to the naked eye. But what most struck me at first in this animal was that it seemed literally to have no other nourishment than the coarse sand by which it was surrounded. And then when, armed with scalpel and microscope, I ascertained something of its organisation, what unheard-of marvels were revealed! In this body, the walls of which scarcely reach the sixteenth part of an inch in thickness, I could distinguish seven distinct layers of tissue, with a skin, muscles, and membranes. Upon the petaloid tentacles I could trace terminal suckers, which enabled the Synapta to crawl up the side of a highly-polished vase. In short this creature, denuded to all appearance of every means of attack or defence, showed itself to be protected by a species of mosaic, formed of small, calcareous, shield-like defences, bristling with double hooks, the points of which, dentated like the arrows of the Carribeans, had taken hold of my hands. If one of these Synapta is preserved alive in sea-water for a short time, and subjected to a forced fast, a very strange phenomenon will be observed. The animal, being unable

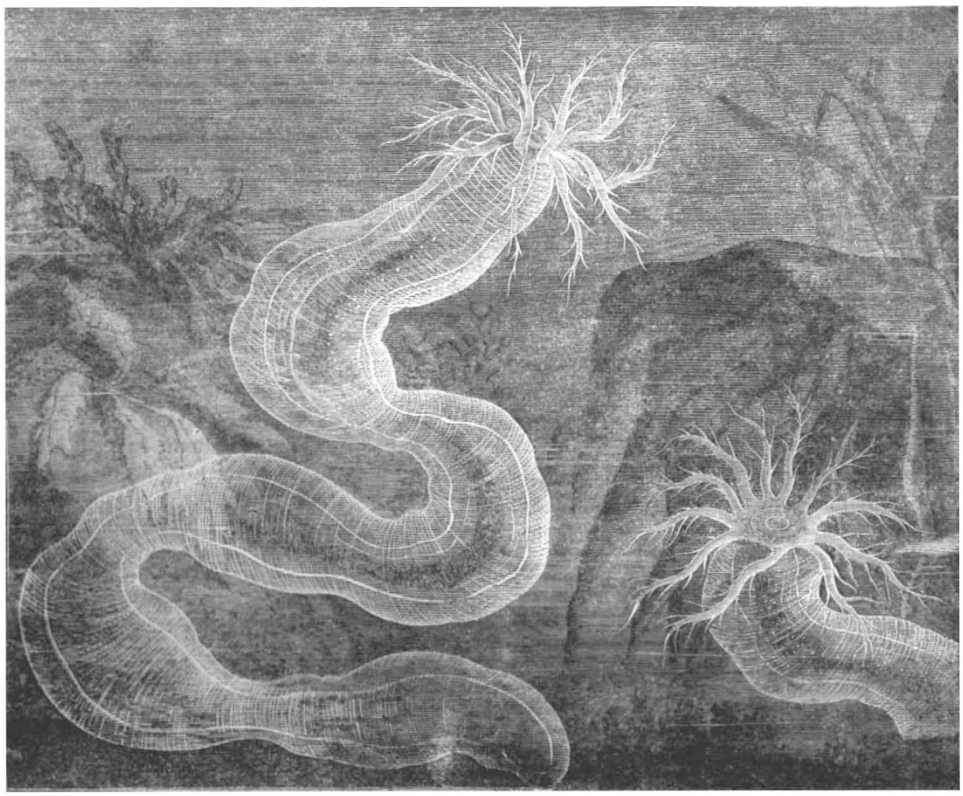

FIG. 3.—*Synapta duvernea.*

to feed itself, successively detaches various parts of its own body, which it amputates spontaneously."

Although most of the illustrations in this volume are very good, and some are good works of art, there are also several which are very poor, and quite unworthy of the text. This is especially the case among the smaller birds, several of which are unrecognisable. A few also have been wrongly named, representing very different creatures from those they are said to be. The most prominent defects of this kind are the figure of the Leucoryx antelope, which is named *Saiga tartarica*, and that of two humming birds, which do duty for sun-birds. These oversights, which no doubt occurred in the London office, since they are far too gross to be imputed to the author of the book, should be corrected in another edition; and if the publishers will substitute better figures for those of the stone-chat, hedge-sparrow, dipper, Java-sparrows and some others which are barely recognisable, the work will be one of permanent use and interest, both as an illustrated manual of the families of the vertebrata and a popular introduction to general natural history.

A. R. W.

ON THE SECULAR CHANGES IN THE ELEMENTS OF THE ORBIT OF A SATELLITE REVOLVING ABOUT A PLANET DISTORTED BY TIDES[1]

THE investigation which forms the subject of this paper is entirely mathematical, and is therefore not of a kind to be easily condensed into a short account.

This paper is the fifth of a series (of which notices have from time to time appeared in NATURE) in which I have endeavoured to trace the various effects on the configuration of a planet and satellite, which must result from tidal friction—the tides in the planet being either a bodily distortion or oceanic. The investigations are, I think, not without interest as a branch of pure dynamics, but this side of the subject is too complicated to be made intelligible without mathematical notation, and it would occupy too much space to explain the methods of treatment.

There is, however, another side of the subject, which must, I think, attract notice, or at least criticism, and this is the applicability of the results of analysis to the history of the earth and of the other planets.

[1] An account of a paper by G. H. Darwin, F.R.S., read before the Royal Society, on December 18.

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We know that no solids are either perfectly rigid or perfectly elastic, and that no fluids are devoid of internal friction, and therefore the tides raised in any planet, whether consisting of oceanic tides or of a bodily distortion of the planet, must be subject to friction. From this it follows that the dynamical investigation must be applicable to some extent to actual planets and satellites. For myself, I believe that it gives the clue to the history of the system, but of course an ample field for criticism is here opened.

The investigation is intended to be more especially applicable to the case of the earth and moon, and therefore, instead of planet and satellite, the expressions earth and moon are used.

The effect of tidal friction upon the eccentricity and inclination of the lunar orbit here affords the principal topic. The obliquity of the ecliptic, the diurnal rotation of the earth, and the moon's periodic time were considered in a paper read before the Royal Society on December 19, 1878, and which will appear in the *Philosophical Transactions* for 1879.

The present paper completes (as far as I now see) the main investigation for the case of the earth and moon, and therefore it is now possible to brings the various results to a focus.

It appears then that, when we trace backwards in time the changes induced in the system of the earth and moon by tidal friction, we are led to an initial state which is defined as follows:—

The earth and moon are found to be initially nearly in contact; the moon always opposite the same face of the earth, or moving very slowly relatively to the earth's surface; the whole system rotating in from two to four hours, about an axis inclined to the normal to the ecliptic at an angle of 11° 45′, or somewhat less; and the moon moving in a circular orbit, the plane of which is nearly coincident with the earth's equator.

This initial configuration suggests that the moon was produced by the rupture, in consequence of rapid rotation or other causes, of a primeval planet, whose mass was made up of the present earth and moon. The coincidence is noted in the paper, that the shortest period of revolution of a fluid mass of the same mean density as the earth, which is consistent with an ellipsoidal form of equilibrium, is two hours twenty-four minutes; and that if the moon were to revolve about the earth with this periodic time, the surfaces of the two bodies would be almost in contact with one another.

The rupture of the primeval planet into two parts is a matter of speculation, but if a planet and satellite be given in the initial configuration above described, then a system bearing a close resemblance to our own, would necessarily be evolved under the influence of tidal friction.

The theory postulates that there is not sufficient diffused matter to materially resist the motions of the moon and earth through space. Sufficient lapse of time is also required. In a previous paper I showed that the minimum time in which the system could have degraded from the initial state, just after the rupture into two bodies, down to the present state, is fifty-four million years. The time actually occupied by the changes would certainly be much longer.

It appears to me that a theory, reposing on a *vera causa*, which brings into quantitative correlation the lengths of the present day and month, the obliquity of the ecliptic and the inclination and eccentricity of the lunar orbit, must have considerable claims to acceptance.

It was stated that the periodic times of revolution and rotation of the moon and earth might be traced back to a common period of from two to four hours. In a previous paper the common period was found to be a little over five hours in length; but that result was avowedly based on a partial neglect of the sun's attraction. In this paper certain further considerations are adduced, which show that, while the general principle remains intact, yet the common period of revolution of the earth and moon must initially have been shorter than five hours to an amount which is uncertain, but is probably large. The period of from two to four hours is here assigned, because it is mechanically impossible for the moon to revolve about the earth in less than two hours, and it is uncertain how the rupture of the primeval planet took place.

But if tidal friction has been the agent by which the earth and moon have been brought into their present configuration, then similar changes must have been going on in the other bodies which make up the solar system. I will therefore make a few remarks on the other satellites and planets.

In the first place it is in strict accordance with the theory, that the moon should always present the same face towards the earth. Helmholtz, was, I believe, the first who suggested tidal friction as the cause of the reduction of the moon's axial rotation to identity with her orbital motion. It is interesting to note in this connection that the telescope seems to show that the satellites of Jupiter, and one at least of the satellites of Saturn, also have the same peculiarity.

The process by which tidal friction brings about the changes in the configuration of a planet and satellite is a destruction of energy (or rather its partial conversion into heat within the planet, and partial redistribution), and a transference of angular momentum from that of planetary rotation to that of orbital revolution of the two bodies about their common centre of inertia.

Now a large planet has both more energy of rotation and more angular momentum; hence it is to be expected that large planets should proceed in their changes more slowly than small ones.

Mars is the smallest of the planets, which are attended by satellites, and it is here alone that we find a satellite revolving faster than the planet rotates. This will also be the ultimate fate of our moon, because after the joint lunar and solar tidal friction has reduced the earth's rotation to an identity with the moon's orbital motion, the solar tidal friction will continue to reduce it still further, so that the earth will rotate faster than the moon revolves.

Before, however, this can take place with us, the moon must recede to an enormous distance from the earth, and the earth must rotate in forty or fifty days instead of in twenty-four hours. But the satellites of Mars are so small, that they would only recede a very short way from the planet, before the solar tidal friction reduced the planet's rotation below the satellite's revolution. The rapid revolution of the inner satellite of Mars may then, in a sense, be considered as a memorial of the primitive rotation of the planet round its axis.

The planets Jupiter and Saturn are very much larger than the earth, and here we find the planets rotating with great speed, and the satellites revolving with short periodic times. The inclinations of the orbits of Jupiter's satellites to their "proper planes" are very interesting from the point of view of the present theory.

The Saturnian system is much more complex than that of Jupiter, and it seems partially in an early stage of development and partially far advanced.

The details of the motions of the satellites are scarcely well enough known to afford strong arguments either for or against the theory.

I have not as yet investigated the case of a planet or star attended by several satellites, but perhaps future investigations may throw further light both on the case of Saturn, and on the whole solar system itself.

The celebrated nebular hypothesis of Laplace and Kant supposes that a revolving nebula detached a ring, which ultimately became consolidated into a planet or satellite, and that the central portion of the nebula continued to contract, and formed the nucleus of the sun or planet.

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The theory now proposed is a considerable modification of this view, for it supposes that the rupture of the central body did not take place until it was partially consolidated, and had attained nearly its present dimensions.

I do not pretend, in these remarks, to have thoroughly discussed the cases of the other planets, and have only drawn attention to a few salient features; in the paper itself the subject is considered at greater length. It will, however, I think, be admitted that the theory agrees with some remarkable facts in the solar system.

G. H. DARWIN

THE SEXUAL COLOURS OF CERTAIN BUTTERFLIES

DR. SCHULTE, of Fürstenwalde, has called my attention to the beautiful colours which appear on all four wings of a butterfly, the *Diadema bolina*, when looked at from one point of view. The two sexes of this butterfly differ widely in colour. The wings of the male, when viewed from behind, are black with six marks of pure white, and they present an elegant appearance; but when viewed in front, in which position, as Dr. Schulte remarks, the male would be seen by the female when approaching her, the white marks are surrounded by a halo of beautiful blue. Mr. Butler, also showed me in the British Museum an analogous and more striking case in the genus Apatura, in which the sexes likewise differ in colour, and in the males the most magnificent green and blue tints are visible only to a person standing in front. Again with Ornithoptera the hind wings of the male are in several species of a fine golden yellow, but only when viewed in front; this holds good with *O. magellanus* but here we have a partial exception, as was pointed out to me by Mr. Butler, for the hind wings when viewed from behind change from a golden tint into a pale iridescent blue. Whether this latter colour has any special meaning could be discovered only by some one observing the behaviour of the male in its native home. Butterflies when at rest close their wings, and their lower surfaces, which are often obscurely tinted, can then alone be seen; and this it is generally admitted, serves as a protection. But the males, when courting the females, alternately depress and raise their wings, thus displaying the brilliantly coloured upper surface; and it seems the natural inference that they act in this manner in order to charm or excite the females. In the cases above described this inference is rendered much more probable, as the full beauty of the male can be seen by the female only when he advances towards her. We are thus reminded of the elaborate and diversified manner in which the males of many birds, for instance the peacock, argus pheasant, &c., display their wonderful plumage to the greatest advantage before their unadorned friends.

The consideration of these cases leads me to add a few remarks on how far consciousness necessarily comes into play in the first acquirement of certain instincts, including sexual display; for as all the males of the same species behave in the same manner whilst courting the female, we may infer that the display is at least now instinctive. Most naturalists appear to believe that every instinct was at first consciously performed; but this seems to me an erroneous conclusion in many cases, though true in others. Birds, when variously excited, assume strange attitudes and ruffle their feathers; and if the erection of the feathers in some particular manner were advantageous to a male whilst courting the female, there does not seem to be any improbability in the offspring which inherited this action being favoured; and we know that odd tricks and new gestures performed unconsciously are often inherited by man. We may take a different case (which I believe has been already advanced by some one), that of young ground birds which squat and hide themselves when in danger immediately after emerging from the egg; and here it seems hardly possible that the habit could have been consciously acquired just after birth without any experience. But if those young birds which remained motionless when frightened, were oftener preserved from beasts of prey than those which tried to escape, the habit of squatting might have been acquired without any consciousness on the part of the young birds. This reasoning applies with special force to some young wading and water birds, the old of which do not conceal themselves when in danger. Again a hen partridge when there is danger flies a short distance from her young ones and leaves them closely squatted; she then flutters along the ground as if crippled, in the wonderful manner which is familiar to almost every one; but differently from a really wounded bird, she makes herself conspicuous. Now i is more than doubtful whether any bird ever existed with sufficient intellect to think that if she imitated the actions of an injured bird she would draw away a dog or other enemy from her young ones; for this presupposes that she had observed such actions in an injured comrade and knew that they would tempt an enemy to pursuit. Many naturalists now admit that, for instance, the hinge of a shell has been formed by the preservation and inheritance of successive useful variations, the individuals with a somewhat better constructed shell being preserved in greater numbers than those with a less well constructed one; and why should not beneficial variations in the inherited actions of a partridge be preserved in like manner, without any thought or conscious intention on her part any more than on the part of the mullusc, the hinge of whose shell has been modified and improved independently of consciousness. CHARLES DARWIN

Down, December 16, 1879

NOTES

WE are much pleased to be able to announce that the Committee of the British Association for the Exploration of Socotra have secured the services of Dr. I. B. Balfour, Professor of Botany at Glasgow, as naturalist. Besides many other qualifications for the post Dr. Balfour has recently taken part in the execution of a similar piece of work as one of the naturalists attached to the station for the observation of the Transit of Venus at Rodriguez. Dr. Balfour will leave for Aden on the 9th inst., and proceed thence to Socotra.

M. PERRIER, the head of the French Survey, has been appointed a Member of the Academy of Sciences. It may be remembered that M. Perrier is a commander on the staff, and has just accomplished one of the greatest geodetic feats on record, the connection of the South of Spain with the Algerian province of Oran. M. Perrier is a supporter of M. Roudaire's scheme, and his appointment is considered likely to accelerate the work of the survey for the great Saharan Railway.

WE are pleased to see that a movement is on foot to erect an educational natural history museum in Perth, as a memorial to the late Sir Thomas Moncrieffe, president of the Perthshire Natural History Society. From a statement sent us by Dr. Buchanan White, we notice that the organisers have a rational idea of what such an institution should be, and their scheme is a comprehensive one, having in view the education of the citizens of the ancient burgh, as well as the collection of objects of natural history connected with the county. A generous citizen of Perth, Mr. Robert Pullar, offers 500*l.* of the 2,000*l.* which it is estimated the building will cost.

M. E. LEVASSEUR, a well-known French geographer, has invented an amusing and instructive geographical game, to which he gives the name of "Tour du Monde." It is played on a large terrestrial globe divided into 232 spherical rectangles, each of which has a number, corresponding to a number on a list,

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