

can do this by assuming the star to be in a steady state." This I cannot believe to be possible.

Prof. Eddington now says that the star "must settle into a state of density and temperature which would produce an outward flow at the required rate." Perhaps; but surely Prof. Eddington's original contention was that the rate of outward flow could not be affected by density and temperature, but depended only on the mass.

J. H. JEANS.

London, July 13.

I AM in general agreement with Mr. Jeans's remarks on the difficulty of obtaining a source of stellar energy more powerful than the Helmholtz contraction. It may be added that there is a conceivable source, which was, I believe, once suggested by Mr. Jeans himself, viz. a gradual annihilation of matter by positive and negative electrons occasionally neutralising one another. This would provide an almost inexhaustible store of energy, but there is the grave objection that it affords no reason why the dense dwarf stars should liberate so much less energy than rarefied stars of the same mass. One would have expected compression to be favourable to the process of cancelling of electrons. The search for an additional store of energy is not at all encouraging; but, on the other hand, there are important arguments against the short time-scale—notably Prof. Strutt's evidence of the age of terrestrial rocks, and the time needed for the tidal evolution of the earth-moon system. I have not felt myself able to combat the arguments on one side any more than on the other; accordingly, in the paper criticised by Mr. Jeans, the question was left entirely open. In the one place where it was necessary to consider the source of stellar energy, I attempted to show that my formula fairly represented both the radio-activity and the contraction hypotheses—having regard to the necessarily approximate character of the investigation.

The opinions in the last paragraph of Mr. Jeans's letter seem much too sweeping. It is desirable to criticise them, because his disbelief in my results is presumably a corollary to his rejection of the possibility of obtaining information from consideration of a stationary or quasi-stationary state. If energy were generated at a fixed rate within the star, the radiation would no doubt have to take place at the same rate; but to bring this about the star must settle into a state of density and temperature which would produce an outward flow of energy at the required rate. We have thus a triangular equation—generation of energy=theoretical emission (depending on the transparency and temperature-distribution)=observed emission (given by the effective temperature). Mr. Jeans assumes that the imposed rate of generation must necessarily be involved in any results that are derived. But we can dispense altogether with the first member, and obtain "new knowledge" from the equation which remains.

July 11.

I AM afraid we can scarcely trespass on your space to enter on the detailed discussion which seems necessary in order to arrive at an understanding. In a paper about to appear in the June *Monthly Notices* I have rearranged my analysis in what is, I believe, a more lucid form. If Mr. Jeans finds the result still unsatisfactory, I hope he will renew the attack in another place.

With regard to his final point, I may give a word of explanation. It is true that I find that the total radiation of a giant star depends only on the mass—to my order of approximation. If a different rate of genera-

tion of energy, fixed and independent of the density, were imposed, the star could not settle permanently in the giant state. If the supply were too small the star would contract, though more slowly than on the Helmholtz theory, and ultimately attain equilibrium in the dwarf state. The case of too large supply scarcely needs to be considered, since it involves an evolution in the reverse direction from that generally accepted. This may, perhaps, be regarded as additional evidence of the difficulty of obtaining a long time-scale by assuming an unrecognised source of energy.

A. S. EDDINGTON.

Cambridge, July 17.

#### FORESTS AND RAINFALL.

THERE are several questions regarding the mutual relations of natural phenomena that appear at first sight so simple that the obvious answers may be received for generations as too clear to require reconsideration. One of these is the influence of forests on rainfall. It seems so natural that if a large area of bare ground is planted with trees which grow into a forest the moisture of the district will be increased by increasing rainfall, diminishing run-off, and, in hot countries, falling temperature, that one scarcely stops to inquire on what evidence the belief is based. Everyone must remember the vivid picture drawn in Marsh's "Man and Nature" of the desolation wrought in Palestine and other Mediterranean lands by desiccation consequent on the destruction of forests and abandonment of cultivation. But in that work, as in most of the writings on this and cognate questions, the motto of the discussion might be *post hoc, ergo propter hoc*.

The problem has been attacked by innumerable writers in Europe and America, and we do not profess to have the mass of heterogeneous literature at our finger-ends. We do, however, retain a general impression of unsatisfactoriness in the methods and results, and the impression is renewed by the latest contribution to the subject, the Indian Forest Bulletin, No. 33. This consists of a "Note on an Inquiry by the Government of India into the Relation between Forests and Atmospheric and Soil Moisture in India," prepared by Mr. M. Hill, Chief Commissioner of Forests of the Central Provinces. Mr. Hill has presented an admirable *précis* of what must be a large mass of official documents, and he appends two excellent memoranda by Dr. Gilbert Walker, the Director-General of Observatories in India. That the good work of Mr. Hill should leave an unsatisfactory impression is not his fault, but his misfortune in having to deal with official reports instead of plain scientific data. The history of the investigation as set out in the bulletin is briefly this:—

In 1906 Lord Morley, then Secretary of State for India, sent to the Viceroy a note from Dr. J. Nisbet, formerly of the Indian Forest Service, pointing out that "the relation of forests towards the mitigation of the severity of famines" had never been adequately considered. Sir William Schlich forwarded with Dr. Nisbet's letter his



opinion that an investigation of the influence of forests on rainfall would be very difficult and unlikely to lead to any definite result. Nevertheless, the Government of India sent out to all the local Governments a request that the subject should be inquired into and all available information collected. In due time the local Governments sent in reports on their own provinces, and these are tersely summarised by Mr. Hill with an admirable neutrality, which nevertheless fails to conceal the fact that the reports differed widely in quality. The general result is stated officially as follows:—

“After a careful examination of the replies received from local Governments, as summarised above, and after consultation with the Director-General of Observatories, the conclusions arrived at by the Government of India were briefly that the influence of forest on rainfall was probably small, but that the denudation of the soil, owing to the destruction of forests, might, as far as India is concerned, be looked upon as an established fact; while as regards the effect of forest preservation on rainfall and the underground water supply, the papers forwarded did not provide sufficient information to justify any change in the principles on which the forest policy of the Government has hitherto been based. It was remarked that these principles were founded mainly on considerations of a directly economic character, connected with the conservation of the grazing resources and forest produce of the country, and that the climatological considerations did not in any way affect these well-established principles.”

The Government of India forthwith sent a second series of questions to the local Governments with the view of ascertaining whether experiments might not be instituted in order to obtain fresh data. These dealt with the local differences within and without forest areas in rainfall, soil water level, and height and duration of floods. The local Governments duly prepared and sent in reports, which were considered by the Government of India in consultation with the Board of Scientific Advice, and the final decision, expressed in five paragraphs, may be summarised thus:—(1) Meteorological stations in specially selected positions inside and outside forest areas would probably yield valuable results, and “if it be found possible to initiate inquiries of this nature further action would be taken.” (2) Observations on soil water level need not be initiated, as the data would be of little value in showing forest influence. (3) Satisfactory experiments on floods could not easily be undertaken, but the belief that forests are beneficial in this respect is confident and almost universal. (4) No material change in the forest area of any province seemed to be contemplated, but if such changes should be made the Government of India desired that local Governments should make efforts to ascertain the effect of such changes on average rainfall. (5) The system of shifting cultivation, by which large areas of forest are annually destroyed in Native States and elsewhere, should be discouraged.

To our mind the method adopted could produce

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no better result than it appears to have done. In a scientific problem such as was set forth, the only function of the State seems to us to be to decide that such an inquiry shall be carried out at the public expense, and that every facility for obtaining data shall be given by all the departments of all the Governments concerned, local and central. It should then be handed over to a competent man of science set free from all other duties and supplied with necessary assistants. His report when complete would be authoritative and epoch-making, if not final, and incidentally his own reputation would be made or marred by his handling of the facts. The total expense would probably be no greater, and the labour of many public servants would not be diverted from the work for which they were trained.

Dr. Gilbert Walker's contributions on the relation of forests and rainfall are given as appendices, but are deprived of most of their scientific value by the omission of the tables and diagrams to which constant reference is made. These, of course, have been published in the memoirs of the Indian Meteorological Department. Dr. Walker fully grasps the difficulty of the inquiry. He shows that in India, as elsewhere, the annual rainfall has a tendency to run in spells of excessive and deficient years, and that if this fact is neglected totally false conclusions as to the influence of forest growth or destruction could easily be arrived at. He lays stress also on the short period available for comparisons on account of the very untrustworthy nature of the Indian rainfall statistics in the earlier years of the work of the Meteorological Department.

Dr. Walker considers that, as Blanford pointed out in 1887, “the only satisfactory evidence would be that obtained by comparing the rainfall of a district when well supplied with forests with that of the same district when the trees were very few.” In our opinion the comparison should not be that of a district A at the time  $t$  with the same district at the time  $t'$ ; but to compare the relation of district A to a contiguous district B at the time  $t$  with the relation of A to B at time  $t'$ , where A is a district that has undergone a great change as regards forest covering, while B has remained unchanged. The reason for this indirect comparison is, of course, to eliminate the effect of the two periods falling in what Prof. H. H. Turner calls different climatic chapters. Another method would be to determine the relation of the isohyetal lines to the configuration of the land on wooded and treeless districts of similar character. As pointed out in the report on the rainfall in the Geological Survey's “Water Supply Memoirs of Hampshire,” the district of the New Forest shows a considerably higher general rainfall than its elevation above sea-level appears to suggest. The subject is both fascinating and important, and the time will no doubt come when increase of accurate observations will enable the vague belief in the beneficial influence of forests on climate to be supported or corrected by definite meteorological evidence.

HUGH ROBERT MILL.