what the lower part of the river has already lost: they tell us what it has been, while it foretells what they shall come to be.

Of course, while only the maps are before me, and the Osage is a long thousand miles away, I do not wish to assert that this sketch of its history is demonstrably true; although I am strongly persuaded that an examination of the region on the ground would discover evidence confirmatory of it. The upland is built of nearly horizontal Paleozoic rocks. If they had stood at their present height above the sea ever since the date of their deposition, they would now be worn down close to sea-level, without retaining any distinct relief. Their narrow valleys show that this supposition is out of the question. The rolling upland in which the narrow valleys are incised is itself a surface of denudation; and as its reliefs are faint, with long gentle slopes and broad open valleys, beneath whose floor the narrow deeper valleys are incised, I am driven to the belief that the upland was for a long time a lowland, and that its gentle eminences are merely the remnants of a once higher mass. The dates at which this older denudation was carried on, and the later date at which the uplift to its new altitude was given, are not well determined; although from analogy with more eastern parts of the country, where the dates of such changes have been better made out, I am inclined to say that the Missouri upland was a lowland well into Tertiary time; and that the new trenches of the Osage and its neighbors were begun in consequence of an uplift somewhere about the close of Tertiary time.

These are suggestions rather than conclusions; but they still serve to illustrate the incentive to geographical study that the topographic maps supply. We all knew that there was a fertile field for study in our home geography; every one in his own district enjoyed cultivating his patch of the field; but now through the publication of these maps, it is as if the whole field was opening to all of us; and a rich geographical product is promised to all who enter it.

SUN-HEAT AND ORBITAL ECCENTRICITY.

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THE reader of Sir Robert Ball's important work, "The Cause of an Ice Age," needs no reminder that its argument rests upon a foundation of theoretical astronomy. To secure the essentials of the discussion one must read between the lines. It is the object of the present paper to select and arrange a few of the more simple inter-linear readings, in the hope that they may be serviceable in that borderland where astronomy, geology, and meteorology have each a claim.

1. "There can be no doubt that when the eccentricity is at its highest point the earth is, on the whole, rather nearer the sun, because, while the major axis of the ellipse is unaltered, the minor axis is least." ("The Cause of an Ice Age," p. 79). This is equivalent to saying that the mean distance of the earth from the sun is a function of the eccentricity of the earth's orbit, and is, moreover, such a function that when the eccentricity is a maximum the function is a minimum. The mean or average length of the radius-vector of an ellipse depends on the law assumed in regard to its variation. From the standpoint of geometry, disregarding kinematical and dynamical considerations, the simplest assumption is, that the vectorial angle is the fundamental variable. If the equation to the ellipse be written

$$r = \frac{a\,(1 - e^2)}{1 + e \cos\theta}$$

and r' be the mean length of the radius-vector, we may easily show that

$$r' = \frac{1}{\pi}\int_0^\pi r\,d\theta = a\,\sqrt{1 - e^2}. \qquad (1)$$

But in any investigation dealing with the amount of light or heat received by the earth a different assumption should be made; for it is clear that if the earth moves most slowly when in aphelion the effect is the same as if it were, on the whole, farther away from the sun. Assuming that the time is the fundamental variable and that the radius-vector sweeps over equal areas in equal times, we may find the average of the radii-vectores corresponding to the successive equal time-intervals. Consider a point moving in a circle whose centre is one focus of the ellipse. Let its areal velocity be equal to that of the point describing the ellipse, and suppose that when the radius-vector of the ellipse has swept through 180°, the radius, r_0, of the circle has swept through the same angle. Then

$$r_0^2\frac{d\theta_0}{dt} = r^2\frac{d\theta}{dt} = 2c = \frac{\pi a^2\sqrt{1 - e^2}}{T},$$

where $2T$ is the periodic time. Integrating between the limits 0° and 180°

$$\pi r_0^2 = \pi a^2\sqrt{1 - e^2}, \quad \text{or} \quad r_0 = a\sqrt[4]{1 - e^2}. \qquad (2)$$

r_0 is thus a minimum when e is a maximum, and *vice versa*. The value r_0 in (2) is greater than the value r' in (1), as we might have known in advance by simply comparing the two assumptions respecting the law of variation of r.

Developing the factor

$$\sqrt[4]{1 - e^2}, \quad r_0 = a\left(1 - \frac{e^2}{4} - \frac{3e^4}{32} - \ldots\right).$$

The present eccentricity of the earth's orbit is 0.01678. According to Leverrier it cannot exceed 0.077747. To take $r_0 = a$, the average of $a\,(1 + e)$ and $a\,(1 - e)$, that is, of the aphelion and perihelion distances, is therefore a close approximation to the mean value obtained with the assumptions above made. Laplace, in stating Kepler's third law, says, "The squares of their times of revolution are as the cubes of the transverse axes of their ellipses." (*Méc. Cél.*, II., i., § 3). He uses the term "mean distance" in speaking of the satellites of Jupiter and Saturn, but not in such a way as to indicate that he meant the semi-major axis. Gauss, in his first mention of the semi-major axis, says, "Hinc semi-axis major, qui etiam distantia media vocatur, fit $= \frac{p}{1 - ee}$". ("Theoria Motus," p. 4). Similarly, Sir John Herschel uses the terms "mean distance" and "semi-major axis" as interchangeable.

2. "The total quantity of heat which the earth receives during each complete revolution will be inversely proportional to the minor-axis of the ellipse." (p. 79). Let dh be the heat-increment received in the time dt, and μ the rate of variation of heat at a unit's distance. Then, since the quantity of heat received varies directly as the time and follows the law of the inverse square,

$$dh = \mu\,\frac{dt}{r^2}.$$

But from Kepler's second law,

$$r^2\frac{d\theta}{dt} = 2c, \quad \text{or} \quad \frac{r^2}{dt} = \frac{2c}{d\theta}. \quad \text{Hence}$$

$$h = \int_0^\pi \frac{\mu\,d\theta}{2c} = \frac{\mu\pi}{2c} \qquad (3)$$

From this it appears that the quantity of heat received in passing from one end of the major-axis around to the other varies inversely as the areal velocity. But

$$2c = \frac{\pi a^2\sqrt{1 - e^2}}{T},$$

and since the length of the year is constant and the major-axis is constant, the areal velocity is to be viewed as a function of e alone. Suppose e becomes e' and let c' denote the new value of the areal velocity. Then $h' = \frac{\mu\pi}{2c'}$, and therefore $h : h' :: c' : c$. But $c : c' :: b : b'$; hence $h : h' :: b' : b$. Again, if we substitute $\frac{\pi a b}{T}$ for $2c$ in (3),

$$h = \frac{\mu\pi T}{\pi a b} = \frac{\mu T}{a^2\sqrt{1 - e^2}} \qquad (4)$$

Hence the amount of heat received in one year is the same that would be received if the earth were to move for a year in a circle whose radius is $a\sqrt[4]{1 - e^2}$.

This accords with the result (2) already found for the mean distance of the earth from the sun. In a paper on the "Intensity of the Sun's Heat and Light" (Smithsonian Contributions to Knowledge, IX.), L. W. Meech calls $\frac{2\pi}{a^2 n \sqrt{1-e^2}}$ "the sum of the intensities during a complete revolution." In this expression n is the mean daily motion and equals $\frac{\pi}{T}$. Substituting $\frac{\pi}{n}$ for T and making μ equal to 1 in (4), the latter reduces to Meech's formula.

3. "If any two chords of the earth's orbit, as AX and BY, be drawn through the sun, S, the amount of heat received in passing over the arc AB equals the amount received in passing over XY." (p. 82). Samuel Haughton ("New Researches on Sun-Heat," 1881) proves by another simple application of Kepler's second law that the quantity of heat received by the earth in a given time is proportional to the angle described in that time by the radius-vector. For

$$r^2\, d\theta = 2c\, dt,$$

$$d\theta = \text{increment of true anomaly},$$

$$\frac{dt}{r^2} = \frac{d\theta}{2c} = \text{heat in the time } dt.$$

This is but a mathematical translation of the argument given by Herschel in "Outlines of Astronomy," 5th ed., § 368 b. The statement made on page 82, "Cause of an Ice Age," is verified by an employment of Haughton's expression. For since

$$dh \propto \frac{dt}{r^2}, \qquad dh \propto \frac{d\theta}{2c}; \text{ hence}$$

$$h \propto \frac{\theta_2 - \theta_1}{2c}. \text{ Now } ASB = XSY = \theta_2 - \theta_1,$$

and the proposition is established. The law that "the amount of heat received in any given interval is exactly proportional to the true anomaly described in that interval" appears to have been first published by Lambert in his "Pyrometrie," 1779.

4. "The total heat received by the earth from equinox to equinox is equal to that received while completing its journey around the remaining part." (p. 83). The preceding demonstration does not involve the inclination of the chords to each other, neither does it involve the direction of either chord. Hence we may make X coincide with B and Y with A, and let the one resulting chord be the line of equinoxes, and the proposition follows.

5. "If δ be the sun's declination the amounts of heat received by the Northern Hemisphere and the Southern are to each other as $1 + \sin\delta$ to $1 - \sin\delta$." (p. 175). Draw a circle representing a section through the centre of the earth (regarded as a sphere). Let the horizontal diameter produced represent the celestial equator projected in a right line EE'. Through the centre of the circle draw AA', making an angle δ with EE'. AA' will be the axis of the cylinder of heat-rays falling upon the earth when the sun's declination is δ. Draw a diameter, DD', perpendicular to AA', and at the upper extremity of DD' draw an element, TT', of the cylinder. To this draw a parallel, CC', intersecting EE' at the circumference of the circle. TT' and CC' evidently include the portion of the cylinder falling on the Northern Hemisphere. If $2R$ is the length of the diameter, the perpendicular distance between TT' and CC' is seen to be $R + R\sin\delta$. Hence if $\frac{2H}{r_0^2}$ be the quantity of sun-heat falling perpendicularly on an area equal to the section of the earth at the mean distance r_0 from the sun in the unit of time, $\left(\frac{R + R\sin\delta}{2R}\right)\frac{2H}{r_0^2}$ is the part falling on the Northern Hemisphere, while the remainder, $\left(\frac{R - R\sin\delta}{2R}\right)\frac{2H}{r_0^2}$, falls on the Southern Hemisphere. These amounts are to each other as $1 + \sin\delta$ to $1 - \sin\delta$.

One or two other propositions will be discussed in a subsequent article.

ON A PHYSIOLOGICAL CLASSIFICATION OF THE OPHIDIA — WITH SPECIAL REFERENCE TO THE CONSTRICTIVE HABIT.

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THE writer would be the last to suggest a classification of any group of animals whatsoever based upon physiological data alone. Function, unless correlated with definite variation of structure, is never to be depended upon as a means of establishing specific differences. In illustration of this, one has only to cite the numerous examples of change of function, not simply within historic times, but even within the memory of living man, owing to variation in the environment of the creatures themselves. Witness the Kea, or New Zealand parrot, and the baboon of South Africa, both of which have become carnivorous since the introduction of sheep into this region; the bees of England, which, in certain districts, have within the last twenty years become frugivorous; and certain colonies of bats, inhabiting the islands of the Gulf of Paria in Trinidad, which have of late years taken to fishing, and have in consequence abandoned their nocturnal habits, and are now strictly diurnal beasts of prey. It is true that in certain isolated cases a change of function is followed by very slight variation of physical structure. In that of the domestic cat the intestine has certainly become elongated, and has probably undergone a further process of elongation in consequence of its less purely carnivorous diet; in particular, the duodenum has become more extended within recent centuries, if one may judge from analogy when comparing the creature with its wild prototypes.

In the case, however, of serpents, the family resolves itself into three groups so naturally in accordance with the manner in which they take their food, as to suggest the justification of a natural grouping founded on this basis.

If we had a specimen of every kind of snake before us, and could watch them in the act of feeding, we should see that they perform this process in three different manners. The majority, numbering probably 1,000 or 1,200 out of the 1,800 known species, simply catch the creatures on which they prey by the prehension of their jaws and long curved teeth, and work them gradually into the gullet on what we may call general principles.

A great disproportion exists between the size of the captor and of the captive. If the serpent be very much larger than the animal which it swallows, the latter is probably engulfed alive; but if, as is commonly the case, the captive is of large diameter proportionately to the œsophagus of the serpent, it is suffocated or crushed to death in the act of swallowing. As may be expected, the serpents that feed in this manner are such as live on what may be termed soft food, — frogs, lizards, fish, or other snakes.

But with the remainder we find two special provisions for the slaughter of the prey previous to deglutition — provisions so remarkable as to place the possessors in an entirely different category to the preceding. In one of these, and by far the smaller of the two subdivisions, numbering probably not more than 220 species altogether, or about one-eighth of the whole number of snakes, we find the death of the prey is encompassed by the injection of a morbific fluid, the venom. That this in the majority of cases serves as ammunition for the destruction of the captive cannot be doubted; but whether this is the primary reason why these creatures are gifted with venom is not so certain, seeing that in many species it probably comes very little into play for this purpose — e. g., in the sea snakes, in which the fangs are so short that the fish on which they live are scarcely scratched by them, and even in the great Ophiophagus, the snake-eating snake of India, whose natural diet consists of animals in which the circulation is so slow and vitality so sluggish as serpents that they are certainly swallowed before any poison could have time to work its effect upon them. In all probability the primary office of this remarkable fluid is to act as a digestive, it having been found by experiment that albumen, pieces of hard-boiled egg, etc., dissolve in this quite as readily as in the gastric juice of any flesh-eating animal. The writer has further established by his own experiments that small animals which have been sub-