gested with pains and skill to make a thoroughly good book. However, the present work is not very faulty in its omissions.

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DARWIN'S TIDES

The Tides and Kindred Phenomena in the Solar System.

By George Howard Darwin. Boston: Houghton, Mifflin & Co. 1898. 8vo, pp. 378.

CSP, identification: Haskell, *Index to* The Nation. See also: Burks, *Bibliography*; *List of Articles*; MSS L 159.99, L 159.101; MS 1411b (s) (draft).

George Howard Darwin (1845-1912), the son of Charles Darwin, was a mathematician and astronomer. He received his formal education at Trinity College, Cambridge, taking a B.A. degree in 1868. He served as Plumian professor of astronomy and experimental philosophy at Cambridge from 1883 until his death. Darwin was an authority on tidal theory, geodesy, and dynamical meteorology.

There are probably not a great many people who feel any burning desire to know just how the tides behave, and just why they behave as they do, and just how predictions of them are made; so that this book may not be much sought after at the mere mention of its title. Readers of it must pass around from mouth to mouth how interesting it is, and how much the author had made of a seemingly most refractory subject. He has shown us that it is possible to write a popular book upon a branch of mathematics without childishness, without sensationalism, and to give it a real value for him who is versed in the science as well as for him to whom it is all new.

The variety of topics that are found pertinent to the general theme is astonishing. No less than twenty chapters treat of nineteen different questions, each of great interest quite apart from the rest, but at the same time the whole nineteen have such a unity that we cannot say that any one of them could have been omitted without serious detriment to the general sketch of this branch of science.

All these topics are so interesting that we hardly know which ones to choose in order to give our readers an idea of the contents of the volume. Perhaps chapter ii., partly (no doubt) from its giving the first marked impression of the work, is as striking as any. It relates to "seiches" in lakes. The word "seiche" is vernacular, we believe, only on the shores of Lake Leman, where alone this phenomenon has attracted the general attention of the inhabitants. It is a rise and fall of the water on the shore of the lake of a few inches, sometimes with a period of about an hour, sometimes in a less regular way. This phenomenon has been investigated, not by a mathematician or physicist, but by a naturalist of the school of De Saussure and De Candolle (not to leave the shore of the lake for exemplars), Dr. Forel of Lausanne, a town well placed for observing the seiches. It is interesting to see the methods of observation of this naturalist in physics; they are very ingenious, and are such as a physicist would hardly have lit upon. The observations render the nature of the seiches quite evident. The commonest are just like the slopping of a tea-cup carried in the hand—that is, the whole mass

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of water of the lake rocks about a nodal line in the middle. In other seiches there are two nodes or even more; but these are infrequent. It is important, in view of phenomena presently to be mentioned, to note the periodic times of these oscillations. The uninodal seiches are observed to have a period of 73 minutes, the binodal of 35 minutes. Ordinary visible waves on the lake have a period of 4 to 5 seconds. Intermediate between these there are waves having a height of from 1-25 to 1-10 of an inch, and of periods of from 45 seconds to 4 minutes. Of course, they can be observed only by a delicate recording instrument. Some of these waves, which Dr. Forel designates as "vibrations," are due to the wind, but the most interesting ones are caused by steamboats. When a steamboat running at full speed is still twenty-five minutes from the pier, as soon as she rounds a point that gives a clear way for the wave the vibrations are plainly marked upon the instrument. After the boat leaves, they are much more violent, and it is more than two hours after her departure before they disappear. These waves are entirely unlike anything that can be seen with the naked eye, as their periods show.

As we have space only for one other example of the interest of the matter of this volume, we will pitch almost at haphazard upon chapter xvi., on tidal friction. Since the tide-wave moves with the moon and sun, from east to west, while the earth rotates daily from west to east, it is plain that the friction of the tide against the earth tends to retard the earth's rotation. Now, since it is the action of the moon that mainly makes the tidal wave, and, therefore, thus retards the earth, and since action and reaction are always equal and opposite, it follows that the moon in thus drawing the earth towards the east must itself be drawn towards the west. But that is the direction in which the moon is moving in its revolution round the earth; and thus the motion of the moon in its orbit is accelerated, as the comparison of ancient and modem observations shows it to be. This acceleration of the moon's velocity causes it to fly off a little further from the attracting centre of the earth, and enlarges its orbit, and the complete revolution in this enlarged orbit takes more time than that in the unenlarged orbit; but since the day is also considerably longer, there are fewer days in the month than there were at first. All this is familiar to everybody who has recently read a good treatise on astronomy. But at this point Mr. Darwin starts a most interesting question. Namely, he asks when this process of gradual recession of the moon from the earth could have first begun. Clearly it must have been going on whenever the moon was making tides upon the earth. It must, therefore, be traced back to the time when the moon was so close to the earth as to form one mass with it, when it would, of course, make no tides. But however the moon came to be thrown off from the earth, it would be likely to preserve its linear velocity tangential to the earth, while, the circumference in which it moved being larger than the earth, the month from the very start must have been longer than the day, which is sufficient to insure the recession of the moon. M. Poincaré, a mathematician of great genius from Nancy, has shown that one form that a mass of liquid rotating about an axis in equilibrium might have, would be a pear-shape, the axis of the pear being at right angles to the axis of rotation. Now there can be little doubt that the pro-

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tuberance at the stem of the pear would tend to become a bulb and finally to be thrown off from the rest. What would ensue? The tides caused by the earth's attraction in the satellite so formed would tear it to fragments. The fragments near the earth would be just small enough to hold together, those further away would be larger, while the part of the satellite farthest from the earth would form a satellite of such a size as to be distant from the earth about two and a half of its diameters, which would be the moon. The small pieces nearest the earth would probably return to the earth. Those somewhat further away may very likely be there yet; for any appearance of them could be distinguished from the zodiacal light only by more careful observations than any that have yet been made. This theory of the genesis of the moon seems to us, we must confess, not so "wild a speculation" as the author is willing to grant that it is.

The only chapters of the book with which we cannot feel ourselves quite satisfied are those which deal with mathematical arguments. We are here sometimes at a loss to understand what it is that the author is aiming at. He seems to be *explaining* the reasoning of the mathematician. But mathematicians, especially when they are dealing with the most difficult applications of mathematics, have not been inventing abstruse and difficult ways of reasoning; on the contrary, they have been trying with all their might to find the simplest and easiest ways; and they are men of great genius and training in finding out simple methods of reasoning. By far the shortest way to understand the reasoning of the mathematician about the tides is to begin by buying a book on the calculus; and when that is mastered, to go through with the rest of the course required for a thorough understanding of hydrodynamics. Any pretended "explanation" of the reasoning shorter than this either is fallacious, or covers only a small and insufficient piece of the reasoning for even a vague conclusion, or it is open to both criticisms.

The author, in his preface, has this remark:

"A mathematical argument is, after all, only organized common sense, and it is well that men of science should not always expound their work to the few behind a veil of technical language, but should from time to time explain to a larger public the reasoning which lies behind their mathematical notation."

There is more than one fallacy here. In the first place, the term common sense, the middle term of the first half-expressed syllogism (whose strict conclusion Mr. Darwin would not have found it convenient to state), is ambiguous. Common sense, in the proper acceptation of the term, resides mainly in the subconscious department of the mind. It informs us how things go in this world of ours, and in this world exclusively. It has nothing whatever to say about the pure hypotheses of the mathematician, and therefore has no bearing whatever upon mathematical reasoning. But it appears that in the sentence quoted something quite different is meant, which is called "common sense" only because these words impart that popular tone and the *bonhomie* which the author is endeavoring to assume. What seems to be meant is, that each step of the mathematical argument is perfectly evident to the vulgar equally with the learned, to the mathematically dull as much as to the mathematically bright, *provided he clearly apprehends the premises.* But this proviso

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contains the whole difficulty. Every mathematical premise contains so many elements, so intricately related, that most minds are unable to apprehend the proposition distinctly. The abibility to do so is precisely what makes the mathematical mind. It is impossible to dissect a mathematical reasoning so that the mathematically very dull can apprehend it, because, when the dissection reaches a certain point, the logical relations become different; and the result is a fallacy.

It is not true, then, in any acceptation of the terms, that a mathematical argument is only organized common sense. As for what is said about a "veil of technical language," it involves an egregious begging of the question. The technical language of science is composed of words intended to aid the search after truth by facilitating the work of the mind in dealing with complicated conceptions. If, instead of fulfilling that purpose, it is that Talleyrand dialect which veils the thought, it ought to be altogether spurned, and will be so treated by every real devotee of science. But the "language" which Mr. Darwin has in mind is not speech—it is the language of algebra and the calculus. To the disciple of Lagrange and Laplace, the analytical formula is simply the most perfect possible description of the hypothetical phenomena. It is something into which geometrical representations ought to be translated, being itself as near pure thought as it is in the nature of thought to be. When it comes to such a question as the phase of a forced oscillation, especially of an oscillation in two dimensions (and such is the problem of the tides), the frankest way is to leave the mathematical argument untouched in that utmost simplicity to which generations of the most skilful reasoners have been able to bring it. By all means illustrate any steps of it that you can, by parallels drawn from familiar experience; but do not attempt to "explain" that which, on the contrary, must explain your explanation. Is there one bicyclist in five hundred who thoroughly understands why his wheel behaves as it does? Is there one in fifty who does not imagine that it stands up because of its rectilinear velocity? How utterly visionary, then, it is to attempt to popularize the mathematics of any less familiar and still more intricate subject.

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