direction, are countless market booths and occasional market places, where the inhabitants can purchase native produce, food, and European luxuries. In the same way, by the sides of the country roads, are built at irregular intervals varying from one to six miles, long low sheds close by some well or running water, where the farm women sit and "make their market." In the farms which extend throughout the country from horizon to horizon as one journeys through it, save where the land is too poor, or the fear of war has desolated the neighbourhood, can be heard the crowing of cocks, the barking of dogs, the shrill laughter of children, and the vociferous clamour of native homestead gossip. For among natives, as among seafaring folk at home, a hundred yards or so is no impediment to polite conversation. From this custom arises the disadvantage that the voices of the people being naturally pitched for distant communication cannot readily be restrained or focussed for nearer ranges of social intercourse. The consequent turmoil and shrill cries are apt at first to unsettle the nerves of an inexperienced traveller, but a few weeks' residence in the country not only accustoms one to their manner of speech, but inures one's system to the sudden shock of their sonorous voices.

Northward from Ibadan, which may be described as the centre of the chief military and commercial power in Yoruba, two days' journey—about 40 miles—through many villages, and a landscape dotted far and near with oil-palms (*Elæis guineensis*) along a road thronged with travellers, brings one to the capital of central Yoruba, Oyo (Awyaw). On leaving Ibadan, Mr. Millson passed, in the course of a morning's march, over 4700 men, women, and children, hurrying into the great city from the farm villages with loads of maize, beans, yams, yam flour, sweet potatoes, fowls, pigs, ducks; or driving cattle, sheep, and goats; or mounted on small native horses which amble quickly along under the combined influence of an Arab ring bit and an armed spur which leaves its traces in deep scores along the flanks of the poor animals. Far and wide the land has for generations, and indeed for centuries, been cultivated by these industrious natives. The hatchet, the fire and the hoe, have removed all traces of the original forest, save indeed where a dark trail of green across the landscape shows where the valley of some narrow watercourse or larger river is hidden among trees. For two or three years at most the land is allowed to lie fallow, while for three or four years double or treble crops are raised with no further cultivation than an occasional scrape with a hoe, and during its fallow time no further care is taken of it than to let a rank growth of reedy grass spring up some 6 or 8 feet in height. Among this grass can be seen the seedlings and young plants of a new forest, which would rapidly take possession were the land to be permanently deserted. In spite of this careless and exhausting method of cultivation the crops maintain an excellent average, and the same plot of ground serves for generations to support its owners.

Mr. Doyle, who accompanies King Gungunhana's two envoys to this country, described his journey from the Mashonaland plateau down through Gazaland to the mouth of the Limpopo. At first the journey was through a broken plateau country, rising to 5000 feet and over, and well adapted for farming operations. After fourteen days' travel, the country suddenly drops from a level of 4000–5000 feet to 860 feet above sea-level. For many miles the altitude was no more than 300 feet, and as it was the rainy season when Mr. Doyle and his companions passed through, they found the country almost entirely a swamp. The actual distance travelled was between 700 and 800 miles, which was traversed in forty-six days.

THE CONDITION OF SPACE.

THE question of the condition of inter-planetary space, with special reference to the possibility that it offers a resistance to the passage of the heavenly bodies, has for long occupied the attention of astronomers, but is even yet far from receiving a satisfactory or definite solution. Three hypotheses seem to be more or less in vogue:—

(1) That it is filled with "ether," differing entirely in its properties from ordinary matter, and offering no resistance to the passage of solid or gaseous bodies. Radiant energy is transmitted by the vibratory motion of the ether, and possibly also the force of gravitation is transmitted by a rotatory motion, though, as Laplace points out, the velocity of the gravitation must be at least 7,000,000 times that of light.

(2) That it is filled with an ether more analogous to ordinary matter, which offers resistance, or with a highly rarefied gaseous medium similar in constitution to our atmosphere.

(3) That it is filled with ether, through which innumerable solid bodies of comparatively small size fly singly or in swarms. When they encounter one another, a gas, or a planet, they become luminous, and present the appearance of fireballs, meteorites; shooting-stars, meteors; comets, meteoric swarms; meteoric dust gives rise to the phenomenon of the aurora borealis. This theory has recently been much extended and admirably advocated by Prof. J. Norman Lockyer, in "The Meteoritic Hypothesis."

If the first hypothesis be true, and space offers no resistance to the passage of the planets, Laplace has shown (*Mém. Acad. des Sciences*, 1784) that any change in their orbits will be periodic, or, in other words, that, with only slight variations from time to time, the present condition of the solar system will continue indefinitely.

If the second hypothesis be true, the resistance, however slight it may be, will tend to retard the motion of the planets. In the case of the earth the friction between the outer layers of the atmosphere and the medium will retard the rotation of the earth, and increase the length of the day. There will also be a resistance to the motion of the earth in her orbit, which will tend to decrease the velocity, and therefore to lengthen the year; but, on the other hand, if the tangential velocity be decreased while the attraction of the sun remains the same, the earth will fall towards the sun, the mean distance will decrease, and therefore the time of revolution will be shortened.

If the third hypothesis be true, the rain of meteorites will have no effect on the rotation of the earth, but will tend to lessen the orbital velocity.

Laplace has discussed some consequences of the second hypothesis in "*Mécanique Céleste*," vii. 6, on secular variations in the movements of the moon and earth which might be produced by the resistance of an ethereal medium spread round the sun. He assumes that the density of the medium is a function of the distance from the sun, and that the resistance varies as the square of the velocity. He concludes that the acceleration produced by the resistance of a fluid ether on the mean motion of the moon is, up to "the present time," insensible; and that the acceleration produced by the same ether on the motion of the earth would be less than 1/100 of that caused to the motion of the moon. These results are extended to other planets and to comets in x. 7, where it is shown that the distance at perihelion remains unchanged, and the only alteration in the orbit is a decrease in the length of the major axis and in the eccentricity.

The question is discussed from a mathematical point of view in several text-books (e.g. Tait and Steele, "Dynamics of a Particle," pp. 279, 379), but in all cases the mathematics are somewhat difficult, and various assumptions have to be made to render the solution possible.

In the case of the earth, if the resistance of the medium be small, the orbit may be considered to be circular, more especially as it follows from Laplace's results that the error introduced decreases with the time, since the orbit becomes more nearly circular. The following brief abstract of the popular treatment suggested by G. A. Hirn in his "*Constitution de l'Espèce Céleste*," pp. 104–108, with the substitution of English values, and the extension of the results to the meteoric hypothesis, may be not without interest at the present time.

Many of the data are so uncertain, that the rough approximations by which mathematical difficulties are avoided probably produce no great loss of arithmetical accuracy in the results.

The *vis viva* of the earth at the end of any period is equal to the *vis viva* at the commencement of the period, less the *vis viva* lost owing to the resistance of the medium, and increased by the *vis viva* due to the fall towards the sun. Transposing, and dividing by $M/2$ —

$$v_r^2 = v_o^2 + v_s^2 - v_t^2.$$

Writing S for the attraction of the sun, and resolving along the radius vector A—

$$v_o^2/A_o = S, \quad \therefore v_o^2 = SA_o.$$

After a time t ,

$$v_t^2/A = S \frac{A_o^2}{A_t^2}, \quad \therefore v_t^2 = SA_o^2/A_t.$$

The acceleration towards the sun is expressed by

$$\frac{d^2 A}{dt^2} + S \cdot \frac{A_0^2}{A_t^2} = 0;$$

and integrating,

$$v_s^2 = 2SA_0 \left(\frac{A_0}{A_t} - 1 \right).$$

Substituting and reducing,

$$v_r^2 = v_0^2 \left(\frac{A_0}{A_t} - 1 \right).$$

Hence the *vis viva* lost, owing to the resistance of the medium, is one-half of the *vis viva* gained by falling through ($A_0 - A_t$) towards the sun, and the presence of a very slightly resisting medium increases the velocity of the earth in its orbit. This increase is easily expressed, since, by Kepler's third law, we may replace (A_0/A_t)³ by (T/T_0)³, where T_0, T are the periodic times at the beginning and end of the period;

$$\therefore v_r^2 = v_0^2 \left\{ \left(\frac{T_0}{T} \right)^3 - 1 \right\}.$$

But the *vis viva* lost owing to the resistance is equal to the work done in forcing the sphere against the resistance of the medium through the distance passed over by the earth during the time. We may assume for simplicity that during the last 2000 years the length of the year has shortened by five seconds; and since the change in the radius vector would be very small, that $A = 23300a$, where a is the radius of the earth, and hence that the distance through which the earth has passed is $2\pi 23300a$ 2000.

M. Hirn, by theory and experiment, shows considerable reason for believing that the formula of Hutton, for the resistance of a medium in terms of the density δ , gives a result not far from the truth. Hence

$$0.451 \times (\pi a^2)^{1.1} \times \delta \times v_0^2 \times 2\pi 23300a \text{ 2000} = \frac{Mv_0^2}{2} \left\{ \left(\frac{T_0}{T} \right)^3 - 1 \right\},$$

$$\text{where } \left(\frac{T_0}{T} \right)^3 - 1 = \left(1 + \frac{5}{31558150} \right)^3 - 1 = \frac{1}{9467445}.$$

$$\therefore \frac{1}{\delta} = (\log^{-1} 14.32278) \times g a^2 / \Delta,$$

where Δ is the absolute mass of unit volume of the material of the earth.

$$\therefore \frac{1}{\delta} = 5.64 \times 10^{14} \text{ cubic feet.}$$

M. Hirn further points out that this decrease of five seconds in the length of the year during a period of 2000 years would be accompanied by a change in the longitude of the earth of more than 205", an amount quite inadmissible since the time of Hipparchus, while the above results have shown that, to produce an acceleration so small as this, the medium must have a rarity such that one pound occupies 564 billions of cubic feet. And the volume occupied by a pound of the gas very nearly varies inversely as the number of seconds gained in the periodic time.

When we pass on to consider the retardation caused by the action of meteorites, we lose the guidance of M. Hirn, but are able to refer for data to Prof. Lockyer's treatise.

About 30 miles, or 158,400 feet per second, may be taken as the average velocity of meteorites (p. 68). Suppose the earth at rest, and struck by a meteorite weighing one pound with this velocity, the *vis viva* of the blow would be $\frac{1}{2g} (158400)^2 = 3.98 \times 10^8$ absolute foot-pounds (p. 64).

But the earth is moving in its orbit with a velocity of 18.4 miles, or 97,130 feet per second; hence, of every three meteorites we may presume that two strike the front, and one the back hemisphere. Further, the velocity of the earth is, in the one case, to be added to, and, in the other case, subtracted from, the velocity of the meteorites. Again, we may assume that the earth is struck about equally all over each hemisphere, and that, owing to its attraction, the blows are vertical, and hence that the energy added and subtracted in each hemisphere in the direction of the motion of the earth is one-half of the total *vis viva*, or for three meteorites, each weighing a pound,

$$\frac{1}{2g} \{ (158400 + 97130)^2 - \frac{1}{2} (158400 - 97130)^2 \} \\ = 4.58 \times 10^9 \text{ foot-pounds.}$$

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Suppose that a meteorite weighing one pound has the specific heat 0.2, which is about double of that of iron; to raise it from -270°C. to 2000°C. , 454 units of heat are required, which are equivalent to about $454 \times 44758 = 2 \times 10^7$ absolute foot-pounds of work—a quantity which may be neglected, in comparison with the total *vis viva* of the meteorite.

The weight of meteorites varies from tons to small specimens (p. 19), and hence we must assume an average weight of μ pounds. According to Newcomb, 20,000,000 meteorites a day enter our atmosphere (p. 69). We may again assume that the action has continued for 2000 years, and caused a shortening in the periodic time of five seconds.

The *vis viva* of the impacts,

$$\mu \times 4.58 \times 10^9 \times \frac{20000000}{3} \times 365 \times 2000,$$

must be equal to the *vis viva* lost by the earth,

$$\frac{1}{2} M v_0^2 \left\{ \left(\frac{T_0}{T} \right)^3 - 1 \right\}, \text{ which is } \frac{4\pi a^3 \times 10.86 \times (97130)^2}{6 \times 9467445};$$

$$\therefore \mu = \frac{1.95 \times 10^{33}}{1.115 \times 10^{19} \times 2000 \times 9467445} \\ = 9240 \text{ pounds, or over 4 tons.}$$

In this case, also, the average mass of the meteorites varies inversely as the shortening of the periodic time. Thus, if the average weight of meteorites is 9 pounds, the shortening would be only 0.005 second—an amount probably inappreciable.

SYDNEY LUPTON.

THE FLOWERS OF THE PYRENEES AND THEIR FERTILIZATION BY INSECTS.¹

THE observations described in this work were made in the Vallée de Luz (Hautes Pyrénées, France), in August 1889 and June 1890, between 900 and 2200 metres altitude. The author has noticed 1801 visits, brought by 507 different insects to 261 different flowers. In the list of the visits, date and altitude are always noted, and in many cases particulars are given about the special habits of insects in visiting flowers. Many of the mentioned insects were not before seen visiting flowers.

The contrivances by which the flowers are fertilized are described for the following species: *Merendera Bulbocodium*, *Asphodelus albus* (lepidopterophilous, proterogynous), *Hyacinthus amethystinus* (proterandrous, adapted to long-tongued bees), *Iris pyrenaica*, *Antirrhinum sempervirens*, *Linaria origanifolia* (adapted to bees, with special entrance for Lepidoptera or Bombylidae), *Linaria pyrenaica*, *Horminum pyrenaicum* (gynomonoecious), *Scutellaria alpina* (adapted to long-tongued bees, with special entrance for Lepidoptera), *Teucrium pyrenaicum* (adapted to bees, with entrance for Lepidoptera), *Dianthus monspessulanus* (lepidopterophilous), *Alsine* sp., *Alsine verna*, *Aconitum pyrenaicum* (resembles the *A. lycoctonum*), *A. Anthora*, *Aquilegia pyrenaica*, *Brassica montana* (lepidopterophilous), *Koripa pyrenaica*, *Reseda glauca*, *Geranium cinereum* (proterandrous, gynodioecious), *Saxifraga longifolia* (proterandrous), *Potentilla alchemilloides*, *Potentilla fragariastrum*.

Some details are given about the construction of the flowers in the following species: *Cirsium eriophorum*, *C. monspessulanum*, *Carduus medius*, *C. carlinoides*, *Centaurea Scabiosa*, *Gnaphalium Leontopodium*, *Angelica pyrenaica*. Almost all those species are illustrated (94 figures), and the explanation of each figure is given in French and in Dutch.

General conclusions.—The relative number of hemitrope Diptera (Syrphidae, Conopidae, and Bombylidae), of allotrope Hymenoptera (all Hymenoptera except the bees), of long-tongued not-social bees and of Coleoptera decreases with increasing altitude. The hemitrope Diptera (all Diptera except those mentioned above) become on the contrary relatively more numerous with increasing altitude; this seems to be also the case with the social long-tongued bees (represented in the Pyrenees by *Bombus* and *Psalithyrus*). Müller came to the same conclusions about the influence of altitude upon the same groups of insects in the Alps.

¹ "De Pyrenéeën bloemen en hare bevruchting door insecten." 226 pages, with five plates, a French résumé, and the explanation of the plates in French. In *Botanisch Jaarboek*, iii., 1891, published by the Botanical Society Dodonæa, in Ghent, Belgium).