or other constructions in tidal waters built during the years 1918, 1919, or even 1917. As the examination for sex can be conducted with speed only during the breeding season, which may shortly end in some localities, it is hoped that anyone knowing of suitable constructions will inform the writer at the address given below.

Evidence of sex-change is apparently already available from Gemmill's observations,[3] made so long ago as 1896. Gemmill found that 3 specimens out of 250 examined by him were hermaphrodite. In the samples quoted above no definite hermaphrodite forms were found, but several were suspected and preserved for microscopic examination. These forms were, however, mainly male or female, and are recorded above tentatively as males and females respectively. Sex-change may be seasonal, as is indeed indicated by Russell's observations on the sex of the common limpet.[4]

The sex-phenomena in the common limpet closely resemble in most respects those found in the slipper limpet, where the small females and large males are accounted for, but in which all the tiny ones—some thousands of which have now been examined—have a penis. It is, however, not impossible, on the evidence available at the moment, that sexual dimorphism without sex-change may explain the phenomena in the common limpet, but this explanation does not seem probable. The observations on the sex of the common limpet cannot all be described here; they will be continued and completed and the results published in the Journal of the Marine Biological Association, Plymouth. Fig. 1 shows a length-sex analysis of the sample of small limpets under 1 in. in length collected at Plymouth. J. H. ORTON.

The Marine Biological Laboratory,
The Hoe, Plymouth.

A Tribute from Prague.

PERMIT me to congratulate you upon the jubilee issue of November 6, which has just reached me and has been received with great pleasure, for the last number of NATURE which reached me before this was that of July 30, 1914!

It may interest readers of NATURE to learn that from that date the Austrian Government prohibited for more than four years the circulation of anything printed in England as a punishment for the regard which, especially during the war, we have always had for your country, to which, with the other Allies, we owe our liberty. To the bodily sufferings of the war was added isolation from nearly the whole civilised world.

In a year's time I shall celebrate the fortieth anniversary of my introduction to NATURE, for while a student of Owens College, Manchester, I purchased in October, 1880, my first copy of the journal, and since that time I have been an ardent reader, contributor, and even Bohemian correspondent. The reading of NATURE's all-round scientific contents has been one of the greatest pleasures of my life in my leisure hours, and the richness of information which I have gathered from it cannot be expressed in better words than those of Dr. Deslandres in the jubilee number. I do not wonder that all attempts at founding a similar scientific and yet popular (in its best sense) journal in other European countries have invariably failed, for there a man of science is usually identical with a professor (a professional worker); and though I am one myself, yet I am of the opinion that the scientific character of NATURE is in no small measure due to the high type of British scientific amateur or student of science for its own sake, which I do not find equalled in any other country in the world.

Even we scientific workers in this remote part of Europe owe sincere thanks to Sir Norman Lockyer, who is a brilliant representative of the "non-professional" English man of science, for providing us with NATURE and conducting it so admirably for so many years. BOHUSLAV BRAUNER.

Chemical Laboratory, Bohemian University,
Prague, November 17.

EINSTEIN'S RELATIVITY THEORY OF GRAVITATION.[1]

II.—THE NATURE OF THE THEORY.

IN the first article an attempt was made to show the roads which led to Einstein's adventure of thought. On the physical side briefly it was this. Newton associated gravitation definitely with mass. Electromagnetic theory showed that the mass of a body is not a definite and invariable quantity inherent in matter alone. The energy of light and heat certainly has inertia. Is it, then, also susceptible to gravitation, and, if so, exactly in what manner? The very precise experiments of Eötvös rather indicated that the mass of a body, as indicated by its inertia, is the same as that which is affected by gravitation.

Also, how must the expression of Newton's law of gravitation be modified to meet the new view of mass? How, also, must the electromagnetic theory and the related pre-war relativity be adapted to allow of the effect of gravitation? With the relaxation of the stipulation that the velocity of light shall be constant, will the principle of relativity become more general and acceptable to the philosophic doctrine of relativity, or will it, on the other hand, become completely impossible?

One point arises immediately. The out-and-out relativist will not admit an absolute measure of acceleration any more than of velocity. The effect, however, of an accelerated motion is to produce an apparent change in gravitation; the measure of gravitation at any place must therefore be a relative quantity depending upon the choice which the observer makes as to the way in which he will measure velocities and accelerations. This is one of Einstein's fundamental points. It has been customary in expositions of mechanics to distinguish between so-called "centrifugal force" and "gravitational force." The former is said to be fictitious, being simply a manifestation of the desire of a body to travel uniformly in a straight line. On the other hand, gravitation has been called a real force because associated with a cause external to the body on which it acts.

Einstein asks us to consider the result of supposing that the distinction is not essential. This was his so-called "principle of equivalence." It led at once to the idea of a ray of light being deviated as it passes through a field of gravitational force. An observer near the surface of the

[3] "On Some Cases of Hermaphroditism in the Limpet (Patella), with Observations regarding the Influence of Nutrition on Sex in the Limpet." By G. F. Gemmill. *Anat. Anzeiger*, xii., pp. 392–94, 1896.

[4] "On the Shell-growth of the Limpet (*Patella vulgata*)." By E. S. Russell. Proc. Zool. Soc., 1909 (1), p. 236.

[1] The first article appeared in NATURE of December 4

earth notes objects falling away from him towards the earth. Ordinarily, he attributes this to the earth's attraction. If he falls with them, his sense of gravitation is lost. His watch ceases to press on the bottom of his pocket; his feet no longer press on his boots. To this falling observer there is no gravitation. If he had time to think or make observations of the propagation of light, according to the principle of equivalence he would now find nothing gravitational to disturb the rectilinear motion of light. In other words, a ray of light propagated horizontally would share in his vertical motion. To an observer not falling, and, therefore, cognisant of a gravitational field, the path of the ray would therefore be bending downward towards the earth.

The systematic working out of this idea requires, as has been remarked, considerable mathematics. All that can be attempted here is to give a faint indication of the line of attack, mainly by way of analogy.

It is no new discovery to speak of time as a fourth dimension. Every human mind has the power in some degree of looking upon a period of the history of the world as a whole. In doing this, little difference is made between intervals of time and intervals of space. The whole is laid out before him to comprehend in one glance. He can at the same time contemplate a succession of events in time, and the spatial relations of those events. He can, for instance, think simultaneously of the growth of the British Empire chronologically and territorially. He can, so to speak, draw a map, a four-dimensional map, incapable of being drawn on paper, but none the less a picture of a domain of events.

Let us pursue the map analogy in the familiar two-dimensional sense. Imagine that a map of some region of the globe is drawn on some material capable of extension and distortion without physical restriction save that of the preservation of its continuity. No matter what distortion takes place, a continuous line marking a sequence of places remains continuous, and the places remain in the same order along that line. The map ceases to be any good as a record of distance travelled, but it invariably records certain facts, as, for example, that a place called London is in a region called England, and that another place called Paris cannot be reached from London without crossing a region of water. But the common characteristic of maps of correctly recording the shape of any small area is lost.

The shortest path from any place on the earth's surface to any other place is along a great circle; on all the common maps, one series of great circles, the meridians, is mapped as a series of straight lines. It might seem at first sight that our extensible map might be so strained that all great circles on the earth's surface might be represented by straight lines. But, as a matter of fact, this is not so. We might represent the meridians and the great circles through a second diameter of the earth as two sets of straight lines, but then every other great circle would be represented as a curve.

The extension of this to four dimensions gives a fair idea of Einstein's basic conception. In a world free from gravitation we ordinarily conceive of free particles as being permanently at rest or moving uniformly in straight lines. We may imagine a four-dimensional map in which the history of such a particle is recorded as a straight line. If the particle is at rest, the straight line is parallel to the time axis; otherwise it is inclined to it. Now if this map be strained in any manner, the paths of particles are no longer represented as straight lines. Any person who accepts the strained map as a picture of the facts may interpret the bent paths as evidence of a "gravitational field," but this field can be explained right away as due to his particular representation, for the paths can all be made straight.

But our two-dimensional analogy shows that we may conceive of cases where no amount of straining will make all the lines that record the history of free particles simultaneously straight; pure mathematics can show the precise geometrical significance of this, and can write down expressions which may serve as a measure of the deviations that cannot be removed. The necessary calculus we owe to the genius of Riemann and Christoffel.

Einstein now identifies the presence of curvatures that cannot be smoothed out with the presence of matter. This means that the vanishing of certain mathematical expressions indicates the absence of matter. Thus he writes down the laws of the gravitational field in free space. On the other hand, if the expressions do not vanish, they must be equal to quantities characteristic of matter and its motion. These equalities form the expression of his law of gravitation at points where matter exists.

The reader will ask: What are the quantities which enter into these equations? To this only a very insufficient answer can here be given. If, in the four-dimensional map, two neighbouring points be taken, representing what may be called two neighbouring occurrences, the actual distance between them measured in the ordinary geometrical sense has no physical meaning. If the map be strained, it will be altered, and therefore to the relativist it represents something which is not in the external world of events apart from the observer's caprice of measurement. But Einstein assumes that there is a quantity depending on the relation of the points one to the other which is invariant—that is, independent of the particular map of events. Comparing one map with another, thinking of one being strained into the other, the relative positions of the two events are altered as the strain is altered. It is assumed that the strain at any point may be specified by a number of quantities (commonly denoted g_{rs}), and the invariable quantity is a function of these and of the relative positions of the points.

It is these quantities g which characterise the gravitational field and enter into the differential equations which constitute the new law of gravitation.

It is, of course, impossible to convey a precise impression of the mathematical basis of this theory in non-mathematical terms. But the main purpose of this article is to indicate its very general nature. It differs from many theories in that it is not devised to meet newly observed phenomena. It is put together to satisfy a mental craving and an obstinate philosophic questioning. It is essentially pure mathematics. The first impression on the problem being stated is that it is incapable of solution; the second of amazement that it has been carried through; and the third of surprise that it should suggest phenomena capable of experimental investigation. This last aspect and the confirmation of its anticipations will form the subject of the next article.

E. CUNNINGHAM.

LORD WALSINGHAM, F.R.S.

LORD WALSINGHAM, whose death from pleurisy took place on December 3, in his seventy-seventh year, was a man very highly esteemed in many circles, and in none more than in those devoted to the study of natural history. As an entomologist he was greatly distinguished, and the work and influence which he brought to bear in promoting the study of insects were widely known, and have borne much good fruit. His work was not of the type associated with the name of Fabre, the famous French observer, but he by no means neglected the study of the living insect, and was keenly interested in every problem on which entomology could help to throw light. He saw also its economic importance, and he had the wisdom to know how greatly its value in every direction depended upon the accurate identification of species, and how this in its turn depended upon good methods of classification and arrangement, and upon an exact and stable system of nomenclature. His own studies, and such influence as he could exert, were, in consequence, largely directed towards the fundamental work of naming and describing species, and improving the means that would lead to their more easy identification.

From an early age Lord Walsingham gave his time freely to a study of the Microlepidoptera, or small moths, and he lost no opportunity to add to his collection of these obscure but very important insects. He maintained his interest in them up to the last, and, a month or so before his death, he was to be seen still working at them in the Natural History Museum, to which his own very large collection, together with a valuable library of entomological works, had been transferred as a gift in the year 1910. He was elected a trustee of the British Museum in 1876, and a fellow of the Royal Society in 1887. As a trustee of the museum, more especially during the time when he was a member of the Standing Committee, he was always actively interested in its affairs, and it was doubtless due to his initiative that the entomological staff was increased, and entomology afterwards made into a separate department. He would like to have seen the staff still further increased, for he was greatly impressed with the necessity of having a large and competent staff to deal with the rapidly accumulating accessions of specimens.

Lord Walsingham was president of the Entomological Society in 1889–90, and in one of his addresses he pointed out that of the more than two million species of insects estimated to be living on the globe, less than a tithe had been named and described, and the vast majority were still altogether unknown. His entomological publications, beginning in the year 1867, were numerous, and always showed careful and accurate work. They appeared in the "Biologia Centrali-Americana," the "Fauna Hawaiensis," in catalogues of the British Museum, and in the transactions and proceedings of the Entomological, Zoological, and Linnean Societies, to each of which he belonged as a fellow; and also in the *Entomologists' Monthly Magazine,* of which he had been one of the co-editors, as well as in other scientific journals. Entomology, however, was not his only interest; ornithology and other branches of natural history shared in his attentions. He was a traveller and a keen sportsman, and in his time was noted as a great shot. He was a graceful and gifted speaker, and as a man of wide knowledge and good judgment was always listened to attentively at the scientific or other meetings in which he used so frequently to take a part. Although he might have made his mark in almost any sphere of life, Science has reason to be gratified that so great a part of his time and work had been devoted to her service.

NOTES.

THE Electricity (Supply) Bill was read a second time in the House of Lords on December 8.

THE council of the Royal Institute of Public Health has appointed Prof. Maurice Nicoll, of the Pasteur Institute, Paris, Harben lecturer for 1920.

WE regret to learn that Prof. A. Werner, professor of chemistry in Zurich University, Nobel prizeman for chemistry in 1913, and foreign member of the Chemical Society, died on November 15 at fifty-two years of age.

SIR RICHARD REDMAYNE, who has been Chief Inspector of Mines since 1908, will shortly resign his post. He proposes to devote himself in the future to the work of the Imperial Mineral Resources Bureau, of which he is the chairman, and to the practice of his profession as a consulting mining engineer.

THE late Dr. John Aitken bequeathed the sum of 1500*l.* to the Royal Society of Edinburgh for the purpose of publishing in book form a collection of his papers read before various societies. He also left to the Universities of Edinburgh and Glasgow any of his dust, colour, or other apparatus which they may wish to possess.

THE Elliot medal for 1918 of the U.S. National Academy of Sciences has been awarded to Mr. C. W. Beebe, of the New York Zoological Society, on the com-