Letters to the Editor.

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Earth Tides, Ocean Tides, and Local Geology.

IT was a source of satisfaction to me to read Dr. J. W. Evans's letter in NATURE of July 12, p. 49, and to note that he recognises the importance of a further study of earth tides. I quite agree with him in thinking that more earth-tide work is likely to be done if seismographic apparatus is adapted to that purpose than if observations are made only with an apparatus of the Michelson-Gale type, or with other apparatus equally refined and specialised. The results that can be obtained with seismographic instruments seem to me well worth having, even if the curves do not show the beautiful smoothness of those of the Michelson-Gale apparatus.

I am obliged, however, to differ with Dr. Evans, for reasons presently to be stated, in regard to the importance which he assigns to the local geology as a cause of anomalous results. Although our knowledge of the tides at sea and our command of mathematical methods are not sufficient for a rigorous computation of the effects of ocean tides on earth tides of like period, nevertheless they are sufficient not only to estimate the order of magnitude of these effects, but also to determine roughly their amount. It thus appears that the effects of the ocean tides are large enough to explain the observed anomalies in the earth tides, and that, in the cases treated by the Japanese investigators cited in my communication to NATURE of June 21 (vol. 113, p. 889), they do explain the anomalies quite as well as the inaccuracies of the method would allow one to expect. Furthermore, the influence of the local geology, although it must exist, is easily seen to be small. The French phrase for earth tides, *marées de l'écorce terrestre*, might seem to imply that earth tides are essentially a crustal phenomenon. Of course, we can observe only in or near the surface of the crust, but the tidal forces extend down to the centre of the earth, and, unless the matter of which the earth is composed is absolutely rigid, the tidal yielding must extend down to the centre also.

We may conceive the earth as divided into concentric spheroidal shells, and we may further suppose that the outermost shell is so thick that within it local geological differences die out, and that every shell within is homogeneous. The tide-producing force is a body force, acting on each particle of matter. Each shell receives the tidal distortion due to all the shells within it, and adds a small contribution of its own.[1] The tidal distortion of the outermost shell is mainly what it receives from the shells within, for we assume that the hypothetical shells never lose contact with one another. They are formed by mere hypothetical boundaries which we insert for our own convenience into a continuous body. The yielding of different parts of the outermost shell to tidal forces must be somewhat different, corresponding to local geologic and geographic conditions, but this difference must be decidedly small in comparison with the whole distortion accumulated from the centre outward.

In the preceding paragraphs the earth tides proper alone have been considered, not the secondary effects of ocean tides of like period. In respect to the latter, the local geologic conditions might be of more importance than in respect to the primary earth tides, for the ocean tides exert a surface pressure, not a body force acting from centre to surface like that which causes the primary earth tides. Even here, however, the effect of local conditions is probably not important, for the secondary effect of the oceanic tides becomes large only when the oceanic tide, that is, the surface pressure, is in approximately the same phase over large tracts of ocean. But when the pressure is applied over a large area it goes deep, that is, a considerable depth must be attained before the effects of surface pressure become small in comparison with the values at the surface. In thus going deep the pressure involves portions of strata that presumably are nearly alike all over the earth and depend but little for their properties on the geology and geography of the portions of the outermost stratum directly above them. The earth tides show the effect of the yielding of the earth as a whole, and to this the outer crust will generally contribute but a small part.

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[1] The outer shells, of course, react on the inner shells, which therefore behave differently from what they would if the outer shells were absent.

The Resonance Theory of Hearing.

IT is surprising that the resonance theory of hearing continues to be revived in one form or another. As soon as the ear is considered in relation to the other sense organs, it becomes apparent that all forms of resonance theory are profoundly unsatisfactory and unphysiological.

In the course of evolution the hearing apparatus derives from the tactile sense. In primitive fishes we have the organs of the lateral line. One of these, placed at the cephalic end, becomes invaginated to form the otic vesicle, which develops into the complicated membranous labyrinth. At first, the sensations are purely tactile, being shocks transmitted through the watery medium. When the surrounding medium becomes air, and the vibrations assume a periodic character, these are registered in the cochlea —a derivation of the otic vesicle—and perceived as sound. Why is the ear alone of all sense organs credited with the capacity for analysing the particular stimulus to which it is adapted to react ? We do not claim this faculty for other organs. The retina perceives white light and does not analyse this into its component spectrum. If there are any analysing structures in the fundus of the eye, these are admittedly scattered all over the retina. The skin, it is true, possesses separate end organs for the sensations of pressure, pain, cold, and heat. But who has ever imagined one end organ which will register say 40° C., and that particular temperature only, while another registers 45° ? Yet it is an apposition of a series of such separately functioning end organs in the cochlea that the supporters of the resonance theory ask us to accept.

The analogy which compares the fibres of the basilar membrane to piano strings continues to appear in all the text-books of physiology. A continuous, very small, spread-out membrane, varying in width from the base upwards in the proportions of approximately 1 and 10, is supposed to contain a series of end organs which must number at least 2000. Each is delicately attuned to vibrate in sympathy with one periodic vibration only. This marvellous collection of resonators must be fully developed at birth. It must remain unchanged throughout life, from the moment a baby picks up sounds until