"The instruments would be returned, in perfect order, as soon as possible after the transit, and, in any case, before the end of 1883.

"All communications should be addressed to the Secretary, Transit Committee, Royal Society, Burlington House."

The Committee, we are informed, is constituted as follows:—The President of the Royal Society is the chairman, the other members being Prof. J. C. Adams, the Astronomer-Royal, the Earl of Crawford and Balcarres, Mr. De la Rue, Mr. Hind, Dr. Huggins, Vice-Admiral Sir G. H. Richards, Prof. H. J. S. Smith, Prof. Stokes, and Mr. E. J. Stone.

DR. J. J. BIGSBY

YET another of the links that have bound the geologists of the present time in association with the early leaders of their science has been severed by the removal of the kindly and venerable form of Dr. Bigsby. Upwards of sixty years ago he began his geological career in North America, devoting himself mainly to the investigation of the structure of the older Palæozoic rocks of Canada and of the adjoining tracts of the States. As secretary to the Boundary Commission under the Treaty of Ghent he had opportunities of investigating the region from Quebec to Lake Superior, and published numerous descriptions, of which the exactness has been amply verified by the subsequent researches of the Geological Survey of Canada. It is chiefly as an admirable pioneer in Canadian geology that his name will be inscribed in the records of scientific progress. But he has other claims to grateful remembrance. Since he returned to spend his later years in this country he has devoted himself with the most untiring patience to the compilation of his "Thesaurus Siluricus" and "Thesaurus Devonicus"—works in which the geological and geographical range of the organisms of the earlier half of Palæozoic time is clearly shown in a series of valuable tables.

Still more recently, in 1877, he presented to the Geological Society a bronze medal which, with a sum of money derived from the interest of a fund also given by him, is to be awarded every two years as an incentive to geological study. The terms according to which he directed that the prize should be given are that the medal and interest from the fund should be awarded "as an acknowledgment of eminent services in any department of geology, irrespective of the receiver's country; but he must not be older than forty-five years at his last birthday, thus probably not too old for further work, and not too young to have done much." The founder lived to see two fitting awards of his prize go to the eminent palæontologists of the United States, Professors O. C. Marsh and E. D. Cope. He died just before the third presentation was made, last week, to Dr. Charles Barrois of Lille.

ON TIDAL FRICTION IN CONNECTION WITH THE HISTORY OF THE SOLAR SYSTEM[1]

THIS paper forms one of a series on the subject of tidal friction which have been read from time to time before the Royal Society and reported in NATURE.

The first part of the paper contains the investigation of the changes produced by tidal friction in the system formed by a planet with any number of satellites revolving about it in circular orbits. As the results cannot be conveniently stated without the aid of mathematical notation, they are here passed over.

The previous papers treated of the effects which tidal friction must have had on the motions of the earth and moon, on the supposition that time enough has elapsed for this cause to have its full effect. It then appeared that we are thus able to co-ordinate together the various elements of the motions of these two bodies in a manner too remarkable to be the product of chance.

The second part of the present paper contains a discussion of the part which the same agency may have played in the evolution of the solar system as a whole and of its several parts.

It is first proved that the rate of expansion of the planetary orbits, due to the reaction of the frictional tides raised by the planets in the sun must be very slow compared with that due to the reaction of the tides raised by the sun in the planets. Thus it would be much more nearly correct to treat the sun as a rigid body, and to suppose the planets alone to be subject to frictional tides, than the converse. It did not, however, seem expedient to attempt to give any numerical solution of the problem thus suggested which should apply to the solar system as a whole.

The effect of tidal friction is to convert the rotational momentum of the tidally disturbed body into orbital momentum of the tide-raising body. Hence a numerical evaluation of the angular momentum of the various parts of the solar system will afford the means of forming some idea of the amount of change in the orbits of the several planets and satellites, which may have been produced by tidal friction. Such an evaluation is accordingly made in this paper, with as much accuracy as the data permit.

From the numerical values so found it is concluded that the orbits of the planets round the sun can hardly have undergone a sensible enlargement from the effects of tidal friction since those bodies first attained a separate existence.

Turning to the several sub-systems, it appears that, although it is possible that the orbits of the satellites of Mars, Jupiter, and Saturn about their planets may have been considerably enlarged, yet it is certainly not possible to trace the satellites back to an origin almost in contact with the present surfaces of their planets, in the same manner as was done for the case of the moon in the previous papers.

The numerical values above referred to exhibit so marked a contrast between the case of the earth with the moon, and that of the other planets with their satellites, that it might *à priori* be concluded as probable that the modes of evolution have differed considerably. The conclusion above stated concerning the satellites of the other planets cannot therefore be regarded as unfavourable to the acceptance of the views maintained in the previous papers. It must, however, be supposed that some important cause of change other than tidal friction has been concerned in the evolution of the solar system and the planetary sub-systems. According to the nebular hypothesis of Laplace, that cause has been the condensation of the heavenly bodies. Accepting that hypothesis, the author then proceeds to consider the manner in which contraction and tidal friction are likely to have worked together.

A numerical comparison shows that, notwithstanding the greater age which the nebular theory assigns to the exterior planets, yet the effects of solar tidal friction in reducing planetary rotation must in all probability be considerably less for the remote than for the nearer planets. It is, however, remarkable that the number expressive of the rate of retardation of the Martian rotation by solar tidal friction is nearly the same as the similar number for the earth, notwithstanding the greater distance of Mars from the sun. This result is worthy of notice in connection with the fact that the inner satellite of Mars revolves with a periodic time much shorter than that of the planet's rotation; for (as suggested in a previous paper) solar tidal friction will have been com-

[1] An account of a paper entitled "On the Tidal Friction of a Planet attended by several Satellites, and on the Evolution of the Solar System," by G. H. Darwin, F.R.S., read before the Royal Society on January 20, 1881.

petent to reduce the planetary rotation without directly affecting the satellite's orbital motion.

It is then shown to be probable that solar tidal friction was a more important cause of change when the planets were less condensed than it is at present. Thus we are not to accept the present rate of action of solar tidal friction as indicating that which has held true in all past time.

It is also shown that if a planetary mass generates a large satellite, the planetary rotation is reduced after the change more rapidly than before; nevertheless the genesis of such a satellite is preservative of the moment of momentum which is internal to the planetary sub-system. This conclusion is illustrated by the comparatively slow rotation of the earth, and by the large amount of angular momentum residing in the system of moon and earth.

An examination of the manner in which the difference of distances of the various planets from the sun will have affected the action of tidal friction leads to a cause for the observed distribution of satellites in the solar system.

According to the nebular hypothesis a planetary mass contracts, and rotates quicker as it contracts. The rapidity of the revolution causes its form to become unstable, or perhaps, as seems more probable, an equatorial belt gradually detaches itself; it is immaterial which of these really takes place. In either case the separation of that part of the mass which before the change had the greatest angular momentum permits the central portion to resume a planetary shape. The contraction and increase of rotation proceed continually until another portion is detached, and so on. There thus recur at intervals a series of epochs of instability or of abnormal change.

Now tidal friction must diminish the rate of increase of rotation due to contraction, and therefore if tidal friction and contraction are at work together the epochs of instability must recur more rarely than if contraction acted alone.

If the tidal retardation is sufficiently great, the increase of rotation due to contraction will be so far counteracted as never to permit an epoch of instability to occur.

Now the rate of solar tidal friction decreases rapidly as we recede from the sun, and therefore these considerations accord with what we observe in the solar system. For Mercury and Venus have no satellites, and there is a progressive increase in the number of satellites as we recede from the sun.

Whether this be the true cause of the observed distribution of satellites amongst the planets or not, it is remarkable that the same cause also affords an explanation of that difference between the earth with the moon and the other planets with their satellites, which has permitted tidal friction to be the principal agent of change with the former, but not with the latter.

In the case of the contracting terrestrial mass we may suppose that there was for a long time nearly a balance between the retardation due to solar tidal friction and the acceleration due to contraction, and that it was not until the planetary mass had contracted to nearly its present dimensions that an epoch of instability could occur.

If the contraction of the planetary mass be almost completed before the genesis of the satellite, tidal friction, due jointly to the satellite and the sun, will thereafter be the great cause of change in the system, and thus the hypothesis that it is the sole cause of change will give an approximately accurate explanation of the motion of the planet and satellite at any subsequent time. It is shown in the previous papers of this series that this condition is fulfilled with the earth and moon.

The paper ends with a short recapitulation of those facts in the solar system which are susceptible of explanation by the theory of the activity of tidal friction. This series of investigations affords no grounds for the rejection of the nebular hypothesis, but while it presents evidence in favour of the main outlines of that theory, it introduces modifications of considerable importance.

Tidal friction is a cause of change of which Laplace's theory took no account, and although the activity of that cause is to be regarded as mainly belonging to a later period than the events described in the nebular hypothesis, yet its influence has been of great, and in one instance of even paramount, importance in determining the present condition of the planets and their satellites.

G. H. D.

INDIGO

IN July, 1878, an account was given in this journal of the synthesis of indigo-blue from phenylacetic acid, accomplished by Prof. Baeyer of Munich (NATURE, xviii. 251). The process there described did not permit of the successful production of indigo-blue on a manufacturing scale at reasonable cost. Since that time Prof. Baeyer has continued to work at the problem, and he has so far succeeded that he has now taken out a patent for the artificial manufacture and application of indigo-blue.

In a paper in the last number of the *Berliner Berichte* Baeyer gives an interesting *résumé* of the steps whereby progress has been slowly made, since 1865, in solving the problem of the synthesis of indigo.

Following up the work sketched in the article already referred to, Baeyer attempted to prepare *orthonitrophenyl acetic aldehyde*, expecting that this substance would yield indol, which may be regarded as the parent substance of the indigo group of compounds. But as the work proceeded Baeyer became more and more convinced that the hypothesis which had guided his earlier work was that which should still regulate his experiments. In 1869 he had written, "In order to prepare indol synthetically it is necessary—in accordance with the formula already given—to introduce a pair of carbon atoms and one nitrogen atom into benzene, and to link these together. The necessary conditions are found in *nitro-cinnamic acid*, if one supposes carbon dioxide and the oxygen of the nitro-group to be removed. And indeed it has been shown that nitro-cinnamic acid yields indol by fusion with potash." The steps in the preparation of indigo-blue, according to Baeyer's patent, are these:—

1. *Cinnamic acid* (or *phenyl acrylic acid*)—

$$C_6H_5 . C_2H_2 . CO_2H.$$

2. *Orthonitrocinnamic acid*—

$$C_6H_4\begin{cases}NO_2\\C_2H_2 . CO_2H.\end{cases}$$

3. *Orthonitrocinnamic acid dibromide*—

$$C_6H_4\begin{cases}NO_2\\C_2H_2Br_2 . CO_2H\ ;\end{cases}$$

prepared by acting on No. 2 with gaseous bromine and crystallising from benzene.

The dibromide in alcoholic solution is then treated with alcoholic potash, in the proportion of 1 : 2 molecules; and after dilution with water

4. *Orthonitromonobromcinnamic acid*—

$$C_6H_4\begin{cases}NO_2\\C_2HBr . CO_2H,\end{cases}$$

is precipitated. By again treating this acid with three molecules of alcoholic potash

5. *Orthonitrophenylpropiolic acid*—

$$C_6H_4\begin{cases}NO_2\\C_2 . CO_2H\end{cases}$$

is produced. When an aqueous solution of this acid is warmed with such feeble reducing agents as grape- or milk-sugar, in presence of caustic or carbonated alkali, indigo-blue separates in crystals. It is not however