the surrounding membrane. If T be constant or symmetrical about the axis of the body, the body is symmetrical. But the abnormal eggs that a hen sometimes lays, cylindrical, annulated, or quite irregular, are due to local weakening of the membrane, in other words, to asymmetry of T. Not only asymmetry of T, but also asymmetry of p_n, will render the body subject to deformation, and this factor, the unknown but regularly varying, largely radial, pressure applied by successive annuli of the oviduct, is the essential cause of the form, and variations of form, of the egg. In fact, in so far as the postulates correspond near enough to actualities, the above equation is the equation of *all eggs* in the universe. At least this is so if we generalise it in the form $p_n+\frac{T}{r}+\frac{T'}{P'}=P$ in recognition of a possible difference between the principal tensions.

(9) In the case of the spherical egg it is obvious that p_n is everywhere equal. The simplest case is where $p_n=0$, in other words, where the egg is so small as practically to escape deforming pressure from the tube. But we may also conceive the tube to be so thin-walled and extensible as to press with practically equal force upon all parts of the contained sphere.

(10) If while our egg be in process of conformation the envelope be free at any part from external pressure (that is to say, if $p_n=0$), then it is obvious that that part (if of circular section) will be a portion of a sphere. This is not unlikely to be the case actually or approximately at one or both poles of the egg, and is evidently the case over a considerable portion of the anterior end of the plover's egg.

(11) In the case of the conical egg with spherical ends, as is more or less the case in the plover's and the guillemot's, then at either end of the egg r and r' are identical, and they are greater at the blunt anterior end than at the other. If we may assume that p_n vanishes at the poles of the egg, then it is plain that T varies in the neighbourhood of these poles, and, further, that the tension T is greatest at and near the small end of the egg. It is here, in short, that the egg is most likely to be irregularly distorted or even to burst, and it is here that we most commonly find irregularities of shape in abnormal eggs.

(12) If one portion of the envelope were to become practically stiff before p ceases to vary, that would be tantamount to a sudden variation of T, and would introduce asymmetry by the imposition of a boundary condition in addition to the above equation.

(13) Within the egg lies the yolk, and the egg is invariably spherical or very nearly so, whatever be the form of the entire egg. The reason is simple, and lies in the fact that the yolk is itself enclosed in another membrane, between which and the outer membrane lies a fluid the presence of which makes p_n for the inner membrane practically constant. The smallness of friction is indicated by the well-known fact that the "germinal spot" on the surface of the yolk is always found uppermost, however we may place and wherever we may open the egg; that is to say, the yolk easily rotates within the egg, bringing its lighter pole uppermost. So, owing to this lack of friction in the outer fluid, or white, whatever shear is produced within the egg will not be easily transmitted to the yolk, and, moreover, owing to the same fluidity, the egg will easily recover its normal sphericity after the egg-shell is formed and the unequal pressure relieved.

GEODETIC INVESTIGATIONS IN THE UNITED STATES.[1]

THE report of the U.S. Coast and Geodetic Survey for 1907 has just been received. For the details of the extensive cartographic work of the bureau in the United States proper, Alaska, Porto Rico, and the Philippines, as well as for the account of the progress of the primary triangulation and levelling of precision, the report itself must be consulted. Certain important work of the survey receives bare mention, as, for instance, the results of the investigation of the earth's figure, based on geodetic operations in the United States. This is owing to the fact that these results were communicated to the International Geodetic Association in a preliminary report which has been published.

Soon after the California earthquake of April 18, 1906, it became evident that the permanent horizontal displacements of large areas covered by triangulation in California had so changed the lengths and directions of the lines joining the triangulation stations as greatly to diminish the value of the triangulation for its primary purpose as a framework for future surveys. During the year, therefore, new triangulation extending from Point Arena to stations south of Monterey Bay was done, which serves to restore the value of the old triangulation by determining the new positions of sixty-one of the old triangulation stations. The triangulation included the Farallon Lighthouse, twenty-two miles to the westward of the great fault accompanying the earthquake, and the stations Mocho and Mount Diablo, thirty-three miles to the eastward of the fault. The new triangulation serves to trace the permanent distortions and displacements of the earth's crust for many miles back from the fault in each direction, and to show that they follow certain regular laws. This is the most extensive and accurate determination by triangulation of the effects of an earthquake which has yet been made anywhere in the world. Appendix 3 of the report gives a full report of this investigation.

A report on the measurement of six primary bases with steel and invar tapes in 1906 is printed as Appendix 4. The invar (nickel steel) tapes have a coefficient of expansion about 1/28th that of steel tapes, hence it is much less difficult to keep the temperature errors within the required limit with invar tapes than with steel tapes. Invar tapes had not been used in the United States until 1906 in primary base measurements. The thorough tests of these tapes, made by using them on six bases in conjunction with the steel tapes formerly used, showed that measurements may be made more conveniently, accurately, and at smaller cost per mile than with the steel tapes, and that the invar tapes are sufficiently durable and stable for safe field use. This demonstration is believed to be a distinct step in advance in base measurement.

The steady progress in the magnetic survey of the United States, and accumulation of magnetic observational data, as mentioned in Appendix 5 of the report, should be of special interest to the surveyor and the navigator, as well as to those pursuing the study of the science of terrestrial magnetism. Throughout the year the measurements of the earth's magnetism were made at places distributed over a majority of the States and territories of the United States, and at numerous places at sea along the Atlantic and Pacific coasts of North and South America, and in Porto Rico and the Philippines. Important information was secured in the equatorial regions. Numerous "repeat" observations were made throughout the country in order to follow as closely as possible the secular change in the magnetic elements. Five magnetic observatories were maintained in continuous operation, and important seismological data were also obtained. The facilities of the observatories were afforded to all investigators who desired to make standardisation comparisons of their instruments, and in response to numerous requests information or observational data was furnished for practical application or for use in special investigations of terrestrial magnetism and allied phenomena.

Appendix No. 6, constituting the concluding portion of a manual of tides, treats of the flow of water, of river tides, tidal currents, permanent currents, annual inequality, lake tides, seiches, and miscellaneous tidal matters. Charts of co-current lines are given for the principal marginal waters along the Atlantic coast of the United States. The numbers upon these lines show the times of the maximum flood current. The dependence of the permanent ocean currents and the annual height inequality upon the prevailing winds is briefly pointed out. Seiches are shown to exist in harbours and other tongues of water, as well as in lakes, but their character is fundamentally different in some respects. The analyses of observations upon the tides of Lake Superior show that they follow closely the equilibrium theory, although the

[1] "Report of the Superintendent of the Coast and Geodetic Survey showing the Progress of the Work from July 1, 1906, to June 30, 1907." (Washington: Government Printing Office, 1907.)

range is only $1\frac{1}{2}$ inches at Duluth and one-third inch at Marquette.

In Appendix No. 7 is given a detailed description, with appropriate illustrations, of the long wire drag, a device for detecting erratic obstructions of small extent in navigable waters. The method of operating can be understood from the simple statement that the drag is a wire varying in length from 480 feet to 1400 feet, supported at suitable intervals, and maintained at any desired depth below the surface of the water. This drag is towed over any given area by launches, and in the area so searched no elevation of the bottom above the depth at which the wire is suspended can escape detection. Buoys floating at regular intervals along the drag indicate to observers in the launches when and where an obstruction is touched, and the spot so indicated is then accurately determined.

This method of sweeping has proved a sure means of detecting pinnacle rocks and similar erratic obstructions which heretofore have eluded the hydrographic surveyor, since it is almost impossible to discover them by lines of soundings with the lead. Only the navigator in whose hands rest many lives and much property can realise the relief from mental strain that comes from knowing that the water in which he is sailing is absolutely free from hidden dangers, or that every menace is charted. The device has proved very satisfactory under widely varying conditions, and marks a decided advance in marine surveying.

The report, or any one of the appendices, may be obtained by interested persons, free of charge, upon application to the superintendent of the Coast and Geodetic Survey, Washington, D.C., U.S.A.

THE MECHANICS OF THE INNER EAR.

THE University of Missouri has recently issued a memoir by Prof. Max Meyer, in which an interesting, instructive, and suggestive attempt is made to explain the mechanism of the cochlea without having recourse to the application of the principle of sympathetic vibration, or rather without the assumption that there exists in the cochlea, in the form of the organ of Corti, a vast number of delicate structures tuned, as it were, to tones of different frequencies. Prof. Max Meyer does not base his views on experimental data; his paper is a purely theoretical discussion as to how the cochlea may act, if we make six fundamental assumptions, none of which can, at present at all events, be tested by direct examination or by direct experiment. His inquiry begins with the movements, in and out, of the stapes at the oval window. The tube filled with fluid is divided into three compartments, the upper, the scala vestibuli, communicating at the apex of the cochlea with the scala tympani, at the foot of which we find the round window, while between the two scalæ we have the cochlear duct, or scala intermedia, composed, in its turn, on one side by the basilar membrane, on which rests the organ of Corti, and on the other by Reissner's membrane. When the base of the stapes is pushed inwards at the base of the scala vestibuli, pressure is communicated to the fluid in the scalæ (the scalæ communicating at the apex of the cochlea by a little opening, the helicotrema), and the membrane of the round window passes outwards, towards the tympanic cavity. It is generally held that with such pressure the fluid in the scalæ moves as a whole, and that pressure is communicated to the whole length of the scala intermedia, and especially to the basilar membrane, and that in this way the nerve-endings in Corti's organ are also submitted to pressure. The question then arises, is there any differentiating mechanism in the basilar membrane or in Corti's organ for tones of different frequencies, or, in other words, have we here an organ capable of analysis? Some deny any such property, while others, since the views of Helmholtz were first promulgated, are of opinion that there does exist an analysing mechanism.

The theory of Prof. Meyer essentially is that when the base of the stapes is pressed inwards a section of the membrana basilaris is also pressed in one direction until it reaches its limit of movement. On the basilar membrane rests the organ of Corti, the delicate hair cells being supported on the backs of the rods or arches of Corti. The membrane of Reissner may be regarded as merely protective, and a similar function Prof. Meyer awards to the arches of Corti, which are a kind of skeleton to prevent the delicate hair cells and nerve endings from being crushed by downward pressure on the membrana basilaris. No one can say what is the function of the membrana tectoria, the cushion-like structure that lies over the apices of the hair cells, and the nerve endings that, according to some histologists, lie between the hair cells. It may be a damper or it may be the arrangement by which pressures are made on the apices of the hair cells or nerve endings. There is thus, according to Prof. Meyer, a movement in one direction of a segment of the membrana basilaris, the direction being towards the scala tympani. When the base of the stapes has passed inwards to its fullest extent, the segment also moves to its limit, and then when the base of the stapes passes outwards the segment passes in the reverse direction, that is, towards the scala vestibuli. The rest of the basilar membrane beyond the segment is undisturbed. It is not known whether the basilar membrane is elastic or not; most probably it is non-elastic, but its backward swing has also its limits, and the velocity of the backward spring is probably slower than its forward swing, seeing that it is weighted on one side by the Corti cells, &c. The intensity of the tone will be determined by the amplitude of movement of the base of the stapes—the extent of the segment being greater as the amplitude is greater, and the reverse. Assuming that the number of nerve fibres in each segment is the same (which is unlikely), the greater the extent of the segment the greater will be the number of nerve fibres irritated, and the greater will be the intensity. The pitch will, of course, depend on the frequency of the movement of the segment, and there is no necessity for the assumption that either segments of the membrana basilaris, or structures upon these, are tuned to certain frequencies. When a compound tone or sound, say a fifth (the frequencies of the components of which are in the ratio of 3 : 2), is sounded, the base of the stapes makes a more complicated movement than that of a simple pendular vibration, and then this compound movement is resolved by two segments of the basilar membrane moving *synchronously, in the ratio* of 3 : 2, and the nerve endings in one segment would be irritated thrice during the time that the nerve endings in the other segment would be irritated twice. Still more, a segment at or near the base of the stapes would move once in the same time, and give rise to the differential tone, and so on.

Prof. Meyer thus recognises the cochlea as an analytic apparatus, without the necessity of any tuned mechanisms, and he works out his theory with great clearness, much ingenuity, and perfect fairness. His explanations of differential tones are in perfect consistence with his theory, and they are graphically delineated. He does not pretend that his theory is an ultimate solution of the problem attacked. Data are still wanting to found a final theory, and when we consider the minute size of the parts involved, it will probably be many a day before these data have been collected. But as experimental, and even observational, research must start from theory, however imperfect, Prof. Meyer has done good service in advancing his views.

The writer would only remark that he finds it easier to conceive the existence in the cochlea of arrangements adapted to frequencies, and consequently of an analysis by resonance, than to think of the membrana basilaris, short as it is, moving in segments when a complex mass of tones is objectively produced. Such a cochlea as Prof. Meyer has conceived might work in the way he thinks, and the writer would suggest that he should make a huge model, with a big piston, and ascertain whether a stout leather non-elastic membrana behaves as he expects it to do. The writer thinks that Helmholtz's resonance theory, with slight modifications, still holds the field, nor does it seem to him to be negatived (and the same remark applies to the theory of Prof. Meyer) even by the difficulties created by a consideration of differences of phase. The physiological effect produced by the relative *intensity* of a com-

1 "An Introduction to the Mechanics of the Inner Ear." By Prof. Max Meyer. Science Series of the University of Missouri Studies. Pp. 140. (1907.) Price 1 dollar.