of the latter. The Conference considers that it should as far as possible be representative of the different Provinces and principal States." This Committee was instructed to meet immediately in order to appoint an Executive consisting of not more than five members and one secretary, which was done, Mr. S. H. Prater, M.L.A., of the Prince of Wales Museum, Bombay, being asked to be Secretary. And it was further pointed out that this Committee would not be able to carry on its work without funds for a clerk, type-writer, stationery, etc., as well as for occasional travelling expenses, for which the Government of India was asked to arrange. Such expenses should obviously not be great, however, and could presumably if preferred be contributed by all the various agencies responsible for the upkeep of museums throughout the country, in which case the individual contributions needed would be very small indeed.

In the course of his inaugural address Sir Girja Shankar Bajpai said to the Conference, "You may rest assured that I have not been sent here to read out what some historian of the future, with a turn for irony, might truthfully describe as the official epitaph of the Markham-Hargreaves' report. The Central Government are genuinely anxious to do whatever in them lies to remedy the defects to which that document has given just prominence." As the first step towards remedying them must clearly, if there is to be no Inspector-General, be the establishment of a small and efficient expert committee to devise ways and means of improvement and to take such further steps as seem most practicable for getting them put into practice, these words can only mean that the Central Government are fully prepared to take the necessary initiative in establishing such a committee on a sound basis. And in the interest of a powerful but much neglected means of developing education and general culture throughout the country we urge them to do so without further delay.

Postulates in the Relativity Theories of Gravitation.*

By V. V. Narlikar.

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SINCE Thomson and Tait published their celebrated work which was known at Cambridge, as the Natural Philosophy of T and T', there have been many theories of gravitation and many relativities. The first noted rebel against Newton was Mach and his clearer conceptions of space, time and inertia have considerably influenced modern research. During the last thirty-five years we have had mathematical relativities due to Einstein, Milne, Synge, Page and Sir Shah Sulaiman. To this list may be added the relativities propounded by philosophers like Broad, Levy and others; but these relativities belong to a different region of thought as a remark from Alexander's work will show, *viz.*, that 'Space is the Body of God and Time is His Soul'. During the last few years and particularly the last few months much basic work has been done on relativistic gravitation from the mathematical point of view. Important papers have been published by Milne, Robertson, Walker, Hoffmann and Whitrow. Although the treatment in some of these papers is obscured by unfair criticism a few of the conclusions reached go very deep and they explain the interconnections between different theories. One is amazed to see how results proved in the theory of groups more than thirty years ago come out useful in this connection.

In the Newtonian theory gravitation means attraction. In Einstein's theory gravitation is interpreted in terms of Gaussian curvatures for a Riemannian space-time. In Milne's theory gravitation is to be understood from the kinematical consequences of the cosmological principle. The fact is, as Eddington and Milne have stressed, that there is probably no such thing as a law of gravitation: but there are a number of gravitational situations. The gravitational situations are provided by

* From a lecture delivered at the Mathematical Conference, Lucknow, March 16, 1938.

the 'falling apple' and the shapes, sizes and motions of the celestial bodies. The atomic nature of matter is itself a gravitational situation but no theory has so far succeeded in explaining it. The macroscopic aspects of the world-structure provide many interesting gravitational situations such as the red-shift and structure of the nebulæ and no modern theory of gravitation can be complete without a cosmology of its own. From the scientific point of view a cosmical situation is as important as the Kepler problem and cosmology can no longer be treated as a speculative attempt to reconcile God with gravitation. A gravitational situation is usually attributed to two sets of causes at work: one is recognised as the set of local causes and the other as that of distant causes. The laws of operation exclusively of the distant causes belong to the domain of cosmology. In the Newtonian theory the effect of the distant causes is summed up in the law of inertia according to which every body, in so far as it can, perseveres in its state of rest or of uniform motion in a straight line. This must be recognised as a law of Newton's cosmology. It furnishes a substratum of bodies in uniform rectilinear motion relative to each other. On the background of this substratum the local causes, which are called forces, are studied to obtain the inverse-square law. In Einstein's theory the flat space of the special theory was found to give the substratum but, later, the theory had to be modified and the substratum was found to be given by a non-static model of the universe of the Friedmann-Lemaitre type. The local causes in this theory are found to be responsible for a curved, Riemannian, space. Even in Milne's theory the classification of causes is made in this manner, the distant causes being responsible for the substratum of particle-observers with kinematical and statistical equivalence while the local causes explain the inverse-square law. The acceleration of a test-particle has been expressly split up by Milne into two parts: one due to the local causes and the other due to the distant ones.

One consequence of this splitting up of the causes into two classes is to give rise to the concepts of 'private' and 'public' space, and of 'private' and 'public' time for the sake of recording the two types of phenomena. As Newton assumed the objective existence of the space-time frame he made no distinction between a private space-time and a public space-time. Mach has pointed out the weakness of Newton's ideology in this connection. In the general theory of relativity the term used is cosmic space-time and not public space-time. The current view is that the cosmic space-time is non-static and hyperbolic. But it must be stated that nothing like the last word has been said on this question. Milne's public space-time can also be shown to be non-static and hyperbolic although the private space-time of each of the particle-observers is Euclidean.

A gravitational situation may also be analysed, in contradistinction to the procedure of Newton, Einstein and Milne, into macroscopic local causes and microscopic local causes. The early attempts by Sir Shah Sulaiman to explain gravitation by means of gravitons and the similar attempt by Synge to explain gravitation by similar particles illustrate this procedure. Synge has evidently not made any progress with his hypothesis and Sir Shah, if I understand right, has now abandoned the gravitons-hypothesis. Any theory whose equations run close to those of Newton's may, in certain cases, give results more satisfactory than Newton's or than those of another theory running close to Newton's. In such a case the superiority of one theory over another can be judged only on the merits of the postulates. One should like to see a clear statement of Sir Shah's postulates so that one may compare them to Newton's. The postulates have got to be very carefully chosen as they are likely to land one into a contradiction. Page's work is an illustration of this. He started on Milne's lines but with particle-observers in a state of uniform acceleration relative to each other and when he found that the line-element of Special Relativity could not be obtained he arrived at the conclusion that his relativity had disproved Einstein's relativity. A mistake was in his postulate that the velocity of light is rectilinear and uniform even in the accelerated frame. The transformation that he claimed to have discovered was known to the students of the theory of continuous groups in 1904.

A postulate in Einstein's theory is that the space-time of a gravitational field is Riemannian. One objection to this is that

it limits the nature of physical space.* An observer must have the freedom to choose his geometry. Poincaré has stated that physical space has no objective existence. Whitehead has objected to this postulate from another point of view. He objects to the casual heterogeneity of space-time on grounds that with such a space-time an observer either knows everything or cannot know anything. If the space-time frame is to be constructed by an observer from his own experiences Whitehead's objection is valid and the procedure adopted by Milne in his theory seems to be the correct one. Robertson has tried to show that even with Milne's procedure a Riemannian line-element is obtained. But it is not as general as Einstein's line-element with ten unknown $g_{\mu\nu}$ and while Milne obtains the equations of gravitation from his precedure Robertson has not obtained them. Milne's procedure is as follows.

Milne has introduced the idea of a particle-observer that is an observer who is located at a point, at any instant, like a particle. Every particle-observer is equipped with a theodolite to distinguish one direction from another, an apparatus for sending and receiving light-signals and a time-sense in order to distinguish whether an event E_1 took place before E_2, after E_2 or simultaneously with E_2. The observer is thus able to represent events by real numbers. It is assumed that such an observer can make observations only at himself. He also associates as a convention a constant c with his signals which enables him to define in a simple manner a space-time frame and also the transformation connecting it with the space-time frame of another observer. It may be noted that in the special theory of relativity laws of nature are supposed to run the same course with respect to observers in uniform relative motion but in the general theory the laws are supposed to be expressible by covariant equations with respect to Gaussian transformations. The Restricted Principle is in keeping with Milne's attitude, but according to him, the invariance with respect to Gaussian transformations and not with respect to particle-observers is a very stringent condition put by general relativity. Milne has therefore proposed the cosmological principle. If A and B are two of the particle-observers they are said to be kinematically equivalent when the totality of A's observations on B can be described in the same form as the totality of B's observations on A. A and B are said to be statistically equivalent when A describes the world including A and B in the same statistical terms as any B. If the observers possessing this two-fold equivalence are called privileged observers the cosmological principle says that corresponding to any moving particle P in the field of a privileged observer A there is another similar particle P in the field of any privileged observer B at the same instant. Milne initially adopted the hypothesis that his observers are in uniform relative motion. But Whitrow has been able to show that with a proper graduation of clocks this assumption can be dispensed with.

For the study of local causes Milne introduces a system of test particles in statistical equilibrium satisfying the Cosmological Principle and an equation like Boltzmann's. From the motions of the test particles Milne has been able to deduce the inverse-square law and equations resembling those of Newtonian dynamics when the observer's private time is changed for the public time. It is evidently a defect of the theory that observers cannot be associated with the particles providing the local causes.

It has been recently shown by Whitrow that Milne's cosmological principle can be replaced by a sample principle and the postulate of spherical symmetry applied by each particle-observer in his neighbourhood and not with respect to the entire universe. It is instructive to compare the content of the sample principle with that of the uniformity postulate used by Robertson. Starting from this postulate and with particle observers such as Milne's Robertson deduces the non-static line-element for the universe and also kinematical and statistical systems similar to Milne's. According to the uniformity postulate 'the description of the whole system as given by A in terms of his immediate measurements is to be identical with the description given by any other fundamental observer B in terms of his measurements.' The sample principle is concerned with observations in the observer's neighbourhood while the uniformity

* Whittaker's review of Milne's recent book "Relativity Gravitation and World-Structure," published in *The Observatory*, 1935, may be referred to on this point.

postulate is concerned with world-wide experiences. Walker has also deduced some of the results obtained by Robertson by using the postulate of spherical symmetry. Robertson has particularly stressed the necessity of superposing a law of gravitation on the kinematical system. On the other hand, Milne has proceeded to explain all gravitational situations as essentially kinematical situations. He has argued that it is not right to derive the material content of a non-static universe, as it is done in relativity, by using gravitational equations which account for both the local causes and the distant causes.

One upshot of all these researches is that if Milne is right, a theory of gravitation must be, in the last analysis, divested of conceptional terms and that if there is anything like a law of gravitation it must be tautological with some fundamental uniformity postulate of an observer's measurements in his own neighbourhood; and, if Poincaré is right, a uniformity postulate of this nature should not restrict the geometry of space-time.

Note (added in proof).—The attention of the reader may be drawn to the recent paper by Milne and Whitrand in *Z. für Astrop.*, **15**, 5, 342 where other important references will also be found.

Irregular Meiosis and Abnormal Pollen-Tube Growth Induced by Acenaphthene.

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CHEMICAL agents like chloral-hydrate, chloroform, ether, alcohol, nicotine sulphate, lactic acid, etc., have been used for inducing irregularities in the mitotic and meiotic processes,[1,2,3,4] which might lead to formation of heteroploid and polyploid cells. More effective agents for this purpose are colchicine[5,6,7] and acenaphthene.[7,8,9] These two chemical agents reduce or completely paralize the activity of the factors that condition the arrangements of the chromosomes into a regular metaphase plate (equatorially) and the formation of a regular spindle. In fact, these two phenomena are causally linked. In the previous publications I recorded some data upon the irregularities of the mitosis induced by these two agents. In the present paper I am giving some new data upon the irregularities in the meiosis and abnormalities in the pollen-tube growth induced by acenaphthene.

For studying the effect of acenaphthene upon the procedure of the meiotic processes, shoots with floral buds from *Nicotiana* species were covered with test-tubes (glass) as shown in Fig. 1. The walls of the tubes were moist and covered from inside with acenaphthene crystals, which sublimate small particles that act upon the buds. In some experiments crystals were also put on the buds directly in addition to those on the tube walls. The test-tubes were closed by cotton from downside in order to keep a

FIG. 1.

A tobacco shoot with floral buds covered with a test-tube (glass) and closed from downside with cotton. The inner sides of the tubes are covered with crystals of acenaphthene.

greater concentration of the sublimating particles around the floral buds.

By this method I treated shoots for 2, 3, 4, 5, 6 and 7 days. The parts of the stems that were under the action of acenaphthene particles in the test-tubes get visibly swollen in 6–7 days. The diameters of *Nicotiana longiflora* treated stems, for example, became