for convenience is called zero. If, therefore, a certain area of this is insulated, it can only remain at the potential of the remainder so long as it receives or loses no charge. If it was losing a charge before it was insulated, it can only be kept at zero potential after insulating by supplying it with the charge lost. In 1906 C. T. R. Wilson designed an instrument by means of which an insulated plate could be kept at zero potential while exposed to the atmosphere, and the charge which had to be supplied to do this could be measured. The result proved an actual loss of negative electricity. The amount of this loss was found to be equal to that which can be calculated from a knowledge of the potential gradient and the conductivity of the air.

Realising that the plate in Wilson's instrument did not exactly represent a piece of the ground and that measurements at odd times could always be objected to, a method was developed in Simla by which a continuous record could be obtained of the charge necessary to keep at zero potential a large area—17 square metres—which was to all intents and purposes a part of the surface of the ground. This instrument was in use for nearly a month, and registered a continuous loss of negative electricity. These experiments indicate clearly that during fine weather negative electricity actually passes from the earth into the air. This disposes of the possibility of the lost charge being renewed uniformly over the whole earth by such processes as the fall of charged dust, friction of the air on the earth's surface, or the absorption of ions from the air. The loss over the whole earth is equivalent to a constant current of more than 1000 amperes. As this loss takes place from all regions of the earth, subject to normal or fine weather conditions, it would appear that the return current can only exist in regions of disturbed weather, and it is known that in such regions the potential gradient is often reversed and the rain charged.

A reversed field certainly causes a flow of negative electricity into the earth, but as the time during which the field is reversed in any one place is only a very small fraction of the time during which it is normal, the flow of electricity would have to be enormous if the loss were made good in this way. Such a large flow could not possibly escape detection, and no one has seriously put forward this as a solution of the problem.

There is still the possibility that the electricity comes to the earth in the disturbed area as a negative charge on the rain. For many years this was the most favoured theory for the supply of the negative electricity, but in 1908–9 measurements were made in Simla which showed that there, at least, the rain carried down more positive than negative electricity. Since then many measurements have been made on the electricity of rain, and now we have before us the results of observations made in Porto Rico, Simla, Vienna, Potsdam, Puy-en-Velay and Dublin. In every one of these cases the Simla result is confirmed, and there can be no doubt now that in all kinds of rain, from the intense rain of thunderstorms to the drizzle of a depression, more positive than negative electricity is brought to the earth. Thus rain, instead of solving our problem, has made it more difficult.

It has been suggested that the charge may be returned in the lightning of thunderstorms. Prof. Schuster has discussed this point in his recent book, "The Progress of Physics" (p. 150), and comes to the conclusion: "It does not seem to me, judging by present information, that lightning discharges from cloud to earth can play an important part in increasing or diminishing the charge of the earth," and there are other reasons, not mentioned by Prof. Schuster, for coming to the same conclusion.

We have now discussed the conditions in disturbed areas and have not found the return current, for neither the reversed field, the precipitation, nor the lightning provides it. Thus the science of atmospheric electricity has come to a deadlock, and there is at present no indications of a way out.[1] We may sum up the position in the following statement. A flow of negative electricity takes place from the surface of the whole globe into the atmosphere above it, and this necessitates a return current of more than 1000 amperes; yet not the slightest indication of any such current has so far been found, and no satisfactory explanation for its absence has been given.

GEORGE C. SIMPSON.

PROF. FRIEDMANN'S TREATMENT OF TUBERCULOSIS.

THE announcement of the successful application of any new method of treating tuberculosis must always arouse intense interest and create new hope among those who are suffering from, or waging war against, this disease. For the latest of these, devised by Prof. Friedmann, of Berlin, it appears to be claimed that it acts not only curatively in cases where tuberculosis has already commenced, but prophylactically where there exists a danger of infection to those not already tuberculous. A large number of cases have been treated in Berlin and Vienna, and it is said that where the disease is not far advanced it is cut short, and that in children as yet unaffected the tissues and organs have been protected against the invading tubercle bacillus. This therapeutic agent appears to be some form or preparation of a non-virulent tubercle bacillus or some bacillus nearly allied which has been deprived of its toxic constituents or products.

In view of the outcome of the experiments made by the Royal Commission on Tuberculosis on the immunisation of animals by the use of injections of living tubercle bacilli, it is almost to be desired that the vaccine is of the nature of a prepared proteid and does not contain any living bacilli, however modified. Judging from the accounts we

[1] Prof. Ebert has proposed an explanation, but against it fatal objections have been raised. Those interested might consult the series of articles which appeared in the *Physikalische Zeitschrift* between March, 1904, and December, 1905.

have seen of the method, it can scarcely be a modification of the "immune body" treatment, with which, it is maintained, some success has been attained. It appears more likely that we have to deal with some modification of Calmette and Guerin's method, in which the bovine tubercle bacillus is cultivated on a glycerinated medium to which a small proportion of ox-bile has been added. Here, after about forty generations of such culture, the bacillus becomes so far modified that when injected intravenously into the bovine animal it is incapable of setting up an active tuberculous process, and so modifies the tissues and especially the wall of the alimentary canal of the treated animal that an ordinary culture of a virulent "bovine" bacillus is no longer able to retain its position in the tissues of the host, and, consequently, is unable to set up any tuberculous process.

It is, of course, too early to pronounce any definite opinion, either favourable or adverse, on these various methods. It must be realised that a certain proportion of the cases in which there is tuberculous infection recover without any special treatment; that others recover when supplied with plenty of fresh air, good food, and when the hygienic conditions generally are favourable, and that these agencies are called into play by all who are engaged in the intelligent study and treatment of tuberculosis.

SIR GEORGE HOWARD DARWIN, K.C.B., F.R.S.

GEORGE DARWIN, whose decease occurred at Cambridge on Saturday, December 7, came, as is well known, of illustrious scientific lineage, having been born in 1845 at Down, the second son of Charles Darwin, author of "The Origin of Species," and thereby the renovator of the biological sciences. Like many contemporaries who attained to distinction in scientific pursuits, his school education was gained under the Rev. Charles Pritchard, F.R.S., afterwards Savilian professor of astronomy at Oxford. He went up to Trinity College, Cambridge, in 1864, graduated as second wrangler and second Smith's prizeman in 1868, the present Lord Moulton being senior; he was elected a fellow of Trinity the same year, and enjoyed the statutory tenure of ten years. In addition to mathematical subjects, he was interested in economic and political science, and with a view to practical life was called to the Bar in 1874. About this time he wrote a well-known statistical memoir on the marriage of first cousins, an early example of the present exact investigations in cognate biological domains. Considerations of health, however, prompted his return to Cambridge, where he devoted himself to mathematical science, especially in its astronomical aspects. He had already initiated his most striking contributions to the subject of the evolution of the solar system, especially the moon-earth system, and to cosmogony in general, when he was elected to the Plumian chair of astronomy and experimental philosophy in 1883. He was re-elected fellow of Trinity, as professor, in 1884, and his marriage dates from the same year.

If one were asked to name a domain in which the power of mathematical analysis had conspicuously asserted itself over phenomena apparently most complex and fortuitous, the prediction of the tides up to their closest details, by procedure now systematised so that it can be applied almost without technical skill, would surely come to mind. The principles of the application of harmonic analysis to this subject were laid down by Laplace, following up the beginnings established long before by Newton; but it was a far cry from this to actual systematic performance. The outstanding name in this magnificent achievement is that of Lord Kelvin, whose intellectual energy kept the subject to the fore, while his inventive genius originated the machines by which calculations too long and laborious for arithmetical processes were reeled off automatically. But it is very doubtful whether tidal practice, in which British methods dominate the world, or the refinements of tidal theory, would stand in their present completeness if Kelvin had not enjoyed the good fortune, when he was himself getting submerged in other problems, of finding a colleague so imbued with the subject, so expert and tenacious amid the complexities of numerical calculation, as George Darwin proved himself to be. His tribute to Lord Kelvin, to whom he dedicated volume i. of his Collected Scientific Papers, which relates to this subject, gave lively pleasure to his master and colleague:—

> Early in my scientific career it was my good fortune to be brought into close personal relationship with Lord Kelvin. Many visits to Glasgow and to Largs have brought me to look up to him as my master, and I cannot find words to express how much I owe to his friendship and to his inspiration.

The practical developments of tidal theory and prediction were published to the world in a series of reports to the British Association, worked out mainly by Darwin, from the year 1883 onward. In 1879 he had broken ground in another direction, entirely fresh. The recognition of lunar tidal friction as a cause of lengthening of the day goes back to Kant. The problem as to how the tidal loss of energy is divided between the earth's rotation and the lunar orbit had baffled Airy; it had been shown by Purser that the principles of energy and momentum conjointly can lead to its solution; but it remained for Darwin to develop, by aid of graphical representations which have become classical, most striking inferences regarding the remote past history of our satellite. This discovery was the starting point of a series of memoirs in the next subsequent years, which applied similar procedure to the precession of the equinoxes and to other features of the solar system.

In the later years of last century, during Lord Kelvin's meteoric visits to Cambridge to attend the annual meetings of the Fellows of Peterhouse,