observation. At page 434 is a rough statement of the results of his researches, the heights being given in Paris lines.

Lat. °	Barometer mercury at O° C.
0	337·0
10	337·5
20	338·5
30	339·0
40	338·0
50	337·0
60	335·5
65	333·0
70	334·0
75	335·5

The expedition might contribute to the examination of this law, not only by giving special attention to the barometer observations at about the critical latitudes 0°, 30°, 65°, 70°, but also by comparing any barometers with which long series of observations have been made at any port they may touch at, with the ship's standard barometer.

It appears probable from Schouw's paper, that certain meridians are meridians of high pressure and others of low pressure.

For comparison of barometer and measures of heights, it appears that the aneroid barometer constructed by Goldschmid of Zurich, would be very useful.

It is very desirable that the state of the barometer and thermometer should be read at least every two hours.

(To be continued.)

TERRESTRIAL MAGNETISM*

II.

THE problem was attacked later on by General Sabine in a much more definite manner, and with much greater chance of success. The earth, as we are all well aware, moves round the sun in an elliptic orbit, the nearest approach of the two bodies occurring at about the time of the winter solstice; if, therefore, there be an annual inequality, it will probably attain its maximum when the earth is in perihelion, and its minimum at aphelion, since the magnetic force is known to vary inversely as the square of the distance. The year was, therefore, divided by Sabine into two equal parts, and the mean of all the observations taken during the six winter months compared with the mean for the six summer months. The records of the three British observatories of Hobarton, Toronto, and Kew all agree in showing that the magnetic intensity of the earth is greater in winter than in summer. This was very satisfactory; but the same calculations have since been made for other magnetic stations, where monthly determinations of the three elements are carried on without interruption, and some of the results are far from confirming the above conclusion; for we find that observatories as near as Kew and Greenwich are in direct opposition on this point. A more extensive series of comparisons will finally show how far this disagreement depends on the accidental nature of the observing stations; but at present the preponderance of the evidence is decidedly in favour of a semi-annual inequality.

A similar investigation of the effect of the moon's action on terrestrial magnetism requires a series of observations made at much less distant intervals than the monthly ones, which suffice for the study of the annual variation. This new question presents itself to our view under a twofold aspect. The effect of the moon may be studied either in its independent action, or as it acts conjointly with the sun; in the former case we must group the observations with respect merely to the position of the moon in its orbit, and, as this is an ellipse with the earth in the focus, the force, varying inversely as the square of the distance, will have its maximum disturbing influence at perigee and its minimum at apogee. The range also of the inequality will depend on the eccentricity of the orbit, and the period of variation will coincide with the siderial, or more strictly the anomalistic, month of a little over twenty-seven days.

But if we consider the moon as acted upon by the sun, receiving its magnetic power, as it does its light and heat, from the central body of our system, or merely having its own inherent magnetism modified by solar action, then we must choose as our unit the lunation, or synodic month of 29·5 days, observing the changes that take place as the moon approaches to or recedes from the sun. A careful sifting of the Greenwich observations led Mr. Airy to a belief in the existence of a menstrual inequality of the declination, attaining its maximum on the fifth day of the moon's age, and of a semi-menstrual inequality of the horizontal force whose maximum occurs on the second day. The solar effect on the moon's magnetic power would, therefore, appear to be cumulative, and not to be fully developed till several days subsequent to the conjunction of the two bodies.

No examination seems to have been as yet made to test the existence of a monthly variation due to the independent action of the moon, as the sole disturbing force.

The sun's rotation on his axis presents another not improbable cause of periodic magnetic disturbance. For if the sun acts as a large magnet directly upon the earth, and the poles of the sun's axis of rotation are not coincident with its magnetic poles, the rotation will present the solar magnetic poles alternately to the earth, and these acting singly, the result must be a synodic inequality, dependent on the period of the sun's rotation. The absence of any such irregularity is adduced, by a recent author on terrestrial magnetism, as a proof that the variations of the earth's magnetic force are due solely to the indirect action of the sun; but Prof. Hornstein has just succeeded in detecting in the magnetic records of Prague and Vienna an inequality in very close accord with the synodic period of the rotation of the solar spots. The magnetic period of 26 days 8 hours would give, as the true time of the sun's rotation, 24d. 13h. 12m., whereas Spörer, from the most accurate observations of spots near the sun's equator, found the time to be 24d. 12h. 59m. It becomes, therefore, probable that the sun has a direct magnetic action upon the earth, but this need not in the least interfere with the probability of its simultaneous indirect action by means of its thermal energy.

Having been able to detect, in the manner just described, the inequalities arising from the orbital motions of the earth and moon, we are immediately tempted to suppose that the diurnal rotation of the earth must also exert a not inconsiderable effect on the magnetism of any particular station on the earth's surface, and possibly even affect terrestrial magnetism as a whole. It is well known that change of temperature has a very powerful influence on magnetism, and therefore we should be astonished to find that the daily range of temperature induced no corresponding range in the earth's magnetic elements. The freely-suspended magnet is the most delicate of thermometers, and consequently, unless we wish the diurnal variation of the earth's magnetism to be completely veiled by the more extensive changes due to the varying heat of the magnet itself, we must take the greatest care to keep the suspended needle in a locality not directly affected by the daily alternations of temperature. Attending to this precaution, by building our magnetic chamber at a considerable depth below the surface of the ground, we still find that there exists a most decided daily range in the motion of the magnet, to which the most delicate thermometer is wholly insensible. This daily range was detected by Graham as early as 1724, and a momentary inspection of nearly any two days' march of the suspended needle will suffice to make this point evident. The maximum west declination, about 2 P.M., is constant throughout the year, whilst the principal minimum varies with the seasons, as do also the secondary maximum and minimum. Canton has accounted for the leading feature in this diurnal change by the fact that the solar heat lessens the magnetic power of that portion of the earth on which it directly falls, and thereby gives a preponderating influence to the opposite portion, whose strength remains undiminished; the needle, therefore, moves towards the West in the morning, and only returns towards the East as the Western sun restores the balance of attracting forces.

But there are other variations of the daily range besides those just mentioned, for not only do most of the inflections of the diurnal curves alter their time with the progress of the sun in his orbit, but the amplitude of the range passes through a constant order of phases as each year advances. Dr. Lloyd discovered that the maximum range of declination in summer is greater than in winter, and Quetelet not only confirms this, but also finds that the range is greater at the equinoxes than at the solstices. It was whilst engaged upon this investigation that the Director of the Brussels Observatory made the curious discovery, that the magnetic energy varies in the same manner as the vegetable force, both attaining their maximum in April, and diminishing gradually until they reach their minimum of intensity in the

* Continued from p. 173.

winter months. Other observers, such as Lamont of Munich, Col. Beaufoy, &c., may be cited in confirmation of the existence of this apparent connection between the vegetative force and that of magnetism, a connection which may perhaps serve to throw some light on the nature of magnetic action. The horizontal force follows a law similar to that of the declination, varying in its daily range with the seasons, and attaining its maximum value in summer.

Another peculiar semi-annual inequality in the diurnal variation has been detected by Mr. Chambers, the times of opposition being the equinoxes. This inequality is found to exist in the observations taken at seven stations—five in the northern, and two in the southern hemisphere. It only lasts from 6 A.M. to 6 P.M., reaching its maximum at 9 A.M. from January to June, and at 3 P.M. from July to December, always passing through the mean value at noon.

If now we turn from the consideration of the effect of the earth's rotation on the direct solar magnetism to examine its influence on that of our satellite, we are again led to expect a positive result, but on very different grounds from those we have just been reviewing. The heat sent to us by the moon, even when full, is so insignificant, that it is requisite to collect the rays in some enormous mirror, such as that of the Earl of Rosse, or to bring them to a focus on a very sensitive thermometer, in order to make it sensible. It would be absurd then to look for any effect that the rotation might produce in the variation of the temperature; but it is very reasonable to expect that the alteration of distance due to the rotation will not be equally insensible. We are not separated from our satellite by more than 240,000 miles, and as the diameter of the earth is nearly 8,000, the rotation may alter the distance of the moon from a station on the earth's surface by about one-thirtieth of the whole distance, and the resulting change of the attracting force must be very considerable. An examination of the Greenwich magnetic observations, arranged according to lunar hours, has led Mr. Airy to the conclusion that no doubt can be entertained as to the existence of a luno semi-diurnal inequality, though he has failed to detect any luno diurnal inequality. He also found so close an agreement between the values of the luno semi-diurnal variation in the years of greater and also of smaller solar curves, that he suggests the two following "conjectural reasons for this remarkable association in the time-law of changes of solar and lunar effect. One is that the moon's magnetic action is really produced by the sun's magnetic action; and a failure in the sun's magnetic power will make itself sensible, both in its direct effect on our magnets, and in its indirect effect through the intermediation of the moon's excited magnetism. The other is, that, assuming both actions, solar and lunar, to act on our magnets indirectly by exciting magnetic powers in the earth, which alone or principally are felt by the magnets, the earth itself may have gone through different stages of magnetic excitability, increasing or diminishing its competency to receive both the solar and lunar action." The ratio of the moon's disturbing action on the horizontal force is to that of the sun as 1 to 20.

We have just been considering the irregularities in the magnetic action of the sun and moon, which arise from the orbital motions of the earth and its satellite, and from the rotation of our globe, but there are still other variations depending on much more complex causes that remain yet to be examined. A very important inequality has been detected in the daily range by several observers, and of late years by Mr. Chambers of the Colaba Observatory. It is a change that takes place in the amplitude of the range, not from season to season, but from year to year, and which completes its cycle in ten or eleven years. Other periodical inequalities of the daily range have been more than suspected, as that of twenty-two years, noticed by Hansteen; and some of these may possibly be found to have a connection with such phenomena as the revolution of the moon's nodes. It will suffice to have mentioned these; but we must not so lightly pass over the decennial period, which is identical with the cycle of those great but irregular disturbances of which we must now say a few words.

The accurate study of magnetic storms was nearly impossible before photography was called to the aid of the observer; but now that every movement of the needle is faithfully recorded by the ever watchful light of the gas jet, a continuous curve shows at a glance the nature, extent, and duration of even the slightest disturbance. The arrangement of these self-recording magnets is extremely simple and equally effective. To each magnet, whose movements we desire to study, is attached a small mirror, and the rays from a gas jet falling on the mirror are sent by it to a cylinder covered with sensitised paper. A lens brings the rays to a focus on the cylinder, and this focus traces on the paper every movement of the magnet. A second mirror fixed immediately underneath the first, but having no connection with the magnet, sends the rays of the gas jet always in the same direction, and thus traces a base line from which the variations of the magnetic curve can be measured with the greatest exactness. A clock turns the cylinder through a complete revolution in twenty-four hours, and the light being cut off for a few minutes every two hours, breaks are thus made in the curve, which serve as an excellent time scale. The magnetic curves, traced in this manner, are in general and lightly irregular lines, which reach their highest point towards 2 P.M., and are more or less curved at all hours of the day. Scarcely a day passes without some apparently accidental departure from the ordinary bend of the line, but these disturbances are often only of short duration. There are, however, occasions on which the magnets seem to be subject to the action of a disturbing force far exceeding in intensity any of those we have been hitherto considering, and subject itself to no apparent laws, but causing the needle not unfrequently to oscillate through several degrees of arc on either side of its mean position. It will be interesting to know what account can be given of this disturbing power, which assumes such Protean shapes, at one time raising a storm that dies away as gradually as it commenced, and at another bursting forth in an instant in all its fury; now continuing its disturbing action for days together, and then imparting but a single momentary impulse; affecting sometimes one element, and then another, and sometimes all together; and finally appearing not unfrequently at the same hour on several successive days.

The coincidence of these disturbances with the passing of earth currents, so perfectly recorded on the Greenwich curves; their never-failing appearance at all auroral displays; their simultaneous occurrence at places the most remote from each other; and lastly the agreement of their period of variation of intensity, as well as their maxima and minima with the decennial period, and the maxima and minima of sun-spot development; all these facts will be most powerful aids towards the solution of our difficulty. Neither is it unreasonable to expect that some light may be thrown upon the question, if we examine with careful attention the not impossible connection of magnetic storms with solar outbursts, or with volcanic eruptions and violent earthquakes, with the variations of the wind, or even with the showers of falling meteors. Much of interest has already been ascertained in connection with these several points, but I will not tax too severely your indulgent patience by entering at present into these details.

I must, however, before concluding, allude for one moment to those researches of De La Rue, Stewart, and Loewy on solar physics, in which they have made a first step towards establishing a connection between the period of solar spots and the relative position of the planets. If this can be maintained; if the solar disturbances are in any way due to the combined action and reaction of the planets, and these again are found to be coincident with the great perturbations of terrestrial magnetism, shall we not be inclined to attribute a wider range to the magnetic force than is in general assigned to it? May not that, which has long been allowed to rank among the most extensively diffused of nature's agents, find a home in each individual member of the solar system, causing them to act and react upon each other as well by their magnetic energy as by their force of gravity? The perfect solution of such a problem would well repay many a year of persevering observation and of assiduous study, and well will those be rewarded by whose labours the general cause of terrestrial magnetism ceases to be one of the unsolved mysteries of cosmical physics.

SCIENTIFIC SERIALS

No. 3 of the *Bulletin de l'Academie Impériale des Sciences de St. Petersburg*, t. xvii., contains seven anatomical papers by Dr. Wenzel Grüber—six on various abnormal muscular forms, and the seventh being an account of the formation of supernumerary wrist-bones.—An appreciative paper on Sir Roderick Murchison is communicated by G. Helmensen. He refers to Murchison's visits to Russia between 1840 and 1845 to study the palæozoic formations. In a *résumé* of results, he mentions, among others, the discovery, in post-pliocene strata in the lower course of the