in manufacturing and other industries at home and abroad." The Commission presented in 1884 an exhaustive and highly informing and stimulating report after nearly three years' inquiry not only in Europe, but also in the United States, which had a profound effect upon public opinion, and led to the passing of the Technical Instruction Act of 1889, which empowered local authorities to rate themselves for the support of technical schools. This was followed by the Act of 1890, whereby nearly 800,000*l*. annually derived from the customs and excise duties was placed at the disposal of local authorities for purposes similar to those of the former Act.

This resulted in the establishment, chiefly by the local authorities, of technical schools and colleges throughout the kingdom, a few of which were effectively equipped and staffed for the training of qualified day students intended for leading positions in the various industries, and some of these schools, like those of certain London polytechnics, Manchester, Glasgow, Sheffield, Bristol, and Belfast, came into intimate relations with their respective universities. The Education Act of 1902, which placed all grades of education, exclusive of the university, under the control of the local authority, had a unifying effect which made it possible to correlate the various forms of education and to bring the opportunity of secondary and technical training within reach of the poor but capable scholar.

Meanwhile, many important industries, notably those producing scientific instruments, chemical ware, fine chemicals, and especially artificial dyestuffs, had passed largely into the hands of German and Swiss firms, as witness their exhibits in the Paris Exhibition of 1900, due entirely to the command on their part of an effective supply of efficient scientific workers, so that they held the "key" of our textile trades so far as printed and coloured goods were concerned. The course of the great war has made clear, however, the innate capacity and resource of the English manufacturer in these and other products of foreign origin, as well as in the fertility of his invention and in the success with which he has met and solved many technical problems arising during its course. Striking evidence of this was displayed in the exhibitions of British scientific products held in London and Manchester in 1918, and in London in 1919, under the auspices of the British Science Guild—an organisation established to further the cause of scientific and technical education and promote attention to scientific method in all national affairs.

Another fruit of the war is the awakened interest in the subject of education on the part of large employers, and especially of the importance of scientific training and research. A Committee of the Privy Council has been instituted for the purpose of encouraging scientific and industrial research, with numerous sub-committees dealing with various sections of industry and with special products. Ten research associations have been formed in respect of the chief industries, and twenty-eight important researches have been undertaken and aided from the fund of 1,000,000*l.* placed at the disposal of the Committee by Parliament.

The Education Act of 1918, which should be made operative without delay, will, when it comes into full effect, supply a far higher type of student for our arts and industries. As showing the advance within the last fifty years, there were at the beginning of that period only four universities which granted degrees in England and Wales, one of which (London) was merely an examining body. Now there are eleven duly incorporated, with numerous colleges attached to them, many of them chiefly concerned with technical training and education. These universities are all well equipped and staffed for the teaching of science and its applications, in the encouragement of which this journal has borne no small share since its foundation in 1869.

Yet we have still far to go if we would keep ourselves abreast of foreign educational enterprise. There were in 1914 twenty-one universities in Germany, with 68,000 students, against eighteen in the United Kingdom, with 27,000 students. There were also eleven technical high schools in Germany, and sixteen other special high schools for agriculture, mining, etc., with 21,000 students, as against 5000 in ours, and in both age and standard of education at entrance their students rank much higher than ours. The State grants to universities and colleges in the United Kingdom were about 500,000*l.*, in Germany nearly 2,000,000*l.*, and in the United States 7,000,000*l.*, but in addition there was given nearly 4,000,000*l.* in private benefactions, as compared with 200,000*l.* in the United Kingdom. To maintain our position as a leading nation in industry and commerce, we need to increase the potentiality of our manhood, to secure which will require a much larger expenditure of money and effort. We want accomplished leaders and a well-educated and highly trained rank and file.

THE PROMOTION OF RESEARCH.

By SIR RICHARD A. GREGORY.

The great inventions of former ages were made in countries where practical life, industry, and commerce were most advanced; but the great inventions of the last fifty years in chemistry and electricity and the science of heat have been made in the scientific laboratory: the former were stimulated by practical wants, the latter themselves produced new practical requirements, and created new spheres of labour, industry, and commerce.—J. T. MERZ.

THE recognition of the value of scientific research as a determining factor of progressive development has been a common note of many public utterances in recent years. Ministers and labour leaders, manufacturers and men of letters, are impressed with the results of experimental inquiry and do homage to those who devote their lives to it. Rarely, however, is the spirit which prompts most scientific investigations understood. "The quickening power of science, only he can know from whose soul it gushes free." It seeks not to use, but to know: its aim is not an engine of war or a profitable invention, but the discovery of new knowledge and the creation of new ideas for all mankind. Researches which have practical applications as their proximate or ultimate ends are not likely in these days to need much advocacy for their support, but those which have no such aims must, like virtue, carry their own reward with them. The standard of value to-day, more than ever it was, is worldly riches, and if all research had to be measured by it science might gain the whole world, but it would lose its own soul by so doing.

When the State or the manufacturer makes provision for research, tangible results are expected, and freedom to explore what, from a practical point of view, seem to be unpromising bypaths is discouraged. To a certain extent Mr. Gladstone was right when in 1872 he termed the intervention of the State as "interference" with science, calculated to discourage individual exertion and so obstruct discovery and progress. The view then taken was that the more science was left to itself the better for it. We are far from accepting this *laissez faire* principle entirely, but there is some truth in it so far as purely scientific research is concerned. Creative genius never has been, and never will be, willing to submit to bureaucratic control or industrial needs, yet it discovers the new lands in which rich fruits are afterwards cultivated for the benefit of the world. While, therefore, we acknowledge with much satisfaction the growing appreciation of research as a means of promoting industrial advance, we trust that the apparently useless and unpractical pursuits of purely scientific workers will be regarded as equally worthy of encouragement.

When the publication of NATURE was begun fifty years ago, experimental research received little or no support from the State. Astronomical work was carried on at the Royal Observatory, Greenwich, and natural history objects were displayed at the British Museum, but there was absolutely no provision in this country for the support of experimental investigation of a modern type. It was pointed out in these columns in 1872 that great laboratories had been erected in Berlin, Leipzig, Bonn, Aix-la-Chapelle, Karlsruhe, Stuttgart, Griefswald, and other places, at the expense of the State, and special provision had been made in them for original scientific research, but no like developments had taken place here. When a deputation of the Council of the British Association waited upon Earl Grey, Lord President of the Council, in 1870, to urge on the Government the issuing of a Royal Commission to inquire into the state of science in England, Lord Grey thought that the whole inquiry was fraught with difficulties, but the object was worthy of a statesman's ambition. The Commission was appointed in the same year, with the seventh Duke of Devonshire as president and Sir Norman Lockyer as secretary; and the volumes of its reports issued from 1871 to 1875 are filled with convincing evidence and far-seeing suggestions.

The terms of reference of the Commission were "to make inquiry with regard to scientific instruction and the advancement of science, and to inquire what aid thereto is derived from grants voted by Parliament, or from endowments belonging to the several universities in Great Britain and Ireland, and the colleges thereof, and whether such aid could be rendered in a manner more effectual for the purpose." The whole position of science in the United Kingdom was surveyed in the volumes of the report of the Commission; and had the recommendations of the Commissioners been acted upon, we should easily have been in advance of all other countries in the applications of science to industry, and have been strongly equipped for all eventualities of peace or of war. Our statesmen had not sufficient knowledge of science to understand its relation to national advancement, or sufficient faith in scientific discovery to believe that provision for it would ultimately benefit the community industrially and politically; and we lost ground in consequence of their neglect.

One of the recommendations of the Commission was that a special department of science should be entrusted with the duty of promoting the scientific interests of the country. It was proposed that a Ministry of Science should be constituted, with a permanent and well-paid scientific council to advise the Government on scientific questions, consider inventions tendered for the use of the State, and conduct or superintend experimental investigations relating to such matters. The Department of Research and Information outlined in the Report on the Machinery of Government issued by the Ministry of Reconstruction a few months ago is intended to serve much the same purposes as were contemplated by the Duke of Devonshire's Commission. It is permissible in this connection to recall a communication to NATURE of June 15, 1871, in which Lt.-Col. A. Strange described the work which a Ministry of Science could undertake, and added, in words which are as apt to-day as they were when they were written:

When we have all scientific national institutions under one Minister of State, advised by a permanent, independent, and highly-qualified consultative body—when we have a similar body to advise the Ministers of War and Marine in strategical science—then the fact that, in accordance with our marvellous constitution, these ministers must almost necessarily be men without pretension to a knowledge of the affairs which they administer, need cause us no alarm. When these combinations have been, as they assuredly will be, sooner or later, effected, the wealth, resources, and intelligence of the nation, having due scope, will render us unapproachable in the arts of peace and unconquerable in war—but not till then.

Though the Ministry of Science advocated fifty years ago has not been realised, the Department of Scientific and Industrial Research established in 1916 fulfils many of its functions and is likely to undertake further work for the co-ordination and development of national scientific activities if the recommendations of the Report on the Machinery of Government are ever carried out. The Department has a fund of one million pounds voted by Parliament as a block grant to be expended over a period of five or six years. This fund is being used to make grants towards the foundation and maintenance of approved associations for research on a co-operative basis. In addition, the Department has at its disposal an annual Parliamentary vote to cover the cost of researches not undertaken by the research associations, to provide grants to research workers, and for administration. The Department also now administers the National Physical Laboratory, which was founded in 1899, and to which the sum of 155,000*l.* is allocated in the Civil Service Estimates for the current financial year.

National provision for scientific work has thus been considerably extended in recent years. The official attitude of earlier days was represented by a reply which the Lords Commissioners of H.M. Treasury made to an application from the British Association in 1872 for a grant of 150*l.* to secure the continuance of some important tidal observations. The reply was:

I am to state that their Lordships have given their anxious attention to the memorial, and that they are fully sensible of the interesting nature of such investigations, but that they feel that if they acceded to this request it would be impossible to refuse to contribute towards the numerous other objects which men of eminence may desire to treat scientifically. Their Lordships must, therefore, though with regret, decline to make a promise of assistance towards the present object out of public funds.

It will be evident from this example of the position of State support for science in England in 1872 that much remained to be done in order to change the official mind which after "anxious attention" had to express "regret" that the Government of these islands could not provide the sum of 150*l.* for tidal observations because further demands might be made for the support of other investigations. It is not too much to say that NATURE has been largely responsible for bringing about a more encouraging attitude towards scientific research on the part both of statesmen and the public generally. Throughout its existence this journal has consistently and persistently advocated increased attention by the State to scientific investigation and the need for liberal endowment of all work by which natural knowledge is increased. It is gratifying to know that the principle of national responsibility for the fostering of these research activities has in recent years been officially accepted.

Fifty years ago the provision made by Parliament for the promotion of science in the United Kingdom was an annual grant of 1000*l*., which was administered by the Royal Society. In 1876 a further grant of 4000*l*. was voted for "the payment of personal allowances to gentlemen during the time they are engaged in their investigations." In 1882 the grant of 1000*l*. was discontinued, and that of 4000*l*. has been included since then in the Civil Service Estimates without increase. The Royal Society, which administers the grant, derives no pecuniary benefit from it, and it only shares to the extent of a few hundred pounds annually in the additional annual grant of 1000*l*. made to assist in defraying the expenses of scientific publication. If this grant were increased to ten times the amount it could be effectively used by scientific societies, for the costs of publication are now very heavy and the output of papers or other works worthy of publication is much greater than when the grant was originally made in 1894.

In the Estimates for 1869–70 a grant of 1000*l*. to the Royal Society, 500*l*. to the Royal Geographical Society, and 300*l*. to the Royal Society of Edinburgh, together with other grants for scientific investigation, were classified together as votes for learned societies, with a total of 12,300*l*. The total amount for scientific and other institutions in the Estimates for 1919–20 is about 114,000*l*., but this includes 47,000*l*. for the Meteorological Office, and 20,000*l*. for the National Museum of Wales. In addition, the grants for investigation and research under the Department of Scientific and Industrial Research are estimated at 93,570*l*., and there is a grant of 12,775*l*. for the Fuel Research Station.

State grants to Colleges of London and Manchester were recommended by the Devonshire Commission in 1874, but the first direct assistance of this kind from the National Exchequer was a grant of 4000*l*. to the University College of Wales in 1883. In 1889–90 a vote of 15,000*l*. was included in the Estimates for University Colleges in England, in addition to 12,000*l*. for the three University Colleges of Wales. The total grant under that vote was then 44,785*l*., and now—thirty years later—the total amount of the grants to be paid out of the Exchequer for the maintenance of university institutions in the United Kingdom during the year 1919–20 is 1,000,000*l*. Though the increase is substantial, there are more institutions to participate in the grant, and much larger staffs and more elaborate equipment are necessary, so that it cannot be said even now that adequate provision has been made by the State for university education.

In university grants and gifts, as in those for research, the tendency is to promote the applied sciences and to overlook the needs of departments concerned particularly with knowledge of no apparent practical value. It is forgotten that the great advances in the industrial sciences of modern times, those which have raised the industrial and commercial life of the community, and so enormously increased its wealth, have had their origin in university laboratories and like places of what may be termed academic study. Investigations and discoveries on the borderlands of science, and leading to no immediately useful results for mankind, are often in the end the most valuable. It is the duty of universities to provide encouragement and training for men and women who possess special capacities for carrying on work of this kind; and a wise State will see that these workers are provided with full facilities for the cultivation of their abilities, as well as freedom to follow what seem to them the most promising paths of investigation. A scientific research laboratory cannot be conducted on the lines of a business house in which each department has to justify its existence by profitable returns. It must be independent of its patron, whether this be represented by a State department or by a governing body of commercial men. Unless this is so, our university laboratories and our research workers in fields of pure science may be reduced to the condition of some of the universities in the United States, amusingly illustrated by President Maclaurin, of the Massachusetts Institute of Technology, as follows:

The superintendent of buildings and grounds, or other competent authority, calls upon Mr. Newton.

Superintendent: Your theory of gravitation is hanging fire unduly. The director insists upon a finished report, filed in his office by 9 a.m. Monday next; summarised on one page; typewritten, and the main points underlined. Also a careful estimate of the cost of research per student-hour.

Newton: But there is one difficulty which has been puzzling me for fourteen years, and I am not quite . . .

Superintendent (with snap and vigour). Guess you had better overcome that difficulty by Monday morning or quit.

The absurdity of the picture is manifest; yet there is a tendency to regard research as more or less routine work in which results can be ordered and measured as they can by methods of scientific efficiency in industry. This is the present danger, and it is the duty of all who cherish increase of knowledge to see that such inhibitory conditions are excluded in our laboratories of creative science.

RESEARCH AND ITS APPLICATION.[1]

RESEARCH in the distant past was the privilege of the few. In chemistry, during the Middle Ages, the alchemists were practically the only men pursuing it, and they in secret, and not always from the highest of motives. Working by themselves as they did, they had not the great advantage of meeting and discussing with others similarly engaged, and using their progress and mistakes to intensify their own increase in knowledge. Thus it has come about that the science of chemistry is little more than a century old, and its tremendous advances only a few decades.

As the foundation of all these advances research is firmly embedded. Without it the structure could not have arisen or the glowing anticipations of the future been even imagined. Twenty centuries ago we were told, "Seek, and ye shall find; knock, and it shall be opened unto you." No one can deny that there have been accidental discoveries, some of great moment; but this has not been, and will not be, a safe dependence. Accidental discoveries are not to be relied on, although they are not to be scorned. In chemistry the accidental good fortunes have usually come to those who were really seeking, although possibly for something far different; but, note this, they were usually made by men qualified to recognise an important discovery when it flashed across their vision.

Research, of course, is not of necessity to result in invention. It may in that respect terminate in a *cul-de-sac* from which with present knowledge there is no egress; or, what more frequently happens, it may lead to a line of reasoning which in time leads to another, and so on, until suddenly a bright light illumines the way and a goal of the greatest importance is attained. Many instances illustrative of this could be mentioned. One only need here be cited, and that because of the importance it has assumed in the light of recent developments.

As early as 1882 men of science rigidly established by chemical research what chemists call the "constitution" of the blue vegetable dye indigo, and clinched that scientific conclusion by preparing the identical material in the laboratory. This particular important addition to human knowledge has remained a discovery merely, yet it so stimulated the search for practicable methods of applying that discovery to human needs that voluminous researches in a number of European countries were undertaken almost at once for that purpose. It remained for a college professor, working in quite a different field, to hit upon the central idea of the successful indigo method of 1897, and to clinch it by appropriate laboratory methods. In 1901, however, one of the so-called "inorganic" chemists, in searching for new worlds to conquer, evolved an idea which he thought would make one of the discarded and discredited methods of making indigo a worthy rival of the only commercially successful indigo method of that day. And he was right! The owners of the 1897 method were forced to look to their laurels.

The chemical knowledge and research that enter into the synthetic production of indigo, as we know it to-day, come from more than three generations of chemists, scattered all over the globe, speaking many languages, researching on many different and separate problems which touch almost every phase of human endeavour; and the end is not yet.

True research must be intentional and intensive. We must really seek if we would find. We must really knock at the doors of the secret chambers of knowledge if they are to be opened to us. We must have imagination, it is true, but we must have more than that. There must be the foundation of sound education and the ability to extend it to embrace new and unexpected knowledge, and apply this in its turn as we progress upwards.

The importance of research is being more and more recognised and understood by the public. One of the most encouraging evidences of this is shown in the preamble and resolution adopted recently by the American Federation of Labour at Atlantic City, indicating as these do a clear appreciation by that great association of how much we all depend on what science will disclose to ameliorate the conditions of the future.

But let our friends of the federation not be content with what the Government can do in the line of their resolution, good as it has been and will be. Let them start a carefully planned series of researches themselves, and follow them up until the truth stands revealed. Employers of labour have been doing this for years. The shining goal of all research is the truth, the whole truth, and nothing but the truth. Thus, starting from different angles, with fairness and thoroughness, the various so-called interests will arrive at the same truth, for there can only be one truth concerning any question. Thus will it come to pass that capital and labour will discover that the true interest of one is the true interest of all, and instead of bickerings and suspicions we shall have that cordial co-operation which is absolutely essential if we are to get the best out of this world of ours.

Scientific discovery is really not a haphazard matter. The art of making it can be cultivated, and definite rules of research can be laid down. Many elements enter into the problem, and these have been very well tabulated by the late Dr. G. Gore in his book, "The Art of Scientific Discovery." He defines the difference between discovery and invention as follows:—"Discovery consists in finding new truths of Nature, whilst invention consists in applying those truths to some desired purpose"; and that definition is sufficiently accurate. Research does not always lead to discovery or discovery to invention, but the sequence is logical.

The application of research has always required a high order of talent. In the future a still higher order of talent will be necessary, but in addition this talent must be prepared by education to do this very thing. How can we produce the leaders who shall adequately combine both the scientific and the practical qualifications that are necessary? This is one of the greatest and most interesting problems awaiting solution by our educators, and on its correct solution depends, in a larger degree than many imagine, the future of successful and contented industry in this country.

The candidate for leadership should have a healthy body, good habits (which involves good character), and a good mind educated to the highest degree attainable. This education should be specialised in the desired direction, while good all round. He should have a thorough knowledge of human nature. To play on the "harp of a thousand strings" requires an unusual acquaintance with the instrument. How many men, otherwise great, have broken down here, sometimes because they have given too much confidence, sometimes not enough, sometimes because they did not know how to select assistants.

Let us proceed to fill our high places of every kind with the men and women specifically prepared to fill them, being assured that the effort to do so will produce an army of those not quite qualified for the top, but of the greatest value to assist those who are. Let us educate for living, certainly; but let us also educate for leadership—that superlative leadership of which civilisation will stand more and more in need as it increases in complexity and reaches higher and higher planes.

[1] Abstract of an address delivered by the President of the American Chemical Society, Dr. W. H. Nichols, at Philadelphia, September 4.

BRITISH BOTANIC GARDENS AND STATIONS.

A MARKED feature of the scientific activities of the past fifty years has been the extensive establishment throughout the British Empire of botanic gardens and botanic stations. The history of such institutions is a long one; it takes us back to the time of the Pharaohs. It is also wide; the Spaniards found, in the Mexico they devastated, establishments of this nature conducted with as much enlightenment and on as elaborate a scale as any then to be met with in Europe.

The motives underlying the creation of such gardens have varied at different times and in different countries. Up to the middle of the sixteenth century the scope of European botanical gardens was mainly confined to the technical task of illustrating as fully as possible what were believed to be the sources of classical simples. During the next hundred years this was extended so as to include such æsthetic and economic novelties as could be made to grow. But by the middle of the eighteenth century, when the Royal Garden at Kew (1759), and the Botanic Garden at St. Vincent in the West Indies (1764), were founded, the purpose of botanical collections had become largely limited to the assemblage of plants interesting because of their rarity.

Presently a healthy reaction against this rather narrow outlook arose, for we find the historical memorandum by Lt.-Col. Kyd, to which the establishment of the famous institution at Calcutta was due (1786), advocating "the propriety of establishing a botanical garden, not for the purpose of collecting rare plants (although they also have their uses) as things of mere curiosity or furnishing articles for the gratification of luxury, but for establishing a stock for disseminating such articles as may prove beneficial to the inhabitants as well as to the natives of Great Britain, and which ultimately may tend to the extension of the national commerce and riches." Already Sir Joseph Banks, with his practical mind, had made representations to the same effect with regard to Kew, urging the utilisation of the Royal Garden as a central institution where information regarding the vegetation of the globe and its economic uses could be accumulated; where useful plants from all quarters could be raised; and whence such plants could be distributed to the overseas possessions of the Crown. Before the close of the first generation of the nineteenth century, many important establishments of the kind had been provided; among these we may note the gardens at Peradeniya in Ceylon, Saharunpur in North-West India, Singapore and Penang in Malaya, Buitenzorg in Java (during the brief occupation of that island by the English), Trinidad in the West Indies, and Sydney in Australia.

The conversion of Kew into the national botanic garden for this country (1841) gave a new impetus to this salutary activity, and under the active guidance of three eminent directors—Sir W. J. Hooker (1841–65), Sir J. D. Hooker (1865–85), and Sir W. T. Thiselton-Dyer (1885–1905)—the tradition established by Banks was vigorously sustained. To this impetus we may attribute the establishment of the famous gardens of Melbourne (1846), Durban (1850), Adelaide (1855), Brisbane (1855), and Jamaica (1857), though in the last case the inability of the local legislature to appreciate the value of science ensured for the garden the fate which had befallen that founded a century earlier in St. Vincent. The great services rendered by Kew to all forms of botanical enterprise have been nowhere more manifest than in the training of those who have proceeded to every quarter of the globe to take charge of the botanic gardens and stations throughout the Empire.

Since 1869, when NATURE was founded, the activities in this direction have continued unimpaired. In 1870 the botanic garden at Wellington in New Zealand was founded. In 1871 the abandoned Jamaica garden was re-established and another was created in Bermuda. In 1879 an important botanic garden was founded at Georgetown, in British Guiana.

Between 1886 and 1890 the botanic garden at St. Vincent, which had long been allowed to lie in abeyance, was restored, and new botanic stations were opened in the islands of Barbados, Dominica, Grenada, St. Lucia, and the smaller islands. The last station to be established in this region was that of British Honduras (1892). Profiting by the experience gained in the West Indies, attention was directed to Africa, and Kew has been instrumental in the establishment of botanic stations in our West African Colonies at Lagos (1887), Aburi in the Gold Coast (1890), Old Calabar (1893), Sierra Leone (1895), and Kaduna in Northern Nigeria (1914). In East Africa the need for a botanic station in Nyasaland was urged by the authorities at Kew, and as a result that at Zomba was founded in 1891. This was followed by the establishment of the botanic garden at Entebbe in Uganda in 1898. The urgency of the need for such an institution in the East Africa Protectorate it has, for some reason, been more difficult to persuade the authorities concerned to realise. But at last (1918) the beginnings of such an institution as has long been called for have been created at Nairobi. The Government of the Sudan, with a keener appreciation of the value of science, lost no time in establishing a botanic garden at Khartum and a botanic station at Jebelin.

Notable additions to the list of botanic gardens were those founded at Hong Kong in 1871, and at Aberdeen in 1897. But the most important of the creations of recent years is that of a great national botanic garden at Kirstenbosch, Cape Town, in 1913. This science owes to the enlightened action of the Government of the Union of South Africa, and to the untiring advocacy and exertions of the late Prof. Pearson. This institution bids fair to become in time the "Kew" of South Africa, and gives promise to be one of the most interesting and valuable scientific gardens in the world.

THE SCIENTIFIC AND TECHNICAL DEPARTMENT OF THE IMPERIAL INSTITUTE.

IN furtherance of its principal object of promoting the utilisation of the resources of the Empire, and in order to supplement its other activities in this direction, the Imperial Institute established in 1896 a scientific and technical department under the direction of Prof. Wyndham Dunstan. The history of the formation of that department and of its work in early years was told by the late Sir Frederick Abel, at that time Director of the Imperial Institute, in the preface to a volume of technical reports and scientific papers published by the institute in 1903. From that account it will be seen that the inception of scientific work at the institute received strong support from his Majesty King Edward and from the Royal Commission of the 1851 Exhibition, whilst the late Lord Playfair was one of its most active supporters.

The principal purpose of the department was to investigate by laboratory researches and technical trials raw materials, and especially those derived from the Empire overseas, as the first step in their commercial utilisation. The work of the department rapidly increased in amount and importance, and the laboratories and staff have been greatly extended in recent years. It is obvious that in the wide sense the scientific investigation of raw materials provides an enormous field, and it was necessary to limit the work of the department to those materials which are considered to be of most importance from a commercial point of view and are best dealt with in this country, and also to a large extent to limit the scientific investigation of these selected materials to the subjects requiring elucidation from the commercial viewpoint. Even with these necessary limitations a large number of scientific papers have been communicated by the staff of the department to the Royal Society, Chemical Society, Society of Chemical Industry, and other societies, whilst a number of materials of promise in scientific research have been passed for investigation to workers in other institutions, including the Universities of Manchester, Liverpool, Leeds, Aberdeen, and London.

To the research laboratories, which are provided with the proper equipment for experimental research, have been added testing plant and machinery for enabling small-scale technical trials of certain raw materials to be carried out. Arrangements have also been made with manufacturers for trials on a commercial scale of materials which appear to be suitable for commercial employment, and the department is now utilised not only for such investigations as have been indicated, but by manufacturers and merchants in this country for obtaining information as to supplies of raw materials, their nature and composition, and also as to their uses and the means of overcoming technical difficulties in regard to their industrial employment.

The scientific results of investigation conducted by members of the staff are, as a rule, communicated to the special societies concerned, whilst records of some of the principal results obtained in their commercial bearings are printed in the quarterly Bulletin of the Imperial Institute.

THE LISTER INSTITUTE OF PREVENTIVE MEDICINE.

THE institute originated from a public meeting summoned by the Lord Mayor in July, 1889, to hear statements from scientific men as to the efficacy of Pasteur's treatment for hydrophobia. The lack of any institute in this country with objects similar to those of the Institut Pasteur in Paris was discussed, and it was pointed out that England should continue to take her share in the discovery of means to control disease and not be dependent upon the national laboratories of France and Germany.

A committee was formed, of which Lister became chairman, and in 1891 the British Institute of Preventive Medicine was founded.

During the first nine years of its existence the permanent income of the institute was hopelessly inadequate to the requirements, but in 1900 it received a gift of 250,000*l.* from Lord Iveagh, which for the first time placed it in possession of an assured income. In 1903 the title of Lister Institute was adopted.

The central institute is situated on the banks of the Thames at Chelsea. It contains laboratories equipped for the study of bacteriology, biochemistry, protozoology, experimental pathology, entomology, etc., and a library and theatre. These accommodate, in addition to the staff, 20–30 graduates who are engaged in researches in some subject pertaining to preventive medicine under the guidance of the staff. The institute is a school of the University of London, and graduates of any university may proceed to the degree of doctor of science after having satisfactorily conducted during two years a research under the direction of a member of the staff who is a recognised teacher in the University.

In addition to its central laboratories in London the institute has a branch where antitoxic sera, bacterial vaccines, and calf-vaccine lymph are manufactured, and where investigations into the improvement of these curative and prophylactic agents, their standardisation, etc., are carried out.

The institute is administered by a governing body of seven, upon which the Earl of Iveagh has three representatives and the Royal Society one. The remaining three are elected by the members.

The income of the institute is derived from two sources, about one-third from endowment and the remainder partly from the sale of antitoxins, etc., and partly from moneys received from Government Departments and municipal authorities as remuneration for investigations and diagnoses carried out at their request.

THE NATIONAL PHYSICAL LABORATORY.

IF fifty years ago a Government had proposed to allocate 150,000*l.* per annum for the furtherance of scientific research, it would have met with an unsympathetic response in Parliament, and in all probability would have been turned out of office as too visionary and unpractical. The growth of the belief in the influence of research on industry and commerce was slow in this country, and was due, perhaps, more to the successful application to the production of electricity and of light of the laws of electromagnetic induction discovered by Faraday than to any other fact. When Dr. (now Sir Oliver) Lodge urged the necessity of a National Physical Laboratory in his address to the Mathematical and Physical Section of the British Association in 1891, Berlin and Paris had already taken action. A committee of the association, under the chairmanship of Sir Douglas Galton, drew up a scheme for the foundation of such a laboratory, and, after a favourable report by a Treasury Committee under Lord Rayleigh appointed to consider the matter, the laboratory was founded in 1901, with Dr. (now Sir Richard) Glazebrook as director and an annual income of 5000*l.* The control was vested in the council of the Royal Society, who appointed an executive committee. Owing to the rapid growth of the work of the laboratory, the financial responsibility became too great for the Royal Society, and the financial control was taken over by the Government in 1918. So well has the laboratory justified its foundation that the Government is prepared not only to make the annual grant mentioned in the opening sentence, but also to support a Department of Scientific and Industrial Research, and National Chemical and Engineering Laboratories are not outside the bounds of possibility.

THE DAVY FARADAY RESEARCH LABORATORY OF THE ROYAL INSTITUTION.

THE Davy Faraday Research Laboratory of the Royal Institution was founded and endowed by the late Dr. Ludwig Mond, F.R.S., with the object of providing opportunity for original investigation to extend knowledge in the domain of pure chemical and physical science by persons (men and women of any nationality) who could satisfy the authorities of the laboratory of their scientific training and qualifications to conduct original research.

The laboratory was opened on December 22, 1896, by his Majesty King Edward VII., who took occasion to point out that "Dr. Mond's foundation was a most important accession to the resources which had been placed at the command of the institution for the advancement of chemical and physical science. The Royal Institution has long enjoyed a world-wide reputation, thanks to the marvellous work of the succession of illustrious men whose researches carried on within its walls have very largely contributed to secure and maintain for this country a foremost position as a source of great discoveries and important advances in science and its applications."

Mr. Robert Mond was nominated in the deed of trust honorary secretary for life.

The managers appointed the late Lord Rayleigh and Sir James Dewar the directors without remuneration.

The following is a selection of inquiries executed in the Davy-Faraday Research Laboratory communicated to scientific societies by fellows of the Royal Society:—Dr. H. Debus, "Contributions to the History of Glyoxalic Acid"; Hugo Muller, "Quercitol, Cocositol, Inositol, Flavon"; Horace T. Brown, "Starch: Its Transformations and Derivatives"; J. Y. Buchanan, "The Specific Gravity of Soluble Salts"; J. Emerson Reynolds, "Silicon Researches"; J. E. Petavel, "Standards of Light" and "Gaseous Explosive Mixtures"; A. Scott, "Atomic Weight of Carbon, etc."; W. J. Russell, "Action of Wood on Photographic Plates in the Dark, etc."

The following papers have been published:—A. Croft Hill, "Reversibility of Enzyme or Ferment Action, etc."; W. Wahl, "Optical Investigations of Solidified Gases, etc."; W. Gluud, "Derivatives of Allylamine, Phenylglycine, etc."; Sir J. C. Bose, "The Response of Inorganic Matter to Stimulus, etc."; Miss Ida Smedley, "Colour Derivatives of Fluorene"; and Miss A. Everett, "Colour Photometry."

THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

THE International Catalogue of Scientific Literature was constituted in 1900 at an International Conference held in London under the auspices of the Royal Society. It is a unique attempt to secure an accurate and exhaustive bibliography of pure science by international co-operation, each country being responsible for the indexing of its own literature. Each volume contains an author index and a subject index. An annual issue is composed of seventeen volumes indexing the seventeen branches into which science is divided for convenience of reference. The books and papers catalogued are those published since January 1, 1901, papers published before that date being indexed in the Royal Society's Catalogue of Scientific Papers.

The control of the catalogue is in the hands of an international council composed of one representative from each country taking part in the work. This council appoints an executive committee, which meets in London, but each of the countries co-operating has its own regional bureau to prepare index cards and send them to a central bureau in London for publication. Since the foundation of the catalogue about three million such cards have been received from the bureaux. More than two hundred volumes have been published.

Until the outbreak of the war in 1914 more than thirty countries were taking part in preparing the catalogue, and the harmony with which they worked together is one of the most remarkable features of the enterprise. Even the Russo-Japanese War did not hinder the delegates of Russia and Japan from meeting at the conferences.

Although the recent war and the present condition of Europe create a difficult position for all international undertakings, it is much to be hoped that means may be found for continuing the work of the catalogue on an international basis, and without sacrificing those distinctive features which have met with such widespread appreciation.

THE TROPICAL DISEASES BUREAU.

THE Tropical Diseases Bureau came into existence in July, 1912, as a development of the Sleeping Sickness Bureau founded in 1908. The main function of the bureau has been to review current papers on tropical diseases, *i.e.* exotic diseases occurring in the tropics and sub-tropics. The medium of publication is the *Tropical Diseases Bulletin,* now in its fourteenth volume. The *Bulletin,* which appears monthly, contains classified summaries of all papers within its scope which come under notice. Each subject is in charge of a "sectional editor," whose initials are appended to his summaries. Thus the results of the most recent researches on tropical disease in every country, new methods of treatment, and improved means of prevention quickly become available for the remote worker in the tropics. Critical reviews of books are also published.

The bureau issues also the *Tropical Veterinary Bulletin* quarterly, the object of which is to deal with the diseases of domestic animals in the tropics in the same way as the *Tropical Diseases Bulletin* does with the diseases of man.

The bureau maintains a library under the charge of Capt. R. L. Sheppard, which contains complete or nearly complete files of all the tropical medical journals, in addition to others, some two hundred series in all, and a large number of reports and reprints. Though the library is mainly intended for the use of the sectional editors, it is open to any inquirer without formality.

The bureau is under the management of a committee appointed by the Secretary of State for the Colonies, the expert members of which are Sir John Rose Bradford, Sir David Bruce, Sir Havelock Charles, Sir Wm. Leishman, Sir Patrick Manson, and, representing veterinary medicine, Sir John M'Fadyean and Sir Stewart Stockman. Dr. A. G. Bagshawe is the director. It is maintained by a grant in aid from the Imperial Treasury and by contributions from the Governments of India, the Sudan, the Union of South Africa, and certain colonies and protectorates, to which copies of its publications are supplied gratis. By the general public the *Tropical Diseases Bulletin* can be obtained at an annual subscription of a guinea, and the *Tropical Veterinary Bulletin* at 10*s*.

The offices of the bureau are at present situated at the Imperial Institute, South Kensington.

WOMEN AT CAMBRIDGE.

IN February, 1896, the council of the Senate reported the receipt of four memorials relating to the admission of women to degrees. A syndicate was appointed to consider the question, and in February, 1897, the majority reported recommending that degrees should be conferred on women by diploma, but not that they should become members of the University on the same terms as men. The liveliest interest in and opposition to these proposals were occasioned, and a discussion lasting three days took place in the Senate House. Finally, in May, 1897, the report was rejected by the Senate, amid scenes of enthusiasm and disorder, by a majority of 1707 to 661.

In May, 1919, the council reported the receipt of two memorials relating to the same subject, and proposed the appointment of a syndicate to consider it. The first memorial stated:—"We believe that the time has passed for the adoption of half-measures, and that women should be admitted to full membership of the University." In the second, objection was taken to the "attempt to force a hasty conclusion on a prejudged issue," and the suggestion made that a solution might be found by allowing women to obtain degrees without becoming full members of the University. This suggestion—which is made now by those who in 1897 opposed the granting of degrees to women at all—is practically the same as that which was rejected by a large majority then, and illustrates how far the attitude towards women has changed in twenty-two years. There are few now who would dare openly to advocate the exclusion of women from the recognition rightly due to their study and their services to learning.

On Thursday, October 30, a discussion on the subject was held in the Senate House. It is clear that a large progressive body of opinion is in favour of removing all restrictions on the studies of women and on their just recognition by the University. It is also clear, however, that there is still an underlying opposition to the idea of a mixed university, which will manifest itself in proposals designed to shelve the question temporarily by the adoption of half-measures. There can be little doubt that in the end all restrictions will be removed; and there are many who believe that it will be wiser and more generous for the University now to allow women the full membership they demand than to have the change forced upon it by outside influence, *e.g.* through the coming Royal Commission.

NOTES.

ANNOUNCEMENT of the approaching fiftieth anniversary of the foundation of NATURE was made in a letter sent a few weeks ago to the presidents of a number of scientific societies, official heads of British universities, and other representatives of progressive knowledge, most of whom are among the contributors to the columns of this journal. The result of this communication has been that we have received numerous cordial messages of congratulation, many of them containing interesting reminiscences associated with NATURE, and all most appreciative of the services it affords to scientific workers. It was hoped that space could have been found to publish these messages this week, but this has proved impracticable. We believe, however, that these testimonies to the close attention paid to the contents of NATURE will interest a wide scientific public, and therefore propose to place a selection from them before our readers in next week's issue.

THE general arrangement of Notes in these columns follows the principle of from man to machine; early paragraphs are concerned with current topics and events, and these are followed successively by Notes on subjects relating to biological, physical, and engineering sciences. The articles on scientific progress which we have been fortunate enough to secure for this issue are arranged in much the same order, so that each has a relationship to the contributions which precede and follow it. In addition to the descriptive articles concerned with different fields of scientific activity, short accounts are given of a few important British institutions established for research purposes since NATURE was first published. These articles will, we think, serve to increase the value of this jubilee number as an epitome of outstanding developments of scientific work during the past fifty years.

ON Wednesday, October 29, Mr. Balfour was inaugurated Chancellor of Cambridge University. In a letter to the Vice-Chancellor dated October 25 he had written:—"In so far as lifelong devotion to the University, unceasing interest in its welfare, and pride in its great services to learning be sufficient qualifications for that high post, I am not unfitted to fill it." His election was unopposed. In presenting the Letters Patent the Vice-Chancellor dwelt upon the needs of the University and upon the possibility of utilising the learning available in the University more fully in the service of the Empire. The new Chancellor agreed that it is the business of the community to make easier the path of those who have shown what the sound learning and scientific training of a university can do for a national cause, but at the same time he felt that, in the main, Cambridge would have to trust, and could well trust, its own powers in the coming arduous days of peace. In all departments of national activity, but especially in the scientific study of the mechanical, economic, chemical, medical, or physical problems of the last five years, our universities—and not least Cambridge—have earned a position in the national estimation which they have never held before. This position carries great opportunities and great obligations with it. The interest of the next few years and their influence on the future history of education and human knowledge are immense. There will undoubtedly be a strong tendency towards the adoption of a more technical education and towards the teaching of "practical" subjects in a university course; this tendency cannot, and must not, be opposed, but at the same time it is most earnestly to be desired that our universities should keep before the eyes of their students the three chief motives for the acquisition and improvement of knowledge: a pleasure in knowledge for its own sake, a sure faith that no attempt to acquire and improve knowledge is vain, and a reasoned belief in the power of knowledge to help and elevate mankind. Cambridge has chosen wisely in electing a Chancellor in whom these motives are so strong, and who possesses in a high degree the power and opportunity of keeping them before the eyes of the best of his countrymen.

MEMORIAL tablets to Lord Lister to be erected at University College, London, will be unveiled on Tuesday, November 11, by Sir George Makins, president of the Royal College of Surgeons, and Sir J. J. Thomson, president of the Royal Society. The Duke of Bedford, president of the Lister Memorial Committee, will preside.

THE VERY REV. W. R. INGE, Dean of St. Paul's, has been appointed Romanes lecturer for 1920 at the University of Oxford. The date and subject of his lecture will be announced later. The late Camden professor of ancient history, Mr. F. J. Haverfield, has bequeathed the residue of his estate, subject to certain charges, in trust to the University for the advancement of the study of Romano-British antiquities.

MR. W. R. COOPER has just retired from the editorial chair of the *Electrician*, having decided to devote the whole of his time to his consulting practice. He was appointed editor of our contemporary in 1906, and under his editorship the journal has represented electrical science at its best, as well as progressive practice. He will be succeeded by Mr. F. H. Masters, who was chief assistant editor at the outbreak of war in 1914.

AT the annual general meeting of the Cambridge Philosophical Society, held on October 27, the following were elected officers of the society for the ensuing session, 1919–20:—*President:* Mr. C. T. R. Wilson. *Vice-Presidents:* Sir W. J. Pope and Sir E. Rutherford. *Treasurer:* Prof. Hobson. *Secretaries:* Mr. A. Wood, Mr. G. H. Hardy, and Mr. H. H. Brindley. *New Members of the Council:* Prof. Inglis, Prof. Seward, Dr. Rivers, Dr. E. H. Griffiths, and Mr. F. A. Potts.

DR. O. L. BRADY, president of the National Union of Scientific Workers, took the chair at a meeting held on October 30 to inaugurate a London branch. He pointed out that the organisation of the union is by branches. Although there are already branches in South Kensington, the Board of Agriculture, the London County Council, and at Woolwich, it was felt that a more central branch should be formed to meet the needs of workers engaged in the City and in the central district of London. A resolution that a London branch of the National Union of Scientific Workers be forthwith formed was passed unanimously, and Dr. H. M. Atkinson and Mr. W. E. King were elected chairman and secretary respectively of the branch.

THE *Times* of November 4 publishes the following message from its New York correspondent, dated November 3:—"The gift of a further 2,000,000*l.* to the Rockefeller Institute by the founder, Mr. John D. Rockefeller, is announced to-day. The institute, which was founded in 1901, has become the largest endowed establishment in the world for medical research. It had already received from Mr. Rockefeller successive gifts to the amount of 5,500,000*l.* and real estate valued at 500,000*l.* The scientific staff numbers sixty-five, and in addition there are 310 persons employed in technical and general services. The latest gift will enable research to be conducted in new fields in biology, chemistry, and physics, as well as in medicine itself, and the study of practical problems relating to disease in men and animals."

AT the Philosophical Congress, held at Bedford College last July, particular interest centred round the physiological researches of Dr. Head and his fellow-workers into the nature of the function of the cortex cerebri. This work has been going on for the last eighteen years. It started with the now classical experiment performed by Dr. Head, with the aid of Dr. Rivers, on the innervation of his own forearm. Following the clue which that experiment afforded, the function of the cerebral cortex in regard to sensation has been more and more clearly elaborated. Injuries due to the war have afforded means of immediately testing theories such as we might have had to wait long for under other conditions. Some of our readers are anxious to know where they can obtain an account of this work. Unfortunately, it is not at present available in the form of a treatise or monograph; it exists only in articles in medical journals. A very clear epitome of the whole theory, however, with illustrative cases, and free from technical terms, is the article by Dr. Head himself on "Sensation and the Cerebral Cortex," which fills the whole number of *Brain*, vol. xli., part ii., issued in 1918. The philosophical interest in the theory was due to the complete scientific refutation it offers of all psychological theories which build up knowledge out of original sense-material. Sensations depend neither for their existence nor for their psychical quality on the cortex cerebri, which has a purely interpretative function in regard to them.

LAST July Sir Robert Hadfield invited a large party of his Sheffield workmen to London to visit the British Scientific Products Exhibition, and also the Science Museum at South Kensington. Included in the party were a number of apprentices, some from the Hadfield works in Sheffield and others from similar establishments in London. Prizes were offered to the boys for the best essays descriptive of the visit. The winning essays, which are now printed for private circulation, are a striking commentary on the interest taken in the visit. To many of the Sheffield boys, who were in London for the first time, the day was a red-letter one. Their keen powers of observation were not confined to the exhibitions only; one at least showed a truly surprising knowledge of the significance of the historical statues he saw on his way from and to the station. More human, perhaps, was the boy lost in admiration for the London 'bus drivers. It is no mean feat of endurance to visit two exhibitions in one day and carry off any sort of coherent idea of what has been seen. The novelty of the event must have given these boys added enthusiasm, for they describe with great clearness machinery and processes which interested them. The essays show the immense educational value of visits of this character, and they are, too, a real tribute to the work of the evening technical schools, where the boys study hard after a day's work.

PROF. FERNANDO SANFORD discusses in the *Scientific Monthly* for October the *ignis fatuus,* one of those "meteoric appearances which have puzzled man since he began to inquire into the relations of phenomena, and which are still unexplainable." He reviews the various theories which have been formulated to explain these appearances. His final suggestion is that "they are little swarms of luminous bacteria which are carried up from the bottom of the marsh by rising bubbles of gas. Many kinds of luminous bacteria are known, and the marshes from which these lights arise are known to be the favoured habitat of some of these kinds. Some at least of these bacteria do not become luminous until exposed to the oxygen of the air. This seems to be true of the bacteria which cause the luminosity of rotten wood, the 'foxfire' of our boyhood."

IN the *Scientific Monthly* for October Prof. J. H. Breasted, the eminent Egyptian scholar, publishes the first part of a lecture on the origin of civilisation, with special reference to the Nile Valley. Following the guidance of Blanckenhorn, he classifies the geology of the Nile Valley, in so far as it bears on the age of man there, into four chief periods:—(1) The Lacustrine Terraces, Pliocene and First Glacial; (2) the Upper River Terrace, Second Glacial; (3) the Lower River Terrace, Third Glacial; and (4) the Alluvium, Lower Fourth Glacial, Upper Post-Glacial. Far back in the European Glacial age the North African plateau was the home of early hunters, who have left signs of their presence not only in flint weapons, but also in a remarkable rock temple in the western desert. From this point he deals with burials and artefacts, including the marvellous ripple-flaked flint implements which are a mystery to craftsmen of the present day. Prof. Breasted leaves the later developments of the culture of prehistoric man in this region to a second article, which will complete a study of unusual interest.

UNDER the title of "The Linguistic Survey of India and the Census of 1911" Sir George Grierson has published a short summary of the great work which he has now brought to a successful termination. The Survey deals with a population amounting to 290,000,000, as compared with 312,000,000 recorded in the census of 1911, the difference being due to the fact that the census covered the whole of India, while large tracts, like Burma, were excluded from the operations of the Survey. In all, 872 different languages and dialects are recorded. The sub-family which contains the greatest number of languages, thirty-two in all, is the Tibeto-Burman, where the population is split up into numerous sections owing to their special environment in a mountainous region. On the other hand, there are only seventeen Indo-Aryan languages spoken by 226,000,000 in the wide northern plains, where facilities of intercommunication promoted fusion of races. If, as an example of similarly circumstanced Aryan groups, we take the Eranian languages spoken in and near India and the Dardic languages, we find that these two branches, like the Tibeto-Burman languages, are spoken in inhospitable mountain tracts, but that, unlike the Tibeto-Burman group, they have a power of persistence. If they do subdivide, the division is not into mutually unintelligible languages, but into mutually intelligible dialects, held together by a common grammatical basis. This summary of the work of a great scientific philologist may be warmly commended to the notice of all students of language.

IN the course of his presidential address to the North-East Coast Institution of Engineers and Shipbuilders on October 24, Mr. A. Ernest Doxford made strong references to the present economic position of the country, and said that much too little publicity has been given to this important matter. This has afforded the extremist his opportunity to inflame the minds of the uninformed, and lead the country perilously near to anarchy. Two great evils have to be fought—greed and ignorance—and both of these can be overcome by education. The first and most important point to consider in education is the qualification of the teacher. He must be sound in first principles, in his facts, and in his reasoning, and must be capable and willing to impart his knowledge to others. One would have thought that a common-sense nation, such as we certainly are, would have seen the absolute necessity of paying well for such qualities; but, instead, we find that the teaching profession is one of the worst paid, with the natural result that we get either inferior or discontented teachers. This discontent is bound to be reflected, to a greater or less extent, in the mind of the pupil, and is the source of a great deal of our social unrest. The brain-power of the teacher is often superior to that of many in other walks of life who are being better paid than he, and the injustice, in many cases, forces him into the band of extremists, where he thinks that a social upheaval may remedy his grievances. Mr. Doxford feels sure that if, in our reconstruction, we put education foremost, we shall remedy not only many of the evils that existed prior to the war, but also the more virulent types that have arisen since.

DR. MURRAY STUART describes, in the Records of the Geological Survey of India (vol. l., p. 28, 1919), the deposits of potash salts in the Punjab Salt Range and Kohat, and adds a paper on the probable origin and history of the rock-salt deposits in this region. The author believes that the salts were originally laid down from an evaporating saline solution, but that their present banded structure, of which a good illustration is given, is due to subsequent flow under pressure. The salt, in fact, is now not a sediment, but a schist. Included iron pyrites, liberating sulphuric acid, has led to the formation of gypsum as a product of contact with limestone, and is also responsible for the presence of mirabilite. The potash salts, whatever their original position in the series, now appear as patches and lenticles in the rearranged foliated mass, and no continuous bed can be expected. "The prospects of obtaining potash from the salt of the Salt Range are not promising."

ONE of the most definite tendencies in British agriculture is towards greater use of mechanical power, though the most satisfactory source of power remains to be ascertained. In the Journal of the Royal Society of Arts for September 26 and October 3 and 10, Dr. J. F. Crowley discusses the use of electricity in agriculture, with special reference to its development in Germany. Farm conditions make portability essential, and a limit is set to the power obtainable from steam or oil engines by their weight. These considerations led to the development of electrical power, which has been so notable a feature of German agriculture in recent years. By far the greater amount of power used on German farms is distributed from central stations by high-tension overhead lines. The transformers and motors may be either fixed or portable, and may be separated by considerable distances. Illustrated descriptions are given of the motors and their use in ordinary agricultural operations. Thinly populated rural districts in Germany secured the advantage of cheap electricity through the growth of numerous rural co-operative societies, which either produced electricity themselves or secured a cheap supply by guaranteeing a certain consumption. The author believes that considerable progress could be made if steps were taken to promote such co-operative movements in the rural districts of this country.

A SERIES of illustrated articles descriptive of the Hell Gate Bridge at New York has been appearing in recent issues of *Engineering*. The article in the issue for October 17 contains an interesting account of the span measurements. It was impossible to secure a satisfactory direct measurement, since no previous structure crossed the river at the site, and the distance between the skewbacks was determined by triangulation. To obtain a check a special steel tape about 1100 ft. long was made, and repeated measurements were taken, making calculated allowances for tension, deflection, and temperature. Difficulty was experienced in making the corrected measurements agree precisely on account of the unequal temperatures of different portions of the tape. There was, however, substantial agreement with the triangulation measurements. The day before the erection of the last panel of the arch-trusses was commenced, careful measurements showed a clearance of 1·75 in. between the extremities of the semi-trusses. A rise in temperature during the night produced a diminished clearance of 0·75 in. next morning. Work was therefore accelerated in order to have the lower chord inserted before the rising temperature eliminated the whole of the clearance. The first chord piece had to be lifted vertically into position rather than revolved from an oblique position in a vertical plane as is customary. The following day was rainy and cloudy, affording more favourable weather conditions.

AN interesting survey of the general position of chemical industries in the chief countries of the world, and especially in France, is contributed by M. René P. Duchemin to the *Revue Scientifique* for October 4. Due to war demands, there has been a considerable over-production of important "heavy" chemicals such as sulphuric acid, nitrogen compounds, chlorine, and bromine; and this not only by the belligerent nations, but by neutral countries also. Factories have been developed and extended, so that they now have much greater productive capacity than heretofore; and, moreover, large stocks were necessarily accumulated by the various Governments to provide for unforeseen contingencies during the progress of hostilities. In some branches of manufacture these stocks represent several years' normal output. Hence the position of the industry as regards the foregoing products is just now a difficult one. For France in particular, unless the industry is to dwindle and vanish, it will be necessary to devise measures for preventing destructive competition by indiscriminate admission of certain chemicals from other countries. The plan adopted by Great Britain, namely, limited importation, to prevent either undue lowering of prices by "dumping" or excessive charges by manufacturers here, is considered by the writer named to be the best for France to follow until something like normal conditions are again reached.

HARDNESS is an extremely important quality, but no satisfactory definition of it has yet been given. The geologist has his scale of hardness, and the engineer has his instruments for measuring the elusive quality. The tests employed by the engineer are good in their way, but they do not, as a rule, measure directly what the manufacturer wishes to obtain in the finished article. A manufacturer of cutlery, for example, is not directly interested in the way his steel gives when a steel ball is placed on it and pressed down with considerable force. But, in spite of the lack of direct applicability in the engineering tests, a good deal can be maintained in their favour, for there is doubtless some connection between the mechanical properties desired by the manufacturer and the readings of the sclerometer, as the instrument for measuring hardness is called. The interpretation of the readings may be difficult, and will probably require the acquisition of knowledge allied to that attained by the skilled craftsman; but, notwithstanding the difficulties, the regular use of a sclerometer can be productive of nothing but good. The Magnetic Sclerometer which has been put on the market by the Automatic and Electric Furnaces, Ltd., 281–283 Gray's Inn Road, London, W.C.1, may prove to be extremely useful in connection with a large and important class of material, viz. hard steels. As its action does not depend upon mechanical phenomena, its range is limited, and it cannot be used for non-magnetic substances. A rod of steel is placed in a yoke so as to form a complete magnetic circuit, and magnetised almost to saturation. The rod is then taken out of the yoke and the remanent magnetism, *i.e.* the magnetism which remains after the rod has been subjected to the demagnetising action of its own poles, is measured. To make the measurement the rod is placed in a coil connected to a ballistic galvanometer, and the kick of the galvanometer-needle is noted on the rapid removal of the rod from the coil. The throw of the needle, which indicates the amount of magnetic flux still remaining in the rod, may be taken as the reading of the sclerometer. In spite of its lack of direct applicability so far as hardness, in the ordinary sense of the word, is understood, the magnetic sclerometer should prove to be an extremely useful instrument in the hands of the trained researcher.

MESSRS. W. HEFFER AND SONS, LTD., Cambridge, have just issued a Catalogue (No. 182) of 1670 second-hand books dealing, among other subjects, with archæology, folk-lore, anthropology and kindred subjects, Egyptology, and philosophy; also with scientific serials. In the latter section we notice a set of the first 102 volumes of NATURE. The list includes the archæological and fine art library of the late Dr. Allen Sturge. A copy can be obtained free upon application.

OUR ASTRONOMICAL COLUMN.

COMETS.—Schaumasse's comet (1911 VII., 1919*d*) was detected on its return by M. Schaumasse at the Nice Observatory on October 29, being of magnitude 12. The observation indicates October 19 as the approximate date of perihelion. The following ephemeris is for Greenwich midnight (corrected approximately by the above observation):—

	R.A. h. m. s.	N. Decl. ° ′	Log *r*	Log Δ
Nov. 5 ...	12 27 23	6 28	0·0914	0·2610
9 ...	12 41 25	5 19	0·0951	0·2622
13 ...	12 55 13	4 11	0·0993	0·2634
17 ...	13 8 47	3 4	0·1038	0·2649
21 ...	13 22 5	1 58	0·1089	0·2666

As the distances from both sun and earth are increasing, the comet will remain faint.

Continuation of the ephemeris of comet 1919*c* for Greenwich midnight:—

	R.A. h. m. s.	S. Decl. ° ′		R.A. h. m. s.	S. Decl. ° ′
Nov. 7	17 0 44	10 30	Nov. 19	17 41 42	16 57
11	17 13 56	12 41	23	17 56 20	19 0
15	17 27 32	14 50	27	18 11 28	20 59

The comet is approaching perihelion and growing steadily brighter, but it is too near the sun for convenient observation.

THE SOURCES OF STELLAR ENERGY.—There have recently appeared two articles on this subject by Profs. Russell and Eddington. The first (Publications Ast. Soc. Pacific, August, 1919) points out the apparent inadequacy of the contraction hypothesis to explain the long duration of the output of energy (far in excess of Lord Kelvin's twenty million years) which is suggested by geology and by various other arguments. Hence it is concluded that there must be some unknown source of energy in the interior of giant stars, which dies down before the dwarf stage is reached. Making the supposition that the temperature is insufficient for the unknown source to come into action in the pre-M stage of giant stars, Prof. Russell shows that this stage would be short and extremely few stars would be in it at a time; he thus explains our failure to detect stars in this stage.

He also points out that the hypothesis would do away with the difficulty which Prof. Eddington expressed about the maintenance of the pulsations in Cepheid variables, viz. that the leakage of heat from the hotter to the colder regions would damp out the oscillations in a few thousand years. For the unknown source would supply heat to the interior at the greatest rate when it was hottest, thus making good the leakage.

Prof. Eddington (*Observatory*, October) makes a bold speculation as regards the unknown source of heat. He reminds us that a large proportion of the total energy of a star is locked up in its atoms, so that the energy would not be exhausted when the star cooled. It would need to be annihilated to liberate all the energy. He asks whether this annihilation of matter may not be going on in giant stars: "When a positive and negative charge collide centrally they go out of existence." He points out that at moderate temperatures the outer electrons of the atom form a protecting cushion; but, in a very high temperature, ionisation is presumed to take place, robbing the nucleus of its protecting electrons and leaving it an exposed target. He makes an estimate that 1 atom out of 5×10^{18} must be annihilated each second. At this rate it would take about 2×10^{11} years to annihilate the whole star, so that the loss of mass in the periods usually assigned to the giant stage would be trifling.

BRITISH SCIENTIFIC SOCIETIES FOUNDED DURING THE PAST FIFTY YEARS.

1869.

Edinburgh Field Naturalists' and Microscopical Society.
Iron and Steel Institute.

1871.

Institution of Electrical Engineers.
Mathematical Association.
Royal Anthropological Institute of Great Britain and Ireland.

1873.

Institution of Municipal and County Engineers.

1874.

Physical Society of London.
Society of Public Analysts and other Analytical Chemists.

1875.

Incorporated Sanitary Association of Scotland.

1876.

Conchological Society of Great Britain and Ireland.
Mineralogical Society.
Physiological Society.
Royal Sanitary Institute.

1877.

Institute of Chemistry of Great Britain and Ireland.

1878.

Folk-Lore Society.
Mining Institute of Scotland.

1879.

Society for the Promotion of Hellenic Studies.

1880.

Aristotelian Society.
The Ophthalmological Society of the United Kingdom.
Scottish Microscopical Society.

1881.

Scottish Natural History Society.
Society of Chemical Industry.

1882.

Royal Academy of Medicine in Ireland.
Royal English Arboricultural Society.
Society of Psychical Research.

1883.

Edinburgh Mathematical Society.

1884.

Anatomical Society of Great Britain and Ireland.
Junior Institution of Engineers (Incorporated).
Marine Biological Association of the United Kingdom.
North-East Coast Institution of Engineers and Shipbuilders.
Royal Scottish Geographical Society.
Society of Dyers and Colourists.

1886.

Institute of Brewing.
Royal Institute of Public Health.

1889.

Institute of Marine Engineers (Incorporated).
Institution of Mining Engineers.
Museums Association.

1890.

British Astronomical Association.

1891.

British Pteridological Society.

1892.

Geographical Association.
Institution of Mining and Metallurgy.
Japan Society.
West of Scotland Iron and Steel Institute.

1893.

Malacological Society of London.

1894.

Child-Study Society.

1896.

British Mycological Society.
Institution of Water Engineers.

1897.

Institution of Heating and Ventilating Engineers (Incorporated).
Röntgen Society.

1899.

Optical Society.

1900.

Ceramic Society.

1901.

African Society.
British Academy.

1903.

Challenger Society.
Faraday Society.
Sociological Society.

1906.

Institution of Automobile Engineers.

1907.

Royal Society of Medicine.
Society of Tropical Medicine and Hygiene.

1908.

Concrete Institute.
Institute of Metals.

1909.

Zoological Society of Scotland.

1910.

India Society.
Society of Engineers (Incorporat
Textile Institute.

1911.

Biochemical Society.

1913.

Institution of Petroleum Technologists.

1916.

Association of British Chemical Manufacturers.

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, October 6.—M. Léon Guignard in the chair.—H. **Deslandres**: Remarks on the constitution of the atom and the properties of band spectra. A continuation of communications previously made on the same subject. Band spectra may be considered as being formed of transversal and longitudinal vibrations, but the exact part of the spectrum which can be attributed to the one or the other of these cannot as yet be precisely determined.—G. **Charpy** and J. **Durand**: A cause of rupture of steel rails and a means of suppressing it. It has been proved by several observers that a frequent cause of breakage of steel rails, not possessing any local faults due to manufacture, consists in the formation of very fine fissures appearing on the surface carrying the wheel after a certain period of use, and it has been proposed that, after a careful inspection of the permanent way, these fissured rails should be detected and removed. The critical age of steel rails appears to be about ten years. The author has found that the incipient cracks are removed by annealing, and suggests a method by which it would be possible to anneal the rails without removal from the track.—E. **Ariès**: The equation of state of ethyl formate.—G. A. **Boulenger**: The genus Saphæosaurus, a Rhynchocephalian of the Kimmeridge formation of Cerin. The examination of the specimens at the Lyons Museum leads the author to agree with the views of L. Lortet as to the classification of this reptile, as opposed to the interpretation of D. M. S. Watson.—N. E. **Nörlund**: An extension of the polynomials of Bernoulli.—M. **Stoïlow**: The analytical representation of functions of several complex variables.—G. **Serf**: The transformations of linear partial differential equations with two independent variables.—J. **Rey**: The experimental predetermination in the laboratory of the characteristic of a lighthouse at the horizon. The distribution of the light intensity in the horizontal plane is studied by means of a series of metallic screens, pierced with a regular series of small holes of accurately known diameter. The results of such a study are shown in a graph.—Ch. **Boulin** and L. J. **Simon**: The action of stannic chloride on dimethyl sulphate. The products of the reaction at a temperature of about 114° C., the boiling point of stannic chloride, are methyl chloride and stannic sulphate.

SYDNEY.

Linnean Society of New South Wales, August 27.—Mr. J. J. Fletcher, president, in the chair.—W. W. **Froggatt**: A new species of wax scale (*Ceroplastes murrayi*) from New Guinea. The author describes a wax scale found on the wild mango in the forests fringing the Kikori River, Delta Division, British New Guinea. The scale, for which the name *Ceroplastes murrayi* is proposed, produces a solid mass of hard, white, wax-like secretion, forming a rounded dome over the resting gravid female coccid. The characters of the female are described. Male unknown.—G. F. **Hill**: Australian Stratiomyidæ (Diptera), with description of new species. Six new species are proposed, belonging to the genera Actina, Hermetia, Odontomyia, Sargus, and Wallacea, two of these genera (Hermetia and Wallacea) not having previously been recorded from Australia.—J. **Mitchell**: Two new Trilobites from Bowning, N.S.W. The Trilobite described in this paper under the name of *Dalmanites* (*Hausmannia*) *loomesi* was formerly joined with *Hausmannia* (*Dalmanites*) *meridianus*, Etheridge and Mitchell. The examination of additional and much better specimens has shown that the two forms are specifically distinct, and accordingly each of the two forms originally described under the name *H. meridianus* has now been given specific rank. The cephalic characters of the other Trilobite proved to be so unusual that the writer deemed it advisable to propose a new genus (Adastocephalum) of the Phacopidæ for its reception. The chief generic feature in the genotype is the absence of glabellar furrows and lobes.—A. A. **Hamilton**: An ecological study of the salt-marsh vegetation in the Port Jackson district.

DIARY OF SOCIETIES.

THURSDAY, NOVEMBER 6.

ROYAL SOCIETY (jointly with the ROYAL ASTRONOMICAL SOCIETY), at 4.30.—Sir Frank Dyson, Prof. Eddington, and Others: Discussion on the Results of the Observations obtained at the Total Solar Eclipse on May 29, 1919.

LINNEAN SOCIETY, at 5.

ROYAL COLLEGE OF PHYSICIANS, at 5.—Dr. A. P. Beddard: Some Remarks on Chronic Arthritis (Bradshaw Lecture).

CHEMICAL SOCIETY, at 8.—F. G. Donnan and W. E. Garner: Equilibra across a Copper Ferrocyanide and an Amyl Alcohol Membrane.—R. R. Le G. Worsley and P. W. Robertson: The Peroxides of Bismuth.—T. M. Lowry and R. G. Early: The Properties of Ammonium Nitrate. Part I. The Freezing-point and Transition-temperatures.—R. H. Vernon: Organic Derivatives of Tellurium. Part I. Dimethyl-telluronium-di-iodide.—J. Reilly and W. J. Hickinbottom: Intramolecular rearrangement of the Alkylarylamine. Formation of 4-amino-*n*-butylbenzene.—H. Swann: A New Modification of 3:4-Dinitrodimethylaniline.—G. Le Bas: (1) The Refractivities of Unsaturated Substances; (2) The Molecular Refractions of Benzene and Aromatic Derivatives.—R. R. Baxter and R. G. Fargher: Some 1:3-Benzodiazolearsinic Acids and their Reduction Products.

ROYAL SOCIETY OF MEDICINE (Obstetrics and Gynæcology Section), at 8.—Dr. D. Robinson: The *Rôle* of the Cinematograph in the Teaching of Obstetrics (Cinematograph Demonstration).—Dr. H. Spencer: Nine Cases of Inversion of the Uterus.

FRIDAY, NOVEMBER 7.

ROYAL SOCIETY OF MEDICINE (Laryngology Section), at 4.

ROYAL ASTRONOMICAL SOCIETY (Geophysical Committee), at 5.—Col. Sir S. G. Burrard, Prof. A. E. H. Love, and Others: Discussion on Isostasy.

TECHNICAL INSPECTION ASSOCIATION (at Royal Society of Arts), at 7.30.—Prof. Baly: The Spectroscope in the Science of To-day.

ROYAL SOCIETY OF MEDICINE (Anæsthetics Section), at 8.30.—Dr. F. E. Shipway: Intratracheal Insufflation of Ether in Operations which involve Bleeding into the Air Passages.

MONDAY, NOVEMBER 10.

ROYAL GEOGRAPHICAL SOCIETY (at Kensington Gore, S.W.7), at 5.—Lt.-Col. G. A. Beazeley: Surveying in Mesopotamia during the War.

BIOCHEMICAL SOCIETY (at King's College), at 5.30.

ROYAL SOCIETY OF MEDICINE (War Section), at 5.30.—Surg.-Rear-Admiral Sir Robert Hill: Presidential Address.

INSTITUTION OF MECHANICAL ENGINEERS, GRADUATES' ASSOCIATION, at 8.—F. M. Green: Modern Steam Turbines.

SURVEYORS' INSTITUTION, at 8.—A. Young: President's Opening Address.

TUESDAY, NOVEMBER 11.

ROYAL COLLEGE OF PHYSICIANS, at 5.—Dr. E. G. Browne: The Origins and Development of Arabian Medicine. I. The Translations (VII.-IX. Cent.). (FitzPatrick Lecture.)

ROYAL ANTHROPOLOGICAL INSTITUTE, at 8.15.—S. Hazzledine Warren: A Stone-axe Factory at Penmaenmawr.

WEDNESDAY, NOVEMBER 12.

CONJOINT BOARD OF SCIENTIFIC SOCIETIES (at Royal Society), at 5.—Discussion of Draft Report on the Metric System.

ROYAL AERONAUTICAL SOCIETY (at Royal Society of Arts), at 8.—C. A. Swan: Some Physical and Psychical Effects of Altitude.

THURSDAY, NOVEMBER 13.

ROYAL SOCIETY, at 4.30.—*Probable Papers*: Prof. W. B. Bottomley: The Effect of Nitrogen-fixing Organisms and Nucleic Acid Derivatives on Plant Growth.—W. Robinson: The Microscopical Features of Mechanical Strains in Timber and the Bearing of these on the Structure of the Cell-wall in Plants.—Agnes Arber: The Vegetative Morphology of Pistia and the Lemnaceæ.—Lt.-Col. R. McCarrison: The Genesis of Œdema in Beri-beri.—W. J. Young, A. Breinl, J. J. Harris, and W. A. Osborne: Effect of Exercise and Humid Heat upon Pulse Rate, Blood Pressure, Body Temperature, and Blood Concentration.

ROYAL COLLEGE OF PHYSICIANS, at 5.—Dr. E. G. Browne: The Origins and Development of Arabian Medicine: II. Four Great Medical Writers of Persia (IX.-XI. Cent.). (FitzPatrick Lecture.)

INSTITUTION OF ELECTRICAL ENGINEERS (At Institution of Civil Engineers), at 6.—Roger T. Smith: Presidential Inaugural Address.

OPTICAL SOCIETY, at 7.30.

FRIDAY, NOVEMBER 14.

ROYAL ASTRONOMICAL SOCIETY, at 5.

ROYAL SOCIETY OF MEDICINE (Clinical Section), at 5.

PHYSICAL SOCIETY, at 5.—S. Butterworth: The Self-Inductance of Single Layer Flat Coils.—Dr. N. W. McLachlan: An Experimental Method of Determining the Primary Current at Break in a Magneto.—F. H. Newman: Note on a Modified Form of the Wehnelt Interruptor. (With Demonstration.)

SATURDAY, NOVEMBER 15.

PHYSIOLOGICAL SOCIETY (at London School of Medicine for Women), at 4.30.

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