Science and Hypothesis.

By Sir OLIVER LODGE, F.R.S.

RECENT speculations in mathematical physics, and acquiescence in treatment in terms of unimaginable abstractions, have raised a general question about the use of hypothesis as a means of coordinating observations, stimulating experiment, and paving the way for a theory. It is possible to experiment not only in the laboratory with matter, but in the study also, with symbols; and a great deal of modern mathematics is of an experimental character. A hypothesis is boldly made, some indication of its plausibility having been detected by a flash of genius; it is then developed and its consequences worked out. If the consequences are evidently leading astray, it is abandoned; but if like Planck's, like de Broglie's, and like Bohr's—to go no further—they lead in a helpful direction, yielding results that can be compared with metrical determinations, then the hypothetical formula attracts attention and begins to be accepted as the basis of a partial theory, even though its full significance is not understood, the reasons for it only dimly apprehended, and though the agencies with their mode of working are in the main unknown.

Experience has shown that a working hypothesis may be a true guide so far as it goes, even though it has in the end to be so extensively supplemented as to be revolutionised. The precision attainable varies in different branches of knowledge: only in a few subjects can the results be expressed and checked with numerical accuracy. In physics and astronomy we have grown accustomed to these precise modes of verification, though even here the verification may not substantiate every detail of the original hypothesis or prevent its complete recasting in the light of further knowledge. The quantum was appealed to as somehow securing the stability of Bohr's electronic orbits; but further treatment by Schrödinger put a different complexion on the electron; and the final word has not yet been said. Still, the quantitative results attained by Bohr's theory, spectroscopically verified to many places of decimals, were amply sufficient to justify us in enthusiastically welcoming the partial clue provided.

Not often is such numerical precision attainable; sometimes only the order of magnitude can be checked, and sometimes the agreement with fact is not quantitative at all. Even in chemistry the constitution of certain molecular compounds was arrived at by a special instinct, and was accepted long before physicists began to scrutinise the molecules and ascertain that their constitution was more or less in accord with the intuitions of genius. In biology such direct verification is still far off, and seldom can any theories be brought to the test of quantitative determination. In anthropology and sociology, in addition to all the other difficulties, an element of caprice enters in. Humanity is not so amenable to law and order as molecules are, and individual behaviour can scarcely be predicted or specified with anything approaching completeness. A statistical result may be arrived at, and the average behaviour of a large group can be stated with approximate correctness, subject to disturbing causes. Even in molecular physics the laws of probability tend to supersede the accurate dynamics of individual occurrences, and we have to be satisfied with a sort of average uniformity variegated and enlivened by individual eccentricities.

Psychologists and psychiatrists seek to penetrate the meaning of perverse peculiarities, and to ascertain the laws of individual behaviour so far as they can. The introduction of what we call chance and caprice makes a scientific treatment more difficult, undoubtedly, but it does not prevent the subject from being pursued in a scientific spirit. Methods and results must vary according to subject matter; and what would be vague in physics and chemistry may be unusually definite in subjects like biology and psychology. Even in physics an element of indeterminism has recently been suspected: certainly the molecules of a gas are behaving in an apparently lawless manner, while yet their average or aggregate behaviour on a large scale is satisfactorily uniform.

As to the illegitimacy of hypothesis in science, that is absurd. Every theory began as a hypothesis. It is to test a hypothesis that every elaborately planned experiment is made. As a digression it may be worth insisting that Newton himself constantly made hypotheses,—his queries at the end of "Optics" are a collection of them,—and gravitational astronomy itself must have begun as a hypothesis. When engaged in deductively working out results of theory on a mathematical scheme, he did indeed, and very properly, say, "I am not making hypotheses," using the present tense in a perfectly grammatical and intelligible manner; though the sentence is often mistranslated or misinterpreted in a form covering both past and future, as if he had said, I do not make, or I never make, hypotheses. Which would have been merely false.

The ether of space is a hypothesis; rendered necessary by the complex behaviour and properties which have to be attributed to what we call empty space, that is, space empty of matter. Regarded philosophically it seems impossible to imagine the space between atoms and worlds as really empty; it is only empty of everything that appeals to our senses and is amenable to direct experiment. The nature of space is inferred, and has to be inferred, from its effects on matter; but the inference that there must be something literally 'sub-stantial' in space, which is really responsible for cohesion, elasticity, and all the other manifestations, is inevitable; though in expressing such behaviour (electrical, optical, gravitational) it is the results and not the mechanism that we formulate, for the mechanism seems to be unlike any mechanism with which we are acquainted, and is still essentially unknown.

Objections to the ether are really objections to the nineteenth century conception of an ether expressed

in terms of mechanical models. No such ether exists : the real ether is too fundamental an entity to be expressed in terms of the sensory perceptions of material behaviour, which is what we usually mean by explanation. In so far as it is unexplained and not amenable to experiment—so long as it is a sort of hypothesis *in vacuo*—the ether may be disliked ; just as Newton disliked the introduction of vague and ill-understood causes, preferring to have none at all to account for action at a distance rather than some entity of which he neither knew nor could ascertain anything. Electricity and magnetism were a sealed book then, and Clerk Maxwell was far in the future.

There are, however, sciences of which the working hypotheses must be vague. The mental sciences are peculiarly in that condition ; we cannot treat of mind in any quantitative manner. The trivial details of experimental psychology skirt about the fringe of the subject, collecting data rather like those of old-fashioned meteorology, in the hope that perhaps some day a comprehensive generalisation will arise which can reduce them to law and order.

All this preliminary is for the purpose of (perhaps unnecessarily) insisting that science exists in many stages of development ; and that we are not at liberty to turn down a nascent science merely because it is still in an infantile and unmetrical or even a capricious condition. Human activities cannot be denied merely because they are inaccessible to calculation and defy prediction.

To take an extreme example : What is called the spiritistic hypothesis is flagrantly objected to, for it appeals to the activities of unknown agencies which cannot at present be satisfactorily brought to book. The supposed agents have human characteristics, and behave as if they were like ourselves, except that they are for the most part out of touch with matter, save under special conditions which it is our business to investigate if we can ; whereas we ourselves, when acting as agents, are not only conscious mental and spiritual entities, but are closely and continuously in touch with matter for a period of the order of a century. Our action on matter makes our behaviour conspicuous and easy to observe, but it has not yet led to any explanation. The connexion between mind and matter is still an unsolved problem, the mechanism of it is only very partially understood—the link between mind and brain is missing,—but that does not prevent our accepting the activities of, say, engineers and architects and artists as a fact. They do deal with matter, in accordance with their plans and designs, whether we understand the process or not.

So if hereafter we find ourselves still existing and active, after we have escaped from our normal organism,—if it turn out that under certain conditions we are able to use the organisms of others, so as still to affect material particles, especially the complex molecules of living protoplasm, and thus display surviving intelligence,—we should hope to be met, not by an *a priori* objection as to the possibility of such activity, but rather by a willingness to study the evidence and a determination to be guided by the facts, as in any other better established and more reputable branch of inquiry.

Still, it does happen that even after some prolonged and impartial study of the facts, the hypothesis of what may be called posthumous activity is still disliked and still provisionally rejected as an attempt at explanation. For example, my distinguished friend, Charles Richet, accepts all the phenomena that I do, or even more, but the tentative explanation of some of them as due to discarnate activity does not appeal to him ; or perhaps I should rather say is only very gradually beginning to appeal to him. And there are other less well-known members of the Society for Psychical Research who stand out against the spiritistic view and strive after every other sort of explanation,—thereby doing good service and constraining a supporter of the hypothesis to bring forward constantly better and better evidence and to realise more clearly the objections that have to be met.

Again, I suspect that contributors to NATURE, and the majority of its readers, regard both the hypothesis and the phenomena which led to it with serious doubt and unconcealed dislike ; some indeed pour contempt on the whole thing as a savage superstition. But the occurrence of the phenomena amid all races and in all periods, though it may arouse prejudice, is no valid argument against the reality of something responsible for those widespread superstitions. Our business is to disentangle them from superstition and to dissect out whatever element of truth they may enshrine. For it has been our experience that an element of truth often does underlie old legends. Explorers often discover that old beliefs had a foundation after all ; witness Schliemann at Troy, Sir Arthur Evans at Crete, and many other examples known to archæologists and palæographers. An ancient belief can scarcely give any appreciable support to a scientific hypothesis, but the existence of such belief is not really injurious and is by no means fatal to it. On the whole, the existence of a tradition is rather favourable than otherwise. At worst it is neutral.

OBJECTIONS TO THE SPIRITUALISTIC HYPOTHESIS FROM A SCIENTIFIC POINT OF VIEW.

With this preliminary let me comment on a sentence extracted from a paper which will shortly appear in the *Proceedings of the Society for Psychical Research*, in which an automatic writer who himself has produced script purporting to be inspired by a fairly recently deceased and comparatively unknown poet, expresses himself as sceptical about the ostensible and superficial significance of the scripts in the following words :—

". . . Regarded as a scientific working hypothesis, spiritism does not seem to me to be a very hopeful avenue of investigation. The spirit hypothesis has a delusive appearance of simplicity, but so also had Kepler's hypothesis of guiding angels. And how remote this was from the complex reality of Einstein's description of gravitation ! In fact, if these supernormal mental phenomena depend on the whims and caprices of departed spirits, then I for one despair of ever being able to discover any law and order in them."

Undoubtedly there is some difficulty, in our present state of comparative ignorance, about specifying or formulating the spiritistic hypothesis in any precise and, so to speak, scientific manner; for it is an appeal to the activity of unknown agents acting by unknown methods, under conditions of which we have no experience, and by means of which we are unaware. We get into touch, or appear to get into touch, with these agencies only when they have affected material objects, for example the brain, so as to produce results which appeal to our normal senses. But the admission that we cannot understand how agents work does not justify our denial of the existence of such working. As I have already hinted, a good deal of modern mathematical physics is in the same predicament. We do not really understand how the properties of the ether, or of what it is now the fashion to call 'space-time,' act in producing the material effect we call weight or gravitation. We know a good deal about it; we can specify with precision the law of 'weight' in so far as it imitates the resultant of an independent and unscreened attraction of every particle for every other. We can say that the earth acts nearly as if its whole mass were concentrated at its centre, that the law of force is different inside and outside, so that it changes abruptly when the surface is penetrated, and that the force attains a peak value at the surface, sloping down differently on the two sides. We can speak of the state of strain or 'potential' to which the force is due, say that it is continuous across the boundary, give the law of its variation with distance, and so on.

Newton, in fact, correctly formulated the whole theory of gravitation considered as action at a distance; but the true mechanism of what seems like a condition of strain or warp in space, brought about by the very existence of matter, was beyond him, as it is still beyond us. In philosophic mood, Newton was never satisfied with his mode of specification. It merely gave the resulting effect of something that simulated the direct attraction of one body on another across apparently empty space; he had to leave the inner meaning of such mysterious action for future discovery.

Einstein discarded the attraction or force exerted by a body at a distance, and replaced it by a geometry of space which would account for, or at least express, the resulting behaviour in a more intimate and, so to speak, less magical manner. An inert body can only be perturbed or guided by something in immediate contact with it; even though the particular modification of that 'something,' which enables it so to act, may be due to the neighbourhood of a distant mass of matter, for reasons which remain to be explored.

The fact that we sometimes have to postulate an unknown agency does not justify our attributing anything capricious to that agency. We are ignorant of how the gravitational agent acts, but we know that it acts in accordance with law and order, so that the results can be duly predicted. Einstein's view (if we may call it Einstein's, though in one form or another it must have been vaguely held by many) is after all *not* so very different from Kepler's asserted hypothesis. What Kepler meant by "guiding angels controlling the planets" (assuming that he used that phrase) I do not know, but I am sure he meant nothing capricious. He must have meant that an unknown something guided the planets in their path; and that is a paraphrase of the modern view. The 'something' is now often spoken of as a warp in space. In so far as Kepler postulated something in immediate touch with a planet and acting directly on it, he had what now appears to be truth on his side; his thesis being perhaps nearer the ultimate truth, though far less practically useful, than Newton's delightfully simple quantitative expression for the indirect action of a distant body.

In order to illustrate direct guidance by contact action, we might take the familiar example of a gramophone needle, which automatically reproduces a prearranged tune, simply by following the path of least resistance. What else, after all, can an inert thing do? That is the meaning of inertia. Animated things are not inert; they need not take the easiest path. A man may climb the Matterhorn for fun. But inanimate unstimulated matter never behaves with any initiative or spontaneity; it is strictly inert. Atoms never err or make mistakes; they are absolutely law-abiding. If they make an apparent error, if a locomotive engine leaves its track, we call it a catastrophe. All machinery works on that principle; every portion takes the easiest path. It is true that to get a coherent result there must have been planning and prearrangement. Certainly! In all cases of automatic working, whether biological or other, that must be an inevitable preliminary. But explorers of the mechanism will detect no signs of mental action by their instruments or their senses. To infer a determining or controlling cause they must philosophise. Indeed, we may go a step further, and emerge from the past into the present, thus: A wireless set talks like a gramophone, and to one accustomed only to gramophones it would seem barbarously superstitious to urge that in the wireless case some (possibly whimsical and capricious) operator was actually in control. Statements may be unpalatable, and yet be true.

Now return to gravitation. Planets behave as if they were attracted by the sun. That is certainly true. But what is attraction? A train is not attracted to its destination: lightning is not attracted to a chimney; but it gets there none the less, by continually taking the easiest path. So it is with a planet. Indeed, one might say that everything inert takes the only path open to it, it has no option. The law is a sort of truism. But the principle, once recognised, has been formulated into a clue; the Principle of Least Action can be expressed mathematically. Once postulate that, and the behaviour of the inanimate portions of the cosmos can be accurately deduced.

The modern statement that the planets move along the line of least resistance, or the easiest path, makes their motion rather closely analogous to that of a railway train guided by the rails. The path and destination of a train are determined by the

continual direct influence of the rails, which make it easier for the train to travel in the right direction than to jump them and go astray. We might, if we chose, admit that the path was laid down or determined by the mentality of the surveyors and designers of the route ; but a Martian spectator with partial information might still wonder at the apparent intelligence which guided one part of a train to Manchester, and another part to Liverpool, in accordance with the wishes of the passengers or the labels on the coaches. If told that an invisible guardian angel switched over the points to produce this result, he might resent the suggestion as absurdly unscientific and preposterous ; as on a purely mechanistic view it would be.

After having studied trains for some time, our spectator might begin to notice the novelty of a motor-car. His first tendency would be to look for the rails in that case also ; and, finding none, he might superstitiously but correctly surmise that a guardian spirit was guiding the car to its destination. In this case, moreover, further experience would soon persuade him that he had to allow for an element of caprice. But even that is not fatal to the truth : he need not throw up his hands in despair. As soon as we introduce the activity of life and mind we get out of mere mechanism, and the results are not easily formulated or predicted. The activities of an animal cannot be expressed in mathematical terms, and yet animal instincts and behaviour are subject-matter for scientific investigation. It is assumed that they obey laws of some kind.

Science is not limited to the accurate data and laws of mathematical physics : and to claim that a hypothesis is unscientific because we cannot formulate it completely, or because we do not understood the method of working, or even because there is a certain amount of capriciousness about it, is more than we have any right to claim. Anthropology and sociology are less advanced sciences than physics and chemistry ; they have to get on as best they can, with a profusion of data, and with the inevitable complications appropriate to live things. Let us not be put out of our stride by the fear of retaining, in modified form, some of the animistic guesses of primitive man. Experience may lead us, as it led him, to contemplate stranger modes of existence, and more whimsical phenomena, than our long study of mechanism has led us to expect. We must put aside prejudice, be guided by the evidence, and strive for truth. The superficial simplicity of materialism has served us well, as a comprehensive covering, for three centuries, and we have made good progress under its protection ; but it is beginning to be threadbare and inadequate, it is not co-extensive with reality, and unsuspected influences are peeping through.

To sum up. A working hypothesis can be followed and developed rationally, without being metrically exact in its early stages. The important question about the spiritistic hypothesis is not whether it is simple or complicated, easy or puzzling, attractive or repellent, but whether it is true. Its truth can be sustained or demolished only by the continued careful critical and cautious method of inquiry initiated by the S.P.R. under the presidency of a guiding spirit or guardian angel called Henry Sidgwick, with the active (and I believe continuing) co-operation of Edmund Gurney and Frederic Myers.

The Supply and Therapeutic Uses of Radium.

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THE law of supply and demand is as true for radium as other commodities. Production has often almost ceased owing to lack of demand, only to be renewed as the demand returns, while sudden demands have sent up the price to prohibitive levels until either competition or diminished requirement has brought it down again.

The three main sources from which radium has been mined on any scale are Czechoslovakia, the United States of America, and the Belgian Congo ; Cornwall and Portugal have also been producers, though on a smaller scale. The low grade of the carnotite deposits in U.S.A. made it impossible for America to compete with production from the large deposits of pitch-blende located by the Union Minière du Katanga in its property in the Congo since this rich source has been developed. Czechoslovakia still produces radium, and in Great Britain there is very little difference in the price of radium coming from there or from the Belgian Congo. Unless the amount bought is as much as several grams, the price is at present £12 per milligram of radium element, with extra charges for certificates of measurement and other services connected with the supply. This price is doubtless one which yields a very big profit to the producers, and it is worth while mentioning that the price of the Belgian radium is graded according to the national purse of the buyer—Britain pays more than do her continental neighbours, and America pays more than Britain. There is radium enough in the earth for the world's needs if it can be paid for.

The therapeutic uses of radium are mainly in connexion with cancer, though it is also used for certain other conditions and some dermatological diseases. The outstanding medical interest in radium-therapy is in determining its value and the best methods of application in the treatment of cancer.

Radium-therapy has gone through several phases. In its earliest years, about 1900, success often attended its use in superficial cancers of low malignancy ; this was followed by attempts at dealing with internal growths by implanting radium in platinum or other metal tubes into them. Dominici from 1909 onwards insisted on the necessity of avoiding the use of easily absorbed beta and gamma rays when radium was actually inserted into the tissues, and said that only " les rayons ultra-pénétrants " should be used.