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"To the solid ground
Of Nature trusts the mind which builds for aye."—WORDSWORTH.

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SATURDAY, JULY 7, 1923.

CONTENTS.

Modern Physics and the Atom.

IN another part of this issue we publish as a special supplement a translation of Prof. N. Bohr's lecture on atomic structure, which was delivered at Stockholm last December on the occasion of receiving the Nobel prize for physics. It seems a fitting occasion to survey the general lines of the recent development of physical theories as to the nature of the atom. The views put forward in Prof. Bohr's address may fairly be regarded as the furthest stage yet reached.

The leading feature of the physics of the twentieth century has been the development of our present concrete picture of the individual atom. In this respect modern physics stands rightly in sharp contrast with previous work—properties of matter in bulk, thermodynamic, electrodynamic, and optical theory. These theories formed the main part of the studies and contributions of physicists before 1900, and advanced with particular rapidity in the latter half of the last century. In all this work, though the atomic nature of matter had already come to general recognition in virtue perhaps of chemical rather than physical evidence, atoms, if recognised at all, play only a secondary part. The reason is that though theories of matter (*e.g.* gases) may be built up on an atomic basis, applications of these theories are always *statistical*; in making them an averaging process is used, and the particular features of an atomic model largely disappear. For example, almost any atomic model will reproduce the main properties of a gas. It is only in the finer points such as the exact variation of viscosity with temperature that the particular form of atomic model becomes relevant, and even here the variation deduced is very insensitive to the model chosen. Crude and vague ideas of the atom—little more than the mere recognition of its existence—were all that were necessary to physics in this phase.

The same is true in a somewhat less striking way of the electronic conception of electricity. This idea became current in a vague form and was shown to be a suitable foundation for the known phenomena of electricity; it was not till some years later that the fundamental experiments on the conduction of electricity through gases first led to a practical demonstration of the existence and main properties of the electron. Just as with atoms, a break-away from statistical deductions was necessary before the electron could be assigned a definite form. The demonstration of its existence and properties, though it belongs historically (1897) to the nineteenth century, is in fact the starting point of what we have called twentieth-century physics.

This concentration on the statistical side was of course inevitable, for the phenomena to which current theories could be applied were mainly concerned, as we have said, with the properties of matter or electricity in bulk. There were, of course, striking and significant exceptions which were already well known for many years before 1900—for example, optical spectra. These had long been recognised as essentially characteristic of particular atoms or molecules, obscured little if at all by any process of averaging. But optical spectra are too complicated and their conditions of excitation too obscure to have formed then a possible basis on which to build theories of atomic structure with any real chance of success. It was necessary to wait first for direct experimental evidence of the more fundamental properties of individual atoms which are unaffected by the widest possible range of external circumstances. It is clear that it is such properties that any atomic model must first set out to reproduce.

The discovery of the nature and properties of X-rays might have provided a new and more hopeful starting point. Here we have evidence of fundamental properties which remain constant and characteristic in all known circumstances. But even this evidence—even, for example, an empirical formulation of Moseley's law—would scarcely have been simple and direct enough for a starting point, and in fact was not available until after the first essential ideas had been otherwise won. The evidence necessary for the start had clearly to refer directly to individual atoms and be such as to lay down with absolute convincingness the main features of atomic structure. It was provided first by the study of radioactivity, and it is difficult to see, as we have tried to show, how any other evidence could have been sufficiently powerful for the purpose. The radioactive evidence soon made it clear that here physicists were concerned with processes connected with the most intimate structure of the individual atom, which outside conditions (physical or chemical) were powerless to affect; and concerned, too, with energy transformations in a single atom so large that the resulting effects could actually be detected. This made it clear that the atom must have an innermost structure, a place apart, the seat of gigantic forces. Ideas of the atom thus began to tend generally in the right direction, and crystallised into the nuclear atom when the nature of the α-particle had been established and the phenomena of its scattering worked out.

It was at this point (1911) that Prof. Bohr's contributions began, and it is convenient to specify the situation in somewhat more detail. It was known that the atom must almost certainly consist of a heavy nucleus, of extremely small size, with a positive electric charge; this nucleus must probably behave, so far as the rest of the world or even the rest of the atom was concerned, as a massive point charge. The nuclear charge must be neutralised in the natural atom by a system of satellite electrons in number equal to the number of units in the nuclear charge. Their arrangement was, however, quite unknown, except that they must with the nucleus compose a structure on the scale of the atom of gas theory—a scale which is exceedingly large and open compared to the dimensions of the nucleus and the electrons themselves. The exact number of satellite electrons or units of nuclear charge was also uncertain, but, by the results of X-ray and α-particle scattering, must be about half the atomic weight. It was almost certain that it was two for helium and one for hydrogen. If these views were to be accepted the hydrogen atom must be very simple—a single heavy nucleus with a unit positive charge, and somewhere near it a single electron; it must also yield the known series spectrum of hydrogen. This was the problem presented to Prof. Bohr. He maintained from the first, and justly as is now admitted by all, that there was no possibility of a solution within the domain of classical electrodynamics, and that the ideas of the quantum theory must be invoked. How these ideas lead inevitably to the accepted hydrogen atom of to-day is set forth at length in the first of his three essays, "The Theory of Spectra and Atomic Constitution," referred to in NATURE of April 21, p. 523, and, more shortly, in the present supplement.

The next essential step was the final assignment of *atomic number*, which connected up once and for all the ordinal number of any atom in the periodic table of the elements, its nuclear charge, the number of its satellite electrons, and its characteristic X-ray spectrum. This assignment, which was, of course, the result of a systematic survey of X-ray spectra, was to some extent directly inspired by the successful theory of the hydrogen atom, and without that theory the full significance of atomic number would have been missed. At this stage (1915) a general grasp had been obtained of the sequence of the elements and of the essential difference between one atom and the next, in full agreement with evidence of an entirely different type—the displacement laws of α- and β-particle radioactive changes.

In the further elucidation of the organisation of the satellite electrons and the interpretation of the periodic table of the elements, Prof. Bohr has played the leading part. The results obtained are described by Prof. Bohr at length in our supplement. It is sufficient to say here that, thanks to this work, we are now confident that the satellite electrons are arranged in groups. We know the number of electrons in each group. They move about the nucleus in orbits, some of the characteristics of which we already know, and these characteristics are the same for all the electrons of a group. We know, further, the order in which the various groups appear in the system of the elements, and even to a limited extent why the actual order must be observed. This information is summarised in the supplement (Fig. 9). The details of the picture—important details—have yet to be filled in, but we can no longer doubt that we are advancing on the right lines.

In conclusion, one may glance for a moment at the profound reaction of these views of atomic structure on physical research. In return for their spectroscopic basis in the Balmer series, they have revolutionised spectroscopy, which is now—X-ray and optical alike—one of the main avenues of advance in physics. They have created a whole new and fruitful branch of study, the excitation of atoms by electronic impacts. They provide a concrete picture of the atom which can form, and is forming every day, a trustworthy basis for the study of all branches of atomic phenomena. Finally, one must expect that the facts of chemistry will not much longer stand apart. Though much formal progress has already been made in the theory of valency, the detailed electronic theory of the structure of molecules has yet to be begun; it will inevitably present grave difficulties. But these views of atomic structure have, for example, already presented us (unasked) with a carbon atom with tetrahedral symmetry; they lead us confidently to expect that the first advances in the detailed theory will not be long delayed.

The Conquest of Malaria.

Memoirs: With a Full Account of the Great Malaria Problem and its Solution. By Ronald Ross. Pp. xi + 547 + 11 plates. (London: John Murray, 1923.) 24*s*. net.

IN Sir Ronald Ross's "Memoirs" information is to be found which will interest the conventional "wide circle of readers," in that the subjects treated must appeal to the Imperialist, the political economist, the sanitarian of the tropics, and the cosmopolitan science research worker; nor will those who respond to the "call of the East" fail to find interest in details of scenery and travels in India and Burma. Among the items illustrating the importance of research in aiding the well-being of communities and nations are discussed the conditions under which the discovery of the agency of malaria conveyance was made, as a result of the laborious experimental efforts of the author. In the section dealing with this subject will be found a tale devoid of technicalities of relentless search for a scientific truth, with its recurring disappointments, baffled schemes, renewed hopes, and ultimate victory, which, in entrancing interest, may compete with Sherlock Holmes's efforts at his best.

For centuries, the problem of malaria afforded a favourite subject in medical writings for opinions and disputations. By 1880 Laveran had found the *plasmodium malariæ* in the blood of human beings; but the vital matter, in respect to prevention, as to how the protozoon gained entrance to man remained a mystery. In 1894 Manson excogitated an hypothesis as to malaria agency, which was published in detail in the *Lancet* (vol. i., p. 1309). Ross was in England in that year. Between the younger man, eager to remedy the distressing conditions arising from this cause in India, and the older, glad to find an enthusiast in malaria prevention, there arose a mutual professional interest and interchange of views, which continued during Ross's labour in that country. It has since been insisted that Ross was a mere marionette under the control of Manson; indeed, that he was "selected"[1] by the latter for this particular work, and that Manson was the "discoverer of malaria."

Where admiration for Manson can justly be given in this matter is in contemplating his reasons for framing the hypothesis of 1894, namely, that it might prove an incentive to research on malaria which, as he asserted (*Journal of State Medicine*, September 1900), "is far and away the most important of the many problems of tropical empire—that empire upon which so much of our present and of our prospective national prosperity depends." No claim to originality was made by him, and with the one exception (added in 1898 to the original conjecture of 1894) that the flagella

[1] This is a particularly inapt contention, seeing that before Ross "selected" himself for this limitless task (p. 131, "Memoirs"), Manson had issued with his hypothesis of 1894 an invitation to medical men in India generally (*British Medical Journal*, vol. i. p. 1309) to undertake research on the lines suggested, and, after Ross had furnished him with results, repeated this invitation in 1896 (*B.M.J.* March 28). In 1898, when Ross had arrived at an important stage of his discovery (*B.M.J.* p. 1576, 1898), Manson decided "again to call the attention of workers on malaria to this promising field for investigation." Further, Ross, both officially and privately, in India strove to induce others independently to undertake the task. Meanwhile Manson did not utilise material available in England (pp. 131, 147 "Memoirs").

of the plasmodium were "flagellated-spores" (which was an error), no originality is recognizable. By dovetailing various views of acknowledged authorities with the analogy of filariasis, as previously suggested by Laveran, he attempted to meet the then current opinion of transmission of malaria to man through the medium of air or water.

The "Memoirs" show that up to 1896 Ross had laboured to prove the hypothesis of Manson, and that mosquitoes, fleas, bugs, horse-flies, and cockroaches had been duly examined, while direct experiments upon human beings had been made as to conveyance by water, with the result that he informed Manson that "the belief is growing upon me that the disease is communicated by the bite of the mosquito" (pp. 176, 190, 193). To this Manson replied, "It may be the mosquito conveys the parasite by biting, but I do not think so—at all events, I do not think so directly." Ross now informed Manson that he was "dying to go away to some regular hotbed of malaria"—the object obviously being to secure possible factors in intense occurrence. He obtained short leave from military duty, and proceeded to a spot popularly held to be the haunt of a deadly form of malaria—Sigur Ghat in the Nilgiris Hills. This resolve was the turning-point of his investigation. A detail concerning his return to Bangalore, where he was stationed, does not appear in his "Memoirs." A friend perceived a mounted man approaching him gesticulating excitedly. This proved to be Ross, who shouted "I've got it—I've got it!" Naturally, a fortune by a sweepstake or the like was "sensed," but a demand for enlightenment elicited the banal reply, "I've got the fever." He had been able to concentrate attention upon air, water, and the mosquito as factors, with the crowning joy of suffering from fever; he was able to adopt a "mathematical line of reasoning," which pointed to the chances of the malarial germ being conveyed by the mosquito direct to man rather than in a form diluted by air or water. Thereafter, he could say with Newton that he did not deal with hypotheses but with facts. On August 20, 1897, Ross identified the first stage of development of the plasmodium in the mosquito. It would deprive the reader of interesting details were the further history of his efforts traced. Suffice it to say that by July 9, 1898, Ross *had not proved but had disproved Manson's hypothesis of 1894*.

Ross has roundly declared time after time, and in various forms, that it was Manson's "great induction which did it—nothing else," and that he had received advice from Manson. These affirmations have been misconstrued. Lister, after entering judicially into the attempted piracy of Ross's discovery by certain Italian savants, gave his opinion thus: "The discovery of the development of the parasite in the mosquito was due solely and simply to Major Ross, who had shown absolute candour, perfect openness of mind, and a readiness to recognise the work of others." Throughout the "Memoirs" these attributes are unconsciously displayed by the author.[2] The advice as to technique given by Manson was based upon special knowledge of filariasis—it was found inapplicable by Ross to his requirements; it was, nevertheless, courteously acknowledged. The "great induction" referred to the function of the flagella, and, when deprived of Manson's erroneous suggestion as to these being spores, did not differ materially from the views expressed previously by Laveran and Mannaberg. Ross, however, justly held that, by insisting that the flagella had some undiscovered yet important biological function, Manson had provided an *incentive* to research, which he handsomely acknowledged.

Manson had the gratification of finding that he had been the factor in inducing one man, among hundreds of potential workers to whom he had made an appeal broadcast, to undertake research on what he believed to be (*British Medical Journal*, 1898, p. 1576) "the logical outcome of well-ascertained facts, . . . and the most promising guide to fresh facts." That one man was Ross, whose inner consciousness, as early as 1890-93, had been stirred to discover means for averting the misery incident to malaria in the populations of India. In his poetic record, under the title "Indian Fevers," he had written, "O God reveal thro' all this thing obscure, the unseen, small, but million-murdering cause" ("Philosophies," p. 21); and, on the day when he realized that his invocation had been answered, wrote, "This day relenting, God hath placed within my hand a wondrous thing; and, God be praised, I know this little thing a myriad men will save."

Ross had definitely undertaken his research—not in the quest of abstract science—but in the interests of preventive medicine. His next hope therefore was to be allowed to apply methods based on his discovery. The Government of India (in which country one million deaths occur yearly from malaria), however, not only failed to issue so much as the usual stereotyped "thanks of Government," but also refused to promise him facilities. Rather than leave matters thus, he retired from the Indian Medical Service; with a pension one-fourth the value he might have secured

[2] At forty years of age, he had still to learn that the compendium to the tenth Commandment—"nor anything that is his"—was liable to be forgotten by pseudo-men of science, and that, with Governments, the axiom "Politics first" and "deil tak' the hinmost" allows little room for financing the interests of so trivial a fad as disease prevention. Difficulties encountered are factors in evolution—sometimes beneficent; in the case of the author, for many years since he arrived at that age of discretion, in public speeches and in literature, he has proved a powerful advocate of aid to research workers.

by continued service. But this personal sacrifice (added to the considerable private expenditure during his investigation) enabled him to complete his work, by demonstrating the applicability of its benefits in West Africa and Ismalia. The King-Emperor has conferred honours (not, however, upon the recommendation of the Government of India) upon the man who had made, as Manson said, the discovery of the century (p. 317).

Following the adoption of anti-malaria methods based on knowledge gained by Ross, invaliding and sickness in the British garrisons in the tropics have been reduced to an extent which must represent many thousand pounds—irrespective of human suffering—saved; great mercantile firms have extended trade to areas they formerly shunned from dread of the malaria fiend, and these share the benefits of commerce consequent upon the opening of the Panama Canal, the construction of which had proved impossible in the hands of the French—owing to the ghastly mortality of employees—in the absence of Ross's methods; during the great War, according to the Official History (vol. 2, p. 238), "the loss of the strength to the armies from the effects of malaria was great, and *but for the preventive methods adopted it might have been incalculably greater*" (italics not in the original). What has the nation, the Parliament of which voted 30,000*l.* to Jenner in token of gratitude, done for this practical philanthropist?

In "Memoirs" covering many years and many localities, the author has left little room for criticism as to accuracy. At p. 223, the date of his first gleam of success is erroneously stated in the text; fortunately, the next page is faced by a facsimile which correctly shows the date to have been August 20, 1897; at p. 327, in referring to Haffkine's good work, it is evident the date 1916 should read 1896; at p. 198, in reference to the use of "bird's malaria," the context would show that the intention is to refer to 1896 and not 1906. The Madras Presidency can claim freedom from the conception that (p. 200) "though plague had broken out for some years in China, almost no precautions had been taken to exclude it from India." It is inaccurate to describe Mr. E. H. Hankin, the able bacteriologist, as "the discoverer of the mode of purifying wells by permanganate of potassium." He did not initiate the method; to him is the credit of showing that the cholera vibrio is killed by the chemical, and is not starved out of existence by its action on organic matter. The Hindu title of "Maharaja" used in connexion with the independent potentate mentioned at p. 101 will doubtless be corrected in future editions of the work.

W. G. KING.

Variable Stars.

Specola Astronomica Vaticana V. Herausgegeben von Johann Georg Hagen, S.J., und Johann Stein, S.J. Die Veränderlichen Sterne. Erster Band: Geschichtlich-Technischer Teil. Von Johann Georg Hagen, S.J. Pp. xx+811. (Freiburg im Breisgau and London: Herder und Co. G.m.b.H., 1921.) 42*s.*

THOUGH the subject of variable stars, apart from still earlier beginnings, has been actively studied for a century, and the realisation of its importance has been reflected in a growing volume of technical literature, it has not hitherto received extended discussion on historical lines in a work exclusively devoted to this branch of astronomy. The first volume of such a work, for which Father Hagen assumed responsibility, has now been completed by the inclusion of a fourth and last part, on the elements of the light-change, the three earlier parts having been issued separately from the year 1913 onwards. The remaining second volume, which will deal with the physical explanations of the phenomena of variable stars, is in the hands of Father Stein, and its appearance will be anticipated with interest.

In these days, when the insistent demand for summaries even to the most condensed papers betrays the fact that honest reading is out of fashion, there is something impressive in an ample and scholarly work like this, with its more than 800 quarto pages. The three earlier parts dealt with the equipment of the observer, the actual observation of variable stars, and the reduction of the observations. References to other methods will be met with incidentally, but it is to the visual method in its historical development that the work is almost exclusively devoted. Naturally there are parts of the subject which are largely independent of the particular method of observation, and the discussion of them will serve a more general application.

To avoid misconception as to the nature of the work and its limitations, it will be well to refer to an explanation given at the outset in the preface. There it is stated clearly that for the principles of photometry, the practical details of astronomical photography, the description of all the various forms of apparatus and those parts of mathematical theory which are involved in the discussion of the observations, the reader must consult in each case the appropriate text-book or even an encyclopædia. To this it should be added that the book contains no figures or illustrations, and that very little space is occupied by tabular matter. Thus it is in no sense a text-book suitable for the needs of the ordinary observer, but an historical work from which the lessons of past experience can be derived from documentary evidence. It may easily be felt that judicious compression of the abundant material, so far from diminishing, would have positively enhanced the value of the work. Moreover, while a full treatment of those technical matters, which have a general character and yet find a particular application in this special subject, would have been out of place, short explanations based on first principles could sometimes have been interpolated with material advantage to the general reader. But it is as an historical work of reference that the volume now completed must be judged, and as such it will bring the author of the "Atlas Stellarum Variabilium" the renewed gratitude of all those who are interested in this branch of astronomy. H. C. P.

The Study of Fossils.

Animals of the Past: an Account of Some of the Creatures of the Ancient World. By F. A. Lucas. Sixth and revised edition. (Handbook Series, No. 4.) Pp. xii+207. (New York: American Museum of Natural History, 1922.) n.p.

In 1901, when Dr. Lucas was a curator of the United States National Museum, he published a most useful popular book on the study of fossils, with special reference to the remarkable extinct vertebrate animals found in North America. A decade later, when he became director of the American Museum of Natural History, New York, he reprinted his work as one of the handbooks of that museum, where it has had a large sale. He now has issued a much-revised edition, with numerous new illustrations from fossils actually in the American Museum.

Dr. Lucas's little treatise is neither a museum guide nor a text-book, but consists of a series of gossipy chapters, each on a special subject, admirably designed to rouse an interest in the study of fossils. He explains their nature, describes how they are collected and made available for science, and leaves the reader in a frame of mind to appreciate more systematic and technical works on the subject. At the end of each chapter, indeed, he refers to some of the more important literature, besides mentioning the chief American museums in which illustrative specimens can be seen.

Among the new matter may be specially mentioned a discussion of Mr. Beebe's theory of the origin of flight in birds, a chapter on flying reptiles with some good illustrations from Seeley's "Dragons of the Air," an account of Tyrannosaurus and the giant Eocene bird Diatryma, additional figures of dinosaurs, and a photograph of the restoration of the American mastodon in the State Museum at Albany. There is also a photograph of an engraved bone found in a cave near Pineville, Missouri, in 1921, which seems to show the rude outline of an elephant, either mammoth or mastodon.

Dr. Lucas writes, of course, primarily for American readers, and it is natural that he should place American discoveries in the front rank; but he is wrong in stating that "the largest single bone of a Dinosaur" is the thigh bone of Brachiosaurus at Chicago—it is three inches shorter than the humerus of the African Gigantosaurus at Berlin. The rivalry between the American palæontologists and their colleagues in the Old World is one of friendly emulation, which has led to great discoveries in more than one hemisphere.

A. S. W.

Our Bookshelf.

Methods and Experiments in Mental Tests. By C. A. Richardson. Pp. 94. (London, Calcutta, and Sydney: G. G. Harrap and Co., Ltd., 1922.) 3*s.* 6*d.* net.

It is difficult to perceive for what type of audience Mr. Richardson's book is intended. If it is meant for readers who have no knowledge of any of the literature on the subject, then it is surely out of place to introduce the subject by a rather perfunctory discussion of the criticisms made against the use of tests. If, on the other hand, it is meant for readers already conversant with some of the work done, then much of the discussion is useless. The same remark applies to the statistical account.

The details of the experimental testing of groups of children are very interesting, but would have been more suitable for an article in a psychological journal than for a book.

The Organisation and Administration of Physical Education. By Prof. Jesse Feiring Williams. Pp. xiii+325. (New York: The Macmillan Company; London: Macmillan and Co., Ltd., 1922.) 9*s.* net.

Dr. Williams urges the necessity for physical education to be placed on a scientific foundation, and gives such a basis with a wealth of detail which is rarely associated with the subject. Indeed, it is carried to an extent which, in Great Britain, is unnecessary. The chapter on health and efficiency is the least scientific; little reliance can be placed on tests involving such factors as height and weight charts, and the ratio of the girth of the arm to that of the chest. The general purpose of the book is good, and it should provide a stimulus to interest in physical education.

Character and the Unconscious: A Critical Exposition of the Psychology of Freud and of Jung. By J. H. van der Hoop. Authorised Translation by Elizabeth Trevelyan. (International Library of Psychology, Philosophy, and Scientific Method.) Pp. viii+223. (London: Kegan Paul and Co., Ltd.; New York: Harcourt, Brace and Co., Inc., 1923.) 10*s.* 6*d.* net.

This is a general and rather superficial account of the theories of Freud and Jung. The author tells us it is the result of nine years' intensive study of the practice and theory of psycho-analysis, which seems to mean that he has been a practitioner during that period. The translation is well done.

Letters to the Editor.

[The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, nor to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. *No notice is taken of anonymous communications.]*

Positive Ray Analysis of Copper.

THE chief difficulty in analysing an element with a high melting-point by means of positive rays lies in the construction of a suitable furnace for evaporating the metal. I have recently succeeded in obtaining rays of copper by using a molybdenum furnace, heated with a coil of molybdenum wire embedded in alundum cement. Three isotopes were observed separated by two units in atomic weight. The relative intensities were about 1·4 : 1 : 1, the lightest being the strongest. Rays of rubidium were also obtained, probably from the cement, and showed two isotopes, as found by Aston with his method of analysis. The relative intensities gave a mean atomic weight of 85·51, in good agreement with the chemical atomic weight 85·45. To obtain agreement with the chemical atomic weight of copper 63·57, it is necessary to suppose the isotopes to be 62, 64, and 66, since this gives a mean atomic weight of 63·76, which is as close as would be expected. A direct comparison with rubidium is desirable, but further experiments will be necessary before the comparison can be regarded as conclusive, since the rubidium rays probably start at the surface of the cement and may fall through a different potential from the copper rays. A few comparisons suggested the even atomic weights, so that we may provisionally take the isotopes of copper as of atomic weights 62, 64, and 66. This seems to mark the first exception to the rule observed by Dr. Aston to hold for chlorine, potassium, bromine, rubidium, and antimony, that elements with odd atomic numbers have isotopes with odd atomic weights, and may be connected with the fact that copper occupies a place in the series of elements where the atomic weights begin to increase rapidly with atomic number.

A. J. DEMPSTER.
Ryerson Laboratory, Chicago,
June 9.

Expansion of the Wings of Lepidoptera after Emergence from the Chrysalis.

No one who has watched a butterfly or moth emerging from the chrysalis can fail to have been impressed by the rapid expansion of the wings. This expansion is not real growth, but merely the opening out of the contents of a carefully packed parcel, and the general character of the changes which occur in the process is well known.

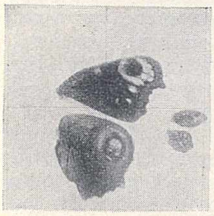


FIG. 1.—Pupal and extended wings of V. Jo (distance between lines = 1 inch). The pupal wings were removed from the chrysalis just before emergence.

The true growth of the wings takes place and is completed in membranous sacs just within the walls of the chrysalis, and the form of the wings can be distinguished from the outside. The position of the wings during their development is such that the upper surface of the fore wing is next to the wall of the chrysalis, and within a day or two from the time of hatching the colours and markings can in many cases be recognised.

Each wing consists of two separate membranes, united with the nervures, on which the scales are mounted, the stems of the scales entering sockets in the membranes placed in fairly symmetrical rows, though the irregular shape of the spaces between the nervures prevents the symmetry being exact.

The point to which the present note is intended to direct attention is the numerical relation between the size of the pupal and expanded wings, and the reason for the constancy of this relation. In all the lepidopterous wings which I have examined the pupal wing has very nearly one-third of the dimensions of the wing of the perfect insect (Fig. 1).

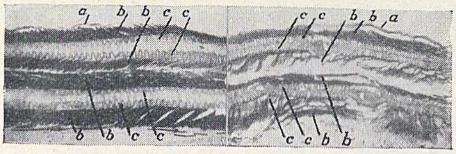


FIG. 2.—Section of pupal wings parallel to the nervures. ×60. FIG. 3.—Section of pupal wings at right angles to the nervures. ×60.
Sections in Figs. 2 and 3 were cut from the chrysalis, and show both the fore and hind wings.

If the fully developed wing is removed from the chrysalis and sectioned, the reason for the one-to-three ratio is immediately evident so far as regards extension parallel to the nervures, but the "accordion" folding whereby the scale-bearing membranes expand in a direction at right angles to the nervures is rather more complex.

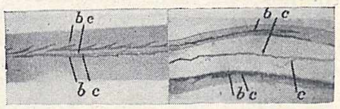


FIG. 4.—Section of extended wings parallel to the nervures. ×60. FIG. 5.—Section of extended wings at right angles to the nervures. ×60.
These sections are from the posterior part of the fore wing not far from the margin.

The section parallel to the nervures is shown in Fig. 2 and diagrammatically in Fig. 6. Here the wing membrane is seen folded so that the distance from fold to fold is the same as the depth of the fold, and therefore the extended is three times that of the folded dimension. To realise the character of folding in the other principal direction, imagine a series of camera bellows fully extended A_1A_2, etc., to be placed side by side, Fig. 9, so that the sides C_1C_2, C_2C_3, etc., will remain in contact when the bellows are contracted. Then remove the lower sides B_1B_2, etc., and join the free edges of C_1C_2, C_2C_3, etc. It is clear that the surface thus formed is developable, and that if, to start with, the bellows are compressed to one-third of their extended length the developed surface will in all directions have three times the dimension which it has when folded.

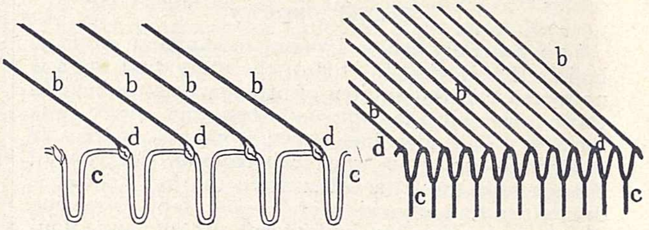
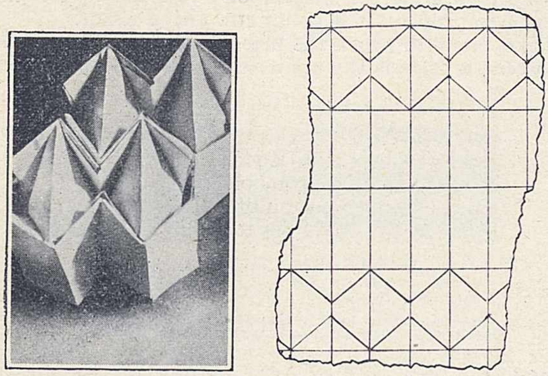


FIG. 6.—Diagrammatic section of pupal wing parallel to the nervures. FIG. 7.—Diagrammatic section of pupal wing at right angles to the nervures.
The letters refer to those in Figs. 2 to 7.—(*a*) Wall of chrysalis; (*b*) scales; (*c*) wing membrane; (*d*) sockets in membrane.

The section of the membrane cut in this direction presents a much more complex appearance (see Figs. 3 and 7) than that parallel to nervures.

The compression to one-third of the extended dimension in the transverse direction appears to be due to the space occupied by the "accordion" folds, and a diagrammatic sketch of the folded membrane seen in plan with the scales removed is given in Fig. 8.



a b

FIG. 8.—(*a*) Bird's-eye view of cardboard model showing the upper surface and side of the folds partly extended. (*b*) Developed surface of card showing the lines of folding.

The positions in which the sockets for holding the stems of the scales occur are shown at *d* in Figs. 6, 7, 8. In the pupal wing the scales are closely packed like the pile of a carpet, but after expansion lie close, and nearly parallel to the extended wing membrane, see Figs. 4 and 5.

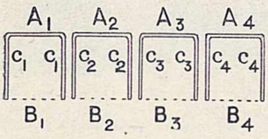


FIG. 9.—To illustrate the formation of an "accordion" folded sheet.

The mechanical means whereby the extension is effected is, I believe, of much the same nature as pumping up a pneumatic tyre, fluid being injected into the nervures by the muscular action of the body; but this is a point requiring further observation. So far as I know, it is only in the Lepidoptera that the 3 to 1 expansion occurs, but it seems probable that the same form of stiffening by injection acts in all wings supplied with nervures.

A. MALLOCK.

April 30.

The Formation of New Egg Cells during Sexual Maturity.

IT is generally believed among mammalian embryologists that during the life of the individual there is no increase in the number of primary oocytes beyond those originally laid down when the ovary was formed. This idea has grown from two sources of evidence—one, from the Weismannian doctrine of the germ-plasm; the other, from the fact that it is difficult to find any evidence for post-natal formation of new oocytes by metamorphosis of any non-germinal ovarian cell.

The problem of the origin of sex-cells in general introduces two questions about which much discussion has taken place. The first of these questions is how the first germ cells arise; the second, whether somatic cells can change into egg cells. Many, accepting fully the work of Beard, that doyen of embryologists, and of Woods, who showed that the germ cells of certain Vertebrata originate as large pale cells of the yolk-sac endoderm, at the same time consider that the view that no somatic cell can metamorphose into a germ-cell needs more evidence than the description of germ-cell migration. Apart from this important question, some zoologists believe that no accession of new egg cells takes place during the post-natal life of any craniate vertebrate, but the evidence produced by Bouin, Braun, Ludwig, and the writer would seem to be conclusive for fish, amphibians, and reptiles.

The attached photo-micrograph (Fig. 1) of the adult frog ovary shows a large ovarian tag containing germ cells in all stages, and it is indisputable that in vertebrates below the mammals seasonal accessions of new germ cells take place.

So far as the mammals are concerned no observer within recent years has attacked the problem, but Edgar Allen in the *American Journal of Anatomy*, vol. 31, No. 5, has now published a paper in which he claims that a cyclical proliferation of the germinal epithelium gives rise to a new addition of young oocytes in the cortex of the adult ovary of Mus at each normal oestrus period. This new paper appears to me to contain the results of much careful work, and it upholds the views expressed by the Waldeyer school of embryologists.

So far as the mammal is concerned, it may be taken that since the necessity for large numbers of fresh proliferated germ cells is usually absent, these do not generally occur in those forms which produce few young. The writer, through the kindness of Prof. J. P. Hill, has lately examined several ovaries of Ornithorhynchus without finding any signs of oogonia in the adult: the material was not extensive enough, in the light of Edgar Allen's work, to pronounce a definite verdict, but I believe Ornithorhynchus does not produce litters of young like the rodent. It is worthy of note that Allen's descriptions of photomicrographs correspond to the descriptions and figures already given by the present writer for Rana and Bufo. Allen's Plate 5 is very striking evidence; he has, moreover, demonstrated completely the cyclical mitotic divisions and activity in the germinal epithelium of Mus.

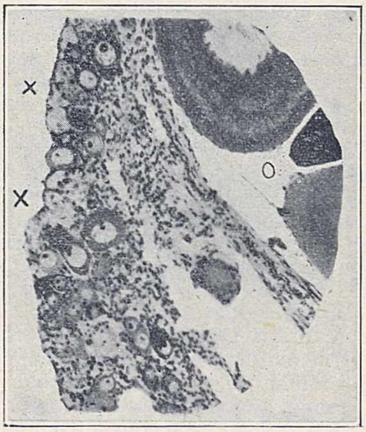


FIG. 1.—Photomicrograph of adult ovary of Rana. At X, X, are leptotene and pachytene stages of oogenesis, as well as large numbers of later oocytes. At O_1 is a part of the rest of the ovary with large eggs.

The opponents of the germinal epithelial theory will naturally say that Allen's cells are derivatives of the migrated primitive germ cells; but unless some obvious difference can be shown to exist between the germinal epithelial cells and the forerunners of the cells described by Allen, we are justified in assuming that the new egg cells are derived from metamorphosed epithelial cells, and certainly from cells which have lost their individuality in the formation of the so-called somatic part of the ovary.

The statement, often made, that only primordial germ cells can produce gametes, and that the metamorphosis of epithelial cells into germ cells does not take place, needs also the assumption that the potentialities of the somatic cells are curtailed by some special cytological mechanism, which, be it marked, has not hitherto been described by any one in the Vertebrata.

The nearest approach to such a mechanism is the chromatin-diminution process in Miastor, an insect in which all but the germ cell nuclei are deprived of part of their chromatin. Nowadays, however, few zoologists wish to repeat the mistake of Weismann in deducing too much from the peculiar cytology of the holometabolous Hexapoda, which develop under special conditions.

J. BRONTË GATENBY.

Trinity College, Dublin,
June 9.

Origin of certain Filamentous Forms from Eocene Beds.

A PAPER by Prof. T. D. A. Cockerell has just appeared entitled "The Supposed Plumage of the Eocene Bird Diatryma" (*Amer. Mus. Novitates*, No. 62, 1923), describing certain filamentous bodies from Eocene (Green River) beds of Colorado.

Prof. Cockerell states that the specimens "are not vegetable fibres, nor are they mammalian hairs," but resemble the simple feathers of birds like the cassowary, and he refers them (with a query) to a new species of Diatryma because this is the only known Eocene bird from which they could have come.

Prof. Cockerell has been good enough to give the original of his Fig. 1B to the Geological Department of the British Museum (Natural History), and an examination of this specimen has failed to convince me that it is not of vegetable origin. Similar strands of filaments occur in Upper Eocene rocks of Haering, Tyrol, for example, and are derived from decayed leaves of palms (*Sabal major*, Ung.), into undecayed portions of which they are sometimes seen to pass. These fibres in specimens from Haering are absolutely indistinguishable from those in the original of Prof. Cockerell's Fig. 1B, and, though it is difficult to arrive at any definite conclusion from such fragmentary material, it seems quite possible that the supposed feathers may be only fibres from a decayed monocotyledonous leaf.

W. N. EDWARDS.

Geological Dept.,
British Museum (Natural History), S.W.7,
May 26.

Hafnium and Celtium.

IT is with great interest that I have read the communications of Dr. Coster and Prof. Hevesy in NATURE on the new element, hafnium. Under the title "Correlation of Atomic Structure and Spectra" (Journal American Chemical Society, xliv., p. 328, 1922) I discussed the properties of the unknown elements from the point of view of Bury's theory of atomic structure, and stated: "No. 72 possibly is Urbain's celtium. But Bury's arrangement gives the electron structure 2. 8. 18. 32. 8. 4 for this element, which is consequently tetravalent, while Urbain describes celtium as being intermediate in chemical character between Lu and Sc, both trivalent elements. A further investigation of the chemical properties and the X-ray spectrum of celtium is therefore desirable." This article was received by the editors of the Journal, November 22, 1921, and, I believe, is the first published suggestion that the chemical properties of celtium as given by Urbain do not agree with theoretical considerations of atomic structure.

HAROLD S. KING.

The Chemical Laboratory, Dalhousie University,
Halifax, Nova Scotia, May 12.

Distribution of *Limnæa pereger* and *L. truncatula*.

SOME recent observations on a subject lately discussed in the columns of NATURE may be of interest.

The freshwater snails, *Limnæa pereger* and *L. truncatula* are widely distributed over this district, where *Distomum hepaticum* is a serious pest: the two molluscan species occur in almost every body of fresh water where the topographical conditions are suitable, excepting only such as are seriously polluted by the effluents from old lead-workings. The hydrogen ion concentration of the fresh waters varies generally from about P_H 6·4 to P_H 6·9.

While studying a neighbouring area, a portion of the Plynlimmon plateau, about 12 to 15 miles from Aberystwyth, I was struck by the almost complete absence of freshwater molluscan species. Two only were found: *L. pereger* and *Ancylus fluviatilis*, the latter in a single locality only, the former in this and one other locality. The hydrogen ion concentrations of the waters in these two localities were P_H 6·4 and P_H 6·5 respectively: both are exceptional figures for the area, where the P_H values as a rule range from 5·8 to 6·2. (Peat bogs abound in the district.)

Laboratory experiments show that *L. pereger* invariably dies within 2 to 3 hours after being placed in water of P_H value 5·6. (Distilled water which had been exposed to the air was used for these experiments; also tap water, which has here about the same P_H value.) A characteristic reaction is given, the first phase of which is the nearly complete extension of the body beyond the shell, with violent twisting movements. Eventually the animal dies in retraction, with much exudation and coagulation of mucus. I intend before long to carry out similar experiments with *L. truncatula*. Several other freshwater species show a similar reaction, the coagulation of the mucus being especially noticeable.

KATHLEEN E. CARPENTER.

Zoological Department,
University College of Wales,
Aberystwyth.

Scientific Names of Greek Derivation.

IN the course of the interesting notice of Stille's "Die Schrumpfung der Erde" in NATURE of June 2, reference is made to "What G. K. Gilbert styled 'epeirogenic' (now written 'epirogenetic')." The latter termination is no doubt more correct, but the spelling of the second syllable involves a more debatable question. Some of us are by no means reconciled to the system of the Latinisation of Greek names, now widely followed, especially on the other side of the Atlantic. It is a distinct misfortune that Greek should reach the nomenclature of science by way of a language poorer in both vowel and consonantal sounds. To write "dinosaur" for "deinosaur" is to obscure the derivation of the word. So long as most of our scientific terms are derived from Greek, it is obviously desirable that they should be written in English in a form as closely similar as possible to the original, so that a student can look them up in a lexicon even if he knows but little more of the language than the letters.

I am glad, however, to see that your reviewer, when he is at liberty to follow his own predilections, prefers to adhere as far as he can to the Greek spelling. Does he not speak of "Okeanos, lord of the great outer seas"?

JOHN W. EVANS.

Imperial College of Science and Technology,
S.W.7, June 4.

As the reviewer referred to, I warmly welcome the remarks of Dr. J. W. Evans on the tendency to modify Greek forms, sometimes beyond recognition, when they are introduced into scientific terminology. I went to some trouble in looking up Gilbert's "epeirogeny," which Sir A. Geikie of course spells correctly in his "Textbook of Geology." I have long clung to "deinosaur," and American authors should bear in mind that the use of an i for ei complicates pronunciation when the terms are handed on to other nations.

The chief offender, however, was Charles Lyell, who knew that he was doing wrong when he wrote his footnote on p. 53 of the third volume of the "Principles of Geology" in 1833. He justified his "Miocene" and "Pliocene" by the use of "encenia" and "icosahedron"; but the result has been the absurd American term "Cenozoic," which, if it means anything, should remind us of the emptiness of life.

The frequent use of the prefix "epi" makes one anxious to preserve "epeirogeny." I wish that we could mark the first e with a stroke to keep it long, and this remark applies also to "Tethys." But in the face of "Epirus," and "Pisistratus," and "Phidias" it is difficult to be logical. May we not attempt, however, as Dr. Evans suggests, to keep our newly invented scientific terminology from degenerating like our common speech?

GRENVILLE A. J. COLE.

On the Significance of "Rings" on the Shells of Cardium and other Molluscs.

IN NATURE of February 3, p. 146, I referred to experiments on determining the rate of growth of a fixed population of marked cockles (*Cardium edule*). In this experiment the box which was fixed in the bed of the River Yealm and contained the cockles was visited monthly, and sometimes at intervals of only a fortnight, for the purpose of measuring the increment in growth since the previous visit. This method of work resulted in an interesting observation on the formation of rings on the shells of the growing cockles. It was found that in the young cockles, *i.e.* up to about 16 mms. in length, dark rings were formed monthly or fortnightly in a majority of cases, on the shells at the size they were when last measured, but that no similar formation of rings could be detected in the larger and generally older shells. On the other hand, both small and large cockles showed distinct rings after the winter period.

In young cockles, growing in length at the rate of one millimetre or more a week, a cessation of shell-growth for a few days as a result of being taken out of their habitat and handled is enough to produce a distinct ring, but older cockles which increase *in length* a very small amount in even a month show no external sign of a small period of cessation in growth. Thus rings on the shells of cockles are undoubtedly due to periods of cessation of shell-growth, and the length of the period necessary to produce an effect depends directly upon the size of the cockle.

In this connexion it is interesting to read the history of cockles picked up haphazard. Some shells I picked up on the shifting sands of the bar at Padstow showed numerous rings close together, and there is no doubt that these rings can be interpreted as periods of cessation of shell-growth probably separated by only a few weeks, and due to the cockles being embedded deep in the shifting sand after rough weather. On the other hand, cockles picked up in protected situations show mostly those rings which can be interpreted as winter rings, but often also near the umbo, tiny rings which may mean the occurrence of a disturbance for only a few days while the individual was young. Similar winter rings have been found by experiment in Crepidula and in many cases in Patella, but Patella may not show winter rings in some situations at Plymouth after a mild winter.

In fishes the indications of periods of growth and of cessation of growth are very important, and in view of the observations mentioned above it would be interesting to know whether the otoliths and scales of *young* fishes, which show distinct rings (apparently produced in winter and summer), would reflect the effects of short periods of an analogous disturbance in the same way as the shell of the cockle.

J. H. ORTON.

Marine Biological Laboratory, Plymouth,
June 19.

A Crystallisation Phenomenon.

THE attached photograph (Fig. 1, natural size) is of interest, as it illustrates a phenomenon which does not appear to have been recorded.

For certain experiments it was necessary to purify some samples of salicylic acid, and recrystallisation from hot water was resorted to. The work was carried out in a litre conical flask, and a layer of crystals was formed at the surface of the solution on cooling. Below this layer many crystals were seen to be suspended by threads, and as the photograph shows, one thread would grow several crystals at different depths in the liquid.

In a bright light, reflection may occasionally be observed from some threads, but generally they are too small to be seen with the naked eye. They are elastic in the sense that, if the vessel is gently swung, the crystals oscillate at the end of their threads, which sometimes form flexible loops instead of hanging vertically. The threads are quite stable, as the suspension remains for months at a time. On one occasion the crystal layer was formed on a small grid of glass fibres and the solution syphoned out; the crystals were left hanging, but the threads could not be distinguished.

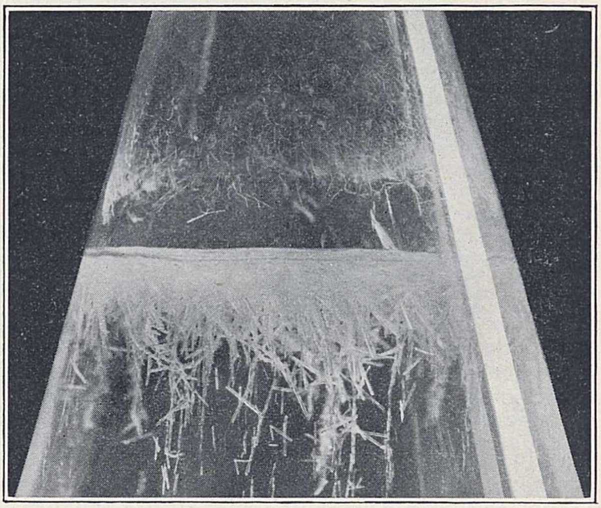


FIG. 1.

I am indebted to Mr. Sowerby of this College for the photograph.

C. R. BAILEY.

Chemistry Department,
University College, London, W.C.1,
June 8.

Studies from a Wireless Laboratory.[1]

By Prof. W. H. ECCLES, F.R.S.

THE studies pursued in a wireless laboratory are mainly of two kinds: first, those directed to the solution of problems that have arisen in the development or use of practical apparatus, and, secondly, those with which we are here concerned, aiming at the application of novel principles or novel physical phenomena to the invention of new methods or apparatus. Little will be said of the methods of wireless communication as they exist to-day; on the contrary, our attention will be devoted to some possibilities of wireless telegraphy—possibilities tested in the laboratory but not yet tried on the large scale. In other words, no attempt will be made to give a record of technical progress accomplished to date but, rather, to discuss wireless communication as it may be.

The new methods to be first described are based upon the phenomena, not yet fully known in detail, which occur when one vibrating body is caused to influence the vibrations of another. Consider the case of a simple pendulum consisting of a weight tied to the lower end of a string the upper end of which is held in the hand, and suppose it is of such a length that it would vibrate freely to and fro in a period of two seconds, when the hand is held still. Then it is easily

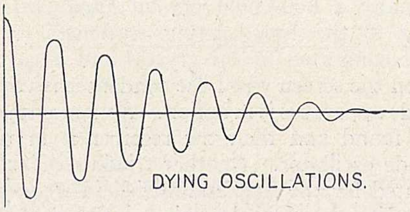


FIG. 1.—Dying oscillations.

seen that on moving the hand horizontally to and fro with a complete period of, say, one second, the pendulum will follow the hand and likewise vibrate with a period of one second. Similarly, when the hand vibrates with a period of, say, three seconds the pendulum will again follow and take the new period. This experiment is very familiar and is known to students of mechanics as an example of the subject of "forced vibration."

A pendulum forced in this manner may be said to vibrate "in time with" the hand, but the experiment shows that it is not "in step with" the hand. It would not be correct to say that it is "in tune with" the hand, since this term is reserved—in electrical physics at any rate—to indicate that the natural period of the free and unpropelled pendulum is the same as the period of vibration of the hand. We may, however, express the state of affairs by saying that the pendulum is forced into accord with the hand and that it is then in the "accordant state." A simple example of this relationship between two alternating movements is seen when a dog, for example, is walking along the road; his hind legs are in time but not in step with his fore legs.

The vibrations of a simple pendulum left free to vibrate with its own period gradually die down as indicated in Fig. 1. The vibration is a dying oscillation, and in such a case the theory of the forced vibrations is easily understood. In a modern wireless laboratory, however, we have to deal with growing and sustained vibrations as in Fig. 2, and in such cases the theory of the accordant state is rather different. This is to be expected—for it is like comparing a living thing to a dying one. Usually the vibrations are sustained by the aid of the triode valves so well known, and the rates of vibration are very high. In order to lead up to an understanding of the accordant state at these high frequencies it is best to study low frequencies first.

For the study of vibrations slow enough to be followed

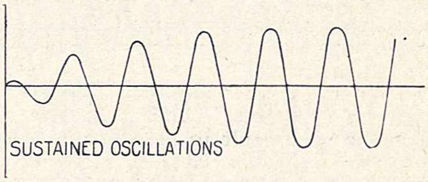


FIG. 2.—Growing and sustained oscillations.

by the eye a new type of oscillator has been designed and constructed and is here exhibited for the first time. Fig. 3 is a diagrammatic plan of the apparatus. The horizontal magnet has a horizontal ebonite rod fixed to it at right angles and the whole is suspended from a vertical torsion wire passing through the centre of gravity. The poles of the magnet confront two horizontal solenoidal coils connected in series with each other and with a battery and diode valve, that is, a thermionic valve of the type invented by Prof. Fleming in 1904 and containing only two electrodes, namely, a filament and a plate. Such a valve possesses the

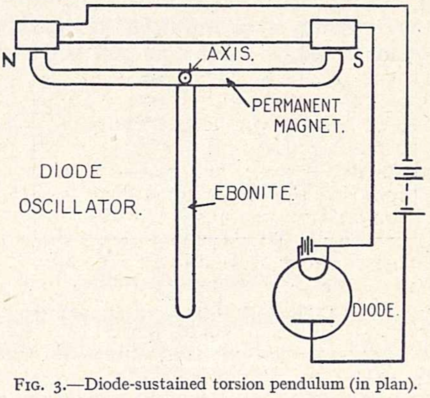


FIG. 3.—Diode-sustained torsion pendulum (in plan).

property that the electron current across the vacuum is sensitive to outside electrical influences if the electrodes have suitable relative positions—an ebonite rod charged by rubbing causes a diminution of the electron current when it approaches the diode and allows the current to increase again when it recedes. The action of this diode-sustained pendulum is now easily explained by supposing it swinging, and noticing that the ebonite rod as it moves to and from the diode causes an alternation of magnitude of the currents in and magnetic fields of the coils, which is automatically in correct time relation

[1] Substance of a discourse delivered at the Royal Institution, Friday, April 13.

to assist the motion of the magnet. By means of a small mirror fixed to the magnet, and a lamp and scale, the building up of the motion from a small initial amplitude is easily seen.

With two such pendulums the accordant state can be studied by eye observation. Dr. Winifred Leyshon is engaged upon this task. As arranged for the investigation one of the pendulums is made the master by sending some of its current through an auxiliary winding influencing the magnet of the other pendulum. The frequency of either the master or of the servant pendulum can be varied by the aid of a movable permanent bar magnet placed near the oscillating magnet. Then it is seen that as one natural period becomes nearly the

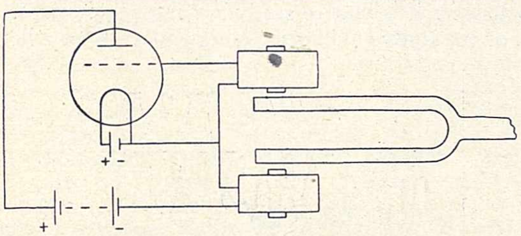


FIG. 4.—Triode-sustained tuning-fork.

same as the other the master catches hold of the servant, compels it to abandon its own natural period and to move in time with the master's—though not necessarily in step. The amount by which the servant is out of step depends upon the difference of the natural periods and therefore can be regulated.

These slow vibrations are seen and not heard; but it is also possible to use vibrators of acoustic frequency and so make the according process evident to the ear. A tuning-fork sustained by a triode is very effective as the master oscillator. The circuit is shown in Fig. 4, from which it will be seen that when the fork is vibrating the induced electromotive force acting upon the grid controls the anode current so as to sustain the motion.

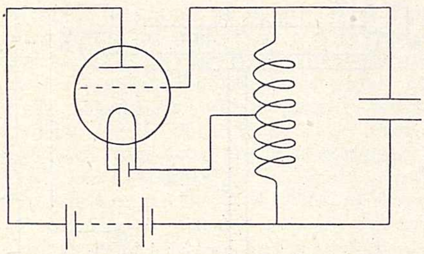


FIG. 5.—Triode electrical oscillator.

(See Eccles and Jordan, "Sustaining the Vibration of a Tuning-fork by a Triode Valve," The *Electrician*, June 20, 1919.)

On the other hand, an electrical oscillation, which is independent of moving matter, makes a good servant oscillator. Its circuit is shown in Fig. 5. The linkage between the two oscillators is effected by passing some of the current from the fork coils through an auxiliary winding on the electrical oscillator. The fork is audible when oscillating because it agitates the air; the electrical oscillations can be made audible by inducing currents in another circuit containing a loud-speaking telephone, and their frequency can easily be altered through a semitone or more by varying slightly the capacity of the condenser shown in Fig. 5. Now, as the natural frequency of the electrical oscillator is made to approach that of the fork, loud throbbings (called "beats") are heard, which become gradually slower until at a certain point the master suddenly drags the servant into time and the throbbings cease. If the movement of the condenser is continued the natural period of the electric oscillator is carried through resonance and then beyond, and finally the servant breaks away from the master and the throbbings indicating their difference of frequency begin anew.

This experiment is reminiscent of that of the two air-blown organ pipes discussed by the late Lord Rayleigh many years ago (*Phil. Mag.*, 1879, Collected Papers, vol. i. p. 409). Rayleigh showed that two organ-pipes nearly in unison dragged each other into a common frequency if brought into propinquity.

The preceding experiments have carried us from vibrations at 2 per second to vibrations at 200 per second; we now pass to the problem of accordance when the vibrations are of frequency 200,000 per second, such as are commonly used in wireless telegraphy and telephony. Such high frequencies are neither seen nor heard, but can be detected by special methods. The electrical oscillator nsed comprises a triode and an inductance and capacity connected as in Fig. 5 and chosen of suitable magnitudes. The detecting apparatus is an inductance coil and variable condenser connected to a crystal detector just as in many a household crystal apparatus used for listening to the broadcasting stations. A galvanometer is connected to the crystal and a spot of light moves on the screen when the condenser is varied while the triode apparatus is in action. A maximum deflexion is soon found and then the receiver is in tune with the triode oscillator. Another triode oscillator is now substituted for the first and varied in frequency until in tune with the crystal receiver. Clearly both triode oscillators are now of approximately the same frequency. Let them both be put into action simultaneously so as to act upon the crystal circuit, and let a pair of auxiliary coils, connected in series, be placed confronting the respective triode oscillators in order to establish a linkage. The crystal circuit is receiving energy from both of the triode oscillators and actuates the galvanometer. The accordant state is then easily found by varying one of the oscillators very slowly and watching the spot of light. At the moment when the two oscillators come within a certain frequency difference, they suddenly pull into time and the spot of light gives a sudden kick. This phenomena was discovered by Dr. J. H. Vincent and described in the Physical Society Proceedings (p. 84, Feb. 1920). One of his curves is reproduced in Fig. 6.

This curve illustrates that as the condenser of one triode oscillator is increased the galvanometer in the crystal circuit shows first an increase and then a very sudden decrease of deflexion. The nearly vertical parts of the curve are due to the establishment of accordance. In a rough way one may explain the phenomenon by saying that at the lowest point of the curve, where there is a sharp cusp, the two oscillators though vibrating in time with each other are oscillating oppositely. In fact one oscillator is moving like the front legs and the other like the hind legs of the dog cited already. The curve or the experiment shows that a very minute variation of the condenser of either oscillator makes the deflexion increase enormously.

There are several ways of applying this novel phenomenon to wireless telegraphy. Two of these may be illustrated here. Suppose one of the two oscillators to be a distant transmitter from which electric waves are proceeding, and that these waves are picked up by the antenna at a receiving station. Let the antenna be coupled to a local oscillator in the relationship of master, and let a tuned detector circuit be acted upon by both the antenna and the local oscillator. Then suppose the local oscillator adjusted until it is in the accordant state with the antenna oscillations, and, in fact, adjusted until the detector current is at the minimum value corresponding to the cusp of Vincent's curve (Fig. 6). It then follows that a very minute variation of the frequency of the oscillations emitted by the distant station will give rise to a deflexion of the galvanometer. It is suggested that signals could be transmitted by up and down changes in frequency—such changes would be far smaller than the changes of frequency employed by the accepted methods of the present day, and thus the interference between stations

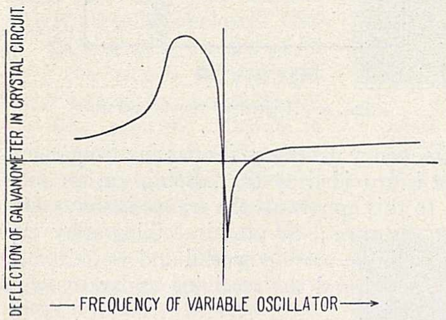


FIG. 6.—Vincent's curve.

would be minimised. There are many easy ways of producing small changes of frequency at the transmitting station.

Another and very different method of signalling may be illustrated by this same apparatus, after again adjusting the receiving apparatus to the minimum deflexion obtained in the accordant state. On trial it is found possible to bring the spot of light to any desired point of the scale—that is, to any desired point on the vertical portion of the Vincent curve—by appropriate adjustments of the frequency of the transmitting unit. These latter adjustments are for this purpose conveniently effected by the motion of a short circuited coil of wire near the inductance coil of the transmitting oscillator. Therefore, to every position of the auxiliary movable coil at the transmitter there corresponds a position of the spot of light actuated by the receiving apparatus. It might even be possible to mark the scales at each place with an alphabet and so communicate intelligence without the aid of the Morse code.

The above-described methods of signalling are based on the discovery of accordance between triode oscillators. Another distinct series of methods can be suggested and illustrated. These methods depend on the fact that the combination of two high-frequency electrical vibrations of slightly differing frequencies yields a throbbing amplitude which may be made of audible frequency and of any desired pitch by adjusting the frequency of either of the original vibrations. The formation of relatively slow throbbings from two quicker oscillations is shown diagrammatically in Fig. 7. The existing modern method of receiving continuous waves known as the heterodyne method utilises this principle in the following way: The transmitting station emits long and short trains of waves

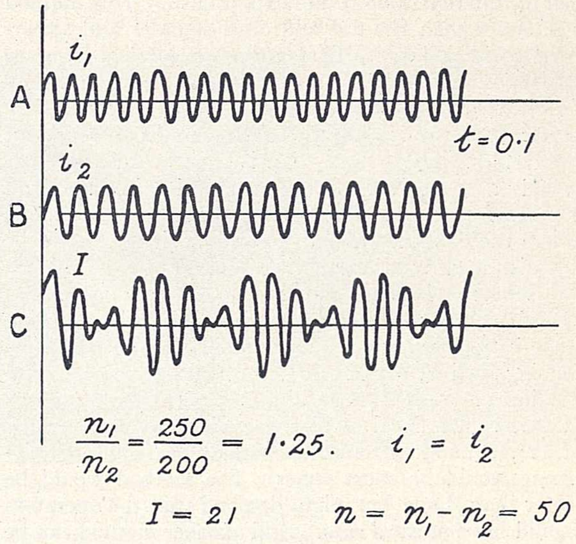


FIG. 7.—Illustrating the heterodyne method of reception.

corresponding to Morse dashes and dots and of frequency, say 200,000 per second. These waves produce in the receiving antenna feeble oscillations which are combined with locally generated oscillations of about the same strength and of frequency, say, 200,500 per second. The result is a compound high-frequency current with 500 throbbings in it per second. These when rectified can be heard in a suitably connected telephone. The long and short trains of waves from

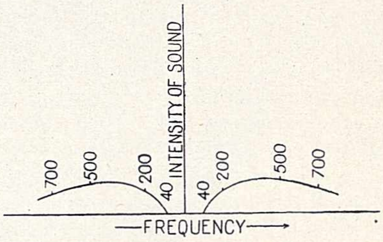


FIG. 8.—Diagrammatic representation of sounds heard in heterodyne reception.

the transmitting station thus give rise to sounds of long and short duration and of constant pitch. The pitch is adjustable by altering the local frequency from 200,500 to other values.

By altering this frequency from, say, 199,300 per second to 200,000 and then to 200,700 the sounds in the telephone run through a continuous scale of notes as represented in Fig. 8. This starts on the left with a note of 700 which falls in pitch to about 40 and becomes inaudible, passes through resonance, becomes audible again, and ascends a scale in opposite order to the first scale. Thus a note of any desired pitch can easily be obtained, but the intensity varies on account of the varying sensibility of the ear and the apparatus. This possibility of variation of pitch makes a number of new methods of wireless signalling feasible. One of the easiest resembles a very early kind of moving needle telegraph apparatus called Bright's bells in which the needle moved to one side and struck a bell in order to indicate a dot and moved to the other side and struck a bell of different tone to indicate a dash. This method was faster than the dot and dash sounder and apparently easier to learn. In its proposed wireless form the transmitting station would emit equal wave trains to represent dots and dashes, say of 200,200 frequency to represent the dots and 200,500 frequency to represent the dashes. Each Morse sign is then heard as a little melody at a receiving station using a local oscillator of 200,000 frequency. Besides the advantage mentioned above there is a likelihood that these signals would be less distorted by atmospheric discharges than are longs and shorts of constant pitch.

Still another simple method consists in utilising three very close high-frequency oscillations at the transmitting station, say 200,200, 200,100 and 200,050, and making a new code for the alphabet out of permutations of these. The local oscillator would have a frequency of 200,000, and therefore the sounds heard in the telephone would be short tunes. The method would be faster than Morse, but might demand that the operators should have musical ears. Still another method can be imagined in which chords of three notes instead of arpeggios are used for the letters of the alphabet, but this might require an even more musical ear.

But there is one kind of chord which every one can recognise without special training, which even the horse can discriminate in the sounds of "whoa" and "gee." The vowel sounds are in fact chords. Lately Sir Richard Paget has given (Vowel Resonances, International Phonetic Association) a list of the chief tones occurring in the English vowels. For example, the vowel sound in the word "calm" contains the tones of frequency 1360 and 810 per second. Suppose, therefore, a transmitting station is arranged to emit simultaneously electric waves of frequencies 201,360 and 200,810, and suppose these waves when received at a great distance are combined with local oscillations of frequency 200,000 per second. Then the tones 1360 and 810 are perceived simultaneously as a chord in the operators' telephones. But this chord by itself is scarcely if at all recognisable as a vowel. Recognition is ensured by superposing a larynx note by aid of a buzzing contact included in the receiving circuit. Then whenever a train of two waves leaves the sending station the vowel is pronounced by the receiving apparatus. This is easily illustrated to an audience by the aid of a loud-speaking telephone. Lecture apparatus for producing and detecting the two vowel sounds represented by *o*, *a*, is shown in Fig. 9. The change of

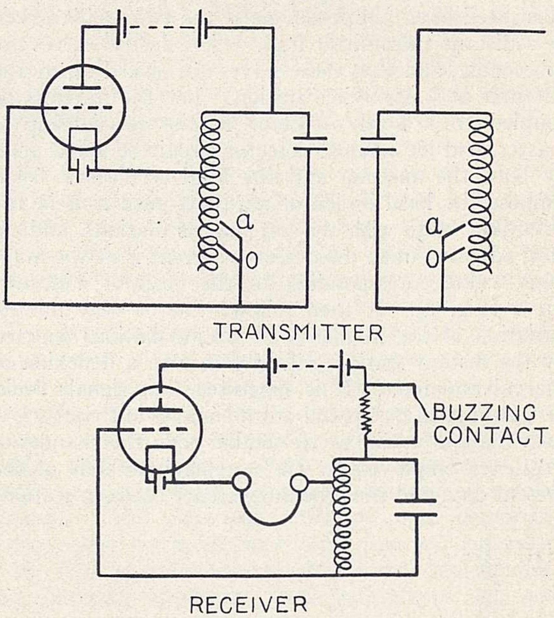


FIG. 9.—Heterodyne vowel apparatus.

radio frequency necessary for passing from one vowel to another is provided by the tappings on the inductance coils. In this apparatus the transmission occurs across a short distance; in practical telegraphy the transmitter would be more powerful and would be provided with an aerial and the receiving apparatus would also have an aerial.

The apparatus, which was built and made to work by Messrs. C. F. A. Wagstaffe and E. S. Smith, two former Finsbury Technical College students, was constructed to produce six vowels, namely, those heard in the words eat, all, hate, shoe, calm, and earth. These six vowels taken in pairs yield thirty-six symbols which, together with the five vowels *a*, *e*, *i*, *o*, *u* representing themselves, amount altogether to forty-one symbols. An alphabet formed in this manner is much briefer than the Morse code; that is to say, there are fewer efforts of the sending key in making the same message. For example, in the word London there are seventeen efforts when Morse is used but only eight when the vowel code is employed. Besides the gain in speed there is a possibility of reception through atmospheric disturbances being more easily accomplished with the vowel code than with the customary dots and dashes of constant pitch, but this can only be tested by actual trials.

Ur of the Chaldees.

By C. LEONARD WOOLLEY.

IN 1919 Dr. H. R. Hall, on behalf of the British Museum, spent three months excavating at Ur. Last summer the British Museum and the University Museum of Philadelphia decided to send out a joint expedition which should continue for a term of years the work begun by Dr. Hall, and clear as much of the site as seemed likely to repay the necessarily heavy cost of a scientific mission. The first season's work of the joint expedition is now over, and the results amply justify the confidence of those who promoted it, and give every promise of even greater success in the future.

Mesopotamian sites are often on a very large scale, and though Ur cannot compare in this respect with Babylon, yet the mounds of the ancient city, spreading in length for some three and a half miles, afford a rather bewildering scope to the excavator. At Babylon, in the course of their eleven years of work, the Germans excavated a number of the most prominent mounds, with excellent results; but there is this drawback to the system, that we have in consequence a number of important buildings or groups of buildings isolated from one another, and can deduce from them very little regarding the lay-out of the town plan. At Ur it will take many seasons to obtain anything like a plan of the whole city, but luckily we are, even thus early in the day, able to learn a great deal about the most important element in the city—the "temenos" or sacred area wherein lay the principal temples and the palace of the king.

Dr. Hall had dug one section of the wall which enclosed this temenos. Last season we traced it for nearly its whole circuit and cleared four out of the six gates by which it was pierced. Inside it the great ziggurat or storied tower of brick is unmistakable, forming, even in its ruined state, a landmark visible for many miles. Dr. Hall excavated part of a building which we have identified as the sanctuary of the great temple of the Moon-god Nannar (the greater part of it has still to be dug). We have completely cleared a smaller temple dedicated to the Moon-god and his consort; and we have been able to fix with tolerable certainty the position of two other temples and of the royal palace. Already, therefore, we know not a little about the topography of the temenos; and as by means of air-photographs we have been enabled to trace, without digging, much of the main outer wall of the city, the problem of where work can most fruitfully be done is simplified to an unusual extent.

The temenos wall was built, as numerous clay dedication-cones inform us, by Ur-Engur, the king who founded the Third Dynasty of Ur about 2300 B.C. It is a hollow or compartment-wall, each wall being over 9 feet thick with 13-foot chambers in the interior. Built of unbaked mud brick, its face relieved by vertical double-rebated grooves, it still stands in places nearly 10 feet high (Figs. 1 and 2). But the existing brickwork is by no means all of the founder's date. Often in its long history it was patched or rebuilt, and in the gateways (where of course repairs were most frequently required) we find records of later restorers dating from Ur-Engur's own grandson, Bur-Sin, to Nebuchadrezzar, king of Babylon (600 B.C.), and Cyrus of Persia (*c.* 535 B.C.). Soon after Cyrus's time, perhaps in the middle of the 5th century, the temenos wall, with all the temples which it enclosed, was destroyed by Zoroastrian iconoclasts. In one of the gateways, last restored by Nabonidus, Cyrus's predecessor, the scorched brickwork and the charred beams of the gate-chamber roof survived as a testimony to religious intolerance. It was just inside this gateway that we found a headless diorite statue of Entemena, king of Lagash and of Ur about 2900 B.C.; it is probable that this ancient and already mutilated figure was unearthed by Nabonidus, who had a passion for archæology, and set up on the ziggurat in front of the gate.

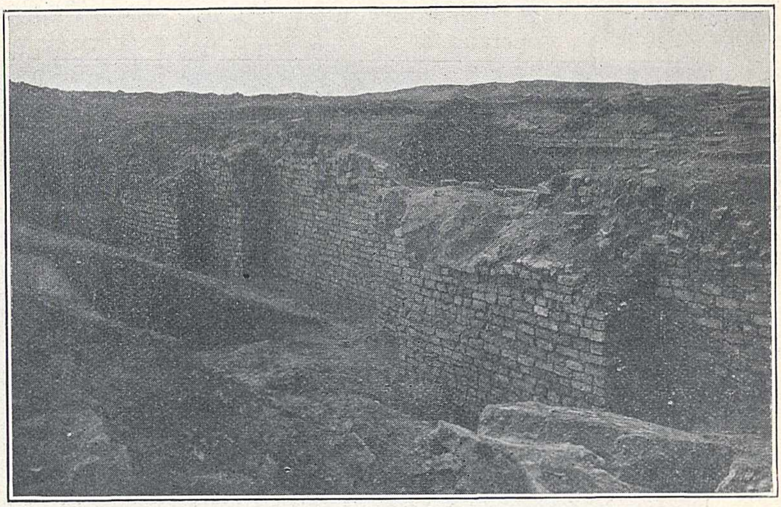


FIG. 1.—Part of the buttressed outer wall of E-nun-makh, the temple of the Moon-god and his consort. The lower part was built by Bur-Sin (2250 B.C.), the upper part by Kudur-Mabug (2000 B.C.): the interior brickwork seen above is by Nabonidus, last king of Babylon (*c.* 550 B.C.). By courtesy of the trustees of the British Museum and the Board of the University Museum, Philadelphia.

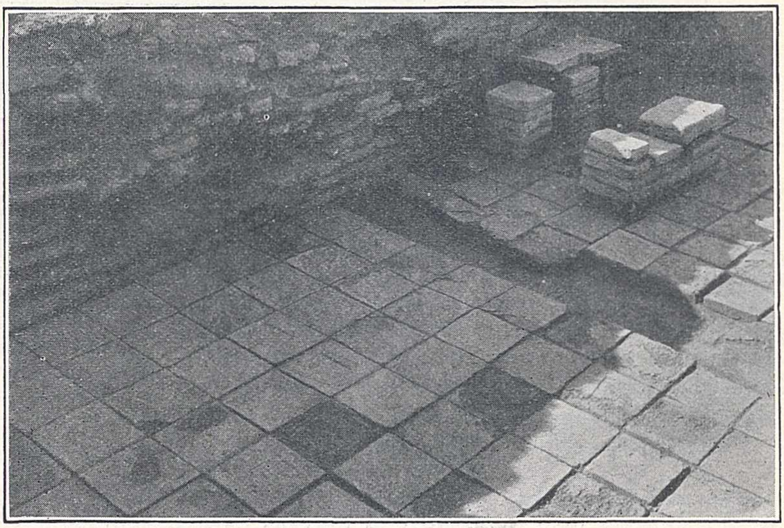


FIG. 2.—Room in the sanctuary of E-nun-makh, the temple of the Moon-god and his consort, showing the old walls, the new floor of bricks laid by Nebuchadrezzar, the side altar with its offering-table, and the groove in the floor for the "chancel screen." By courtesy of the trustees of the British Museum and the Board of the University Museum, Philadelphia.

The temple of the Moon-god and his consort was a foundation far older than the temenos wall. When Ur-Engur repaired it, as he did, it had already been twice rebuilt, and the original builder is lost to us in the mists of antiquity. That the temple was in use by 2650 B.C. we know, for we found in it fragments of decorative stone vases dedicated by kings of Agade at that time—but probably it was venerable enough then (Fig. 3). Bur-Sin, the second in descent from Ur-Engur, thoroughly rebuilt the place; so did Kudur-Mabug (about 2000 B.C.) and Kuri-Galzu (four hundred years later); but then, and until another thousand years had passed, the form of the temple remained the same: like a human body regularly renewing its tissues, the old building was still itself though its bricks changed. So careful were the royal builders to keep to the old times that, as a rule, each left one or two courses of his predecessor's building *in situ* to serve as a guide to the new bricklayers, and as a result the lower parts of the walls which survive to-day sandwich into a few feet successive periods of history covering two and perhaps three thousand years. Nebuchadrezzar was the first to embark on a radical alteration. The original five-roomed sanctuary had been private, the god's own house, hidden away behind priests' chambers and stores and approached only by a winding passage. Nebuchadrezzar did away with all the service-rooms in front of the door, substituting for them a wide-open court with a smaller upper court whereon stood the altar. The alteration clearly points to a change from a secret ritual to public or congregational worship such as that referred to in the Bible story of the Three Children.

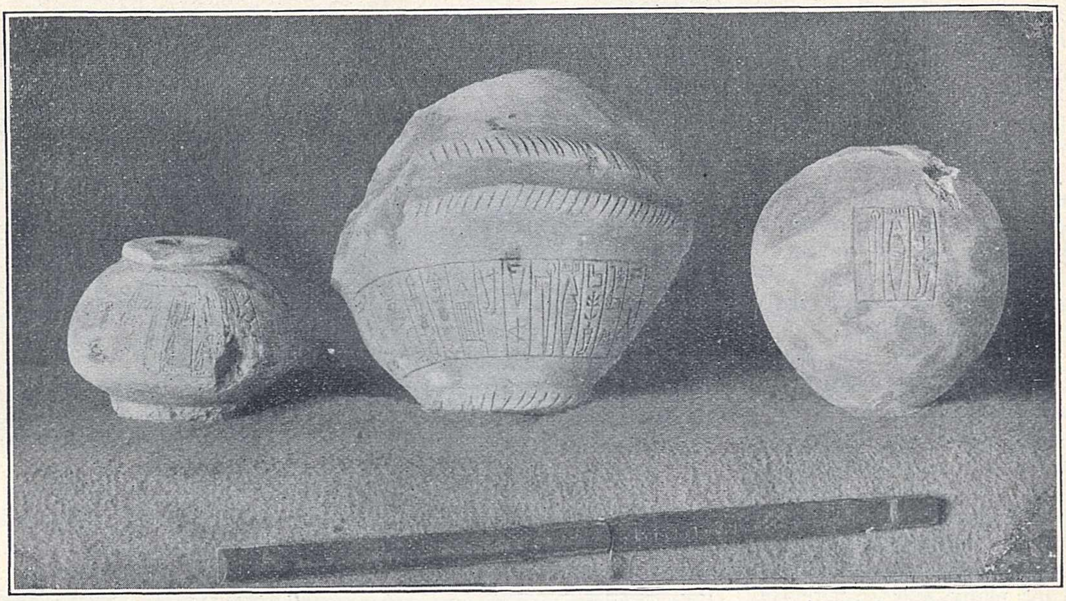


FIG. 3.—1, Votive alabaster mace-head of Ur-Engur (2300 B.C.). 2, 3, Votive alabaster mace-head and vase of Rim-mush, King of Agade (2650 B.C.). By courtesy of the trustees of the British Museum and the Board of the University Museum, Philadelphia.

The number of objects found in the course of the excavations was very great, including jewellery of the Neo-Babylonian and Persian periods, ivories and bronzes, hundreds of inscribed tablets, mostly of the time of the Third Dynasty (2300–2000 B.C.), terra-cotta reliefs, carved and inscribed stone vases, pottery, glass and stone beads, etc., etc. A special exhibition of these will be arranged at the British Museum as soon as possible, and illustrated lectures describing the progress of the excavations will also be given.

Current Topics and Events.

THE present outbreak of small-pox in Gloucester is very different from the tragedy of 1895–96. The number of cases in that frightful epidemic was 1981: and the number of deaths was 434. On the present occasion, the number of cases, up to now, has been about one-tenth of that number. As in other places, so in Gloucester, a very mild type of small-pox has appeared: indeed, so mild that, to some people, the very nature of small-pox seems to have changed. Still, the possibility remains that the disease will, some day or other, recover its old virulence. Besides, it appears that some of the Gloucester cases have been serious. Thus, at a meeting of the city council on June 27, the Mayor spoke of "some of the fearful sights" in the wards of the Isolation Hospital, and said that he should never forget them: and the chairman of the Health Committee spoke of "severe and ghastly" cases in the same hospital. Unhappily, so mild were the first cases that they were mistaken for chicken-pox. The best authority on the rules for avoiding this mistake between small-pox and chicken-pox is Dr. Wanklyn: and his writings are worth reading. The mildness of the epidemic, the controversy over its nature, the frequent concealment of cases, and the work of the anti-vaccinationists, have brought about a most unfortunate state of affairs in Gloucester. The fear is that Gloucester is steadily exporting small-pox to neighbouring towns.

THE first presentation of the Paterno medal was made on July 19 during the meeting of the International Union of Pure and Applied Chemistry in Cambridge. The chairman, Sir William Pope, explained that subscriptions had recently been collected to form a foundation to commemorate the many contributions made to chemistry in so many of its fields by Prof. Emanuele Paterno. It had been decided that the memorial should take the form of a gold medal to be awarded every three years for the most noteworthy discovery made in chemistry. Prince Ginori Conti, the president of the Italian Chemical Society, announced that at a recent meeting in Rome the committee appointed had unanimously nominated Dr. F. W. Aston as the recipient of the first award for his work in theoretical chemistry in connexion with the mass-spectrograph and isotopes. Prof. Paterno then presented the medal. Dr. Aston in replying expressed his sincere thanks for the great honour done to Cambridge and to himself by the award. He emphasised the importance of such international prizes as promoting goodwill between nation and nation, and expressed the hope that the distinguished chemist who made the presentation would be spared to assist at many similar occasions in the future. Although the work for which the award was made was almost entirely physical, he reminded the chemists present that his first published researches were in the domain of organic chemistry, and that to-day all definite distinction between physics and chemistry had been swept away by the discovery of the electrical constitution of matter.

NEWS of Mr. K. Rasmussen's researches in Arctic Canada have been published in the *Times* in a dispatch written in December 1922. The east coast of Melville Peninsula from Repulse Bay to Fury and Hecla Straits was charted, and extensive studies were made of the little-known Eskimo tribes in that region. These tribes, the Aiviliks and Igdluliks, have been largely influenced by the whalers who used to visit the coast in the latter half of last century. The whalers took the Aiviliks into their service as boatmen, finding them far superior for this purpose to the Eskimo of Greenland. The result was that the kayak fell into disuse and there are now no kayaks on this coast. Hunting sea animals plays a small part in the lives of these Eskimo, and the use of modern hunting gear, which alone is employed, will die out with the disappearance of the men trained by the whalers. Seal-hunting is not widely pursued, and consequently there is a shortage of blubber. In winter the snow huts are generally unheated, and Eskimo have to rely on good furs for warmth. Mr. Rasmussen found them hardy to an incredible degree. During summer many families move inland for trout-fishing and reindeer-hunting, but reindeer are scattered and not numerous. Hunting begins in July or August, which is the earliest time that the skins are fit for clothing. During the present summer Mr. Rasmussen, with one Eskimo companion, proposed to travel across Arctic Canada to Alaska and over Bering Strait to visit the Eskimo in Siberia. Other members of his expedition were to study the tribes of Melville Peninsula, and cross the interior of Baffin Land to the Hudson Bay Co.'s post on Home Bay. The result of all these researches promises to elucidate the problem of Eskimo origins.

ON Monday, July 2, the Prince of Wales opened the new anatomy, biology, and physics department of Guy's Hospital Medical School. The new building, which completes the rebuilding scheme started some twenty-seven years ago, consists of five floors. It provides accommodation for the teaching of embryology and histology in connexion with anatomy and for surgical research work, while close at hand is the new biology department. The transference of the physics department to the new building has provided increased space for the organic and biochemical side of the chemistry department.

THE twenty-fifth anniversary of the graduation, *honoris causa*, of Prof. F. A. H. Schreinemakers in the University of Leyden on July 7 is being marked by the issue of a special number of the *Recueil des travaux chimiques des Pays-Bas* which will contain more than sixty articles in English, French, German, and Italian by various colleagues, pupils, and friends, in Holland and elsewhere, of Prof. Schreinemakers. Copies of this number (price 8*s.* 6*d.*) can be obtained from Miss W. C. de Baat, Leyden (Holland), Jan van Goyenkade 30.

ACCORDING to the *Chemiker Zeitung*, Prof. A. Einstein has been elected a member of the order Pour le Mérite.

LORD CRAWFORD AND BALCARRES has been elected a trustee of the British Museum, in succession to Lord Rosebery, who has resigned.

IT is stated by the Ottawa correspondent of the *Times* that the Canadian Parliament has unanimously voted an annuity of 1500*l.* for Dr. Banting, the discoverer of the insulin treatment of diabetes, to enable him to carry on his scientific work.

THE French Association for the Advancement of Science is holding its annual meeting at Bordeaux on July 30-August 4. Communications regarding the meeting should be addressed to the secretariat of the Association at 28 rue Serpente, Paris, 6^{e}.

PROF. F. GOWLAND HOPKINS has been awarded the gold medal of the Royal Society of Medicine, which is given triennially to a scientific worker, man or woman, " who has made valuable contributions to the science and art of medicine."

AT a meeting of the Royal Society of Edinburgh held on July 2 the following foreign honorary fellows were elected: Prof. E. B. Wilson, professor of zoology, Columbia University, New York; M. M. Boule, director of the Institute of Human Palæontology, Paris; Prof. A. F. Holleman, professor of organic chemistry at the University of Amsterdam; Dr. A. A. Noyes, Institute of California, Pasadena; Prof. T. W. Richards, professor of chemistry, Harvard University, Cambridge, Mass.; Prof. Tullio Levi-Civita, professor of mathematics (higher analysis) at the University of Rome; Prof. Henri Bergson, honorary professor of the College of France; and M. Alfred Angot, late director of the Central Bureau of Meteorology, Paris.

At the annual general meeting of the Röntgen Society on June 5, the following officers were elected :-- *President* : Sir Oliver J. Lodge ; *Vice-Presidents* : Sir Ernest Rutherford, Dr. A. E. Barclay, and Dr. F. W. Aston ; *Hon. Treasurer* : Mr. G. Pearce ; *Hon. Editor* : Dr. G. W. C. Kaye ; *Hon. Secretaries* : Dr. E. A. Owen, Mr. R. J. Reynolds ; *Council* : Mr. C. Andrews, Dr. G. B. Batten, Lt.-Col. Kenelm Edgcumbe, Mr. N. S. Finzi, Mr. W. Hope-Fowler, Dr. F. L. Hopwood, Dr. J. E. A. Lynham, Mr. G. H. Orton, Prof. A. W. Porter, Prof. S. Russ, Dr. R. W. A. Salmond, and Mr. W. E. Schall.

In the report of the council of the British Medical Association it is stated that the British Medical Association in Australia has instituted a gold medal for the purpose of perpetuating the appreciation of services rendered by members of the British Medical Association in Australia. The medal has on one side the figure of Æsculapius in relief, and on the obverse a wattle wreath, with the wording "The British Medical Association in Australia," "For Distinguished Service," with loop and ribbon of royal blue. It is to be presented at the congress of the British Medical Association in Australasia to be held in Melbourne in November, and the first recipients will be Dr. R. H. Todd and Dr. W. T. Hayward.

A successful "commemoration day" was held at Livingstone College on June 13, Sir Leonard Rogers being in the chair. Various speakers testified to the benefit of the training received at the College, which is designed to give to missionaries the elements of medical knowledge. The College would be self-supporting if a sufficient number of students were sent to the College regularly, but at present this is not so, and about 500*l*. is urgently needed.

The Marlborough College Natural History Society has long been prominent in maintaining an interest in field-studies, and through them in the essential beauty of the earth, among those who otherwise might grow up on the old conventional lines of public-school education. The report for 1922 (Marlborough : the *Times* Offices, 1923) records the proceedings of a number of sections, including those of astronomy and archæology ; the latter is carrying out actual excavations on the site of Castrum Merlehergæ (pp. 37-45). The botanical section has added two new species to the local list during the year. Perhaps the most striking signs of activity are the geological excursions taken in Scotland, during which the members were very kindly guided by Mr. G. W. Tyrrell, lecturer in the University of Glasgow, over ground dealt with in his own researches. Mr. A. G. Lowndes (p. 57) gives a lucid account of the conditions under which the pitchstones of the dykes in the Isle of Arran were formed, and this is accompanied by a plate of thin sections as seen under the microscope. The other photographic illustrations, including birds' nests in their natural surroundings, add much to a stimulating production. We are sure that members of this firmly established Society carry the memories of its field-days to their more ambitious journeys on *safari* in Kenya, or in dug-outs on Malayan seas.

The University of Chicago Press, Chicago, Illinois, has just issued a third edition of its very useful illustrated catalogue of astronomical photographs. The photographs have been reproduced mainly from negatives taken at the Yerkes Observatory, and have been issued for the convenience of the general public, the man of science, the student, and the lecturer. They comprise lantern slides, transparencies, and prints, issued at uniform prices ; but, at an extra cost, they may be obtained modified in size or other qualities, to meet individual needs. Card descriptions of the lantern slides also are published. The photographs appear to cover the whole range of observational astronomy, and include, in addition, a number of views of astronomical instruments and portraits of famous astronomers of the past and present. There are, finally, a few stereograms, chiefly of the moon, planets, and comets. A large number of the photographs were taken by the late Prof. Barnard, among which his well-known and beautiful pictures of the Milky Way and of dark markings in the sky are particularly welcome. Of great value to teachers and lecturers are the photographs of stellar spectra, with terrestrial comparison spectra, illustrating the Doppler displacements due to relative motion of the star and the earth in the line of sight. Reproductions of two of these photographs are given in the catalogue ; they show the effect with unusual clearness and beauty. It would have been a great boon to teachers of astrophysics if the publishers had found it possible to include a complete series of typical spectra, in the visible region, of the various Harvard types. Only the violet and ultra-violet regions are now accessible. The catalogue should prove extremely useful to all who are interested in any way in the observation of the heavens.

The Manila Weather Bureau sets a praiseworthy example to many larger institutions in the comparative promptness—judged by post-War standards—with which it issues its volume of magnetic observations for the calendar year 1919. Until 1904 the observatory was at Manila, whence it had to be removed, on account of electric tramway disturbances, to Antipolo, twelve miles distant from the city. It started its new career in 1911, and its annual reports have since then been modelled on the pattern adopted by the U.S. Coast and Geodetic Survey. Hourly values of declination and horizontal and vertical magnetic force are given, together with the daily mean, maximum, minimum, and range for each element. Mean diurnal inequalities are given for each month and for the five quietest and five most disturbed days per month. These inequalities are also summarised in separate tables : the inclusion of a table of daily variation of the total force might perhaps be dispensed with.

A useful pamphlet published by the United States Coast and Geodetic Survey (Special Publication No. 93, price 30 cents) deals with Reconnaissance and Signal Building. The author, Mr. J. S. Bilby, writes from experience of actual cases arising in the routine of field work, and dwells on the practical difficulties that are encountered in a preliminary reconnaissance for precise triangulation. The first part of the publication discusses the character and strength of triangulation figures, selection of sites, and intervisibility of stations. The second part deals with signal building, and includes practical directions, with detailed plans and specifications. The section on hydrographic signals is specially interesting. Signals of some kind or other, either ashore or afloat, are frequently necessary in the location of soundings off a low flat coast. Full plans and illustrations and a note of the amount of material required are given.

THE third number of volume i. of the *Japanese Journal of Botany* has just been issued by the National Research Council of Japan. In addition to botanical papers, it contains reviews of the current Japanese botanical literature, much of which is published only in Japanese and has hitherto been unavailable to workers in other countries. This is therefore a valuable feature of the Journal, and should be of much service in making more widely known the work of Japanese botanists. The present number contains papers in English and German, chiefly on genetical subjects, as well as abstracts of the principal botanical papers which have appeared in Japan during the period April-September 1922.

M. MARCELLIN BOULE, the eminent French anthropologist, in the Huxley Memorial Lecture for 1922, published in the Journal of the Royal Anthropological Institute (vol. lii., 1922), describes the services rendered to the study of man by the late Prince Albert I. of Monaco. The Prince, impressed by the importance of the remarkable cave records in southern France, devoted much attention to the development of these discoveries, of which M. M. Boule gives an interesting account. One important result of his work was the establishment of the Institute at Monaco, where the treasures recovered from the caves find a suitable home, and where the study of them can be conducted.

Our Astronomical Column.

D'ARREST'S COMET.—This interesting periodic comet is due at perihelion in two months, and its detection in July may be hoped for, as it is well placed in the evening sky. Mr. F. R. Cripps has calculated the perturbations by Jupiter and gives the following elements and ephemeris (for midnight) in B.A.A. Journal for May:—

$$T = 1923 \text{ Sept. } 14\cdot12 \text{ G.M.T.}$$

$$\left.\begin{array}{l} \omega = 174^\circ\ 7'\ 15'' \\ \Omega = 143\ \ 32\ \ 18 \\ i = 18\ \ 3\ \ 47 \end{array}\right\} 1925\cdot0 \qquad \begin{array}{l} e = 0\cdot6169 \\ \log a = 0\cdot5478 \\ \log q = 0\cdot1311 \end{array}$$

	R. A.	N. Decl.	log r	log Δ
July 8.	16h 26·0m	12° 19′	0·193	9·856
,, 12.	16 25·2	11 6		
,, 16.	16 25·2	9 42	0·181	9·847
,, 20.	16 26·1	8 8		
,, 24.	16 28·1	6 24	0·170	9·841

The comet is nearest to the earth at the end of July and brightest in mid-August. The moon will cause difficulty in the latter part of July. The positions given above lie in the southern part of Hercules, and are nearly due south at the end of twilight.

There is no further confirmation of the announcement of the discovery of a comet by Abbot at Athens.

THE COMING OF THE PERSEIDS.—Mr. W. F. Denning writes: "Early meteors from the great August shower are occasionally visible at the beginning of July. They should be carefully observed, as it is desirable to ascertain the opening date of the display. A few meteors, if observed at two stations, might satisfactorily settle the question, though, at its first oncoming, the shower is but slightly manifested. This year there will be no moonlight to interfere with the maximum on about August 11 or 12, and with clear weather the event should be witnessed under good conditions. There is no reason for expecting that the ensuing return will be one of very rich character, but the Perseids form an annual spectacle of meteoric activity not equalled by any other system. A maximum of special intensity was witnessed on the morning of August 12, 1921, when the hourly number of meteors visible to an observer was 250. There is evidence to show that the shower presents itself most richly at intervals of 11·75 years, but more observations are required. Its duration continues over the two summer months of July and August.

"The Perseid shower will be supplemented by other radiants, the following being among the more prominent ones visible at or from about the middle of July and, in certain cases, for some time afterwards:—

16°+31°	47°+44°	303° −10°	334°+73°
22 +21	270 +47	303 +24	335 +58
25 +43	292 +53	312 +62	339 −12
42 +22	281 +44	315 +48	343 +12

There are certainly more than 100 different systems in play, but the great majority of them are feeble and apparently the relics of nearly exhausted streams which possibly formed rich displays in ancient times."

PERTURBATIONS OF THE MINOR PLANETS.—Prof. A. O. Leuschner has published a useful report on this subject as a Bulletin of the Research Council of the National Academy of Sciences, Washington. It deals with twenty-three interesting planets, including the four bright ones, Eros, Andromache, and the six Trojan planets. Tables are given of all orbits published, with a statement of the method by which they were derived.

It is obvious that the vast host of minor planets can only be observed efficiently if there is a methodical division of labour. Arrangements for this had been made before the War, which threw them into confusion, and it is welcome news that Prof. Leuschner's Bureau is again making arrangements for this purpose. At present planets that are better known are frequently observed to an unnecessary extent, while others are neglected. Marseilles Observatory has published numerous orbits and ephemerides of late years, but it has not been in touch with all the countries where observations were being made. One point emphasised in the report is the importance of giving clear information in all published orbits of the materials that were used in obtaining them, and the perturbations that were applied. Several cases are quoted in which this information is lacking.

Research Items.

AN EGYPTIAN STATUE OF MENKAURA IN LONDON.—In *Ancient Egypt*, 1923, part i., Prof. Flinders Petrie describes a remarkable figure in white alabaster, acquired some time ago for University College, London. It shows a further development of the great Khofra statue. There the king's head is shielded by the falcon's wings which are spread out behind the head-dress; here the king is himself the falcon god, entirely human in front view, entirely bird-like at the back. The lower part is incomplete, but the figure was probably seated. The resemblance to the *bourgeois* figure of Menkaura is obvious at first sight; and the development of the protecting falcon would accord with this representing the successor of Khofra. It can scarcely be questioned that it came from one of the two temples of Menkaura.

EXCAVATIONS IN UPPER SIND, INDIA.—A dispatch from the Bombay correspondent of the *Times*, published in the issue of June 25, summarises a report of excavations in Upper Sind carried out by Mr. R. D. Banerji, of the Indian Archaeological Survey, on the ruins of an ancient city now known as Mohenjidaro or Mohenjodhari, six miles from Dokri on the North-Western Railway. The highest mound in these ruins, which cover more than two hundred acres, was selected for excavation. It proved to be a Buddhist shrine on an artificial platform situated on an island in the old bed of the Indus. This platform was protected from the effects of high floods by retaining walls some 40-50 feet high. Two more mounds excavated produced remains of shrines dating from the second century A.D. during the reign of the great Kushan Emperor Vasudeva I., A.D. 158–177. A stratum below the shrine contained what were apparently the remains of an older shrine which had been burnt, possibly by Scythian invaders. There are two most interesting features in these investigations. The first is the discovery of a number of coins representing the earliest copper currency of North-Western India, and differing from any discovered hitherto in India in being dye-struck and not punch-marked. These coins also afford the oldest representation of the Fire-Altar of the ancient Persian religion on Asiatic coins, and furnish evidence that this religion and Buddhism flourished side by side. The second point of particular interest is the discovery in one group of coins of inscriptions in unknown characters, as yet undeciphered, which it is maintained are hieroglyphs or ideograms differing from Egyptian hieroglyphs. This is claimed to be the only recorded discovery of a new type of hieroglyph in Asia; but Sir J. Marshall, Director-General of Archæology in India, has since pointed out that these pictographs are similar in character to those from Harappa in the Punjab.

DISCOVERY OF A MIDDEN AND FIRE-HEARTH AT CHARK, NEAR GOSPORT.—In the June issue of *Man*, Lieut.-Colonel J. H. Cooke describes the result of excavations on Chark Common, about one mile from the shores of Spithead. They included a midden and camp fireplaces which were coeval. The midden is unique of its kind, though it is not as large as some of the great shell-heaps on the Continent, but it is the only example of a midden in Britain in which the contents are unmixed with relics of later cultures. Its principal features are the character of the deposits in which it is embedded, the many species of shells it contains, the well-marked types of implements found in it and around the adjacent fire-hearths, and the total absence of any fragments of pottery or metal. It is attributed to the Robenhausen period of the Stone Age, which immediately preceded the Bronze Age.

FOSSIL CRABS FROM HAITI.—Some Brachyuran Crustacea from the Pleistocene and Miocene deposits of Haiti form the subject of a short paper by Miss Mary J. Rathbun (Proc. U.S. Nat. Mus., vol. lxiii. art. 9). One genus, Mithrax, which is widely distributed throughout the West Indies, had not before been found fossil, but is now recorded from the Pleistocene.

MESOZOIC INSECTS OF QUEENSLAND.—Fossil remains of insects are not usually found associated in great abundance at any one spot, so that the discovery of a six-inch seam full of such remains, and that from so low a geological horizon as the Trias, is a noteworthy occurrence. The layer in question was disclosed at Denmark Hill, Ipswich, some few miles west of Brisbane, Queensland, and the description of its insect contents has been undertaken by Dr. R. J. Tillyard and Mr. B. Dunstan. The first part, just issued, is by Mr. Dunstan (Queensland Geol. Surv. Publication, No. 273), and deals with introductory matter and the Coleoptera of the deposit. After describing the section from both the physical-geographical and the geological aspect, the author is tempted to speculate on the cause of the wholesale destruction of insects here manifest. From a study of the phenomena occurring at the hot springs at Einasleigh, Northern Queensland, where the edges of the pools are lined with myriads of wings and elytra, from which the soft parts have evidently been removed by the hot bubbling water, while insect fragments float about and then disappear down the stream, Mr. Dunstan infers that similar conditions governed the formation of the Triassic deposit. The major portion of the paper is devoted to full and careful descriptions of the fifty-eight species, belonging to twenty genera, the bulk of which are of course new, referable to some eight families. The Hydrophilidæ are the most numerous. One could have wished, however, that the seven plates had been executed in a style more consonant with the rest of the work.

A NEW GRASS.—In the *Kew Bulletin*, No. 5 of 1923, D. K. Hughes describes and figures an interesting grass, *Streptolophus sagittifolius* Hughes, which has been grown at Kew from fruits received from Mr. J. Gossweiler, director of the Botanic Garden, Angola. Conspicuous features of the new genus are the sagittate leaf blades, lifted away from the leaf sheaths upon slender petioles which are set at a sharp angle to the main stem, and the flowering panicles, which owe their characteristic appearance to the fact that the branchlets are reduced to slightly flattened bristles which are fused at the base into clusters.

EARTHQUAKES AND PHEASANTS.—Pheasants, it has long been known, are peculiarly sensitive to the effects of slight tremors, and in many earthquake countries they are supposed to give notice of a coming shock. Prof. Sekiya's attempt, nearly forty years ago, to study the behaviour of pheasants before and during earthquakes was unsuccessful, probably because the birds were not under natural conditions. Recently, Prof. Omori (Bull. Imp. Earthq. Inves. Com. of Japan, vol. 11, 1923, pp. 1-5) has been able to observe those living in a neighbouring park, usually within a distance of a hundred yards, and during the quiet hours of the night. In three years he recorded 22 cases of the disturbance of pheasants. On seven occasions the birds crowed before the tremor was felt, on five at the same time, and on five afterwards. In four cases they crowed while no tremor was felt, though slight movements were recorded by the seismographs; and in only one case did an earthquake occur without the accompaniment of pheasant-crowing. Thus, in half the cases observed, the movement was noticed by pheasants more readily than by a trained observer under good conditions.

NORTH SEA FISHERIES IN 1920–22.—There was something unusual in the physical conditions of the North Sea in 1920–22. A much greater influx of Atlantic water occurred, and the pelagic fauna showed marked deviations from its normal character. The pelagic tunicate, Salpa, appeared in great numbers, and there were swarms of medusæ in regions where they had not usually been seen in quantity. The herring fishery of 1921 was very poor, both as regards the catches made and the quality of the fish. The latter were ill-nourished, and this may be regarded as an indirect effect of the changed physical conditions. Several papers that have appeared recently provide data for a treatment of this remarkable hydrographic occurrence. *Rapports et Procès-Verbaux*, vol. xxix., published in May by the International Council for Fishery Investigations, gives the first report of a committee formed to investigate the Atlantic slope W. and S.W. from the British Isles, and hydrographic and planktonic results for the year 1921 are recorded. *Publications de Circonstance*, Nos. 78, 79, and 80, also published by the Council (in April), contain papers by A. C. Hardy, J. N. Carruthers, and J. R. Lumby, dealing with the plankton, the non-tidal movements of North Sea water, and the salinity and temperature of the southern North Sea and English Channel during 1921. The results are interesting and of importance for a consideration of the causes of the unusual conditions of the North Sea mentioned above. That inadequate food-supply does not completely explain the failure of the herring fishery of 1921 is apparent from results obtained by Mr. B. Storrow (Report of the Dove Marine Laboratory, Cullercoats, Northumberland, for 1922). There was an actual shortage of fish having three winter rings on their scales; this result was obtained from a great number of careful measurements made at Cullercoats. Therefore, whatever happened to make the fishery a failure happened about 1917 as well as in 1921. The failure characterised the North Sea fishery but not that of the Firth of Clyde, and there the 1917 year class of fish was well represented.

CONSTITUTION OF DOLOMITE.—Dolomite has always been regarded by mineralogists as a definite compound, $CaCO_3,MgCO_3$, the reason for this conclusion being apparently the very constant composition of different specimens of the mineral from various parts of the world. The suggestion has recently been made by Spangenberg that the mineral is a solid solution of calcite and magnesite, the limits of miscibility being placed between the proportions $CaCO_3,2MgCO_3$ and $2CaCO_3,MgCO_3$. The substances prepared by him, however, have not the properties of dolomite. The matter has recently been investigated by Mr. A. E. Mitchell, at the suggestion of Prof. Donnan, and the results of some preliminary experiments are given in the May issue of the Journal of the Chemical Society. The dissociation pressure curves of calcite, magnesite, and dolomite have been determined from 700° to 1200°. In the case of calcite it is shown that the equation of Nernst is in good agreement with the results, the more complicated equation of Johnson being not only unnecessary but inaccurate. The curve for dolomite lies about half way between those of calcite and magnesite. Some measurements of the specific heats were made, in order to apply the Nernst equation, and an attempt to measure the heat of formation of dolomite gave the small value of 4·52 kg. cal. per mol. It is concluded that the dissociation of dolomite occurs according to the equation $CaCO_3,MgCO_3 = CaO,MgO + 2CO_2$. The experiments have not, however, been carried far enough to enable a decision to be made as to whether dolomite is a compound or a solid solution.

MOISTURE IN FRESHLY FELLED TIMBER.—In the Notes of the Royal Botanic Garden, Edinburgh, for January 1923, Prof. W. G. Craib has a third paper upon the "Regional Spread of Moisture in the Wood of Trees." As described in the earlier papers, specially selected trees are carefully felled and sections of timber taken for investigation, moisture determinations being separately carried out for blocks at different depths right across the section; this process is repeated at different levels and the results expressed graphically. This interesting line of research not only provides data of great practical interest to the forester, but also contributes to our knowledge of the ascent of sap in trees. Prof. Craib has previously shown that in winter there appears to be considerable storage of sap in the heart-wood of *Acer Pseudoplatanus*, the sap moving outwards later until it is mainly in the outer ring of young wood as the transpiration current becomes active in the summer. The present paper demonstrates a somewhat similar but slower change of sap distribution in the wood of the holly, while in resinous conifers no storage of sap in the heart-wood takes place, probably because the resin hinders radial migration of the sap. In the non-resinous yew tree there is again a storage of sap in the heart-wood. A very interesting plate shows the distribution of sap in a tree of *Populus trichocarpa*, felled on a windy day. In the sapwood on the side towards the wind there is the usual high percentage of moisture, but on the side away from the wind it has fallen very low. Prof. Craib's further papers will be awaited with interest, and there will be general congratulations from his colleagues that this paper seems to show him well on the way to a full renewal of the scientific activities so severely interfered with by his accident at the time that the British Association met in Edinburgh.

EWING'S NEW FERROMAGNETIC MODEL.—In our issue for March 9, 1922, p. 321, we gave an account of the new model of an atom of a ferromagnetic material proposed by Sir Alfred Ewing as an improvement on that brought forward by him in 1890. A portion only of the atom was taken as capable of alignment with the external field, and the controlling force on this part was considered to be due in the main to the fixed portion of the atom. In the February issue of the Science Reports of the University of Sendai, Profs. Honda and Okubo examine the new theory, and show that it is not in agreement with the discontinuous changes of magnetic properties which are found in steels during heating and cooling between 700° and 730° C., nor with those found in pure iron at 910° and 1410° C. respectively. They conclude that the quantitative extensions of the older theory made by them in 1916 and 1917 reproduce the hysteresis loop and the effects of temperature on magnetisation much more accurately than does the new theory.

The Pasteur Centenary Celebrations.

THE national celebrations which took place throughout France on May 24-June 1 in honour of Louis Pasteur are unique in history, for never before has such a splendid tribute been paid to the memory of a man of science.

The invitations to attend the celebrations were issued jointly by the rector and council of the University of Paris and the rector and council of the University of Strasbourg. The celebrations began on May 24 in Paris with an evening reception tendered by the President of the Republic at the Palace of the Elysée, where a large and distinguished company consisting of diplomatic and scientific representatives from practically all parts of the world were assembled.

On the morning of May 25 Dr. Roux and his colleagues at the Institut Pasteur held a reception, after which the visitors defiled before the tomb of Pasteur, which was decked with floral tributes. Among these, there being many, may be mentioned the wreaths sent by the British Government and the Royal Society, the latter resting at the foot of the monument. Afterwards bronze commemorative medals were distributed among the guests, who had signed their names in a volume which will afford a valuable record of the occasion. Driving homeward along the Boulevard Pasteur, the vehicles conveying the guests halted for a short time in the Place Pasteur before the beflagged monument of Pasteur. In the afternoon the British delegates were summoned by invitations from the University of Paris and Association France-Grande-Bretagne to the "Salle des Autorités" at the Sorbonne, where a tablet commemorating the meeting of Lister and Pasteur was unveiled and the British Ambassador made an appropriate speech. Immediately thereafter followed the ceremonial gathering in the Grand Amphitheatre of the Sorbonne, about 2700 persons being assembled, in the presence of M. Alexandre Millerand, President of the Republic (Chairman), M. Paul Appell, rector of the Paris Academy and president of the council of the University of Paris, Government and academic representatives and others, the picture afforded being most impressive and recalling that painted by Rixens in commemoration of Pasteur's Jubilee in 1892, fine colour effects being afforded by the many academic robes and uniforms. The ceremony began with the singing of the Marseillaise by a large choir of girls to the accompaniment of the band of the Garde Républicaine, the whole audience standing at attention. M. Paul Appell, M. Léon Bérard (Minister of Education and Fine Arts) delivered speeches and were followed by the Papal Nuncio, who conveyed the Pope's blessing on the occasion. As Government delegates, Prof. W. H. Welch spoke on behalf of the United States and Sir Charles Sherrington on behalf of the British Empire; delegates from other countries followed, most of them reading speeches in a French that was difficult to follow. Finally M. Strauss, Minister of Hygiene, delivered an impassioned speech after the foreign delegates had severally presented congratulatory addresses on behalf of various universities and learned bodies, these being handed over unread with no semblance of order. Addresses were presented from the Universities of Oxford, Cambridge, Edinburgh and Liverpool, the Royal Colleges of Physicians and Surgeons of London and Edinburgh, and numerous other bodies.

On May 26 were issued postage stamps (values 10, 30, and 50 centimes) bearing the portrait of Pasteur. A reception was held at the École Normale by M. Gustave Lanson, the director, and the guests were shown the "Cabinet Pasteur" with its interesting mementoes of Pasteur's sojourn and activities at that institution. M. Lanson read out a hitherto unpublished letter of Pasteur's addressed to the French Ministry appealing for financial aid in the prosecution of his researches. This letter revealed the personality of Pasteur in a remarkable manner, his clearness of thought and marvellous prescience being strikingly exhibited; the whole audience was thrilled and felt that M. Lanson's opening words, that he was "about to let Pasteur himself speak to the audience," were indeed justified. It is to be hoped that the letter will soon be published. The company next walked to No. 10 rue des Feuillantines close-by, to witness the unveiling of a tablet upon the house where Pasteur lived as a student, and, finally, in the evening, a reception was given at the Hôtel de Ville by the Municipality of Paris. Here, as at the Élysée, there were representations by artists of the Comédie Française, and Opéra, etc., the recitation of two of Pasteur's speeches by M. Léon Bernard, of the Comédie, invoking much enthusiasm among the hearers. The speeches were those delivered by Pasteur (*a*) at Dôle in 1883, when a tablet was affixed to the house in which he was born, and (*b*) at the Sorbonne in 1892, on the occasion of his jubilee. An eloquent passage from the latter speech was frequently quoted by orators in the days that followed, and it may well be cited here from a printed copy which was thoughtfully distributed to the guests at the centenary celebration:

"Jeunes gens, jeunes gens, confiez-vous à ces méthodes sûres, puissantes, dont nous ne connaissons encore que les premiers secrets. Et tous, quelle que soit votre carrière, ne vous laissez pas atteindre par le scepticisme dénigrant et stérile; ne vous laissez pas décourager par les tristesses de certaines heures qui passent sur une nation. Vivez dans la paix sereine des laboratoires et des bibliothèques. Dites-vous d'abord: Qu'ai-je fait pour mon instruction? Puis, à mesure que vous avancerez: Qu'ai-je fait pour mon pays? jusqu'au moment où vous aurez peut-être cet immense bonheur de penser que vous avez contribué en quelque chose au progrès et au bien de l'humanité. Mais, que les efforts soient plus ou moins favorisés par la vie, il faut, quand on approche du grand but, être en droit de dire: J'ai fait ce que j'ai pu."

On Sunday, May 27, the Lycée Pasteur was inaugurated in the morning. In the afternoon l'Accueil Franco-Britannique and Dr. and Mme. Tuffier received the British delegates in the charming home of the latter, which, we may mention incidentally, contains a fine collection of pictures. In the evening there were gala representations at the Opéra and Théâtre Français in honour of the foreign delegates. Throughout France, ladies and schoolgirls collected money for the scientific laboratories of the country, some ten differently designed badges, mostly bearing the effigy of Pasteur, being pinned with the tricolor to persons who helped by contributions. All the badges were inscribed on the back with the words: "Journée Pasteur, mai 1923. Au profit des Laboratoires," and a quotation from Pasteur reading: "Sans laboratoires les savants sont des soldats sans armes."

On May 28 the guests were conveyed to the Palace of Versailles, where a banquet was held in the "Gallerie des Batailles," some 900 persons participating under the presidency of M. Reibel, Minister of the Liberated Regions. The latter, in his speech, cited with special emphasis Pasteur's advice to men of science: "Luttons donc dans le champ pacifique de la science pour la prééminence de nos patries respectives. Luttons, car la lutte c'est l'effort, la lutte c'est la vie, quand la lutte a le progrès pour but," adding that it was surely necessary that Pasteur's pronouncement should be repeated "in this Palace with its many significant associations." M. Reibel's speech was followed by those of diplomatic representatives which could not be heard by many because they were delivered across the centre of the very long gallery.

On May 29 some of the guests attended a morning presentation of the cinematograph film entitled "Pasteur" designed to popularise his work. In the afternoon the Institut de France held a garden party at Chantilly, the castle with its art treasures being thrown open for inspection.

Many left Paris on May 30 to attend the concluding ceremonies at Strasbourg, where in the evening a reception was held in the Palais du Rhin.

On May 31 a monument of Pasteur was inaugurated in front of the University of Strasbourg in the presence of the President of the Republic accompanied by M. Poincaré (Prime Minister), M. Strauss (Minister of Hygiene), M. Valery-Radot and others, academic dress being worn by University representatives, a few of whom presented addresses to the University which they delivered into the President's hands. Orations were delivered by M. Charléty (rector of the University), M. Haller (president of the Academy of Sciences), Prof. Bordet (Pasteur Institute, Brussels), and finally M. Millerand spoke with the eloquence of a practised orator in a voice that carried far, his speech being remarkably good. There followed a banquet at noon attended by some thousand persons at the Palais des Fêtes under the presidency of MM. Millerand and Poincaré, speeches that were more or less audible being delivered by the Mayor of Strasbourg, M. Alapetite (Commissioner General of the Republic), M. Strauss, and others. Following upon the banquet the company assembled at the Palais du Rhin, the ex-Emperor's former palace, to witness the procession of Alsatian Societies before the President; it was a stirring sight, which deeply moved all beholders, to see the representatives from all parts of Alsace and Lorraine, lads and maidens dressed in the characteristic costumes of their districts stepping along briskly hand in hand to the music of numerous bands that accompanied them, while a deeper note was struck as veterans of the War and of the war of 1870 defiled past, all saluting the President of the Republic. There followed the opening ceremonies at the Pasteur Museum and the International Exhibition of Hygiene and an evening reception at the Hôtel de Ville given by the Mayor of Strasbourg. Speeches were made in connexion with these ceremonies, those delivered by Prof. Borrel (Commissary General of the Exhibition) and M. Poincaré being the most notable. The scene at the Hôtel de Ville was remarkable when, from the balcony, M. Millerand addressed the populace assembled in the square and twenty thousand people with upturned faces sang the Marseillaise to the accompaniment of massed bands; it was a sight which none who witnessed it can forget.

The Comité du Centenaire de Pasteur was responsible for all arrangements and, except in minor matters, did their work admirably. The programme was rather overfilled and no lists were available to aid the participants in discovering the names of those who attended the celebrations. A reduction of 50 per cent. was allowed on the cost of tickets from the frontier to Paris, while free first-class return tickets were issued between Paris and Strasbourg to those who had been invited. During two days of the festivities in Paris motor omnibuses were to be found at seven "points de concentration" chosen with regard to the hotels at which delegates resided, thereby affording a very convenient way of transporting them to the various places where ceremonies took place, gentlemen from the Pasteur Institute and others serving as guides to the different parties. Special trains and motor transportation were, moreover, provided for the excursions to Versailles and Chantilly.

Owing to the short time that was at the disposal of the organisers, the Pasteur Museum and the Exhibition at Strasbourg were scarcely ready for inspection, the majority of the exhibits still remaining in their packing cases, this being indeed unfortunate. It is therefore inexpedient to attempt a description of the few objects that could be seen.

Those who attended the celebrations brought away mementoes of the occasion apart from the medal which they received at the Institut Pasteur. Of printed matter may be mentioned the "Souvenir des Fêtes Nationales de la Commémoration du Centenaire de la Naissance de Pasteur, célébrés à Paris, en Franche-Comté et à Strasbourg du 24 au 31 mai, 1923" (Paris: Imprimerie Nationale, 1923). This includes a chronology of Pasteur's chief discoveries (1847–1885), a facsimile of his birth certificate, three portraits of Pasteur at different ages, pictures of his birthplace, homes, and grave, striking citations from his writings, and a facsimile autograph and signature reading: "La grandeur des actions humaines se mesure à l'inspiration qui les fait naître. L. Pasteur, 27 mars 1887." The tasteful menu at the Versailles banquet and the programmes at the gala performances on May 27 bore an excellent profile portrait of Pasteur in flat relief, stamped on silvered paper, reproduced after the well-known plaque by O. Roty. The programmes distributed at Dr. Tuffier's reception and at the Hôtel de Ville bore the finely reproduced profile head of Pasteur executed by R. Lalique. At a private dinner given to some of the delegates, M. Calmette distributed to his guests some finely wrought silver medals bearing Pasteur's head modelled by G. Prudhomme and bearing the dates 1822–1922. It should be mentioned, to avoid confusion, that the national celebration was somewhat belated. In point of date, the true centenary had been previously celebrated in December 1922 at the Institut Pasteur, but these celebrations were, however, more of a domestic character.

During the festivities in Paris, the President of the Republic with a small party left for Franche-Comté, where, on May 26, he visited the house in which Pasteur was born at Dôle, attended a ceremony before Pasteur's monument there and participated at a soirée at Lons-sur-Sonier. On May 27 the presidential party visited the parental house of Pasteur at Arbois and attended ceremonies at Salins and Besançon, university functions at Besançon following on May 28 and 29, *i.e.* prior to the advent of the party in Strasbourg.

It may be mentioned incidentally that the Société de Biologie of Paris celebrated the seventy-fifth anniversary of its foundation on May 26-28, it being arranged that its meetings should clash as little as possible with those relating to the Pasteur centenary. Nevertheless, the present writer unfortunately found it impossible to attend both functions because time for rest was required between the events that constituted the very full programme.

Those who participated in the celebrations above described in a somewhat inadequate manner will have brought away, as did the writer, a delightful recollection of having revived friendships and established firmly new ties across the water.

GEORGE H. F. NUTTALL.

Cambridge Meeting of the International Union for Pure and Applied Chemistry.

THE International Union for Pure and Applied Chemistry met at Cambridge on Sunday, June 17, under the presidency of Sir W. J. Pope, and carried out the programme previously outlined in these columns (June 16, p. 825). The countries which have now joined the Union are the following—The Argentine, Australia, Belgium, Canada, Czechoslovakia, Denmark, France, Great Britain, Greece, Holland, Italy, Japan, Luxemburg, Norway, Peru, Poland, Portugal, Roumania, Spain, Switzerland, the United States of America, Uruguay, and Yougoslavia; over one hundred delegates representing the chemical interests of these countries were in attendance at Cambridge. A feature of the meeting was the presentation of several comprehensive reports on subjects which at the moment present special chemical interest; these were printed and distributed beforehand, and at the meeting brief summaries were presented by their authors, after which general discussions took place.

The report on "The Study of Soap Solutions and its Bearings upon Colloid Chemistry," presented by Prof. J. W. McBain, included a statement of the chief conclusions arrived at by its author in his extended studies of the properties of salts of the higher fatty acids. About one-half of the electrical conductivity of a soap solution is due to a negative carrier, which does not exhibit osmotic activity and is therefore colloidal; this is the ionic micelle, and consists of highly charged and solvated ionic particles. Accompanying the ionic micelle is the undissociated colloidal electrolyte, which consists of electrically neutral micelli. Interesting contributions to the discussion were made by Prof. H. E. Armstrong and Prof. W. D. Bancroft. Dr. E. K. Rideal presented a report on "Recent Developments in Contact Catalysis," in which the conception of Hardy and Langmuir, that adsorption of reactants occurs in monomolecular and orientated films, is shown capable of application to the reactions at the surface of charcoal, studied by Van Kruyt, and at the surface of the enzyme, oxidase, present in liver tissue, as studied by Hopkins.

The report contributed by Prof. J. F. Thorpe and Dr. C. K. Ingold consisted in a summary of the recent work of the authors on "Some New Aspects of Tautomerism." It is claimed that the original definition of the term "tautomerism" should be broadened, in accordance with modern investigation, and that the term should apply to all reversible isomeric change; a reasoned classification of the various types of tautomeric change which have been more carefully studied during recent years is then given. The report by Prof. F. G. Hopkins, on "Chemical Mechanisms involved in the Oxidations which occur in the Living Body," describes the success which has attended the attempts to elucidate the nature of the oxidation processes involved in living tissues by a simple chemical mechanism. In the resulting discussion, Prof. C. Moureu drew a parallel between the course of these apparently complex reactions and the catalytic oxidation of aldehydes which he has himself studied. Mr. W. Barlow showed and described a number of solid models which he has devised for the interpretation, in accordance with the valency volume law, of the results of the X-ray analysis of crystalline materials by the Laue and Bragg method; incidentally he demonstrated an hitherto unknown mode of partitioning space into identical polyhedra.

A large proportion of the time of the meeting was devoted to the work of the numerous committees which are engaged in the attempt to systematise practice throughout the world in connexion with nomenclature, abbreviations, standard methods, tables of constants, and the like.

It was decided that the Union will hold its meeting next year in Copenhagen, on the invitation of the chemical representatives of Denmark. At the concluding ceremony honorary degrees of the University of Cambridge were conferred on a number of distinguished visitors whose names were announced in the preliminary statement on the meeting (NATURE, June 16, p. 825).

Tercentenary of the Oxford Botanic Garden.

THROUGHOUT the three hundred years of its existence, the Oxford Botanic Garden can never have looked more radiant than it did on Saturday, June 23, when it welcomed the distinguished company which met to celebrate the tercentenary of its foundation. Sheltered by high and stately walls from the incessant north-east winds which in spring play havoc in more exposed gardens, it gave the impression of serene beauty, the more impressive because of the simplicity of the lines on which it has been laid out.

Those, however, who know the rigours of the Oxford climate will ascribe the luxuriance of growth of the plants in the garden rather to skill in cultivation than to good fortune with respect of site. For although the walls which surround the garden do, indeed, give shelter, the soil is none too kindly and the Thames water is too near the surface to make cultivation a light or easy task. It was, therefore, no less a tribute to their own perspicacity than to Mr. Baker, the superintendent of the gardens, that more than one speaker referred in terms of admiration to the skill in cultivation which the gardens displayed.

The Chancellor of the University, Lord Curzon, who presided at the tercentenary celebrations, spoke on gardens with the simple sincerity which proves his title to be ranked among the goodly company of true gardeners, and nothing in his speech gave more pleasure to the company which were met together under the trees of the garden than his reminiscences of the happy hours which as undergraduate and fellow he had passed in the Oxford Botanic Garden. For surely this old garden has for three centuries irradiated a happy influence on successive generations whose feet have walked therein and whose eyes have been refreshed by its scenes of peaceful beauty.

Sir David Prain, who followed the Chancellor, traced in a masterly way the history of the Garden from the time of its foundation, by the beneficence of Henry Lord Danvers, on St. James's Day (July 25), 1622. He reminded his hearers that it was in this Garden that the first greenhouses erected in England were put up, and that it was there that experiments were first made in methods of heating them. Bobert the elder and the younger, men of great wisdom; Morison, the great professor of botany and a pioneer of systematic botany; Sherard, the founder of the chair which bears his name; Sibthorpe, who deserves the title of a great botanical explorer; and Daubeny, versatile and generous, are names which will always live, not only in the history of the Garden but also in that of botany. In more recent times, Bayley Balfour and Sydney Vines have maintained the great traditions of the Garden so that, in despite of difficult times which have occurred in the past and may recur in the future, the permanence and usefulness of the Garden are assured.

The chairman of the curators, Sir Herbert Warren, whose knowledge of the Garden extends over fifty years, in the course of a delightful speech in which he referred to the love which the Garden has inspired in the minds of Oxford men, omitted to mention the great and beneficent part which he himself has played in steering the Garden through the recent difficult years when costs have been so high and the financial resources of the University have been so strained. In helping the Garden to meet the financial difficulties inherent in these times, the University has shown wisdom and understanding that, it may be hoped, will touch the imagination of a generous benefactor and make the Garden secure for all time, not only as a place of botanical study, and as a repository of herbaria of historic and present importance, but also as a quiet sanctuary wherein men who love plants may study and admire them.

Prof. Seward, who in the absence of Lord Ullswater spoke on the subject of gardens as aids to botanical teaching and research, congratulated the University on the fact that gardens and laboratories, library and herbarium, were all assembled in one site. He referred to the generosity of Mr. Reginald Cory and other benefactors in aiding the Cambridge Botanical Garden to maintain itself, and expressed the belief that the value of the work done at Oxford and the need for assistance required only to be known to ensure the supplementing of existing resources by private benefaction.

After the formal ceremony the visitors, who numbered some 500, inspected the gardens and laboratories, admiring particularly the famous tank houses wherein the blue water-lilies (*Nymphæa zanzibarensis*, *N. gigantea*, and *N. stellata*) thrive with amazing floriferousness in company with many other Nymphæas, *Nelumbium speciosum*, the white rose-tipped Egyptian Bean of Pythagoras, *Cyperus papyrus*, graceful and historical and the source of the papyrus of antiquity, and a large assemblage of aquatic and marsh plants, all of which are of interest and collectively give a memorable impression of luxuriance which few parts of the tropics can rival.

After tea in the gardens the ceremony terminated, the departing guests averring that few among them had realised so clearly as they now did the vital part which botanic gardens play and have played in the social life of civilised communities.

University and Educational Intelligence.

EDINBURGH.—Prof. F. Gowland Hopkins, Cameron prizeman for 1922, delivered two lectures in the University on June 27 and 28 respectively, on the present position of the vitamin question. The Cameron prize, which was founded in 1878, is awarded annually to an investigator who in the course of the five years immediately preceding has made an important addition to practical therapeutics.

SHEFFIELD.—Dr. P. J. Daniell has been appointed to the Town Trust chair of mathematics.

AN Edward K. Dunham lectureship has been established at Harvard University in memory of the late Prof. E. K. Dunham, for many years professor of pathology in the Bellevue and University Medical College of New York City (*Science*, June 15). According to the terms of the gift, which is made by Prof. Dunham's widow, the lectures are to be given annually by eminent investigators and teachers in medical science or one of the contributory basic sciences, and there is no restriction as to the nationality of the lecturer. It is hoped that the foundation may "serve to bind closer the bonds of friendship and understanding between students and investigators in this and foreign countries."

AN outline of President Harding's plan for reorganising the educational activities of the Federal Government was given by the United States Commissioner of Education at the recent annual meeting of the Department of Superintendence of the National Education Association. The plan is a part of a comprehensive scheme, foreshadowed by the President in his first message to Congress and presented to the Senate in February, for a reorganisation of all the executive departments, including the establishment of a department to promote citizenship and general welfare. The educational work now carried on by some thirty separate agencies, belonging to six of the principal departments and several independent establishments, is to be included along with certain other services, the whole costing at present 700 million dollars a year, in a new Department of Education and Welfare comprising education, public health, social service, and veteran relief. The Division of Education, which will be under a permanent assistant secretary, will take over, *inter alia*, in addition to the Bureau of Education and the Board for Vocational Education, the Smithsonian Institution, including the National Museum and Art Gallery, the International Exchange Service, the Bureau of American Ethnology, the Astrophysical Observatory, the National Zoological Park, and the International Catalogue of Scientific Literature, and will create and direct an entirely new bureau for promoting physical education. The scheme is to come before Congress in December.

THE work of the University of London during the year 1922–23, measured by the usual statistical standards, shows a notable expansion. The Principal Officer, while careful to point out that the great mass of the university's continuous achievement is the expression of imponderable forces, directs attention to figures 75-200 per cent. higher than the corresponding figures for 1913–14, and points out that "we have passed well beyond the wash of what was commonly regarded as the abnormal demand for educational facilities that followed the great deliverance of 1918"; the figures are as follows: admissions (8498), candidates for degrees (3191), candidates for matriculation and registration (19,985), and other examinations (7663), and internal students (8881). There has been a noticeable decrease in the percentage of successful to total candidates from 53 in 1913–14 to 32 in 1922–23. The "growth of ignorance" among the younger generation to which Prof. John Burnet directed attention recently in the Romanes lecture is apparently not confined to Scotland. Indicative of the ever-growing specialisation of the subjects of the curricula is the increase in the number of Boards of Studies from 27 with 374 members in 1900 to 42 with 1051 members. That the senate is alive to the dangers incidental to this specialisation and resolved to guard against them is shown by its creation of a Board of Studies in "the principles, history, and method of science," designed to embrace not only the natural and mathematical sciences, but also logic, ethics, history, pedagogy, economics, linguistics, archæology, scholarship, and medicine.

Societies and Academies.

LONDON.

Royal Society, June 28.—V. H. **Blackman**, A. T. **Legg**, and F. A. **Gregory**: The effect of a direct electric current of very low intensity on the rate of growth of the coleoptile of barley. The coleoptile (sheathed plumule or young stem) of barley seedlings is exposed to an electric discharge from a point charged *positively* to about 10,000 volts (crest value) and placed at such a height above the coleoptile that a current of $0{\cdot}5 \times 10^{-10}$ amp. passes through it, the current density being 4×10^{-9} amp. per cm.^{2} Under these conditions the rate of growth is markedly accelerated from the first hour onward, showing in the third hour a percentage increase above that of the control plants of $7{\cdot}53 \pm 1{\cdot}95$. After the cessation of the current a well-marked after-effect, greater than the direct effect, is observed, the enhanced rate of growth steadily continuing and showing a percentage increase of $15{\cdot}68 \pm 2{\cdot}62$ above that of the controls. The after-effect is greater with a short period of discharge of 1 hour than with a longer period of 3 hours. When the point is *negatively* charged the rate of growth is increased during the first hour, but the increase becomes less with time. An after-effect follows, but it is markedly less. The gaseous products of the discharge and the "electric wind" play little or no part in the stimulation of growth observed. The current alone appears to be of importance.—M. S. **Pembrey**, N. W. **MacKeith**, W. R. **Spurrell**, E. C. **Warner**, and H. J. **Westlake**: Observations on the adjustment of the human body to muscular work. In the dyspnœa produced by running there is a disturbance of the acid-base equilibrium of the body; the relief of "second wind" is the result of adjustments effected chiefly by the respiration, circulation, and excretion by the kidneys and skin. The sense of discomfort during dyspnœa is associated with increased pulmonary ventilation, the sense of relief at the onset of second wind with diminished ventilation. Oliguria, or anuria, appears as a constant feature during running, even after taking 560 c.c. of tea as a diuretic. It leads to a temporary retention of acid, which helps the body to get rid of carbon dioxide and obtain oxygen; the water spared is available for excretion by the lungs and skin, and will produce by evaporation greater cooling than it would if it were discharged as urinary water. The suspension of the activity of the kidneys appears to be due to an outflow of constrictor impulses to the renal vessels.—Miss R. M. **Tupper-Carey** and J. H. **Priestley**: The composition of the cell wall at the apical meristem of stem and root. The walls of the apical meristem of stem and root differ in the ease with which cellulose may be detected in them with iodine reagents. Macro- and micro-chemical experiments show that the cellulose in the wall of the root meristem is masked by its combination with other substances, particularly proteins and fatty acids. In the shoot meristem, the cellulose is closely linked with larger quantities of pectin, but less protein and fatty acid are present, especially when the shoot is growing in the light. —L. J. **Harris**: The titration of amino- and carboxyl-groups in amino-acids, polypeptides, etc.—F. A. E. **Crew**: Studies in intersexuality. II. Sex-reversal in the fowl.—W. **Finkler**: Analytical studies on the factors causing the sexual display in the mountain newt (*Triton alpestris*).—G. A. **Schott**: On the scattering of X- and γ-rays by rings of electrons. The effect of damping of the incident radiation. Damping of the usual type, of an amount compatible with the production of moderately sharp lines in the X-ray spectrum, increases slightly the total scattering of short waves, such as the hard γ-rays, although it decreases slightly that of long waves. A single electron ring, such as is postulated in hydrogen and ionised helium on Bohr's theory, is completely unaffected by this type of damping. It seems scarcely possible that damping can diminish the total scattering for any type of atom below the amount required by the simple pulse theory.—P. A. **MacMahon**: On a class of transcendents of which the Bessel functions are a particular case.—L. C. **Martin**: The photometric matching field. Improvement in the visibility of faint contrasts observed with central vision can be obtained by stimulating the peripheral regions of the retina. An increase in precision of the order of 30 per cent. is obtained in photometric matches by surrounding the photometric field with a larger area of approximately equal brightness.—G. P. **Thomson**: Test of a theory of radiation. Experiments with positive rays show that visual and photographic effects can be obtained with trains of waves shorter than those produced in the emission of a quantum of light.—A. Ll. **Hughes** and P. **Lowe**: Intensities in the helium spectrum. The curve showing the intensity of any spectrum line as a function of the energy of impact of the electrons is characteristic of the series to which it belongs. The intensities in the doublet system all decrease rapidly as the energy of impact is increased from 34 volts. The principal series, $1S - mP$, of the singlet system is characterised by a very great increase in intensity as the energy of impact is increased from 34 volts up to about 80 volts, beyond which there is little change. The lines of the diffuse series, $1P - mD$, all show a maximum at about 75 volts. The lines of the sharp series, $1P - mS$, after a small initial rise to 60 volts, decrease slightly.—A. A. **Dee**: The effect of quenching from above the carbide transition temperature upon the magnetism of steel. The magnetism of steel at ordinary temperatures is not materially altered by quenching from above the transition temperature of iron carbide, and therefore the return of the carbide to the ferromagnetic state is not retarded by sudden cooling from above the transition temperature.—T. S. P. **Strangeways** and H. E. H. **Oakley**: The immediate changes observed in tissue cells after exposure to soft X-rays while growing *in vitro*. Exposures for gradually increasing periods, varying from 5 minutes to 2 hours, were used. There is a latent period of about 15 to 20 minutes before the changes produced in the cells by irradiation can be recognised. After 5 minutes irradiation development of new dividing cells is lessened. After exposure of 20 minutes or longer the formation of new dividing cells practically ceases. After exposure of 5 minutes granular changes and fragmentation of the chromosomes occurs in some cells in mitosis at metaphase and anaphase. After exposure of 25 minutes or longer some cells in mitosis show clumping of the chromosomes at metaphase. As the time of exposure increases there is increase in size and alteration in structure of the cytoplasm, nucleus, and nucleolus of some fully formed cells. After an exposure of 60 minutes, affected cells become disorganised, and eventually cytoplasm and nucleus break up and appear to go into solution in the surrounding medium.—W. B. **Hardy** and Ida **Doubleday**: Boundary lubrication: the latent period and mixtures of two lubricants.—C. T. R. **Wilson**: Investigations on X-rays and β-rays by the cloud method. Pt. I.—X-rays. The tracks of the electron ejected from the atom which emits the quantum of radiation and that of the electron ejected from the atom which absorbs the radiation can be identified.

Two classes of β-ray tracks are produced in air by the primary action of X-radiation of wave-length less than about 0·5 Å: (*a*) those of ejected electrons with initial kinetic energy comparable to a quantum of the incident radiation, and (*b*) tracks of very short range. The short-range electrons are ejected nearly along the direction of the primary X-rays. The short-range tracks are probably related to the phenomena which have led to the postulation of a "J"-radiation. Of the ordinary long-range tracks, the majority have a large forward component comparable with the lateral component; about 20 per cent. are ejected almost exactly at right angles to the primary X-ray beam; others have a large backward component. Partial polarisation of the primary beams is indicated by the direction of ejection of a number of the β-particles being in one plane—that containing the direction of the cathode rays in the X-ray tube. β-rays in air exposed to X-rays frequently occur in pairs or groups. The pairs probably consist of one K electron ejected by the direct action of the primary X-rays, and of a second electron ejected by the combined action of primary radiation and of the K-radiation from the atom from which the first electron was ejected. Pt. II.—β-rays. The tracks of fast β-particles are very nearly straight over distances of several centimetres. Near the end of their range the deviations are of three kinds: (*a*) sudden deviations often through large angles up to 180°, the results of a close approach to the nucleus of an atom; (*b*) sudden deviations ranging up to 45°, due to a close approach to an electron which is in consequence ejected to form a branch track generally approximately at right angles to the deflected primary track; (*c*) gradual deviations due to an accumulation of deviations of (*a*) or (*b*) type. The range of the β-ray as measured along the track is approximately proportional to the square of the kinetic energy or to the fourth power of the velocity (Whiddington's law) for ranges from about 0·1 m. to 2 cm.; the range is 1 cm. when the kinetic energy of the particle is about 21,000 volts. The primary ionisation (*i.e.* number of atoms from which electrons are ejected by the direct action of primary β-rays) is about 90 per cm. for a velocity of 10^{10} cm. per sec., and is approximately inversely as the square of the velocity. The total ionisation per cm., including that due to secondary β-particles of range too short to form visible branch tracks, is about three or four times as large as the primary. In portions of some of the tracks not only is the primary ionisation recorded, but also the ions which each of these electrons has itself produced may be counted.—C. V. **Raman** and K. R. **Ramanathan**: The molecular scattering of light in carbon-dioxide at high pressures.—W. A. **Davis** and J. V. **Eyre**: The discontinuity of the hydration process.—G. M. B. **Dobson**: A flicker type of photoelectric photometer giving high precision.—H. D. **Smyth**: The ionisation of nitrogen by electron impact.—G. M. B. **Dobson**: Measurements of the sun's ultra-violet radiation and its absorption in the earth's atmosphere.—H. **Hartridge** and F. J. W. **Roughton**: A method of measuring the velocity of very rapid chemical reactions.—W. T. **Astbury**: The crystalline structure of anhydrous racemic acid.—E. **Ponder**: The measurement of percentage hæmolysis. I.—H. M. **Fox**: Lunar periodicity in reproduction.—Marjory **Stephenson** and Margaret D. **Whetham**: Studies in the fat metabolism of the Timothy grass bacillus. II. Carbon balance sheet and respiratory quotient.—H. R. **Hewer**: Studies in amphibian colour changes. II.—R. H. **Burne**: Some peculiarities of the blood-vascular system of the Porbeagle shark (*Lamna Cornubica*).—A. E. **Boycott** and C. **Diver**: The inheritance of sinistrality in *Limnæa peregra*.

EDINBURGH.

Royal Society, May 21.—Prof. F. O. Bower, president, in the chair.—R. **Kidston** and W. H. **Lang**: (1) On *Palæopitys Milleri* (McNab). The original specimen of this stem with secondary thickening was described by Hugh Miller, and later named by McNab. A second specimen, discovered by the Geological Survey of Scotland, includes the primary central region, 1·5 mm. in diameter, surrounded by a zone of secondary xylem about 1 cm. thick. The secondary wood consists of tracheides and medullary rays. The tracheides are remarkable in having multiseriate, porose pitting on both radial and tangential walls. The primary central axis appears to have consisted of tracheides without admixture of parenchyma. There is evidence of strands of protoxylem, consisting of narrow spiral tracheides, close to the periphery of the primary xylem, just within the secondary wood. In the absence of any traces going to lateral appendages it is impossible to determine the affinities of this complex stem. It might have belonged to some gymnospermous plant, but it is equally possible that it was the stem of some archaic pteridophyte of the Middle Old Red Sandstone Period. (2) Notes on fossil plants from the Old Red Sandstone of Scotland. I. *Hicklingia Edwardi*, K. and L. Under this name a unique specimen of a Middle Old Red Sandstone plant is described and figured. It was discovered many years ago by the late Mr. G. Edward, and is preserved in the University of Manchester Museum. It occurs as an incrustation, and suggests comparison with a plant of the nature of the Rhyniaceæ spread out on a slab of Caithness flagstone. Diverging from an obscure basal region is a tuft of linear axes, without leaves, but branched dichotomously and laterally. There are indications of the presence of a slender central strand. Many of the stems terminate in oval carbonised bodies that are evidently large sporangia. The plant is compared with Rhynia and Hornea, which are known as petrifactions from the Rhynie Chert.—W. T. **Gordon**: The genus Pitys. Fossil trees belonging to this genus have been known since 1831, and it was in describing these specimens that thin sections of fossil wood were first used. A recent discovery at Gullane has disclosed twigs and stems of this type, in some cases still clothed in bark and in two specimens with leaves attached. These leaves resemble petioles in their structure, and are undoubtedly phyllodes. *Pitys dayi* affords evidence of the phyllode theory of leaf formation in gymnosperms. Pitys shows marked resemblance to Araucaria as regards the structure of the wood (recognised long ago) and the leaf-traces and leaves.

PARIS.

Academy of Sciences, June 11.—M. Albin Haller in the chair.—Edouard **Imbeaux**: The artesian basins of Australia. A map of Australia is reproduced showing the artesian basins known at the present time, taken from the report of the interstate conference on artesian water held at Adelaide in 1921.—M. Jean Perrin was elected a member of the section of general physics in succession to the late M. E. Bouty.—Paul **Montel**: Algebraic relations of class one or zero.—René **Garnier**: Uniform functions of two independent variables defined by the inversion of an algebraic system to total differentials of the fourth order.—Charles N. **Moore**: The summability of Cesàro for double Fourier's series.—Louis **Bachelier**: The general problem of discontinuous statistics.—

Stanislas **Millot**: Simplified solutions of problems of Laplace on the probability of causes.—B. **Hostinský**: The equilibrium of electricity on a cylindrical surface. —Th. De **Donder**: Synthesis of the gravific.—Adolphe **Lepape**: The radioactivity of the springs from some watering-places in the Pyrenees (Bagnères-de-Luchon, Vernet, les Escaldes, Thuès) and of the Central Plateau (la Bourboule, Royat, Saint-Nectaire, Sail-les-Bains). Determinations of the radium emanation in gases and waters from forty-four springs. Search for the thorium emanation gave mostly negative results, a few springs only showing a trace.—Albert **Nodon**: The relations between the radioactivity of radium and the activity of solar radiations. —F. **Bourion** and E. **Rouyer**: The determination of double salts in solution by the boiling-point method. A discussion of the validity of the rule of mixtures as applied to the boiling-point elevations of solutions of two electrolytes.—Jacques **Bardet**: The arc spectrum of celtium. The material used contained as impurities only zirconium and a trace of lead, and was obtained from zircons from Brazilian monazite sand. Wave-lengths of the lines in the region between 2300 and 3500 Å. are given.—Paul **Pascal**: Researches on the constitution of insoluble alkaline metaphosphates. The insoluble alkaline metaphosphates are not monometaphosphates, but furnish a remarkable example of colloids prepared at a temperature of about 850° C. The normal formula, MPO_3, should be restricted to the salts obtained starting with ethyl hexametaphosphate.—S. **Glixelli**: The influence of neutral salts on the silica gels. The acid properties of colloidal silica are increased by the addition of salts of the alkalis: the effects observed can be explained by assuming that the (OH) ions are adsorbed by the particles of silica.—A. **Mailhe**: The catalytic decomposition of the anilides. An account of the decomposition of acetanilide at 400° C. in the presence of nickel and of copper.—R. **Fosse** and A. **Hieulle**: Xanthyl derivatives of allophanic acid, thiosinamine and of allantoine.—Conrad **Kilian**: The folds of the "Tassilian enclosure" of the central Saharan massif of Ahaggar.—A. **Boit**: The rôle of the superficial folds in the structure of the formation at Morvan.—Ch. **Maurain** and Mme. de **Madinhac**: The secular variation of the intensity of the terrestrial magnetic field at Paris. Bauer has suggested the use of a local magnetic constant $G=\sqrt{H^2+(Z/2)^2}$, where H and Z are the horizontal and vertical components of the magnetic field at any point. From an examination of the records for Coimbra, Pola, Paris, Kew, Greenwich, and De Bilt, it is shown that G reached a maximum in 1902. The value of G increases with the latitude of the stations.—J. **Giral** and F. A. **Gila**: The use of sodium chloride as a standard in the estimation of the halogens in sea water. The salts present in sea water have no appreciable influence on the quantitative determination of chlorine.—J. J. **Thomasset**: Relations between the dentine and dental enamel in a fossil fish (Sargodon).—P. **Bugnon**: The homologies of cotyledonous leaves.—L. **Blaringhem**: Heredity in mosaic of the doubling of the flowers in *Cardamine pratensis*.—A. **Guillaumin**: The vacuum as a means of prolonging the germinating faculty of seeds. Seeds of radish, wheat, and lettuce, after preservation in a vacuum in the dark for 12 years, showed unimpaired powers of germination.—A. de **Puymaly**: The adaptation to aerial life of a green alga (*Chlamydomonas fungicola*).—Marc. **Bridel**: Biochemical study of the composition of *Monotropa Hypopitys*: a new glucoside, monotropeine. The new glucoside was isolated in a pure crystalline condition, 2 gm. being obtained from 5200 gm. of material. It is hydrolysed by emulsion giving a blue precipitate. Monotropeine is not identical with aucubine.—Charles **Henry**: A new test for sense of touch.—Jules **Courtier**: Experiments on a new test for the sense of touch. Results of the application of the method described in the preceding communication to nineteen subjects.—P. **Masson** and Louis **Berger**: A new mode of internal secretion.—Louis **Desliens**: The measurement of arterial pressure by the bleeding method. A very exact hæmodynamometric method and present application. The artery is punctured by a hollow needle communicating with a delicate pressure-gauge of the aneroid type. The instrument before use is filled with a saline solution to prevent coagulation.—J. **Lopez-Lomba**: Changes of weight of the organs of the guinea-pig during C-avitaminosis.—F. **Franchette**: The pneumo-anæsthesiograph. An account of an instrument designed to evaluate and record the amplitude and frequency of the respiratory movements during anæsthesia.—Emile F. **Terroine** and H. **Barthélemy**: The composition of the eggs in the course of ovogenesis in the brown frog (*Rana fusca*).—M. **Caille** and E. **Viel**: The detection of small quantities of antimony and bismuth in biological liquids. An application of the antipyrine-potassium iodide reagent described in an earlier communication.—M. **Lemoigne**: The production of β-oxybutyric acid by certain bacteria of the *B. subtilis* group.—Charles **Pérez**: The casting of the shell of decapod crustaceans carrying parasites (Epicaridæ).—Boris **Ephrussi**: The sexuality of *Clava squamata*.—C. **Levaditi** and T. **Nicolau**: Tissue immunity in neurotrope ectodermosis.—Emile **Gautrelet**: Monomethylorthophospho-salicylic acid.

Official Publications Received.

Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia, Jaarverslag 1922. Pp. 26. (Weltevreden, Java: Landsdrukkerij.)

Survey of India. General Report 1921-22, from 1st October 1921 to 30th September 1922. Prepared under the Direction of Col. C. H. D. Ryder. Pp. vi+49+8 maps. (Calcutta: Survey of India.) 2·4 rupees; 4s.

Southern Rhodesia. Report of the Director, Geological Survey, for the Year 1922. Pp. 10. (Salisbury, Rhodesia.)

Nauka Polska: jej Potrzeby, Organizacja i Rozwój. (La Science Polonaise: ses Besoins, son Organisation et ses Progrès.) Tom 4. Pp. ix+590. (Warszawa: Im. Mianowskiego.)

Koninklijk Nederlandsch Meteorologisch Instituut. No. 106: Ergebnisse Aerologischer Beobachtungen, 10, 1921. Pp. xiii+83. No. 108: Seismische Registrierungen in De Bilt, 7, 1919. Pp. xi+68. No. 110: Oceanographische en Meteorologische Waarnemingen in den Atlantischen Oceaan, Maart, April, Mei (1856-1920.) Tabellen. Pp. iii+186. 15 Fl. Planches. Pp. 24. 7.50 Fl. (Utrecht: Kemink en Zoon.)

Diary of Societies.

TUESDAY, JULY 10.

SOCIOLOGICAL SOCIETY (at Leplay House, 65 Belgrave Road), at 5.45.—C. Dawson: Progress and Decay in Ancient and Modern Civilisations (Lecture).

THURSDAY, JULY 12.

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

TUESDAY, JULY 17.

ROYAL SOCIETY OF MEDICINE, at 5.—General Meeting.

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The Structure of the Atom.[1]

By Prof. N. BOHR.

THE GENERAL PICTURE OF THE ATOM.

THE present state of atomic theory is characterised by the fact that we not only believe the existence of atoms to be proved beyond a doubt, but also we even believe that we have an intimate knowledge of the constituents of the individual atoms. I cannot on this occasion give a survey of the scientific developments that have led to this result; I will only recall the discovery of the electron towards the close of the last century, which furnished the direct verification and led to a conclusive formulation of the conception of the atomic nature of electricity which had evolved since the discovery by Faraday of the fundamental laws of electrolysis and Berzelius's electrochemical theory, and had its greatest triumph in the electrolytic dissociation theory of Arrhenius. This discovery of the electron and elucidation of its properties was the result of the work of a large number of investigators, among whom Lenard and J. J. Thomson may be particularly mentioned. The latter especially has made very important contributions to our subject by his ingenious attempts to develop ideas about atomic constitution on the basis of the electron theory. The present state of our knowledge of the elements of atomic structure was reached, however, by the discovery of the atomic nucleus, which we owe to Rutherford, whose work on the radioactive substances discovered towards the close of the last century has much enriched physical and chemical science.

According to our present conceptions, an atom of an element is built up of a nucleus that has a positive electrical charge and is the seat of by far the greatest part of the atomic mass, together with a number of electrons, all having the same negative charge and mass, which move at distances from the nucleus that are very great compared to the dimensions of the nucleus or of the electrons themselves. In this picture we at once see a striking resemblance to a planetary system, such as we have in our own solar system. Just as the simplicity of the laws that govern the motions of the solar system is intimately connected with the circumstance that the dimensions of the moving bodies are small in relation to the orbits, so the corresponding relations in atomic structure provide us with an explanation of an essential feature of natural phenomena in so far as these depend on the properties of the elements. It makes clear at once that these properties can be divided into two sharply distinguished classes.

To the first class belong most of the ordinary physical and chemical properties of substances, such as their state of aggregation, colour, and chemical reactivity. These properties depend on the motion of the electron system and the way in which this motion changes under the influence of different external actions. On account of the large mass of the nucleus relative to that of the electrons and its smallness in comparison to the electron orbits, the electronic motion will depend only to a very small extent on the nuclear mass, and will be determined to a close approximation solely by the total electrical charge of the nucleus. Especially the inner structure of the nucleus and the way in which the charges and masses are distributed among its separate particles will have a vanishingly small influence on the motion of the electron system surrounding the nucleus. On the other hand, the structure of the nucleus will be responsible for the second class of properties that are shown in the radioactivity of substances. In the radioactive processes we meet with an explosion of the nucleus, whereby positive or negative particles, the so-called α- and β-particles, are expelled with very great velocities.

Our conceptions of atomic structure afford us, therefore, an immediate explanation of the complete lack of interdependence between the two classes of properties, which is most strikingly shown in the existence of substances which have to an extraordinarily close approximation the same ordinary physical and chemical properties, even though the atomic weights are not the same, and the radioactive properties are completely different. Such substances, of the existence of which the first evidence was found in the work of Soddy and other investigators on the chemical properties of the radioactive elements, are called isotopes, with reference to the classification of the elements according to ordinary physical and chemical properties. It is

[1] Lecture delivered at Stockholm, December 11, 1922, on the occasion of the receipt of the Nobel prize in physics for the year 1922. English translation by Dr. Frank C. Hoyt.

not necessary for me to state here how it has been shown in recent years that isotopes are found not only among the radioactive elements, but also among ordinary stable elements; in fact, a large number of the latter that were previously supposed simple have been shown by Aston's well-known investigations to consist of a mixture of isotopes with different atomic weights.

The question of the inner structure of the nucleus is still but little understood, although a method of attack is afforded by Rutherford's experiments on the disintegration of atomic nuclei by bombardment with α-particles. Indeed, these experiments may be said to open up a new epoch in natural philosophy in that for the first time the artificial transformation of one element into another has been accomplished. In what follows, however, we shall confine ourselves to a consideration of the ordinary physical and chemical properties of the elements and the attempts which have been made to explain them on the basis of the concepts just outlined.

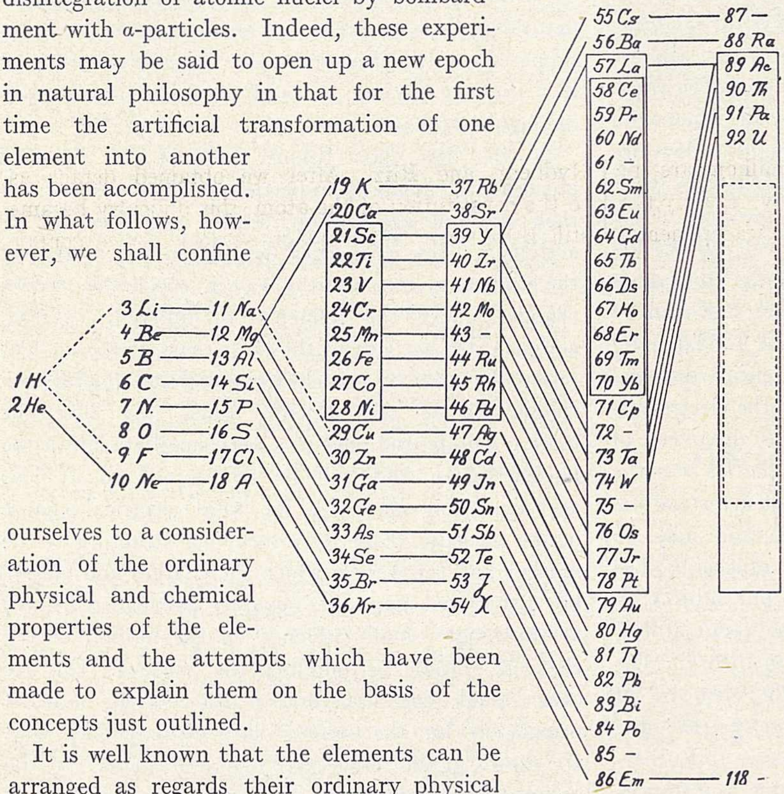

Fig. 1.

It is well known that the elements can be arranged as regards their ordinary physical and chemical properties in a *natural system* which displays most suggestively the peculiar relationships between the different elements. It was recognised for the first time by Mendeléeff and Lothar Meyer that when the elements are arranged in an order which is practically that of their atomic weights, their chemical and physical properties show a pronounced periodicity. A diagrammatic representation of this so-called periodic table is given in Fig. 1, where, however, the elements are not arranged in the ordinary way but in a somewhat modified form of a table first given by Julius Thomsen, who has also made important contributions to science in this domain. In the figure the elements are denoted by their usual chemical symbols, and the different vertical columns indicate the so-called periods. The elements in successive columns which possess homologous chemical and physical properties are connected with lines. The meaning of the square brackets around certain series of elements in the later periods, the properties of which exhibit typical deviations from the simple periodicity in the first periods, will be discussed later.

In the development of the theory of atomic structure the characteristic features of the natural system have found a surprisingly simple interpretation. Thus we are led to assume that the ordinal number of an element in the periodic table, the so-called atomic number, is just equal to the number of electrons which move about the nucleus in the neutral atom. In an imperfect form, this law was first stated by Van den Broek; it was, however, foreshadowed by J. J. Thomson's investigations of the number of electrons in the atom, as well as by Rutherford's measurements of the charge on the atomic nucleus. As we shall see, convincing support for this law has since been obtained in various ways, especially by Moseley's famous investigations of the X-ray spectra of the elements. We may perhaps also point out, how the simple connexion between atomic number and nuclear charge offers an explanation of the laws governing the changes in chemical properties of the elements after expulsion of α- or β-particles, which found a simple formulation in the so-called radioactive displacement law.

Atomic Stability and Electrodynamic Theory.

As soon as we try to trace a more intimate connexion between the properties of the elements and atomic structure, we encounter profound difficulties, in that essential differences between an atom and a planetary system show themselves here in spite of the analogy we have mentioned.

The motions of the bodies in a planetary system, even though they obey the general law of gravitation, will not be completely determined by this law alone, but will depend largely on the previous history of the system. Thus the length of the year is not determined by the masses of the sun and the earth alone, but depends also on the conditions that existed during the formation of the solar system, of which we have very little knowledge. Should a sufficiently large foreign body some day traverse our solar system, we might among other effects expect that from that day the length of the year would be different from its present value.

It is quite otherwise in the case of atoms. The definite and unchangeable properties of the elements demand that the state of an atom cannot undergo permanent changes due to external actions. As soon as the atom is left to itself again, its constituent particles must arrange their motions in a manner which is completely determined by the electric charges and masses of the particles. We have the most convincing evidence of this in spectra, that is, in the properties of the radiation emitted from substances in certain circumstances, which can be studied with such great precision. It is well known that the wave-lengths of the spectral lines of a substance, which can in many cases be measured with an accuracy of more than one part in a million, are, in the same external circumstances, always exactly the same within the limit of error of the measurements, and quite independent of the previous treatment of this substance. It is just to this circumstance that we owe the great importance of spectral analysis, which has been such an invaluable aid to the chemist in the search for new elements, and has also shown us that even on the most distant bodies of the universe there occur elements with exactly the same properties as on the earth.

On the basis of our picture of the constitution of the atom it is thus impossible, so long as we restrict ourselves to the ordinary mechanical laws, to account for the characteristic atomic stability which is required for an explanation of the properties of the elements.

The situation is by no means improved if we also take into consideration the well-known electrodynamic laws which Maxwell succeeded in formulating on the basis of the great discoveries of Oersted and Faraday in the first half of the last century. Maxwell's theory has not only shown itself able to account for the already known electric and magnetic phenomena in all their details, but has also celebrated its greatest triumph in the prediction of the electromagnetic waves which were discovered by Hertz, and are now so extensively used in wireless telegraphy.

For a time it seemed as though this theory would also be able to furnish a basis for an explanation of the details of the properties of the elements, after it had been developed, chiefly by Lorentz and Larmor, into a form consistent with the atomistic conception of electricity. I need only remind you of the great interest that was aroused when Lorentz, shortly after the discovery by Zeeman of the characteristic changes that spectral lines undergo when the emitting substance is brought into a magnetic field, could give a natural and simple explanation of the main features of the phenomenon. Lorentz assumed that the radiation which we observe in a spectral line is sent out from an electron executing simple harmonic vibrations about a position of equilibrium in precisely the same manner as the electromagnetic waves in radio-telegraphy are sent out by the electric oscillations in the antennæ. He also pointed out how the alteration observed by Zeeman in the spectral lines corresponded exactly to the alteration in the motion of the vibrating electron which one would expect to be produced by the magnetic field.

It was, however, impossible on this basis to give a closer explanation of the spectra of the elements, or even of the general type of the laws holding with great exactness for the wave-lengths of lines in these spectra, which had been established by Balmer, Rydberg, and Ritz. After we obtained details as to the constitution of the atom, this difficulty became still more manifest; in fact, so long as we confine ourselves to the classical electrodynamic theory we cannot even understand why we obtain spectra consisting of sharp lines at all. This theory can even be said to be incompatible with the assumption of the existence of atoms possessing the structure we have described, in that the motions of the electrons would claim a continuous radiation of energy from the atom, which would cease only when the electrons had fallen into the nucleus.

The Origin of the Quantum Theory.

It has, however, been possible to avoid the various difficulties of the electrodynamic theory by introducing concepts borrowed from the so-called quantum theory, which marks a complete departure from the ideas that have hitherto been used for the explanation of natural phenomena. This theory was originated by Planck, in the year 1900, in his investigations on the law of heat radiation, which, because of its independence of the individual properties of substances, lent itself peculiarly well to a test of the applicability of the laws of classical physics to atomic processes.

Planck considered the equilibrium of radiation between a number of systems with the same properties as those on which Lorentz had based his theory of the Zeeman effect, but he could now show not only that classical physics could not account for the phenomena of heat radiation, but also that a complete agreement with the experimental law could be obtained if—in pronounced contradiction to classical theory—it were assumed that the energy of the vibrating electrons could not change continuously, but only in such a way that the energy of the system always remained equal to a whole number of so-called energy-quanta. The magnitude of this quantum was found to be proportional to the frequency of oscillation of the particle, which, in accordance with classical concepts, was supposed to be also the frequency of the emitted radiation. The proportionality factor had to be regarded as a new universal constant, since termed Planck's constant, similar to the velocity of light and the charge and mass of the electron.

Planck's surprising result stood at first completely isolated in natural science, but with Einstein's significant contributions to this subject a few years after, a great variety of applications was found. In the first place, Einstein pointed out that the condition limiting the amount of vibrational energy of the particles could be tested by investigation of the specific heat of crystalline bodies, since in the case of these we have to do with similar vibrations, not of a single electron, but of whole atoms about positions of equilibrium in the crystal lattice. Einstein was able to show that the experiment confirmed Planck's theory, and through the work of later investigators this agreement has proved quite complete. Furthermore, Einstein emphasised another consequence of Planck's results, namely, that radiant energy could only be emitted or absorbed by the oscillating particle in so-called "quanta of radiation," the magnitude of each of which was equal to Planck's constant multiplied by the frequency.

In his attempts to give an interpretation of this result, Einstein was led to the formulation of the so-called "hypothesis of light-quanta," according to which the radiant energy, in contradiction to Maxwell's electromagnetic theory of light, would not be propagated as electromagnetic waves, but rather as concrete light atoms, each with an energy equal to that of a quantum of radiation. This concept led Einstein to his well-known theory of the photo-electric effect. This phenomenon, which had been entirely unexplainable on the classical theory, was thereby placed in a quite different light, and the predictions of Einstein's theory have received such exact experimental confirmation in recent years, that perhaps the most exact determination of Planck's constant is afforded by measurements on the photo-electric effect. In spite of its heuristic value, however, the hypothesis of light-quanta, which is quite irreconcilable with so-called interference phenomena, is not able to throw light on the nature of radiation. I need only recall that these interference phenomena constitute our only means of investigating the properties of radiation and therefore of assigning any closer meaning to the frequency which in Einstein's theory fixes the magnitude of the light-quantum.

In the following years many efforts were made to apply the concepts of the quantum theory to the question of atomic structure, and the principal emphasis was sometimes placed on one and sometimes on the other of the consequences deduced by Einstein from Planck's result. As the best known of the attempts in this direction, from which, however, no definite results were obtained, I may mention the work of Stark, Sommerfeld, Hasenöhrl, Haas, and Nicholson.

From this period also dates an investigation by Bjerrum on infra-red absorption bands, which, although it had no direct bearing on atomic structure, proved significant for the development of the quantum theory. He directed attention to the fact that the rotation of the molecules in a gas might be investigated by means of the changes in certain absorption lines with temperature. At the same time he emphasised the fact that the effect should not consist of a continuous widening of the lines such as might be expected from classical theory, which imposed no restrictions on the molecular rotations, but in accordance with the quantum theory he predicted that the lines should be split up into a number of components, corresponding to a sequence of distinct possibilities of rotation. This prediction was confirmed a few years later by Eva von Bahr, and the phenomenon may still be regarded as one of the most striking evidences of the reality of the quantum theory, even though from our present point of view the original explanation has undergone a modification in essential details.

The Quantum Theory of Atomic Constitution.

The question of further development of the quantum theory was in the meantime placed in a new light by Rutherford's discovery of the atomic nucleus (1911). As we have already seen, this discovery made it quite clear that by classical conceptions alone it was quite impossible to understand the most essential properties of atoms. One was therefore led to seek for a formulation of the principles of the quantum theory that could immediately account for the stability in atomic structure and the properties of the radiation sent out from atoms, of which the observed properties of substances bear witness. Such a formulation was proposed (1913) by the present lecturer in the form of two postulates, which may be stated as follows:

1. Among the conceivably possible states of motion in an atomic system there exist a number of so-called *stationary states* which, in spite of the fact that the motion of the particles in these states obeys the laws of classical mechanics to a considerable extent, possess a peculiar, mechanically unexplainable stability, of such a sort that every permanent change in the motion of the system must consist in a complete transition from one stationary state to another.

2. While in contradiction to the classical electromagnetic theory no radiation takes place from the atom in the stationary states themselves, a process of transition between two stationary states can be accompanied by the emission of electromagnetic radiation, which will have the same properties as that which would be sent out according to the classical theory from an electrified particle executing an harmonic vibration with constant frequency. This frequency ν has, however, no simple relation to the motion of the particles of the atom, but is given by the relation

$$h\nu = \mathrm{E}' - \mathrm{E}'',$$

where h is Planck's constant, and E′ and E″ are the values of the energy of the atom in the two stationary states that form the initial and final state of the radiation process. Conversely, irradiation of the atom with electromagnetic waves of this frequency can lead to an absorption process, whereby the atom is transformed back from the latter stationary state to the former.

While the first postulate has in view the general stability of the atom, the second postulate has chiefly in view the existence of spectra with sharp lines. Furthermore, the quantum theory condition entering in the last postulate affords a starting point for the interpretation of the laws of series spectra. The most general of these laws, the combination principle enunciated by Ritz, states that the frequency ν for each of the lines in the spectrum of an element can be represented by the formula

$$\nu = \mathrm{T}'' - \mathrm{T}',$$

where T″ and T′ are two so-called "spectral terms" belonging to a manifold of such terms characteristic of the substance in question.

According to our postulates, this law finds an immediate interpretation in the assumption that the spectrum is emitted by transitions between a number of stationary states in which the numerical value of the energy of the atom is equal to the value of the spectral term multiplied by Planck's constant. This explanation of the combination principle is seen to differ fundamentally from the usual ideas of electrodynamics, as soon as we consider that there is no simple relation between the motion of the atom and the radiation sent out. The departure of our considerations from the ordinary ideas of natural philosophy becomes particularly evident, however, when we observe that the occurrence of two spectral lines, corresponding to combinations of the same spectral term with two other different terms, implies that the nature of the radiation sent out from the atom is not determined only by the motion of the atom at the beginning of the radiation process, but also depends on the state to which the atom is transferred by the process.

At first glance one might, therefore, think that it would scarcely be possible to bring our formal explanation of the combination principle into direct relation with our views regarding the constitution of the atom, which, indeed, are based on experimental evidence interpreted on classical mechanics and electrodynamics. A closer investigation, however, should make it clear that a definite relation may be obtained between the spectra of the elements and the structure of their atoms on the basis of the postulates.

The Hydrogen Spectrum.

The simplest spectrum we know is that of hydrogen. The frequencies of its lines may be represented with great accuracy by means of Balmer's formula:

$$\nu = \mathrm{K}\left(\frac{1}{n''^2} - \frac{1}{n'^2}\right),$$

where K is a constant and n' and n'' are two integers. In the spectrum we accordingly meet a single series of spectral terms of the form K/n^2, which decrease regularly with increasing term number n. In accordance with the postulates, we shall therefore assume that each of the hydrogen lines is emitted by a transition between two states belonging to a series of stationary states of the hydrogen atom in which the numerical value of the atom's energy is equal to $h\mathrm{K}/n^2$.

Following our picture of atomic structure, a hydrogen atom consists of a positive nucleus and an electron which—so far as ordinary mechanical conceptions are applicable—will with great approximation describe a periodic elliptical orbit with the nucleus at one focus. The major axis of the orbit is inversely proportional to the work necessary completely to remove the electron from the nucleus, and, in accordance with the above, this work in the stationary states is just equal to $h\mathrm{K}/n^2$. We thus arrive at a manifold of stationary states for which the major axis of the electron orbit takes on a series of discrete values proportional to the squares of the whole numbers. The accompanying Fig. 2 shows these relations diagrammatically. For the sake of simplicity the electron orbits in the stationary states are represented by circles, although in reality the theory places no restriction on the eccentricity of the orbit, but only determines the length of the major axis. The arrows represent the transition processes that correspond to the red and green hydrogen lines, Hα and Hβ, the frequency of which is given by means of the Balmer formula when we put $n'' = 2$ and $n' = 3$ and 4 respectively. The transition processes are also represented which correspond to the first three lines of the series of ultra-violet lines found by Lyman in 1914, of which the frequencies are given by the formula when n is put equal to 1, as well as to the first line of the infra-red series discovered some years previously by Paschen, which are given by the formula if n'' is put equal to 3.

This explanation of the origin of the hydrogen spectrum leads us quite naturally to interpret this spectrum as the manifestation of a process whereby the electron is bound to the nucleus. While the largest spectral term with term number 1 corresponds to the final stage in the binding process, the small spectral terms that have larger values of the term number correspond to stationary states which represent the initial states of the binding process, where the

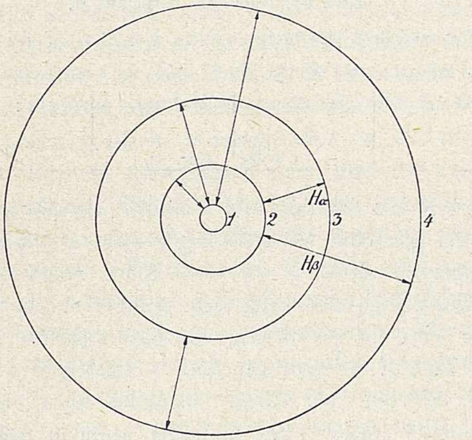

Fig. 2.

electron orbits still have large dimensions, and where the work required to remove an electron from the nucleus is still small. The final stage in the binding process we may designate as the normal state of the atom, and it is distinguished from the other stationary states by the property that, in accordance with the postulates, the state of the atom can only be changed by the addition of energy whereby the electron is transferred to an orbit of larger dimensions corresponding to an earlier stage of the binding process.

The size of the electron orbit in the normal state calculated on the basis of the above interpretation of the spectrum agrees roughly with the value for the dimensions of the atoms of the elements that have been calculated by the kinetic theory of matter from the properties of gases. Since, however, as an immediate consequence of the stability of the stationary states that is claimed by the postulates, we must suppose that the interaction between two atoms during a collision cannot be completely described with the aid of the laws of classical mechanics, such a comparison as this cannot be carried further on the basis of such considerations as those just outlined.

A more intimate connexion between the spectra and the atomic model has been revealed, however, by an investigation of the motion in those stationary states where the term number is large, and where the dimensions of the electron orbit and the frequency of revolution in it vary relatively little when we go from one stationary state to the next following. It was possible to show that the frequency of the radiation sent out during the transition between two stationary states, the difference of the term numbers of which is small in comparison to these numbers themselves, tended to coincide in frequency with one of the harmonic components into which the electron motion could be resolved, and accordingly also with the frequency of one of the wave trains in the radiation which would be emitted according to the laws of ordinary electrodynamics.

The condition that such a coincidence should occur in this region where the stationary states differ but little from one another proves to be that the constant in the Balmer formula can be expressed by means of the relation

$$K = \frac{2\pi^2 e^4 m}{h^3},$$

where e and m are respectively the charge and mass of the electron, while h is Planck's constant. This relation has been shown to hold to within the considerable accuracy with which, especially through the beautiful investigations of Millikan, the quantities e, m, and h are known.

This result shows that there exists a connexion between the hydrogen spectrum and the model for the hydrogen atom which, on the whole, is as close as we might hope considering the departure of the postulates from the classical mechanical and electrodynamic laws. At the same time, it affords some indication of how we may perceive in the quantum theory, in spite of the fundamental character of this departure, a natural generalisation of the fundamental concepts of the classical electrodynamic theory. To this most important question we shall return later, but first we will discuss how the interpretation of the hydrogen spectrum on the basis of the postulates has proved suitable in several ways, for elucidating the relation between the properties of the different elements.

Relationships between the Elements.

The discussion above can be applied immediately to the process whereby an electron is bound to a nucleus with any given charge. The calculations show that, in the stationary state corresponding to a given value of the number n, the size of the orbit will be inversely proportional to the nuclear charge, while the work necessary to remove an electron will be directly proportional to the square of the nuclear charge. The spectrum that is emitted during the binding of an electron by a nucleus with charge N times that of the hydrogen nucleus can therefore be represented by the formula:

$$\nu = \mathrm{N}^2\mathrm{K}\left(\frac{1}{n''^2} - \frac{1}{n'^2}\right).$$

If in this formula we put N = 2, we get a spectrum which contains a set of lines in the visible region which was observed many years ago in the spectrum of certain stars. Rydberg assigned these lines to hydrogen because of the close analogy with the series of lines represented by the Balmer formula. It was never possible to produce these lines in pure hydrogen, but just before the theory for the hydrogen spectrum was put forward, Fowler succeeded in observing the series in question by sending a strong discharge through a mixture of hydrogen and helium. This investigator also assumed that the lines were hydrogen lines, because there existed no experimental evidence from which it might be inferred that two different substances could show properties resembling each other so much as the spectrum in question and that of hydrogen. After the theory was put forward, it became clear, however, that the observed lines must belong to a spectrum of helium, but that they were not like the ordinary helium spectrum emitted from the neutral atom. They came from an ionised helium atom which consists of a single electron moving about a nucleus with double charge. In this way there was brought to light a new feature of the relationship between the elements, which corresponds exactly with our present ideas of atomic structure, according to which the physical and chemical properties of an element depend in the first instance only on the electric charge of the atomic nucleus.

Soon after this question was settled the existence of a similar general relationship between the properties of the elements was brought to light by Moseley's well-known investigations on the characteristic X-ray spectra of the elements, which was made possible by Laue's discovery of the interference of X-rays in crystals and the investigations of W. H. and W. L. Bragg on this subject. It appeared, in fact, that the X-ray spectra of the different elements possessed a much simpler structure and a much greater mutual resemblance than their optical spectra. In particular, it appeared that the spectra changed from element to element in a manner that corresponded closely to the formula given above for the spectrum emitted during the binding of an electron to a nucleus, provided N was put equal to the atomic number of the element concerned. This formula was even capable of expressing, with an approximation that could not be without significance, the frequencies of the strongest X-ray lines, if small whole numbers were substituted for n' and n''.

This discovery was of great importance in several respects. In the first place, the relationship between the X-ray spectra of different elements proved so simple that it became possible to fix without ambiguity the atomic number for all known substances, and in this way to predict with certainty the atomic number of all such hitherto unknown elements for which there is a place in the natural system. Fig. 3 shows how the square root of the frequency for two characteristic X-ray lines depends on the atomic number. These lines belong to the group of so-called K-lines, which are the most penetrating of the characteristic rays. With very close approximation the points lie on straight lines, and the fact that they do so is conditioned not only by our taking account of known elements, but also by our leaving an open place between molybdenum (42) and ruthenium (44), just as in Mendeléeff's original scheme of the natural system of the elements.

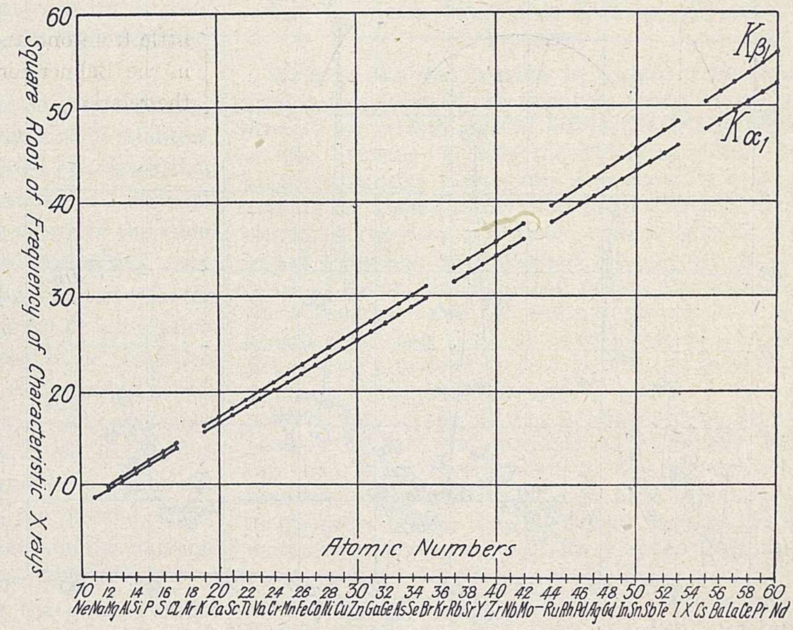

FIG. 3.

Further, the laws of X-ray spectra provide a confirmation of the general theoretical conceptions, both with regard to the constitution of the atom and the ideas that have served as a basis for the interpretation of spectra. Thus the similarity between X-ray spectra and the spectra emitted during the binding of a single electron to a nucleus may be simply interpreted from the fact that the transitions between stationary states with which we are concerned in X-ray spectra are accompanied by changes in the motion of an electron in the inner part of the atom, where the influence of the attraction of the nucleus is very great compared with the repulsive forces of the other electrons.

The relations between other properties of the elements are of a much more complicated character, which originates in the fact that we have to do with processes concerning the motion of the electrons in the outer part of the atom, where the forces that the electrons exert on one another are of the same order of magnitude as the attraction towards the nucleus, and where, therefore, the details of the interaction of the electrons play an important part. A characteristic example of such a case is afforded by the spatial extension of the atoms of the elements. Lothar Meyer himself directed attention to the characteristic periodic change exhibited by the ratio of the atomic weight to the density, the so-called atomic volume, of the elements in the natural system. An idea of these facts is given by Fig. 4, in which the atomic volume is represented as a function of the atomic number. A greater difference between this and the previous figure could scarcely be imagined. While the X-ray spectra vary uniformly with the atomic number, the atomic volumes show a characteristic periodic change which corresponds exactly to the change in the chemical properties of the elements.

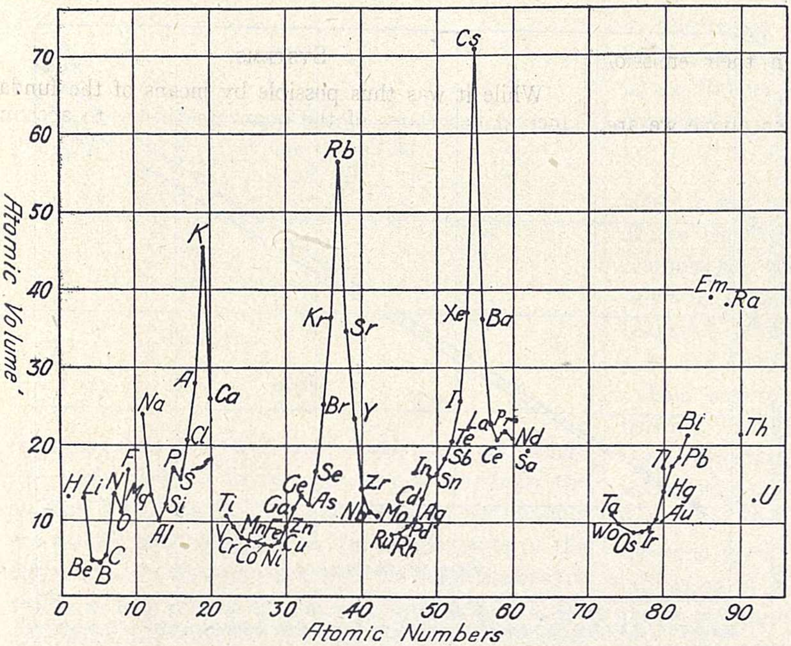

FIG. 4.

Ordinary optical spectra behave in an analogous way. In spite of the dissimilarity between these spectra, Rydberg succeeded in tracing a certain general relationship between the hydrogen spectrum and other spectra. Even though the spectral lines of the elements with higher atomic number appear as combinations of a more complicated manifold of spectral terms which is not so simply co-ordinated with a series of whole numbers, still the spectral terms can be arranged in series each of which shows a strong similarity to the series of terms in the hydrogen spectrum. This similarity appears in the fact that the terms in each series can, as Rydberg pointed out, be very accurately represented by the formula $K/(n+\alpha)^2$, where K is the same constant that occurs in the hydrogen spectrum, often called the Rydberg constant, while n is the term number, and α a constant which is different for the different series.

This relationship with the hydrogen spectrum leads us immediately to regard these spectra as the *last step of a process whereby the neutral atom is built up by the capture and binding of electrons to the nucleus*, one by one. In fact, it is clear that the last electron captured, so long as it is in that stage of the binding process in which its orbit is still large compared to the orbits of the previously bound electrons, will be subjected to a force from the nucleus and these electrons, that differs but little from the force with which the electron in the hydrogen atom is attracted towards the nucleus while it is moving in an orbit of corresponding dimensions.

The spectra so far considered, for which Rydberg's laws hold, are excited by means of electric discharge under ordinary conditions and are often called arc spectra. The elements emit also another type of spectrum, the so-called spark spectra, when they are subjected to an extremely powerful discharge. Hitherto it was impossible to disentangle the spark spectra in the same way as the arc spectra. Shortly after the above view on the origin of arc spectra was brought forward, however, Fowler found (1914) that an empirical expression for the spark spectrum lines could be established which corresponds exactly to Rydberg's laws with the single difference that the constant K is replaced by a constant four times as large. Since, as we have seen, the constant that appears in the spectrum sent out during the binding of an electron to a helium nucleus is exactly equal to 4 K, it becomes evident that spark spectra are due to the ionised atom, and that their emission corresponds to *the last step but one in the formation of the neutral atom* by the successive capture and binding of electrons.

Absorption and Excitation of Spectral Lines.

The interpretation of the origin of the spectra was also able to explain the characteristic laws that govern absorption spectra. As Kirchhoff and Bunsen had already shown, there is a close relation between the selective absorption of substances for radiation and their emission spectra, and it is on this that the application of spectrum analysis to the heavenly bodies essentially rests. Yet on the basis of the classical electromagnetic theory, it is impossible to understand why substances in the form of vapour show absorption for certain lines in their emission spectrum and not for others.

On the basis of the postulates given above we are, however, led to assume that the absorption of radiation corresponding to a spectral line emitted by a transition from one stationary state of the atom to a state of less energy is brought about by the return of the atom from the last-named state to the first. We thus understand immediately that in ordinary circumstances a gas or vapour can only show selective absorption for spectral lines that are produced by a transition from a state corresponding to an earlier stage in the binding process to the normal state. Only at higher temperatures or under the influence of electric discharges whereby an appreciable number of atoms are being constantly disrupted from the normal state, can we expect absorption for other lines in the emission spectrum in agreement with the experiments.

A most direct confirmation for the general interpretation of spectra on the basis of the postulates has also been obtained by investigations on the excitation of spectral lines and ionisation of atoms by means of impact of free electrons with given velocities. A decided advance in this direction was marked by the well-known investigations of Franck and Hertz (1914). It appeared from their results that by means of electron impacts it was impossible to impart to an atom an arbitrary amount of energy, but only such amounts as corresponded to a transfer of the atom from its normal state to another stationary state of the existence of which the spectra assure us, and the energy of which can be inferred from the magnitude of the spectral term.

Further, striking evidence was afforded of the independence that, according to the postulates, must be attributed to the processes which give rise to the emission of the different spectral lines of an element. Thus it could be shown directly that atoms that were transferred in this manner to a stationary state of greater energy were able to return to the normal state with emission of radiation corresponding to a single spectral line.

Continued investigations on electron impacts, in which a large number of physicists have shared, have also produced a detailed confirmation of the theory concerning the excitation of series spectra. Especially it has been possible to show that for the *ionisation* of an atom by electron impact an amount of energy is necessary that is exactly equal to the work required, according to the theory, to remove the last electron captured from the atom. This work can be determined directly as the product of Planck's constant and the spectral term corresponding to the normal state, which, as mentioned above, is equal to the limiting value of the frequencies of the spectral series connected with selective absorption.

The Quantum Theory of Multiply-Periodic Systems.

While it was thus possible by means of the fundamental postulates of the quantum theory to account directly for certain general features of the properties of the elements, a closer development of the ideas of the quantum theory was necessary in order to account for these properties in further detail. In the course of the last few years a more general theoretical basis has been attained through the development of formal methods that permit the fixation of the stationary states for electron motions of a more general type than those we have hitherto considered. For a simply periodic motion such as we meet in the pure harmonic oscillator, and at least to a first approximation, in the motion of an electron about a positive nucleus, the manifold of stationary states can be simply co-ordinated to a series of whole numbers. For motions of the more general class mentioned above, the so-called *multiply-periodic* motions, however, the stationary states compose a more complex manifold, in which, according to these formal methods, each state is characterised by several whole numbers, the so-called "quantum numbers."

In the development of the theory a large number of physicists have taken part, and the introduction of several quantum numbers can be traced back to the work of Planck himself. But the definite step which gave the impetus to further work was made by Sommerfeld (1915) in his explanation of the fine structure shown by the hydrogen lines when the spectrum is observed with a spectroscope of high resolving power. The occurrence of this fine structure must be ascribed to the circumstance that we have to deal, even in hydrogen, with a motion which is not exactly simply periodic. In fact, as a consequence of the change in the electron's mass with velocity that is claimed by the theory of relativity, the electron orbit will undergo a very slow precession in the orbital plane. The motion will therefore be doubly periodic, and besides a number characterising the term in the Balmer formula, which we shall call the *principal quantum number* because it determines in the main the energy of the atom, the fixation of the stationary states demands another quantum number which we shall call the *subordinate quantum number*.

A survey of the motion in the stationary states thus fixed is given in the diagram (Fig. 5), which reproduces the relative size and form of the electron orbits. Each orbit is designated by a symbol n_k, where n is the principal quantum number and k the subordinate quantum number. All orbits with the same principal quantum number have, to a first approximation, the same major axis, while orbits with the same value of k have the same parameter, *i.e.* the same value for the shortest chord through the focus. Since the energy values for different states with the same value of n but different values of k differ a little from each other, we get for each hydrogen line corresponding to definite values of n' and n'' in the Balmer formula a number of different transition processes, for which the frequencies of the emitted radiation as calculated by the second postulate are not exactly the same. As Sommerfeld was able to show, the components this gives for each hydrogen line agree with the observations on the fine structure of hydrogen lines to within the limits of experimental error. In the figure the arrows designate the processes that give rise to the components of the red and green lines in the hydrogen spectrum, the frequencies of which are obtained by putting $n''=2$ and $n'=3$ or 4 respectively in the Balmer formula.

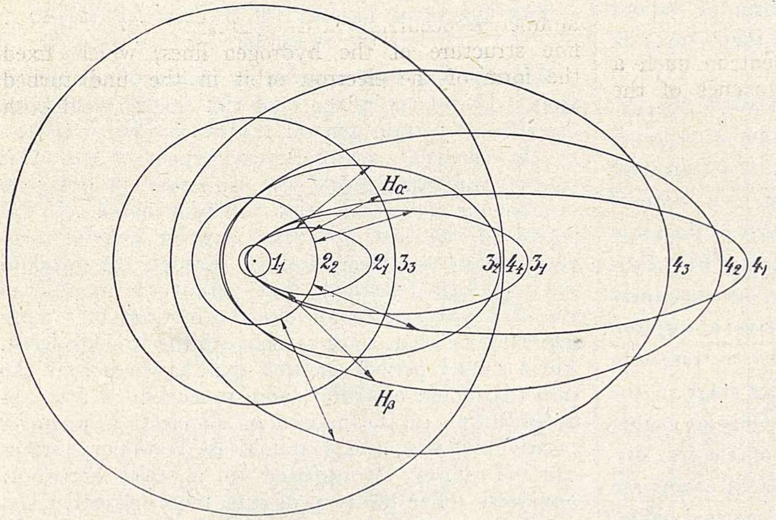

FIG. 5.

In considering the figure it must not be forgotten that the description of the orbit is there incomplete, in so much as with the scale used the slow precession does not show at all. In fact, this precession is so slow that even for the orbits that rotate most rapidly the electron performs about 40,000 revolutions before the perihelion has gone round once. Nevertheless, it is this precession alone that is responsible for the multiplicity of the stationary states characterised by the subordinate quantum number. If, for example, the hydrogen atom is subjected to a small disturbing force which perturbs the regular precession, the electron orbit in the stationary states will have a form altogether different from that given in the figure. This implies that the fine structure will change its character completely, but the hydrogen spectrum will continue to consist of lines that are given to a close approximation by the Balmer formula, due to the fact that the approximately periodic character of the motion will be retained. Only when the disturbing forces become so large that even during a single revolution of the electron the orbit is appreciably disturbed, will the spectrum undergo essential changes. The statement often advanced that the introduction of two quantum numbers should be a necessary condition for the explanation of the Balmer formula must therefore be considered as a misconception of the theory.

Sommerfeld's theory has proved itself able to account not only for the fine structure of the hydrogen lines, but also for that of the lines in the helium spark spectrum. Owing to the greater velocity of the electron, the intervals between the components into which a line is split up are here much greater and can be measured with much greater accuracy. The theory was also able to account for certain features in the fine structure of X-ray spectra, where we meet frequency differences that may even reach a value more than a million times as great as those of the frequency differences for the components of the hydrogen lines.

Shortly after this result had been attained, Schwarzschild and Epstein (1916) simultaneously succeeded, by means of similar considerations, in accounting for the characteristic changes that the hydrogen lines undergo in an electric field, which had been discovered by Stark in the year 1914. Next, an explanation of the essential features of the Zeeman effect for the hydrogen lines was worked out at the same time by Sommerfeld and Debye (1917). In this instance the application of the Postulates involved the consequence that only certain orientations of the atom relative to the magnetic field were allowable, and this characteristic consequence of the quantum theory has quite recently received a most direct confirmation in the beautiful researches of Stern and Gerlach on the deflexion of swiftly-moving silver atoms in a non-homogenous magnetic field.

THE CORRESPONDENCE PRINCIPLE.

While this development of the theory of spectra was based on the working out of formal methods for the fixation of stationary states, the present lecturer succeeded shortly afterwards in throwing light on the theory from a new view-point, by pursuing further the characteristic connexion between the quantum theory and classical electrodynamics already traced out in the hydrogen spectrum. In connexion with the important work of Ehrenfest and Einstein these efforts led to the formulation of the so-called *correspondence principle*, according to which the occurrence of transitions between the stationary states accompanied by emission of radiation is traced back to the harmonic components into which the motion of the atom may be resolved and which, according to the classical theory, determine the properties of the radiation to which the motion of the particles gives rise.

According to the correspondence principle, it is assumed that every transition process between two stationary states can be co-ordinated with a corre-

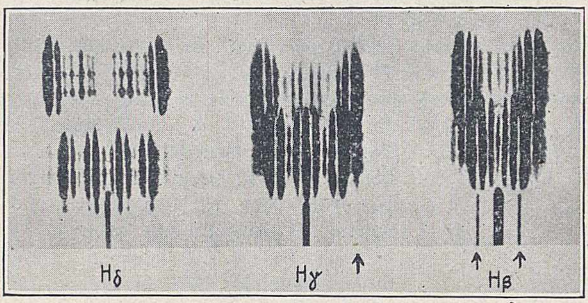

FIG. 6.

sponding harmonic vibration component in such a way that the probability of the occurrence of the transition is dependent on the amplitude of the vibration. The state of polarisation of the radiation emitted during the transition depends on the further characteristics of the vibration, in a manner analogous to that in which on the classical theory the intensity and state of polarisation in the wave system emitted by the atom as a consequence of the presence of this vibration component would be determined respectively by the amplitude and further characteristics of the vibration.

With the aid of the correspondence principle it has been possible to confirm and to extend the above-mentioned results. Thus it was possible to develop a complete quantum theory explanation of the Zeeman effect for the hydrogen lines, which, in spite of the essentially different character of the assumptions that underlie the two theories, is very similar throughout to Lorentz's original explanation based on the classical theory. In the case of the Stark effect, where, on the other hand, the classical theory was completely at a loss, the quantum theory explanation could be so extended with the help of the correspondence principle as to account for the polarisation of the different components into which the lines are split, and also for the characteristic intensity distribution exhibited by the components. This last question has been more closely investigated by Kramers, and the accompanying figure will give some impression of how completely it is possible to account for the phenomenon under consideration.

Fig. 6 reproduces one of Stark's well-known photographs of the splitting up of the hydrogen lines. The picture displays very well the varied nature of the phenomenon, and shows in how peculiar a fashion the intensity varies from component to component. The components below are polarised perpendicular to the field, while those above are polarised parallel to the field.

Fig. 7 gives a diagrammatic representation of the experimental and theoretical results for the line Hγ, the frequency of which is given by the Balmer formula with $n''=2$ and $n'=5$. The vertical lines denote the components into which the line is split up, of which the picture on the right gives the components which are polarised parallel to the field and that on the left those that are polarised perpendicular to it. The experimental results are represented in the upper half of the diagram, the distances from the dotted line representing the measured displacements of the components, and the lengths of the lines being proportional to the relative intensity as estimated by Stark from the blackening of the photographic plate. In the lower half is given for comparison a representation of the theoretical results from a drawing in Kramers' paper.

The symbol $(n'_{s'} - n''_{s''})$ attached to the lines gives the transitions between the stationary states of the atom in the electric field by which the components are emitted. Besides the principal quantum integer n, the stationary states are further characterised by a subordinate quantum integer s, which can be negative as well as positive and has a meaning quite different from that of the quantum number k occurring in the relativity theory of the fine structure of the hydrogen lines, which fixed the form of the electron orbit in the undisturbed atom. Under the influence of the electric field both the form of the orbit and its position undergo large changes, but certain properties of the orbit remain unchanged, and the subordinate quantum number s is connected with these. In Fig. 7 the position of the components corresponds to the frequencies calculated for the different transitions, and the lengths of the lines are proportional to the probabilities as calculated on the basis of the correspondence principle, by which also the polarisation of the radiation is determined. It is seen that the theory reproduces completely the main feature of the experimental results, and in the light of the correspondence principle we can say that the Stark effect reflects down to the smallest details the action of the electric field on the orbit of the electron in the hydrogen atom, even though in this case the reflection is so distorted that, in contrast with the case of the Zeeman effect, it would scarcely be possible directly

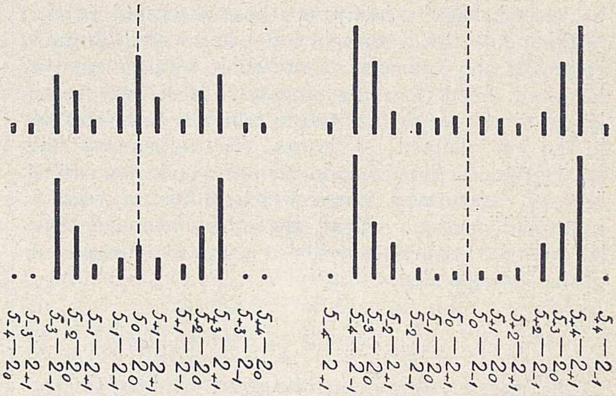

FIG. 7.

to recognise the motion on the basis of the classical ideas of the origin of electromagnetic radiation.

Results of interest were also obtained for the spectra of elements of higher atomic number, the explanation of which in the meantime had made important progress through the work of Sommerfeld, who introduced several quantum numbers for the description of the electron orbits. Indeed, it was possible, with the aid of the correspondence principle, to account completely for the characteristic rules which govern the seemingly capricious occurrence of combination lines, and it is not too much to say that the quantum theory has not only provided a simple interpretation of the combination principle, but has further contributed materially to the clearing up of the mystery that has long rested over the application of this principle.

The same view-points have also proved fruitful in the investigation of the so-called band spectra. These do not originate, as do series spectra, from individual atoms, but from molecules; and the fact that these spectra are so rich in lines is due to the complexity of the motion entailed by the vibrations of the atomic nuclei relative to each other and the rotations of the molecule as a whole. The first to apply the postulates to this problem was Schwarzschild, but the important work of Heurlinger especially has thrown much light on the origin and structure of band spectra. The considerations employed here can be traced back directly to those discussed at the beginning of this lecture in connexion with Bjerrum's theory of the influence of molecular rotation on the infra-red absorption lines of gases. It is true we no longer think that the rotation is reflected in the spectra in the way claimed by classical electrodynamics, but rather that the line components are due to transitions between stationary states which differ as regards rotational motion. That the phenomenon retains its essential features, however, is a typical consequence of the correspondence principle.

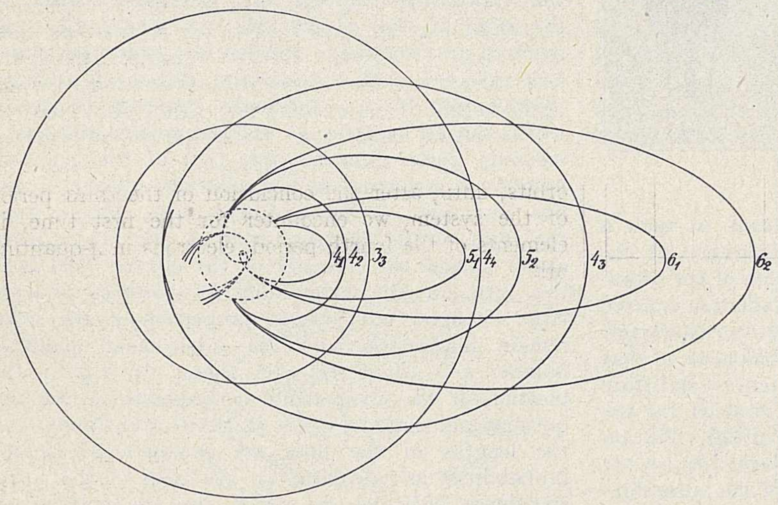

Fig. 8.

The Natural System of the Elements.

The ideas of the origin of spectra outlined in the preceding have furnished the basis for a theory of the structure of the atoms of the elements which has shown itself suitable for a general interpretation of the main features of the properties of the elements, as exhibited in the natural system. This theory is based primarily on considerations of the manner in which the atom can be imagined to be built up by the capture and binding of electrons to the nucleus, one by one. As we have seen, the optical spectra of elements provide us with evidence on the progress of the last steps in this building up process.

An insight into the kind of information that the closer investigation of the spectra has provided in this respect may be obtained from Fig. 8, which gives a diagrammatic representation of the orbital motion in the stationary states corresponding to the emission of the arc-spectrum of potassium. The curves show the form of the orbits described in the stationary states by the last electron captured in the potassium atom, and they can be considered as stages in the process whereby the 19th electron is bound after the 18 previous electrons have already been bound in their normal orbits. In order not to complicate the figure, no attempt has been made to draw any of the orbits of these inner electrons, but the region in which they move is enclosed by a dotted circle. In an atom with several electrons the orbits will, in general, have a complicated character. Because of the symmetrical nature of the field of force about the nucleus, however, the motion of each single electron can be approximately described as a plane periodic motion on which is superimposed a uniform rotation in the plane of the orbit. The orbit of each electron will therefore be to a first approximation doubly periodic, and will be fixed by two quantum numbers, as are the stationary states in a hydrogen atom when the relativity precession is taken into account.

In Fig. 8, as in Fig. 5, the electron orbits are marked with the symbol n_k, where n is the principal quantum number and k the subordinate quantum number. While for the initial states of the binding process, where the quantum numbers are large, the orbit of the last electron captured lies completely outside of those of the previously bound electrons, this is not the case for the last stages. Thus, in the potassium atom, the electron orbits with subordinate quantum numbers 2 and 1 will, as indicated in the figure, penetrate partly into the inner region. Because of this circumstance, the orbits will deviate very greatly from a simple Kepler motion, since they will consist of a series of successive outer loops that have the same size and form, but each of which is turned through an appreciable angle relative to the preceding one. Of these outer loops only one is shown in the figure. Each of them coincides very nearly with a piece of a Kepler ellipse, and they are connected, as indicated, by a series of inner loops of a complicated character in which the electron approaches the nucleus closely. This holds especially for the orbit with subordinate quantum number 1, which, as a closer investigation shows, will approach nearer to the nucleus than any of the previously bound electrons.

On account of this penetration into the inner region, the strength with which an electron in such an orbit is bound to the atom will—in spite of the fact that for the most part it moves in a field of force of the same character as that surrounding the hydrogen nucleus—be much greater than for an electron in a hydrogen atom that moves in an orbit with the same principal quantum number, the maximum distance of the electron from the nucleus at the same time being considerably less than in such a hydrogen orbit. As we shall see, this feature of the binding process in atoms with many electrons is of essential importance in order to understand the characteristic periodic way in which many properties of the elements as displayed in the natural system vary with the atomic number.

In the accompanying table (Fig. 9) is given a summary of the results concerning the structure of

	1_1	$2_1 2_2$	$3_1 3_2 3_3$	$4_1 4_2 4_3 4_4$	$5_1 5_2 5_3 5_4 5_5$	$6_1 6_2 6_3 6_4 6_5 6_6$	$7_1 7_2$
1 H	1						
2 He	2						
3 Li	2	1					
4 Be	2	2					
5 B	2	2(1)					
– –	–	– –					
10 Ne	2	4 4					
11 Na	2	4 4	1				
12 Mg	2	4 4	2				
13 Al	2	4 4	2 1				
– –	–	– –	– –				
18 A	2	4 4	4 4				
19 K	2	4 4	4 4	1			
20 Ca	2	4 4	4 4	2			
21 Sc	2	4 4	4 4 1	(2)			
22 Ti	2	4 4	4 4 2	(2)			
– –	–	– –	– – –	–			
29 Cu	2	4 4	6 6 6	1			
30 Zn	2	4 4	6 6 6	2			
31 Ga	2	4 4	6 6 6	2 1			
– –	–	– –	– – –	– –			
36 Kr	2	4 4	6 6 6	4 4			
37 Rb	2	4 4	6 6 6	4 4	1		
38 Sr	2	4 4	6 6 6	4 4	2		
39 Y	2	4 4	6 6 6	4 4 1	(2)		
40 Zr	2	4 4	6 6 6	4 4 2	(2)		
– –	–	– –	– – –	– – –	–		
47 Ag	2	4 4	6 6 6	6 6 6	1		
48 Cd	2	4 4	6 6 6	6 6 6	2		
49 In	2	4 4	6 6 6	6 6 6	2 1		
– –	–	– –	– – –	– – –	– –		
54 X	2	4 4	6 6 6	6 6 6	4 4		
55 Cs	2	4 4	6 6 6	6 6 6	4 4	1	
56 Ba	2	4 4	6 6 6	6 6 6	4 4	2	
57 La	2	4 4	6 6 6	6 6 6	4 4 1	(2)	
58 Ce	2	4 4	6 6 6	6 6 6 1	4 4 1	(2)	
59 Pr	2	4 4	6 6 6	6 6 6 2	4 4 1	(2)	
– –	–	– –	– – –	– – – –	– – –	–	
71 Cp	2	4 4	6 6 6	8 8 8 8	4 4 1	(2)	
72 –	2	4 4	6 6 6	8 8 8 8	4 4 2	(2)	
– –	–	– –	– – –	– – – –	– – –	–	
79 Au	2	4 4	6 6 6	8 8 8 8	6 6 6	1	
80 Hg	2	4 4	6 6 6	8 8 8 8	6 6 6	2	
81 Tl	2	4 4	6 6 6	8 8 8 8	6 6 6	2 1	
– –	–	– –	– – –	– – – –	– – –	– –	
86 Em	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4	
87 –	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4	1
88 Ra	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4	2
89 Ac	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4 1	(2)
90 Th	2	4 4	6 6 6	8 8 8 8	6 6 6	4 4 2	(2)
– –	–	– –	– – –	– – – –	– – –	– – –	–
118 ?	2	4 4	6 6 6	8 8 8 8	8 8 8 8	6 6 6	4 4

FIG. 9.

the atoms of the elements to which the author has been led by a consideration of successive capture and binding of electrons to the atomic nucleus. The figures before the different elements are the atomic numbers, which give the total number of electrons in the neutral atom. The figures in the different columns give the number of electrons in orbits corresponding to the values of the principal and subordinate quantum numbers standing at the top. In accordance with ordinary usage we will, for the sake of brevity, designate an orbit with principal quantum number n as an n-quantum orbit. The first electron bound in each atom moves in an orbit that corresponds to the normal state of the hydrogen atom with quantum symbol 1_1. In the hydrogen atom there is of course only one electron; but we must assume that in the atoms of other elements the next electron also will be bound in such a 1-quantum orbit of type 1_1. As the table shows, the following electrons are bound in 2-quantum orbits. To begin with, the binding will result in a 2_1 orbit, but later electrons will be bound in 2_2 orbits, until, after binding the first 10 electrons in the atom, we reach a closed configuration of the 2-quantum orbits in which we assume there are four orbits of each type. This configuration is met for the first time in the neutral neon atom, which forms the conclusion of the second period in the system of the elements. When we proceed in this system, the following electrons are bound in 3-quantum orbits, until, after the conclusion of the third period of the system, we encounter for the first time, in elements of the fourth period, electrons in 4-quantum orbits, and so on.

This picture of atomic structure contains many features that were brought forward by the work of earlier investigators. Thus the attempt to interpret the relations between the elements in the natural system by the assumption of a division of the electrons into groups goes as far back as the work of J. J. Thomson in 1904. Later, this view-point was developed chiefly by Kossel (1916), who, moreover, has connected such a grouping with the laws that investigations of X-ray spectra have brought to light.

Also G. R. Lewis and I. Langmuir have sought to account for the relations between the properties of the elements on the basis of a grouping inside the atom. These investigators, however, assumed that the electrons do not move about the nucleus, but occupy positions of equilibrium. In this way, though, no closer relation can be reached between the properties of the elements and the experimental results concerning the constituents of the atoms. Statical positions of equilibrium for the electrons are in fact not possible in cases in which the forces between the electrons and the nucleus even approximately obey the laws that hold for the attractions and repulsions between electrical charges.

The possibility of an interpretation of the properties of the elements on the basis of these latter laws is quite characteristic for the picture of atomic structure developed by means of the quantum theory. As regards this picture, the idea of connecting the grouping with a classification of electron orbits according to increasing quantum numbers was suggested by Moseley's discovery of the laws of X-ray spectra, and by Sommerfeld's work on the fine structure of these spectra. This has been principally emphasised by Vegard, who some years ago in connexion with investigations of X-ray spectra proposed a grouping of electrons in the atoms of the elements, which in many ways shows a likeness to that which is given in the above table.

A satisfactory basis for the further development of this picture of atomic structure has, however, only recently been created by the study of the binding processes of the electrons in the atom, of which we have experimental evidence in optical spectra, and the characteristic features of which have been elucidated principally by the correspondence principle. It is here an essential circumstance that the restriction on the course of the binding process, which is expressed by the presence of electron orbits with higher quantum numbers in the normal state of the atom, can be naturally connected with the general condition for the occurrence of transitions between stationary states, formulated in that principle.

Another essential feature of the theory is the influence, on the strength of binding and the dimensions of the orbits, of the penetration of the later bound electrons into the region of the earlier bound ones, of which we have seen an example in the discussion of the origin of the potassium spectrum. Indeed, this circumstance may be regarded as the essential cause of the pronounced periodicity in the properties of the elements, in that it implies that the atomic dimensions and chemical properties of homologous substances in the different periods, as, for example, the alkali-metals, show a much greater similarity than that which might be expected from a direct comparison of the orbit of the last electron bound with an orbit of the same quantum number in the hydrogen atom.

The increase of the principal quantum number which we meet when we proceed in the series of the elements, affords also an immediate explanation of the characteristic deviations from simple periodicity which are exhibited by the natural system and are expressed in Fig. 1 by the bracketing of certain series of elements in the later periods. The first time such a deviation is met with is in the 4th period, and the reason for it can be simply illustrated by means of our figure of the orbits of the last electron bound in the atom of potassium, which is the first element in this period. Indeed, in potassium we encounter for the first time in the sequence of the elements a case in which the principal quantum number of the orbit of the last electron bound is, in the normal state of the atom, larger than in one of the earlier stages of the binding process. The normal state corresponds here to a 4_1 orbit, which, because of the penetration into the inner region, corresponds to a much stronger binding of the electron than a 4-quantum orbit in the hydrogen atom. The binding in question is indeed even stronger than for a 2-quantum orbit in the hydrogen atom, and is therefore more than twice as strong as in the circular 3_3 orbit which is situated completely outside the inner region, and for which the strength of the binding differs but little from that for a 3-quantum orbit in hydrogen.

This will not continue to be true, however, when we consider the binding of the 19th electron in substances of higher atomic number, because of the much smaller relative difference between the field of force outside and inside the region of the first eighteen electrons bound. As is shown by the investigation of the spark spectrum of calcium, the binding of the 19th electron in the 4_1 orbit is here but little stronger than in 3_3 orbits, and as soon as we reach scandium, we must assume that the 3_3 orbit will represent the orbit of the 19th electron in the normal state, since this type of orbit will correspond to a stronger binding than a 4_1 orbit. While the group of electrons in 2-quantum orbits has been entirely completed at the end of the 2nd period, the development that the group of 3-quantum orbits undergoes in the course of the 3rd period can therefore only be described as a provisional completion, and, as shown in the table, this electron group will, in the bracketed elements of the 4th period, undergo a stage of further development in which electrons are added to it in 3-quantum orbits.

This development brings in new features, in that the development of the electron group with 4-quantum orbits comes to a standstill, so to speak, until the 3-quantum group has reached its final closed form. Although we are not yet in a position to account in all details for the steps in the gradual development of the 3-quantum electron group, still we can say that with the help of the quantum theory we see at once why it is in the 4th period of the system of the elements that there occur for the first time successive elements with properties that resemble each other as much as the properties of the *iron group*; indeed, we can even understand why these elements show their well-known paramagnetic properties. Without further reference to the quantum theory, Ladenburg had on a previous occasion already suggested the idea of relating the chemical and magnetic properties of these elements with the development of an inner electron group in the atom.

I will not enter into many more details, but only mention that the peculiarities we meet with in the 5th period are explained in much the same way as those in the 4th period. Thus the properties of the bracketed elements in the 5th period as it appears in the table, depend on a stage in the development of the 4-quantum electron group that is initiated by the entrance in the normal state of electrons in 4_3 orbits. In the 6th period, however, we meet new features. In this period we encounter not only a stage of the development of the electron groups with 5- and 6-quantum orbits, but also the final completion of the development of the 4-quantum electron group, which is initiated by the entrance for the first time of electron orbits of the 4_4 type in the normal state of the atom. This development finds its characteristic expression in the occurrence of the peculiar family of elements in the 6th period, known as the *rare-earths*. These show, as we know, a still greater mutual similarity in their chemical properties than the elements of the iron family. This must be ascribed to the fact that we have here to do with the development of an electron group that lies deeper in the atom. It is of interest to note that the theory can also naturally account for the fact that these elements, which resemble each other in so many ways, still show great differences in their magnetic properties.

The idea that the occurrence of the rare-earths depends on the development of an inner electron group has been put forward from different sides. Thus it is found in the work of Vegard, and at the same time as my own work, it was proposed by Bury in connexion with considerations of the systematic relation between the chemical properties and the grouping of the electrons inside the atom from the point of view of Langmuir's static atomic model. While until now it has not been possible, however, to give any theoretical basis for such a development of an inner group, we see that our extension of the quantum theory provides us with an unforced explanation. Indeed, it is scarcely an exaggeration to say that if the existence of the rare-earths had not been established by direct chemical investigation, the occurrence of a family of elements of this character within the 6th period of the natural system of the elements might have been theoretically predicted.

When we proceed to the 7th period of the system, we meet for the first time with 7-quantum orbits, and we shall expect to find within this period features that are essentially similar to those in the 6th period, in that besides the first stage in the development of the 7-quantum orbits, we must expect to encounter further stages in the development of the group with 6- or 5-quantum orbits. However, it has not been possible directly to confirm this expectation, because only a few elements are known in the beginning of the 7th period. The latter circumstance may be supposed to be intimately connected with the instability of atomic nuclei with large charges, which is expressed in the prevalent radioactivity among elements with high atomic number.

X-ray Spectra and Atomic Constitution.

In the discussion of the conceptions of atomic structure we have hitherto placed the emphasis on the formation of the atom by successive capture of electrons. Our picture would, however, be incomplete without some reference to the confirmation of the theory afforded by the study of X-ray spectra. Since the interruption of Moseley's fundamental researches by his untimely death, the study of these spectra has been continued in a most admirable way by Prof. Siegbahn in Lund. On the basis of the large amount of experimental evidence adduced by him and his collaborators, it has been possible recently to give a classification of X-ray spectra that allows an immediate interpretation on the quantum theory. In the first place it has been possible, just as in the case of the optical spectra, to represent the frequency of each of the X-ray lines as the difference between two out of a manifold of spectral terms characteristic of the element in question. Next, a direct connexion with the atomic theory is obtained by the assumption that each of these spectral terms multiplied by Planck's constant is equal to the work which must be done on the atom to remove one of its inner electrons. In fact, the removal of one of the inner electrons from the completed atom may, in accordance with the above considerations on the formation of atoms by capture of electrons, give rise to transition processes by which the place of the electron removed is taken by an electron belonging to one of the more loosely bound electron groups of the atom, with the result that after the transition an electron will be lacking in this latter group.

The X-ray lines may thus be considered as giving evidence of stages in a process by which the atom undergoes a *reorganisation* after a disturbance in its interior. According to our views on the stability of the electronic configuration such a disturbance must consist in the total removal of electrons from the atom, or at any rate in their transference from normal orbits to orbits of higher quantum numbers than those belonging to completed groups; a circumstance which is clearly illustrated in the characteristic difference between selective absorption in the X-ray region, and that exhibited in the optical region.

The classification of the X-ray spectra, to the achievement of which the above-mentioned work of Sommerfeld and Kossel has contributed materially, has recently made it possible, by means of a closer examination of the manner in which the terms occurring in the X-ray spectra vary with the atomic number, to obtain a very direct test of a number of the theoretical

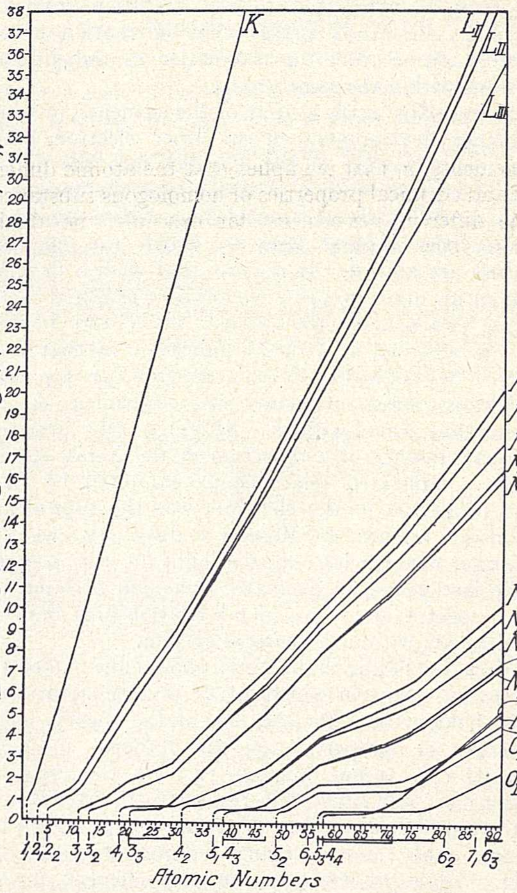

Fig. 10.

conclusions as regards the structure of the atom. In Fig. 10 the abscissæ are the atomic numbers and the ordinates are proportional to the square roots of the spectral terms, while the symbols K, L, M, N, O, for the individual terms refer to the characteristic discontinuities in the selective absorption of the elements for X-rays; these were originally found by Barkla before the discovery of the interference of X-rays in crystals had provided a means for the closer investigation of X-ray spectra. Although the curves generally run very uniformly, they exhibit a number of deviations from uniformity which have been especially brought to light by the recent investigation of Coster, who has for some years worked in Siegbahn's laboratory.

These deviations, the existence of which was not discovered until after the publication of the theory of atomic structure discussed above, correspond exactly to what one might expect from this theory. At the foot of the figure the vertical lines indicate where, according to the theory, we should first expect, in the normal state of the atom, the occurrence of n_k orbits of the type designated. We see how it has been possible to connect the occurrence of every spectral term with the presence of an electron moving in an orbit of a definite type, to the removal of which this term is supposed to correspond. That in general there corresponds more than one curve to each type of orbit n_k is due to a complication in the spectra which would lead us too far afield to enter into here, and may be attributed to the deviation from the previously described simple type of motion of the electron arising from the interaction of the different electrons within the same group.

The intervals in the system of the elements, in which a further development of an inner electron group takes place because of the entrance into the normal atom of electron orbits of a certain type, are designated in the figure by the horizontal lines, which are drawn between the vertical lines to which the quantum symbols are affixed. It is clear that such a development of an inner group is everywhere reflected in the curves. Particularly the course of the N- and O-curves may be regarded as a direct indication of that stage in the development of the electron groups with 4-quantum orbits of which the occurrence of the rare-earths bears witness. Although the apparent complete absence of a reflection in the X-ray spectra of the complicated relationships exhibited by most other properties of the elements was the typical and important feature of Moseley's discovery, we can recognise, nevertheless, in the light of the progress of the last years, an intimate connexion between the X-ray spectra and the general relationships between the elements within the natural system.

Before concluding this lecture I should like to mention one further point in which X-ray investigations have been of importance for the test of the theory. This concerns the properties of the hitherto unknown element with atomic number 72. On this question opinion has been divided in respect to the conclusions that could be drawn from the relationships within the periodic table, and in many representations of the table a place is left open for this element in the rare-earth family. In Julius Thomsen's representation of the natural system, however, this hypothetical element was given a position homologous to titanium and zirconium in much the same way as in our representation in Fig. 1. Such a relationship must be considered as a necessary consequence of the theory of atomic structure developed above, and is expressed in the table (Fig. 9) by the fact that the electron configurations for titanium and zirconium show the same sort of resemblances and differences as the electron configurations for zirconium and the element with atomic number 72. A corresponding view was proposed by Bury on the basis of his above-mentioned systematic considerations of the connexion between the grouping of the electrons in the atom and the properties of the elements.

Recently, however, a communication was published by Dauvillier announcing the observation of some weak lines in the X-ray spectrum of a preparation containing rare-earths. These were ascribed to an element with atomic number 72 assumed to be identical with an element of the rare-earth family, the existence of which in the preparation used had been presumed by Urbain many years ago. This conclusion would, however, if it could be maintained, place extraordinarily great, if not unsurmountable, difficulties in the way of the theory, since it would claim a change in the strength of the binding of the electrons with the atomic number which seems incompatible with the conditions of the quantum theory. In these circumstances Dr. Coster and Prof. Hevesy, who are both for the time working in Copenhagen, took up a short time ago the problem of testing a preparation of zircon-bearing minerals by X-ray spectroscopic analysis. These investigators have been able to establish the existence in the minerals investigated of appreciable quantities of an element with atomic number 72, the chemical properties of which show a great similarity to those of zirconium and a decided difference from those of the rare-earths.[2]

I hope that I have succeeded in giving a summary of some of the most important results that have been attained in recent years in the field of atomic theory, and I should like, in concluding, to add a few general remarks concerning the view-point from which these results may be judged, and particularly concerning the question of how far, with these results, it is possible to speak of an explanation, in the ordinary sense of the word. By a theoretical explanation of natural phenomena we understand in general a classification of the observations of a certain domain with the help of analogies pertaining to other domains of observation, where one presumably has to do with simpler phenomena. The most that one can demand of a theory is that this classification can be pushed so far that it can contribute to the development of the field of observation by the prediction of new phenomena.

When we consider the atomic theory, we are, however, in the peculiar position that there can be no question of an explanation in this last sense, since here we have to do with phenomena which from the very nature of the case are simpler than in any other field of observation, where the phenomena are always conditioned by the combined action of a large number of atoms. We are therefore obliged to be modest in our demands and content ourselves with concepts which are formal in the sense that they do not provide a visual picture of the sort one is accustomed to require of the explanations with which natural philosophy deals. Bearing this in mind I have sought to convey the impression that the results, on the other hand, fulfil, at least in some degree, the expectations that are entertained of any theory; in fact, I have attempted to show how the development of atomic theory has contributed to the classification of extensive fields of observation, and by its predictions has pointed out the way to the completion of this classification. It is scarcely necessary, however, to emphasise that the theory is yet in a very preliminary stage, and many fundamental questions still await solution.

[2] For the result of the continued work of Coster and Hevesy with the new element, for which they have proposed the name hafnium, the reader may be referred to their letters in NATURE of January 20, February 10 and 24, and April 7.