eye-witness, who also stated that the cones produced by the trees in question always proved seedless. The trees, curiously, were all females, and had no opportunity of impregnation. In further reference to the diœcious character of this genus of Conifers, I am informed that the Maresfield trees, as indicated, failed to produce fructiferous cones until males were planted within suitable proximity to them. Pertaining, further, to the sexuality of the Araucaria, I believe that a distinguishing character exists in the size of the foliage, that of the cone-bearer being considerably the larger.

Bearing on the sudden fruition of the Inveraray tree, it may be interesting to relate a parallel case, which occurred upwards of twenty years ago, when I was residing in the neighbourhood of Stratford-on-Avon. A fine specimen of that beautiful Spanish silver fir (*Picea Pinsapo*), on one windy day, became prostrate, and exposed, to my surprise, the greater portion of its main roots in a fungous, diseased condition, thus solving the problem why the tree had for the last few years assumed a stunted growth. Fortunately, however, as two or three of the main roots on one side of the tree remained intact, I resolved to raise it to its former position, after having cut away every vestige of diseased or broken roots; which was successfully accomplished by the aid of a stout rope and pulley-block, and a dozen able men. Subsequently the tree did not appear to suffer materially from the trying ordeal it had been subjected to, and my anticipations of its resuscitation were shortly afterwards justified by a healthy renewed growth, and the interesting appearance, in the course of two or three years, of a crop of beautiful cones, specimens of which I exhibited at one of the Royal Horticultural meetings in 1869, and for which a "Special Certificate of Merit" was awarded. Evidently the cause of this abnormal fruition—as in the case of the Inveraray Araucaria—was owing to arrested growth. In conclusion, I may add that I failed to discover the real cause of the decay of the Picea's roots, but attributed it to something unsuitable in the almost impervious damp subsoil, the fungous condition being only consequential.

WILLIAM GARDINER.

Harborne, Birmingham, November 15.

P.S.—Respecting the sexuality of the Araucaria, it would be instructive as well as interesting could any of your correspondents define any comparative specific character possessed by the plants, such, for instance, as the foliage or general habit, when in their earlier life, and whereby they may be distinguished.—W. G.

EARLY this summer the Araucarias of large size around Terregles House, near Dumfries, were in fruit. Many of the shed cones were lying at the base of the plants. Several years ago I saw a fine Araucaria in fruit in the manse garden, Colvend, Kirkcudbrightshire; but learned from the incumbent that the sight was a rare one. About the middle and end of October, this year, we had numerous trees of the mountain ash from which the leaves had fallen, but which stood glittering, laden with red berries. Clouds of fieldfares arrived, at first noisy and shy, perching on the tops of larch-trees. They devoured these berries, and, getting bolder, invaded my garden, and clustered on a mountain ash in such numbers that there could not be less than 200 at one time. At two visits of one hour each, in one day, every berry disappeared from that tree. Now the flocks of fieldfares are no longer visible, and the berries of the hawthorn and other wild fruit do not seem to attract them, while not a berry of the mountain ash could be picked up for many miles.

JAMES SHAW.

Dumfriesshire.

THE GENESIS OF TROPICAL CYCLONES.

ACCORDING to the views of Dr. Hann, as explained in a previous number of this journal, (Nov. 6, p. 15) the storms of the temperate zone originate, not in the convective ascent of warm damp air (an explanation, however, which he appears to admit in the case of tornadoes), but in great vertical movements of the upper air-currents, which commence over the equator as the anti-trades, and set continuously towards the poles, being gradually diverted eastwards in consequence of the earth's rotation. Owing to the spherical form of the earth's surface, these currents become irregularly congested as they necessarily converge on reaching higher latitudes, and thus give rise to anticyclones, or tracts of excessive accumulation and pressure, and to cyclonic vortices in the intervals. Admitting this view as at least highly probable, the question now to be considered is how far similar conditions hold good in low latitudes. Do the cyclones of the tropical zone originate in like manner, or are they not rather primarily due to the conditions of the lower atmosphere, to the production and condensation of vapour over a calm region, and the creation of an upcast current?

In the first place, it is to be observed that in low latitudes those causes which impede the even flow of the upper currents are at a minimum. Their tendency to congestion must vary as the contraction of the degrees of longitude in successive parallels of latitude; and whereas between latitude 40° and 50°, for instance, this amounts to 16 per cent. of the length of the degree, and between 50° and 60° to 22 per cent., between 5° and 15° it is little more than 3 per cent. Accordingly, the non-periodic oscillations of the barometer, which, in Europe, frequently amount to an inch in the course of a day or two as cyclones and anticyclones successively sweep past, in the latitude of Madras (13° N.) rarely much exceed a tenth of an inch in the whole course of a month. But cyclones originate certainly as low down as latitude 8°, and instances have been recorded in 7° and even 6°.[1]

On the other hand, the supposed alternative cause, viz. the production and condensation of vapour, is at a maximum in low latitudes, and the facts recorded by Eliot, Pedler, and others who have traced out the early history of Bay of Bengal cyclones, go to show that their formation is determined by the inrush of a saturated current from the equatorial sea, and that this inrush is preceded by at least one or two days of disturbed squally weather in the birthplace of the storm. Moreover, the evident relations of these storms to the features of the terrestrial surface, always in the early stages of their existence, and frequently after they have been maturely developed, seem to admit of no other conclusion than that they are, primarily at least, phenomena of the lower atmospheric strata, even though at a later period the vortical movement may be imparted to the greatly elevated anti-trade, and so be carried forward into higher latitudes. And lastly, as Dr. Hann has himself shown, the temperature test, which he rightly appeals to as crucial, and which in his hands has led to the overthrow of the condensation theory of extra-tropical storms, does not fail when applied (as far as the data admit of) to the case of tropical cyclones. On each of these points some further elucidation is necessary.

First, as regards the place of their origin; and in these remarks I shall restrict myself to the storms of the Bay of Bengal and the adjacent Indian continent, which have been more closely studied than those of other tropical seas. A chart given by Mr. Eliot in his recently published "Hand-book of Cyclonic Storms in the Bay of Bengal" shows that they are generated with about equal frequency in all parts of the bay betweeen N. latitudes 8° and 18°. Between latitude 18° and the Bengal coast they are much more frequent, though generally of less intensity. But they are formed very rarely indeed over any part of the Indian peninsula. I can remember but one such case during an experience of many years' daily study of the weather charts. And although they originate somewhat more frequently in Lower Bengal during the height of the monsoon, even these instances are rare in comparison with those of storms generated at the head of the bay during the same season. With but few exceptions, therefore, they are formed only over the sea, and these exceptions are nearly all restricted to the low plain immediately north of the bay. If the original impulse were a vortical movement of the higher atmosphere, it

[1] See the list of storms in Appendix II. to the "Weather and Climates of India."

would be difficult to account for this practical limitation of the storm cradle to the surface of the bay; whereas on the alternative assumption the reason is obvious.

Next, with respect to season and antecedent circumstances. The fierce and destructive cyclones which accompany the changes of the monsoons are generated chiefly in the south of the bay in the spring and late autumn, and further north at the beginning of the summer and in the earlier autumn months; while during the height of the summer monsoon, the less severe storms, which I have elsewhere distinguished as "cyclonic storms," are formed in the extreme north of the bay, and occasionally, though rarely, over the plains of Bengal; in which case they never attain to any great strength. Over the storm cradle at the outset, and everywhere to the north of it, the atmosphere is calm and sultry, or moved only by light variable winds; and at the change of the monsoons, when storms are formed far out in the bay, the atmospheric pressure is nearly uniform all over the bay, and even over the land there are only those slight differences, it may be either of excess or defect, that are due to the normal distribution of the season. Cyclone formation seems to be but little if at all affected by the barometric condition of the atmosphere over the Indian continent. But storms always originate somewhere beyond the northern limit of that saturated equatorial atmosphere which is itself fed by the southern trade winds, and is the reservoir from which is drawn the rainy summer monsoon. In this direction the pressure is always somewhat higher, but until the cyclone has formed, the gradients are gentle.

Thus the average birthplace of storms advances and recedes with the northern limit of the southern monsoon, being always situated beyond it in the region of nearly uniform and relatively low pressure, calms, or light and variable winds, which extends over a greater or less area beyond that limit.

Over the cradle of a storm, the formation of a vortex is always preceded by disturbed squally weather, during which the barometer falls slightly over the disturbed area. In most instances this lasts for two or three days, sometimes longer, and during this period there is but little rain around the coasts of the bay. As this preliminary occurrence of squally weather is a point of some importance, I will quote a passage describing it more fully from Mr. Eliot's recent work:—"The history of all cyclones in the bay shows that they are invariably preceded for longer or shorter periods by unsettled squally weather, and that during this period the air over a considerable portion of the bay is gradually given a rapid rotatory motion about a definite centre. During the preliminary period of change from slightly unsettled and threatening weather to the formation of a storm more or less dangerous to shipping, one of the most important and striking points is the increase in the number and strength of the squalls which are an invariable feature in cyclonic storms from the very earliest stages. First of all the squalls are comparatively light, and are separated by longish intervals of fine weather, and light variable or steady winds, according to the time of year. They become more frequent, and come down more fiercely and strongly, with the gradual development of the storm. The area of unsettled and squally weather also extends in all directions, and usually most slowly to the north and west. If the unsettled weather advances beyond this stage (which it does not necessarily do), it is shown most clearly by the wind directions over the area of the squalls. The winds always settle down into those which invariably occur over an area of barometric depression or cyclonic circulation, or, in other words, are changed into the cyclonic winds of indraught to a central area of low barometer and heavy rain. As soon as the wind directions indicate that a definite centre of wind convergence has been formed in the bay, it is also found that the centre never remains in the same position for any considerable interval of time, but that it moves or advances in some direction between north-east and west, with velocities which not only differ very considerably in different storms, but also at different stages of the same storm."

Such being the facts, as gathered from the detailed study of a great number of storms, their most probable interpretation seems to be somewhat as follows. It may be taken as an established fact that rain is, practically in all cases, the result of the dynamic cooling of ascending air, and that whenever the rain is accompanied by squalls this ascent is irregular and spasmodic. If so, the weather that precedes a cyclonic circulation, as described in the foregoing paragraph, indicates that over a previously calm area the lower atmosphere gradually acquires a spasmodic ascending movement, at first sporadic but gradually becoming concentrated as the influx of the surrounding atmosphere impresses a spiral movement on the general mass. With the influx of the saturated current from the south, this action is greatly accelerated, and the vortical movement which has originated in the lower atmosphere is imparted to the higher atmospheric current, which carries it forwards, at first slowly, and then with increased velocity, as the movement gradually extends to the higher and more rapidly moving current of the general atmospheric circulation.[1] Were the seat of the original disturbance in the bosom of the upper current, it is difficult to see why the disturbed condition of the lower atmosphere should remain stationary during the incubation of the storm, or why it should exist sometimes for two or three days in anticipation of the spiral circulation, which, on this hypothesis, is the determining impulse of the whole phenomenon.

I am not aware that anyone has as yet made a special study of the circumstances under which the storms of the temperate zone originate. Some of them doubtless enter this zone from the tropics. But as the result of a somewhat cursory examination of the Atlantic charts published by the Meteorological Council, others appear to be formed very rapidly either as secondary eddies in the circulation of the North Atlantic atmosphere around Iceland, or in the V-shaped depressions between two neighbouring anticyclones. In neither case does there appear to be that prolonged incubation that characterizes the Bay of Bengal storms; notwithstanding that heat and vapour must be far less active agents in high than in low latitudes. Indeed, this consideration seems to add support to Prof. Hann's views, while it also tends to strengthen the probability that tropical and extra-tropical storms arise from a different class of actions.

Further evidence that tropical cyclones are originally and chiefly phenomena of the lower atmosphere is afforded by the fact that even the most violent storms are often broken up by hills of very moderate height. Notably was this the case with the destructive Backerganj cyclone of November 1, 1876, a very large and violent storm, which nevertheless broke up on reaching the low hills of Tipperah; and perhaps a majority of the cyclones that cross the Coromandel coast from the bay are dissipated by the ghats and hill-groups of the Carnatic, few of which exceed 5000 feet in height. In these cases, a disturbed state of the atmosphere indicated by heavy rain outlasts the cyclone sometimes for two or three days, but the strongly-marked vortical circulation disappears.

It has been suggested to me by Prof. Hann that even

[1] This assumes, of course, that the poleward current of the general circulation exists normally above the calms and variable currents of the monsoons, and such is equally the assumption of the opposite hypothesis. The observations on the progress of the Krakatão dust-cloud indicate only a very rapid westerly current, circulating around the globe in the equatorial zone in August. Those of the movements of high clouds at Calcutta and Allahabad, at a much less elevation than the Krakatão dust-cloud, indicate very variable directions in the summer and autumn, but chiefly southerly at Calcutta, and west or south-west almost exclusively at both stations during the remainder of the year. See the tables in the "Weather and Climates of India," pp. 60, 61.

if the severe cyclones of the transitional periods of the monsoons arise in the way I have above indicated, the milder but more lasting "cyclonic storms" of July and August which are generated in the extreme north of the bay, and which often traverse a great part or the whole of Central and North-Western India before they break up, may nevertheless be formed in the same manner as those of the temperate zone. But this seems to me extremely improbable. With the single exception of the place of their origin, the circumstances of their formation are essentially identical with those of the former class. Moreover, the track which they almost invariably follow seems to be determined by the distribution of the monsoon currents, being along the trough of low pressure which lies between the easterly and westerly branches of the monsoon of Northern India. Although the belt of broken hilly ground running across Central India is generally traversed by the storm vortex, the winds which mainly feed it from the bay have a clear sweep up the great Gangetic plain, and those from the Bombay coast, after surmounting the ghats, have a tolerably unimpeded course across the Deccan plateau, whereas in such cases as the Backerganj cyclone, the whole broad range of the Arakan Yoma, from 5000 to 7000 feet in height, presents an obstacle to the single feeding current from the Bay of Bengal.

I come lastly to the crucial test of temperature—to the question, namely, whether the mean temperature of the air-column in a tropical cyclone is such as to render it specifically lighter than the surrounding atmosphere, and therefore such as to promote an ascending movement. We have indeed in this case no high-level observations to appeal to, such as are furnished to Dr. Hann by the Alpine and other mountain observatories for the storms of the temperate zone. But Dr. Hann has made a rough computation which enables us to bring it fairly to the test, and which in the case of European storms was found to give a result entirely justified by observation. In a paper published in the September number of the *Meteorologische Zeitschrift* he has computed the temperatures of the air-column over a tropical cyclone at different elevations, on the assumption of adiabatic cooling, and has compared these with the average normal temperatures of the atmosphere at the same elevations as deduced from the observations of Newera Eliya, Dodabetta, and Antisana. As the result, he finds that the mean temperature of the former is probably about 2° C. higher than that of the latter, and therefore such as to produce an upward movement of the cyclonic atmosphere, with an acceleration equal to about $\frac{1}{300}$ of the force of gravity. It may indeed be somewhat greater than this, since in his computation Dr. Hann has assumed a temperature of 28° C. or 82°·4 F., and a relative humidity of only 80 per cent. for the atmosphere of the cyclone at sea-level. In point of fact, observation shows that in a cyclone in the south of the bay the temperature at the sea-level is 79° or 80°, but that the air is saturated, or close upon saturation. Making this correction of the data, the mean temperature of the cyclonic air-column will be about 3° C. higher than that of a normal atmosphere, equivalent to an accelerating force of $\frac{1}{200}$ of gravity.

From every point of view, then, whether we regard the place and circumstances of their origin, their behaviour after formation, their physical constitution, or the relative activity of the causes supposed to be concerned in their production, the conclusion seems irresistible that tropical cyclones originate in a manner quite different from that ascribed to the storms of the temperate zone; that they are in their early stages a disturbance of the lower atmosphere; and that the primary impulse is given by the ascent and condensation of vapour.

These remarks apply only to the "cyclones" of the beginning and end of the summer monsoon, and the "cyclonic storms" of the summer months. The storms that traverse Northern India in the winter and early spring, which always travel eastward, and but very rarely descend within the tropic, are of quite a different character, and may not improbably originate in the manner suggested by Prof. Hann.

HENRY F. BLANFORD.

THE DE MORGAN MEDAL.[1]

IN 1869 Lord Rayleigh commenced the long series of papers and memoirs in Mixed Mathematics, which the Council had in view in making the award, with an article (*Philosophical Magazine*, vol. xxxviii., third series) "On some Electro-magnetic Phenomena considered in connexion with the Dynamical Theory," founded on Clerk-Maxwell's celebrated "Dynamical Theory of the Electro-magnetic Field" (Phil. Trans., 1865), the subject being "Examples of Electro-magnetic Problems illustrated by comparison with their Mechanical Analogues." I may add, to complete the key-note, thus struck, of Lord Rayleigh's scientific career, that these theoretical results were followed up in the next year by an account of "An Electro-magnetic Experiment," viz. the magnetizing effect of an induced current as dependent on the self- and mutual inductions of the circuits—an early instance of the author's practice of making theory and experiment, or concrete example, illustrate one another. This combination of experimental with mathematical skill and fertility of resource has been conspicuous in Lord Rayleigh's later memoirs on the "Determination of the Ohm and B.A. Unit of Resistance in Absolute Measure" (Roy. Soc. Proc., vol. xxxiv., and Phil. Trans., vol. clxxiii., 1882.)

Confining myself to those earlier memoirs and papers by Lord Rayleigh in which mathematical investigation predominates, the next which calls for notice is one of considerable length, "On $\int_0^1 Q_n Q_{n'} d\mu$ ($Q_n Q_{n'}$ being Laplace's coefficients of orders n, n'), with an Application to the Theory of Radiation" (Phil. Trans., 1870); in which, instead of the two Q's being multiplied together and integration then effected, the flank of the difficulty is ably turned and the object attained with comparative ease. The mathematical results are illustrated by their application to the problem of "finding the stationary condition when a uniform sphere is exposed to radiation from infinitely distant surrounding bodies."

"A Memoir on the Theory of Resonance" (Phil. Trans., 1871), is the first of Lord Rayleigh's numerous essays in the mathematical theory of sound, which were preliminary, or have been a sequel, to his well-known Treatise, of which the two volumes appeared successively in 1877 and 1878.

The subject of the Memoir is an investigation of air-waves (of the fundamental note) in hollow spaces, whose three dimensions are small in comparison with the wave-length, and which communicate with the atmosphere by necks similarly limited. The theory is shown to be applicable to cases of multiple resonance, as when two or more such hollow spaces are connected by necks and communicate with the external air by necks.

The question of the calculation of c, a factor or coefficient occurring in some of the differential equations, is treated in a noteworthy manner, suggested by the remark that, if the air were replaced by uniform conducting matter of unit specific conducting power, and the sides of the vessel by insulators, c would be the measure of electric conductivity between the interior of the vessel and external space, "an analogy freely availed of, . . .

[1] Address to the London Mathematical Society on the occasion of the presentation of the De Morgan Medal to Lord Rayleigh, November 13, 1890, by the President, J. J. Walker, F.R.S.