by conducting their artificial cultivation in a particular way, and by transmission through the system of an animal differing in nature from that in which the disease naturally occurs. When the chain of discoveries reached the point of showing that bacilli could be reared outside the body in an artificial soil or cultivating medium, a great advance was made towards obtaining a full knowledge about them, as it placed the observer in a more favourable position for the successful prosecution of research by enabling him to vary and control his conditions in a manner that could not otherwise have been effected. Although much has been accomplished, it must be said much still remains to be done. In the case of a few bacilli the life-history has been pretty clearly made out. Cultivated in a certain way they retain their virulence, no matter through how many successions they pass. The last product in a series of successive cultivations is as virulent as the parent stock. By modifying the conditions under which the cultivation is carried on, the successive products of descent may be gradually weakened until they become harmless. Such being the case, any desired degree of attenuation may be obtained, and by inoculation with a virus brought down to the proper strength the non-fatal affection may be occasioned which gives immunity from subsequent liability to take the disease under exposure to contagion. The knowledge thus acquired has been already practically turned to account upon a large scale for checking the ravages of that exceedingly fatal disease among cattle known as anthrax, or splenic fever, and through the success attained much sacrifice of life has been averted. If this can be accomplished for one disease, and more than one can be mentioned, is there not ground for believing that means will be found for placing others of the class in the same position? Attempts are being made in this direction. All eyes throughout the civilised world are, indeed, at the present moment fixed upon the work of Pasteur in Paris with reference to hydrophobia. It would be a great achievement for this frightful disease to be brought under subjection, and certainly the results that have been obtained appear to give hopes that an approach to something of this kind has been arrived at. Looking at the nature of the disease, there is nothing inconsistent with its being dependent upon a bacillus, or microbe, as Pasteur calls it. On the contrary, owing its origin as it does, when occurring naturally, to inoculation with the poisoned secretion of an affected animal, and taking into view the facts that have been learnt in connection with its transmission by artificial inoculation, evidence points to such in reality being the case. If due to a bacillus, why may not this bacillus be open to attenuation in the same manner as that of anthrax? If thus open to attenuation, why not susceptible of producing a non-fatal form of affection? And if this condition has been produced and passed through, why should not protection be thereby given against the subsequent development of the disease as a result of the primary inoculation from the bite of the rabid animal? Such a train of reasoning is quite legitimate, and for the application of the principle of action to which it leads, there is this advantage on the side of hydrophobia, that from the prolonged period usually taken for incubation after the introduction of the poison in the ordinary way, time is given for the artificial inoculations by subcutaneous injection to produce their effect and to render the system refractory to the further development of disease. I have been an eye-witness of Pasteur's work. It is from the nerve centre, the seat from which the symptoms of the disease start, that he obtains his virus. Employed for inoculation in a fresh state it produces a fatal disease, and the disease has been transmitted successively on through a number of animals, with the result that the last affected animal yields as strong a virus as the first. Kept in a pure, dry air, attenuation advances, and after a certain time the nerve centre loses its disease-producing power. Used for inoculation at a given period of preservation it produces an effect which renders an animal resistant to the influence of inoculation with the virus in a fresh state, and Pasteur contends that it acts similarly when the virus has been introduced in the ordinary way. The treatment of persons bitten by rabid animals by inoculation with attenuated virus has now been on its trial a considerable time, and a large experience gained. Judgment, it must be stated, still stands in suspense; but it must also be said that the results obtained tell decidedly in favour of the view advanced. The other method by which it has been recently experimentally found that the virulence of bacilli can be weakened is by transmission through an animal of a different nature from that in which the disease naturally occurs. This, in reality, represents the principle at the foundation of the system of vaccination, discovered by Jenner at the close of the last century. It may now be regarded as an accepted conclusion that vaccine-lymph is the virus of small-pox modified by transmission through the cow. Jenner's discovery consisted in showing that the result of vaccination with the lymph of cow-pox affords as much protection against small-pox as an attack of small-pox itself. This was the fact he educed, but the knowledge possessed in his time did not permit of its being looked at in any further way than as a simple fact or truth of Nature. Viewed, however, with the light that has been thrown upon it by the researches of the present day, we see not only the fact, but also its explanation: we see that the principle of action of the procedure proposed by Jenner, which has conferred such incalculable benefit upon mankind, is based upon the attenuating effect upon the small-pox virus of the human species by transmission through another animal; and knowing this, the prospect is presented of its being rendered susceptible of application for the control of other diseases. Whether this should prove so or not, at all events advantage is gained by the knowledge acquired. Need I say anything more to exhort you, in accordance with the duty that has devolved upon me? Surely the acquirement of knowledge, giving us as it does greater power in the exercise of our calling, and thereby promoting the high and noble object of rendering our lives more useful to our fellow-creatures—surely this is a sufficient incentive, following the words of Harvey, 'to search and study out the secrets of Nature by way of experiment.'"

NOTE ON THE ASTRONOMICAL THEORY OF THE GREAT ICE AGE[1]

THE following calculation has convinced me that Mr. Croll's theory affords an adequate explanation of the Ice age. I compute the total quantity of heat received by each hemisphere of the earth during summer and winter respectively as follows:—

Let $2H/a^2$ be the quantity of sun-heat falling perpendicularly on an area equal to the section of the earth at the mean distance a from the sun in the unit of time.

Let δ be the sun's north declination. Then the share received by the northern hemisphere will be

$$\frac{H}{a^2}(1 + \sin\delta),$$

and by the southern

$$\frac{H}{a^2}(1 - \sin\delta).$$

At the distance r, and in the time dt, the heat received in the northern hemisphere will be

$$\frac{H}{r^2}(1 + \sin\delta) \,.\, dt;$$

but we have

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

whence the expression becomes

$$\frac{H}{h}(1 + \sin\delta) \,.\, d\theta;$$

but we have

$$\sin\delta = \sin\theta \,.\, \sin\epsilon,$$

where ϵ is the obliquity.

The total heat received by the northern hemisphere from the vernal to the autumnal equinox is

$$\int_0^\pi \frac{H}{h}(1 + \sin\epsilon\sin\theta) \,.\, d\theta = \frac{H}{h}(\pi + 2\sin\epsilon).$$

We have thus the following theorem:—

Let $2E$ be the total sun-heat received in a year over the whole earth; then this is divided into shares as follows:—

$$\text{Northern hemisphere, summer, } E\frac{\pi + 2\sin\epsilon}{2\pi},$$

$$\text{,, winter, } E\frac{\pi - 2\sin\epsilon}{2\pi};$$

with identical expressions for the summer and winter in the southern hemisphere.

[1] Paper read at the Royal Irish Academy on May 24, 1886, by Sir Robert Stawell Ball, LL.D., F.R.S. Communicated by the Author.

If we make $\epsilon = 23° 27'$ we find that the heat received during the summer (equinox to equinox) of each hemisphere is ·627 *E*, while the heat during the winter of each hemisphere is ·373 *E*. More briefly still. If each hemisphere receives in the year a quantity of sun-heat represented by 365 units, then 229 of these are during summer, and 136 during winter. These figures are independent of the eccentricity of the earth's orbit.

The length of the summer is defined to be the interval when the sun's centre is above the equator. The length will of course vary with the eccentricity and with the position of the equinoxes on the orbit. We need only take the extreme case where the line of equinoxes is perpendicular to the major axis of the orbit. The maximum difference between the length of summer and of winter is thus

365 days × eccentricity.

I take the maximum eccentricity of the earth's orbit to be

0·0745,

this being the mean of the values by Leverrier, Lagrange, and Stockwell (see Croll, "Climate and Temp.," p. 531), and, therefore, the greatest difference between summer and winter will be about 33 days, *i.e.* one season is 199 days, and the other is 166 days.

The total quantity of heat received during the year on each hemisphere is practically independent of the eccentricity; but the mode in which that heat is received at the different seasons will vary, and thus give rise to the following extreme cases:—

GLACIAL

(Summer)	229	heat units spread over	166	days.
(Winter)	136	,, ,,	199	,,

INTERGLACIAL

(Summer)	229	heat units spread over	199	days.
(Winter)	136	,, ,,	166	,,

We hence deduce the following, where unity represents the mean daily heat for the whole year on one hemisphere:—

GLACIAL

Mean daily sun-heat in summer (short) ...	1·38
,, ,, winter (long) ...	·68

INTERGLACIAL

Mean daily sun-heat in summer (long) ...	1·16
,, ,, winter (short) ...	·81

PRESENT (NORTHERN HEMISPHERE)

Mean daily sun-heat in summer (186 days)	1·24
,, ,, winter (179 days)...	0·75

These figures exhibit a thermal force of great intensity. The unit represents all the mean daily heat received from the sun by which the earth is warmed up from the temperature of space. The heat unit in fact maintains a temperature perhaps 300°, or even more, above what the earth would have without that heat. Each tenth of a unit may thus roughly be said to correspond to a rise or fall of mean temperature of 30° or more. The long winter of 199 days, when the average heat is only two-thirds of a unit, leads to the accumulation of ice and snow, which form the Glacial epoch. The short winter of 166 days, where the temperature is ·06 of a unit above that of our present winter, presents the condition necessary for the mild interglacial epoch.

THE BRITISH ASSOCIATION

SECTION H—ANTHROPOLOGY

The Native Tribes of the Egyptian Súdan, by Sir Charles Wilson, K.C.B.—These may be divided into four distinct groups—the Hamitic, Semitic, Núba, and Negro; but the first three only were dealt with in this paper. The largest tribe in the Súdan is the Kabbabish. They extend from Dongola to the confines of Darfúr; they speak a pure Koranic Arabic, and have a tradition that they came from Tunis; they are possibly of Berber descent, but the Sheikhs are apparently of Arab origin. They are divided into two great branches and several minor clans. One clan, Kawahleh, appears to be of Arab origin.

The Celtic and Germanic Designs on Runic Crosses, by Prof. W. Boyd Dawkins.—The author said that although it is generally assumed by archæologists that the early Irish manuscripts, such as the illuminated Gospels of St. Cuthbert and St. Chad, are of pure Irish art, and that consequently the interlacing "rope-" or "basket-work" pattern is distinctly Irish and Celtic, such an assumption is not warranted by experience. A consideration of the distribution of the designs on ornaments and monuments in the British Isles and in France, Scandinavia, and Germany, lead to the conclusion that the art was probably derived from the centres of civilisation in South Europe, principally Greek and Etruscan, and it has clearly been proved by Chantre to have been introduced into France from Italy. The square interlacing pattern does not occur in France or the British Isles in association with any remains of a date anterior to the movement of the Germanic tribes against the Roman Empire, and as it is only found in regions into which the German tribes penetrated, it may be concluded that it is distinctly Germanic, and not Celtic, still less "pure Irish."

The Scientific Prevention of Consumption, by G. W. Hambleton.—There are two distinct objects to be accomplished in the prevention of consumption. On the one hand we have to secure an adequate amount of breathing capacity in proportion to the rest of the body, and on the other to prevent either compression of the chest or injury to the lungs. This can be done by adopting those measures that tend to the development of the breathing capacity, and suppressing or obviating those conditions that compress or injure the lungs. By adopting measures is meant placing men, women, and children under conditions of habitation, clothing, education, and urging upon them habits that tend individually and collectively to develop the lungs.

Dragon Sacrifices at the Vernal Equinox, by George St. Clair, F.G.S.—The object of this paper was to show that human sacrifice, which prevailed extensively in early times, was a custom connected especially with the vernal equinox, and that the offerings were made to appease a mythical dragon which made its demand at that time. The dragon of mythology was identified and defined, and it was shown in what sense he opened his jaws at the spring season of the year. Human sacrifice was practised more especially at the spring of the year, or (in other instances) in honour of deities who once presided over equinox constellations. Artemis and Cronus, to whom this homage was chiefly shown, were both connected with the zodiacal sign Scorpio, and, according to M. Ernest de Bunsen, Scorpio was the starting-point of the primitive calendar. If the festival of Saturn did not get displaced or misplaced through the precession movement, it was still a festival in honour of the god of the under-world, and that meant death and the grave. Tradition says that human sacrifices were abolished by Hercules. As Scorpio rises with Hercules, and ceases to be a dark sign, the mythology is consistent with itself.

Evidence of Pre-Glacial Man in North Wales, by Dr. Henry Hicks, F.R.S. — The author in this paper described the conditions under which a number of flint instruments were discovered during the researches carried on by Mr. E. B. Luxmore and himself in the Ffynnon Beuno and Cae Gwyn Caves, in the Vale of Clwydd, in the years 1884-86. Last year a grant was made by the British Association for the purpose of carrying on the explorations, chiefly with the object of obtaining further evidence as to the age of the deposits in the caverns. The results obtained this year are highly confirmatory of the views which he (Dr. Hicks) had previously held, and have a very important bearing on the antiquity of man in Britain. It was found that the main entrance to the Cae Gwyn Cave had been blocked up by a considerable thickness of Glacial beds, which must have been deposited subsequently to the occupation of the cave by the Pleistocene mammals. A shaft was dug through these beds in front of the entrance to a depth of over 20 feet, and in the bone-earth, which extended outwards under the Glacial beds on the south side of the entrance, a small well-worked flint flake was discovered. Its position being about 18 inches beneath the lowest bed of sand, it seemed to be clear that the contents of the cavern must have been washed out by marine action during the great submergence in mid-Glacial times, and then covered by marine sand and an upper covering of boulder-clay. He believed that the flint implements, lance-heads, and scrapers found in the caverns were also of the same age as this flint flake, and hence that they must have been the work of pre-Glacial man.

The Recent Exploration of Gop Cairn and Cave, by Prof. Boyd Dawkins.—This was a paper on the exploration of Gop Cairn and Cave, near Gop Hall, New Market, St. Asaph, now being carried on by Mr. Pochin, Mr. P. G. Pochin,