whatever, in which the law of statistical constancy prevails, the series, in each case, being arranged according to gradations of the quality in question. Each individual is measured against his neighbour, and it is quite unnecessary to have recourse to any external standard. As regards a scale of equal parts, the lecturer made use of a converse application of the law of "frequency of error," which he illustrated by many experiments, and which showed that in a row (say as before) of nuts, if we took those which occupied the three quarterly divisions (1st quarter, centre, 3rd quarter) as the three elementary graduations of size, a range of successive graduations would be obtained by the following series, in which the places of the nuts are supposed to be reckoned from the end of the row where the large nuts are situated, and to be given in per-thousandths of the entire length of the row. It might be called the "Common Statistical Scale" (S. S.). The place of $+ 4°$ would be at 4 thousandths from large end; $+ 3°$, at 21 thousandths; $+ 2°$ at 89; $+ 1$, at 250; $0°$ at 500; $- 1°$ at 750; $- 2°$ at 911; $- 3°$ at 979; and $- 4°$ at 996, or 4 thousandths from the small end of the row. Thus if we say that the size of a nut is $+ 2°$ S. S., we absolutely define it. Anybody can procure such a nut independently by getting a quart of nuts and arranging them. Also we know that the difference between a nut of $+ 4°$ S. S. and $+ 1°$ S.S. is $3°$, and therefore three times as great as between one of $+ 2°$ S. S. and the latter. It cannot be affirmed that this is a precise scale of equal parts for all qualities, but it is found to hold surprisingly well in a great variety of vital statistics; perhaps, too, the mere thickness of tissues may be a chief element in the physical basis of life. This scale appears, at all events, more likely to be nearly approximative to one of equal parts, for qualities generally, than any other that can be specified, and it certainly affords definite standards subject to the law of statistical constancy. The habit should therefore be encouraged in biographies, of giving copious illustrations which tend to rank a man among his contemporaries, in respect to every quality that is discussed, in order to give data for appraising those qualities in terms of the Statistical Scale. By the general use of a system of measurement like the above, social and political science would be greatly raised in precision.

Regarding education, the lecturer disavowed speaking of what might be suitable for boys generally, but he summarised the replies of the scientific men with reference to their own special experience, and notwithstanding the diversity of branches of science, he found unanimity in their replies. They commonly expressed a hatred of grammar and classics, the old-fashioned system of education being utterly distasteful to them. The following seems the programme they themselves would have most liked:—1. Mathematics, rigorously taught up to their capacity, and copiously illustrated and applied, so as to throw as much interest into its pursuit as possible. 2. Logic. 3. Some branch of science (observation, theory, and experiment), some boys taking one branch and some another, to insure variety of interests under the same roof. 4. Accurate drawing of objects connected with that branch of science. 5. Mechanical handiwork. All these to be rigorously taught. The following not to be taught rigorously: reading good books (not trashy ones) in literature, history, and art. A moderate knowledge of the more useful languages taught in the easiest way, probably by going abroad in vacations. It is abundantly evident that the leading men of science have not been made by much or regular teaching. They craved for variety. Those who had it, praised it; and those who had it not, concurred in regretting it. There were none who had the old-fashioned high-and-dry education who were satisfied with it. Those who came from the greater schools usually did nothing there, and have abused the system heartily.

INFLUENCE OF GEOLOGICAL CHANGES ON THE EARTH'S ROTATION

AT the annual meeting of the Geological Society of Glasgow, on Feb. 12, the president, Sir William Thomson, F.R.S., gave an address on the above subject, of which the following is an abstract:—

He first briefly considered the rotation of rigid bodies in general, defining a principal axis of rotation as one for which the centrifugal forces balance while the body rotates around it. He then took the case of the earth; and, having pointed out the position of its present axis, showed that if from any cause it were made to revolve round any other, that would be an "instantaneous axis," changing every instant, and travelling through the solid, from west to east, in a period of 296 days round the principal axis It would shift continually in the figure, owing to the varying centrifugal force of two opposite portions of the body. This would produce, by centrifugal force, a tide of peculiar distribution over the ocean, having 296 days for period. An inclination of the axis of instantaneous rotation to principal axis of 1″, or 100 ft. at the earth's surface, would produce rise and fall of water in 45° latitude, where the effect is greatest, amounting to ·17 of a foot above and below mean level.

He noticed, in passing, the application of these dynamical principles to the attraction which the sun and moon exercise on the protuberant parts of the earth, tending to bring the plane of the earth's equator into coincidence with the ecliptic. This causes an incessant change, to a certain limited extent, in the position of the axis of rotation, thereby occasioning what is known as the "precession of the equinoxes." Having illustrated these remarks by some interesting experiments, Sir William Thomson proceeded to consider more particularly the circumstances according to which the axis of the earth might become changed through geological influences, and the consequences of any such change. The possibility of such a change had been adduced to account for the great differences in climate which can be shown to have obtained at different periods in the same portion of the earth's surface. In the British Isles, for example, and in many other countries, there is clear evidence that at a comparatively recent period a very cold climate—much colder than at present—prevailed; while in the same places the remains of plants and animals belonging to several preceding eras indicate a high temperature and a comparatively tropical climate. The question arose, can changes in the earth's axis account for these changes of climate? In the present condition of the earth, any change in the axis of rotation could not be permanent, because the instantaneous axis would travel round the principal axis of the solid in a period of 296 days, as already stated. Maxwell had pointed out that this shifting of the instantaneous axis in the solid would constitute in its period a periodic variation everywhere of "latitude," ranging above and below the mean value, to an extent equal to the angular deviation of the instantaneous axis of rotation from the principal axis; and, by comparing observations of the altitude of the Pole-star during three years at Greenwich, had concluded that there may possibly be as much as $\frac{1}{2}''$ of such deviation, but not more.

In very early geologic ages, if we suppose the earth to have been plastic, the yielding of the surface might have made the new axis a principal axis. But certain it is that the earth at present is so rigid that no such change is possible. The precession of the equinoxes shows that the earth at present moves as a rigid body; and during the whole period of geologic history, or while it has been inhabited by plants and animals, it has been practically rigid. Changes of climate, then, have not been produced by changes of the axis of the earth. The learned professor then inquired what influences great subsidences or great elevations in different parts of the earth might have on the axis of rotation. No doubt the removal of a large quantity of solid matter from one part of the globe to another would sensibly alter the principal axis, as well as the axis of rotation, which so nearly coincides with it; but it could be shown that it would produce in the latter only about 1-300th part of the change produced in the former. We know too little of the changes in the interior of the earth accompanying such changes on its surface to be able to state results with certainty. But he estimated that an elevation, for example, of 600 feet on a tract of the earth's surface 1,000 miles square and 10 miles in thickness, would only alter the position of the principal axis by *one-third of a second*, or 34 feet. He called attention to the effect of tidal friction and subterranean viscosity in reducing any such deviation, and pointed out that it must be exceedingly slow; using for evidence the observationally proved slowness of the diminution of the earth's rotational velocity, and of the inclination of its equator to the ecliptic. It therefore seemed probable that geological changes had not produced any perceptible change in the principal axis or in the axis of rotation within the period of geological history.

OBSERVATIONS OF MAXIMUM AND MINIMUM SEA-TEMPERATURES BY CONTINUOUS IMMERSION

WHEN the Scotch Meteorological Society was instituted, now nearly twenty years ago, observations on sea-temperature were set on foot at the suggestion of the late Prof. Fleming, and have since been continued. These observations were made by the immersion of thermometers with small cisterns attached, and were taken at the surface and at a depth of 6 feet. Besides these, special observations were made for me on the temperature of the flood and ebb tide at depths extending to 50 feet in the Pentland Frith,* and hourly observations continued at intervals during four years ending in 1863 by Capt. Thomas, R.N., at depths extending to 60 feet.† Such occasional observations seemed to me to be insufficient to show properly the changes in temperature to which the sea is subject, and in August 1872 I suggested to my friend, Prof. Wyville Thomson, the propriety of ascertaining, on his exploring voyage, maximum and minimum temperatures by means of thermometers constantly immersed in the sea. For this purpose a thin malleable iron plate of an oval shape, as shown in Fig. 1, is fixed to the outside skin of the ship so as to form a small cell into which the sea-water finds ready ingress through numerous perforations. This cell, which need not project more than two inches, so as not to cause any appreciable obstruction to the speed of the vessel, should extend so far under the smooth water level as to prevent its lower end from rising above the trough of the sea, or an upright pipe might be placed within the vessel. In sailing ships there might be a cell on each side so as to secure constant immersion while the ship "is on a wind." In this cell a frame carrying a maximum and minimum thermometer slides in checks so as to be capable of being raised above water to the level of the cabin or the deck, where there should be a porthole to admit of the instruments being read and the indices being readjusted.

An arrangement similar in principle to that described was made in the *Challenger* exploring vessel before she left on her voyage.

In this way, during the whole of an over-sea voyage, regular observations of maxima and minima may be obtained as often as may be desired. This arrangement is peculiarly suitable to floating lights, and the Scotch Meteorological Society have been in correspondence with the Mersey Board in order to establish observations at the North-West Lightship.

The Marquis of Tweeddale in 1872 proposed that the Scotch Meteorological Society should enter upon the investigation of the migrations of fishes, and particularly those of the herring, in connection with sea-temperatures and weather generally, and his Lordship informed me that in his opinion it was likely that the herrings followed belts of water of a higher temperature than that of the sea generally.

In carrying out his Lordship's suggestion the Society has been favoured through the courtesy of the Fishery Board with returns of the daily catch of herrings and of the weather from the different fishing districts of Scotland for the last two years; and already two elaborate reports on the subject have been drawn up by Mr. Buchan, the Secretary, and published, which give good ground to hope that some positive results of considerable im-

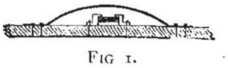

FIG 1.

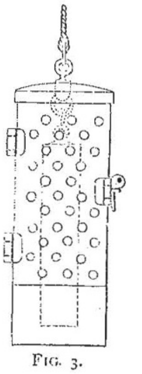

FIG. 3.

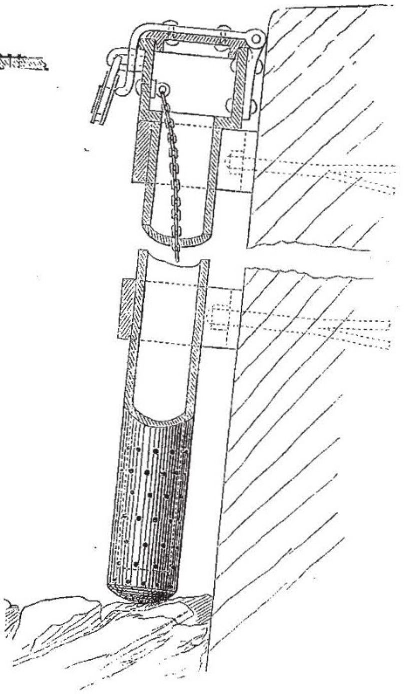

FIG. 2.

portance will be obtained. With reference to this investigation, I suggested, for piers and harbours, the adoption of a cast-iron pipe for containing the thermometer as shown in Fig. 2, and application was accordingly made to the Trustees of Peterhead harbour, where observations by continuous immersion have been made by Mr. William Boyd, F.R.S.E., since May 1873. It is to be regretted that these observations have in the meantime been stopped, owing to a ship having come in contact with the pipe.

In addition to observations near the surface at floating lights, it would be extremely desirable to have thermometers immersed at greater depths, and for this purpose a copper vessel weighted below should be used, as represented in Fig. 3, with perforations in the upper part and a cistern about 4 in. deep in the lower part. The Scotch Meteorological Society, at its meeting on February 9 last, authorized an application to the different lighthouse authorities for sanctioning these deep-water observations as well as those of the surface and of the air.

THOMAS STEVENSON.

* "Edin. Phil. Jour." Nov. 25, 1857.
† "Jour. Scot. Met. Soc." vol. i., p. 256.