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LI. *Thoughts on the supposed Variations in the Axis and Poles of the Earth.* By Professor BODE, of Berlin *.

IT is highly worthy of remark, that, notwithstanding the harmony which prevails in the course of the planets round the sun, and in their rotation, as well as in regard to the parallelism of their axes, great variations are found in the inclination and position of the latter, and in the periods of the rotation of these bodies.

This depends on the different influence which the sun has on a planet during its rotation, or the variation of its astronomical seasons, and on the inclination of its axis in regard to its orbit; for the sun, in his course from the one tropic to the other, passes over an arch equal to twice the complement of this inclination; and therefore the less the inclination, he must advance nearer to the poles, and employ much less time in proceeding from the equator towards either tropic.

Now, as it is known from observations that there are some planets the axes of which have a much greater or much less inclination than that of our earth, the great variations which must naturally thence result in regard to the beneficent influence of the sun's light and heat, will give a quite different nature to their fields, productions, and inhabitants.

The inclination of the axis of our earth, which is $66\frac{1}{2}$ degrees, seems to be well adapted for promoting its fertility and rendering it habitable, as the sun employs six months in moving from the equator towards either pole, and again returning; by which means the effect of his rays in producing that heat and light so indispensably necessary to the animal, vegetable, and mineral kingdom, increases and decreases in a much slower and gradual manner. The two temperate zones occupy the greater part of the earth's surface, and these remain habitable as far as possible towards either pole.

The direction and inclination of the axes of the different planets are as little proportioned to their different distances from the sun, as their periods of rotation, size, density, mass, and sphericity; as is well known by observations which have been made. Now, as there must be sufficient grounds for this arrangement, it may be ascribed, in my opinion, to the matters of different specific gravity of which the earth and the other planets are composed, and to their mixture; in consequence of which, immediately after their formation, their

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hemispheres on each side of their orbit, which always divides the body in the middle, were put in perfect equilibrium.

Our earth as well as every other planet is carried round the sun by the radius vector, (the straight line drawn from the planet to the sun,) as the centripetal forces continually act according to that line, or in a perpendicular direction. But this line of attraction, during the revolution of the earth, on account of the continual parallelism of its axis, forms with the latter very different angles; and yet the duration and period of the rotation remain unaltered. This great difference in the angles has therefore no influence whatever in this respect; and it appears that there exists some other great power capable of preserving the direction and inclination of the axis unchanged, and which, in my opinion, may be ascribed also to the sun.

Our earth during its annual course, revolving from west to east, turns in succession every part of its surface to the sun, and at the same time revolves from east to west on a line passing through its centre perpendicular to the plane of its orbit; or passing through the poles of the ecliptic, as a second axis, for the purpose of constantly maintaining the parallelism of its proper axis of rotation. Now, if it can be admitted that the sun produces this revolution of the earth in the plane of the ecliptic corresponding with the arch of its orbit, this, in my opinion, is a more natural explanation of the parallelism of the earth's axis than when it is considered merely as the consequence of a certain established position of it incapable of alteration; as this principle is applicable only to the action of mechanical powers on bodies that move and revolve in a straight line; whereas the sun is continually drawing our earth from the straight line, and carrying it around it in a cruciform manner.

According to this theory, we may easily conceive how it is possible that a planet the axis of which, by the equilibrium of its heterogeneous parts established at its creation, is put into a certain direction, subjected to certain laws, may, by the powerful influence of the sun, be made to deviate from it so that its axis shall assume another position and inclination, or, in other words, change its poles.

Our earth, in consequence of slow or sudden variations of the last kind, would produce in the heavens the following phenomena:

1st, If the inclination of the earth's axis should change, the zodiac would be still the same, but the obliquity of the ecliptic would be greater or less; the equator would pass through other stars; and, in this case, all countries lying

under the same parallels of latitude would experience a like change in regard to the duration of the seasons.

2d, If the axis of the earth, without changing its inclination, should acquire a new direction towards some other quarter of the heavens, the two points γ and \triangle , where the ecliptic intersects the equator, and all the other circles connected with it, would pass through other points of the ecliptic. This would make no change in the duration of the seasons, or the state of the sun at noon.

3d, If the inclination as well as position of the axis should be changed, a result compounded of both the above cases would take place.

4th, But if the earth should be carried around the sun in another plane, the result would be a new apparent course of the sun. The seasons would remain the same, or acquire some change in their duration, according as the axis should be inclined as at present, or in a different manner towards the new orbit, and all the countries of the earth would participate in this change. These four cases, however, have no influence on the elevation of the pole of any place.

5th, On the other hand, should the poles of the earth change their place, the obliquity of the ecliptic would also be changed, the equator would pass through other countries, and the elevation of the pole of these countries would be changed. This change of the pole, however, can take place only in the direction of some meridian; and consequently from north to south, and from south to north. By these means one half of the equator would be carried over northern and the other over southern countries; and therefore all countries would not equally participate in the changes thence occasioned in the duration of the seasons; at least, all countries lying under the same southern or northern zones could not come together into the torrid zone, or into an uniform situation.

If the alteration of the pole should take place in the direction of the meridian that passes through the solstices, neither the ecliptic nor the different quarters of the earth would experience any change; the obliquity of the former only would be altered as well as the position of the equator in proportion to the above alteration. Should the alteration of the pole take place in the direction of any other meridian, a change would be produced in the different quarters of the globe, the obliquity of the terrestrial equator, and the signs of the ecliptic. In the last place, should the pole move along the meridians passing through either of the equinoctial points, the above phenomena would take place, and the points of the ecliptic,

ecliptic, 0° ♄ and ♀, would be transferred to ♄ and ♀, and north and south to east and west.

A question now arises, whether any traces exist on the surface of our globe which seem to show that the inclination of the earth's axis has ever changed either suddenly or progressively, or whether the pole has altered its place? On the first view, it would appear that this question ought to be answered in the affirmative.

Many naturalists and geologists, in order that they might more easily explain the general deluge, and why marine productions are often found at a considerable depth under the earth's surface, or on the tops of high mountains; how the remains of austral plants, and of terrestrial and aquatic animals, could have been conveyed to the northern regions, and buried there in the bosom of the earth; how the different strata of mountains have been formed, and other phenomena of the like kind, have been able, as is well known, to contrive no better hypothesis than to suppose that some derangement of the poles of the earth, or changes in the inclination of its axis, must have taken place in former times.

But, in my opinion, the determination of this question belongs rather to astronomers than to geologists, because by the former it may be considered under a more general point of view, viz. what connection exists between the position of the earth's axis and the sun, and the attractive power in the solar system; and what observations have been made in regard to the position and direction of their axes, from which, by analogical reasoning, we may explain the relation between causes and effects when such changes take place.

The ablest astronomers and geometers have shown that the small annual recession of the equinoctial points to the west, of about 51 seconds, and the revolution of the earth's axis around the poles of the ecliptic, which thence follows in the course of 25,700 years, arise from the united action of the attractive power of the sun and moon on the spheroidal form of the earth. As long, therefore, as this attraction of the sun and moon acts in an uniform manner, it seems to be impossible that any continued or very perceptible changes in regard to the earth's axis can take place.

It is, however, found by observations, that in the course of many centuries an alteration, though very small, has taken place in the inclination of the earth's axis. At present it is 23 minutes greater than it was in the time of Hipparchus, that is, above 2000 years ago.

In consequence of this observation it has been apprehended that the ecliptic may, at some future period, coincide with the

the equator; the sun, of course, be continually in the equator; and the axis of the earth acquire a perpendicular direction; by which means the cold of the polar regions and in the temperate zones will become greater, and consequently the fitness of the earth for being inhabited, as well as its culture and fertility, must decrease.

But La Grange and La Place have freed us from any uneasiness on this head, as they have proved, by ingenious calculations and conclusions, that this small change in the inclination of the earth's axis is an effect of the mutual attraction of the planets on the orbit of our earth; that since the time of Hipparchus it has contributed in an uniform manner to the decrease of the obliquity of the ecliptic, or the increase of the above inclination; that it does not always continue; but that, properly, the above supposed axis of the earth's rotation perpendicular to the ecliptic, in consequence of this action of the planets, moves in very long periods around the poles of the orbit of the earth which lie in the neighbourhood of the poles of the ecliptic.

According to these observations, the variation in the obliquity of the ecliptic is merely a nutation of the earth's axis, which, since the time of Hipparchus, has occasioned a very small decrease in it, but will afterwards become stationary, and then produce an increase.

Schubert, of Petersburg, has found, by La Grange's formula, that the obliquity of the ecliptic in the period of 65,000 years always remains between $20^{\circ} 43'$ and $27^{\circ} 45'$. At present it is about 43 minutes less than the mean of the above two quantities, and will still decrease, for 4900 years, to $22^{\circ} 53'$; after which it will again increase.

Hence may be deduced very important consequences in regard to the durable state of our earth, on which distant bodies, in the course of its annual revolution, exercise an action; but these bodies, on account of their situation and great distance, are able to produce only very small and periodical nutations, by which the maintenance of the whole is promoted, and the earth preserved from great and disastrous changes. As long as the present constitution of the solar system remains the same, these small and harmless periodical nutations will take place.

But if the earth's axis and its poles are secured by such powerful bonds from all sudden or progressive changes, those apparent changes and revolutions which we observe at and under the surface of our earth must be referred to other causes than a change in the earth's axis, or displacement of its poles; and this will be still more evident when it is considered

sidered how trifling such changes are in regard to the whole earth, and whether its centre of gravity could by these means suffer any alteration.

A cursory view of geology will show how little we know of the interior parts of the earth, and how small a portion of it is subject to our dominion and research. Of the 21,951,022 square leagues, which is the extent of the earth's surface, the lands that rise above the ocean comprehend only about one-third, or seven millions. Now if we suppose, which perhaps ought to be taken into account, that the height of the land above the ocean is 6000 feet, or $1\frac{1}{4}$ mile, (though few lands are so high;) and that the depth of the ocean is the same; this in a globe of one inch diameter would scarcely amount to the fiftieth part of a line, or the fifth part of a moderate sized grain of sand; and this whole external crust, of 6000 feet in thickness, contains only the 1100th part of the whole number of cubic miles, which form the solid content of the earth.

Now all those traces of revolutions in the earth which geologists have been able to observe, have been found either in the above-mentioned crust, into which no one has ever penetrated above a fourth part of that depth, (for the greatest depth to which mines have been dug is not more than 1500 feet;) or in the bowels or at the top of moderate sized mountains, the height of which on a globe a foot in diameter would not amount to a grain of sand.

Can it be supposed that revolutions have taken place in this thin crust of the earth capable of altering its centre of gravity, and at the same time the place of its poles and its axis, so much as some have supposed, in order to account for various phænomena, such as that of the bones of the elephant, &c. being dug up in Germany, and even in Siberia; or if, by some violent action of the powers of nature in the universe, mountains have been several times overturned, and sea and land changed their situation; would these catastrophes, which must have occasioned great devastation among the human race at the periods when they took place, have been able in any manner to change the position of the earth's axis and of its poles? By no means: they must have been of much less consequence, in that respect, than the devastation which an insect would occasion in a globe a foot in diameter by gnawing the paper with which it is covered: and who will assert that the centre of gravity of such a globe would by these means be deranged?

A change in the position of the earth's axis, or of its poles, can be supposed to take place only when the whole mass of
which

which it consists is entirely inverted, and its homogeneous and heterogeneous parts mixed together in confusion. But in this case, the exterior crust of the earth which we inhabit would be wholly transformed; mountains, countries, and seas, would change their places, and be conveyed to the height or depth of a hundred miles perhaps, and more: and how is it possible that man, who can penetrate only to a very small depth in the earth, should be able to observe such remains of the old world?

Besides, the globe, which is of a spheroidal form, revolves round its less diameter, which is five miles shorter. Now, if the angle of the inclination of this axis should be suddenly or gradually changed, its rotary motion would not be deranged, but the obliquity of the ecliptic would be exposed to changes, of which, according to observations made at all periods, no traces have been found. But if the poles of the earth should leave their place, a new axis would be produced, the direction of its diurnal rotation would form another equator, and the spherical form would be changed. But the immense centrifugal force would be continually producing the most dreadful revolutions in the land and sea, and the remains of the antient population would be buried so deep in the earth as to escape the researches of succeeding generations.

The poles of our earth, at present, seem to occupy the most commodious positions; for as, on account of the cold, they are uninhabitable to beings of our species, whatever be the inclination of the earth's axis, the ocean has been assigned them as their place, and all the lands of the earth are situated around them, that, during the daily rotation and annual revolution of the earth round the sun, its surface may as much as possible be exposed to the beneficent effects of that luminary in his course from the equator towards the poles. If we should transfer the north pole, for example, to the middle of Asia, the south pole would fall in South America, and an immense tract of cultivated land, on account of the cold, would be converted into uninhabitable deserts. It is, however, highly probable, that the present poles, since the formation of the earth, as we are at present acquainted with its surface, consisting of sea and land, have always had the same inclination.

As far as such astronomical observations go back, and the antiquity of these amounts to 4450 years, when a Chinese astronomer observed (exactly according to the precession of the equinoxes) the star α in the northern Dragon in the neighbourhood of the north pole, no phenomena have taken place

place in the heavens which give reason to suppose any considerable variation in the inclination of the earth's axis, or in the place of the poles. What Herodotus therefore says, respecting the legends of the Egyptian priests, is mere fables; for if the sun, in the course of 11000 years, actually changed the place of his rising and setting three times, so often must the place of the poles, and consequently the climate of Egypt, have been changed. But supposing this to have been the case, how could the inhabitants of so level a country preserve themselves from utter destruction during the repeated transformation of land into water, which must have been the consequence of these changes? By a mere increase or decrease in the present inclination of the earth's axis, which is $66\frac{1}{2}^{\circ}$, Germany, for example, could never be transferred into what is called the torrid zone. In the first case, if the inclination should be changed to 90° , the sun in summer would be removed about $23\frac{1}{2}^{\circ}$ further towards the south from that country. In the second case, if the inclination should decrease to 30° , the sun would go to the distance of 60° from the equator, and in summer pass twice over Germany in a perpendicular direction; but in winter he would be invisible for a month, and the cold there would be much more intense than at present. On this account, neither the austral plants nor elephants could ever thrive in such a climate.

If Germany was ever situated in the torrid zone, or near the equator, the north pole must have been situated in the Pacific ocean between Asia and America, and the south pole at the southern extremity of Africa, more than 3000 miles from the places which they occupy at present. The north-east part of Asia must in that case have been nearer the north pole than at present, and Siberia in the temperate zone.

But as the bones of the elephant have been found under the earth in the northern parts of Siberia as well as in Germany, both countries must have been situated in the torrid zone: but, in this case, the north pole must have been situated in California, and the south pole in Madagascar, above 4000 miles from their present place. If the poles were ever in that situation, it may be asked, If elephants existed then in Siberia and Germany, where were the forefathers of those which now exist in the East Indies and Africa? as these countries at that period must have been in the middle of the south temperate zone, or partly in the frigid zone.

Thus there are manifest contradictions in so readily supposing a displacement of the pole, and when the revolutions which such a change must have produced, in regard to the surface of the earth and sea, are not taken into consideration.

A natural

A natural consequence follows. If our northern districts of the earth were ever situated in the torrid zone, a part of the present torrid zone (for it is not possible that this should have been the case with the whole of it) must have occupied the south temperate zone, or the frigid zone. If elephants could exist in those southern districts, at that time forming the temperate and frigid zone, or if Germany and Siberia were suddenly transported more than four thousand miles towards the north pole, could these animals withstand this general revolution of the surface of the earth and ocean? Or, during this catastrophe, were some of these ponderous animals transported over the land and sea to their present place of abode, in order to propagate their breed?

These questions cannot be answered; but are unnecessary, if we are convinced, from the principles here explained, that such displacements of the poles of the earth are not admissible.

But as the bones of elephants and the remains of austral plants are found under the earth in northern countries, this may be explained in the most natural way, by supposing that formerly a species of these large animals and austral plants existed in the temperate north latitudes; for it is certain that many petrified shells and plants, as well as the impressions of insects, are found under the earth, the originals of which are unknown; or that the present temperate zone enjoyed in the antient world a warmer physical temperature.

Are there not some proofs, generally speaking, that the mass of the cold in the north increases, and that the ice is more and more accumulated in the neighbourhood of the north pole; that even our vegetables do not possess the same degree of perfection, and betray symptoms of degeneration, though the smallest displacement has never taken place in the poles of the earth, and no change in the inclination of the earth's axis that could have an influence on the climate? Is not the cold more widely diffused in the southern hemisphere than in the northern, though both are equally exposed to the sun, and though the sun in summer is many thousand miles nearer the former than the latter?

The physical climates of the earth however, and particularly the two temperate and two frigid zones, as they are far more exposed to the varied influence of the sun's rays than the torrid zone, appear to have been subjected to great variations at long intervals. But these depend much on local and temporary circumstances, and are not determined merely by the different effects of the sun's influence, in consequence of his annual return. They are at the same time, owing to the chemical fermentation in the mixture of the component

component parts, occasioned by the accession of heat; to the solution and decomposition of these substances so different in their nature, evaporated from the surface of the earth, whether land or water, which is filled with animal and vegetable bodies; and to these vapours being in part conveyed into the atmosphere, and there converted into other matters, and being again sent back to it in the form of fertilizing moisture.

In the last place, all our observations have hitherto shown that without the globe of the earth there is no power capable of producing such irregularities in its poles and its axis.

It was long believed indeed that comets were capable of producing such revolutions. Who knows, said some, whether one of these bodies may not have approached too near to our earth; and, being furnished with too great attractive power, may have deranged its axis or its pole, or dragged its train over us; and, setting every thing on fire, may have laid waste sea and land, altered the earth's centre of gravity, and occasioned a general devastation?

But our present more accurate knowledge of the orbits and nature of these celestial bodies will never admit of any supposition of this kind. It is known from certain experience, and the consequences thence deduced, that these masses have very little specific gravity, and therefore must possess a very weak attractive power. According to every appearance, they seem to be composed of minute molecule mixed with the fine ethereal matter of light, and their trains are only highly subtile luminous and transparent substances; so that we have very little to apprehend from either of them.

No historian worthy of credit ever makes mention of the disastrous effects of comets on our earth; and mankind are now too enlightened to be led into error by what the prejudice, superstition, and ignorance of former times have handed down to us on this subject.

Even in modern times comets have passed very near our earth, without producing any remarkable phenomena, either in regard to the atmosphere or the common course of the weather; and much less were the poles or the axis of the earth any way affected by their approach; otherwise some traces of it would not have escaped the researches of the modern astronomers. On the other hand we know, by experience, that comets which have passed near to our earth, or the other planets, in their way to the sun, have suffered some perturbation in their orbits by the attractive power of the latter.

I will not however assert that our earth, before it was completely formed and rendered habitable, and before every part

part of it was brought into complete equilibrium and stability, may not have experienced some changes and variations, in consequence of which its poles and its axis may have been in some measure deranged; but all the traces of such changes hitherto discovered in the thin crust within the reach of our observation seem to prove that they were produced by partial changes in the situation of certain parts of the land or sea, which were in no manner able to displace the earth's centre of gravity, or to derange its poles and its axis.

In the course of a thousand years, revolutions of this kind may take place in regard to the earth's surface, in consequence of its organization, on account of the many chemical mixtures and solutions which are capable of continually exciting the active powers of nature; but the equilibrium, and powerful law of mutual attraction, by which one world is connected with another, may free us from all apprehension in regard to any derangement of the poles or axis of the earth capable of being followed with disastrous consequences.

LII. *Observations on the Manner in which the Spider (Aranea Diadema) spins its Web.* By M. C. G. LEHMANN *.

IT must be allowed by those who have any knowledge of entomology, that the natural history of spiders has been much neglected; for, notwithstanding the great progress which has been made in that science, we are as yet very little acquainted with the organization, mode of life, and propagation of the most common kinds of these animals; and many species make a figure in our systems and cabinets which differ from each other only by their age or their sex. These insects, so remarkable on account of their industry and manner of life, are viewed with a sort of contempt and aversion, which would be inexplicable did we not know the great power of those impressions and prejudices which we receive in our youth. These in general are communicated to us by people who are the least qualified to give the mind that direction necessary for the purposes of life, and who in particular seem to have united to inspire us with a dread of spiders. Hence the complaint of so many naturalists, that this aversion always deters them from observing and accurately examining these insects; and those who have undertaken to do so have

* From *Der Gesellschaft Naturforschender Freunde zu Berlin Neue Schriften*, vol. iii. 1801.

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