adults of transition forms from Nautiloidea to Ammonoidea, and set down his convictions that the Ammonoidea must have been derived from Nautilus through these transition forms, the gradations being Nautilini, Goniatites, Ammonites. Barrande then pictures this same naturalist as attempting to verify his apparently well-founded conclusions by opening a species of Goniatite with the anticipation of discovering within, at the apex, or young shell, an identical form and structure to that which he had been accustomed to find in the Nautiloidea, and his consequent confusion, and the overthrow of his theory, upon the exposure of a different form. Barrande's argument deals fairly with every point; and his facts are crushing refutations of the usual direct, simple modes pursued by embryologists in handling the question of the evolution of types. Barrande's work had no orators or lecturers to translate it; and the hypothesis of the embryologists, and even evolution itself, escaped an attack, which, if supported by powerful influences, might have shaken the popular faith in the new school of thought.

Hyatt has denied that there were such great and essential differences between the embryos of the Nautiloidea and those of the Ammonoidea; and they certainly seem to have been more alike than was supposed by M. Barrande. The fact, however, remains, that Barrande saw clearly that the embryos of these two nearly allied groups, which are united by most authors into one order, were, even in the Silurian, more easily separable from each other than some of the adult forms. When we can add to this, his discovery and thorough demonstration of the distinctness of the different types of fossils in the Silurian, and their sudden mode of appearance, we see clearly that he succeeded in doing the work which has thrown the greatest light upon the most obscure and interesting periods of the world's history, and which has furnished a temperate and healthy opposition to the theory of evolution. His faults of logic were unavoidable, with his mathematical and Cuvierian education, and strong feelings of loyalty to his masters in science; but these are only slight scratches upon the face of the vast monument erected by his labors, his discoveries, his eighty-three years of unblemished moral and faithful life, and his personal sacrifices for the advancement of science and the truth.

WHIRLWINDS, CYCLONES, AND TORNADOES.[1] — V.

CYCLONIC circulation has thus far been described as if it were effected in radial lines in to and out from the centre; but here, as in the whirlwind, perfect radial motion is impossible. A horizontal rotary motion would soon be established near the centre by the inequality of the inblowing winds. It is found, however, that all storms yet studied turn from right to left in the northern hemisphere, and from left to right in the southern (fig. 9). Such constancy points to something more regular than the accidental strength of the winds, — to some cause that shall always turn the indraughts to the right of the centre as they run in towards it in the northern hemisphere, and to the left in the southern hemisphere; and this cause is found in the rotation of the earth on its axis.

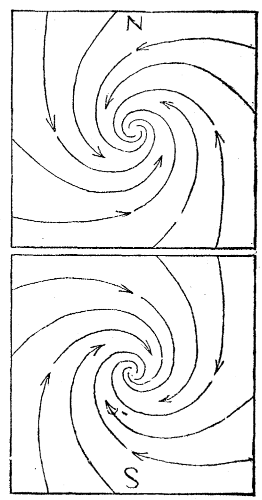

FIG. 9.

There is a force arising from the earth's rotation that tends to deflect all motions in the northern hemisphere to the right, and in the southern to the left; and this deflecting force varies with the latitude, being nothing at the equator, and greatest at the poles. It may be found that this statement differs from that generally made: namely, that moving bodies are deflected only when moving north or south, and not at all when moving east or west: for it is thus that Hadley (1735) and Dove (1835) explained the oblique motion of trade-winds, and that Herschel and others explained the rotation of storms. But this is both incorrect and incomplete; for a body moving eastward is deflected as well as when moving northward, and the actual deflective force is greater than that accounted for in Hadley's explanation.

[1] Continued from No. 43.

It is this deflective force, acting on winds from all sides, as was first shown by Tracy[1] (1843), that combines with the centripetal tendency of the surface-winds to give rise to the inward spiral blowing of the storm (fig. 10), — a constant feature of all cyclones.

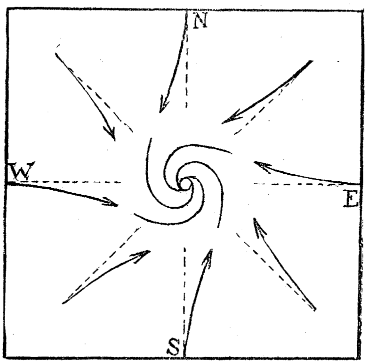

FIG. 10.

In all hurricanes, the winds greatly increase in strength as they near the centre of the storm, and at the same time their path becomes more nearly circular. A cause of this was briefly stated for the whirlwinds: but it now must be more fully analyzed; and it will be best to begin the attempt by resolving the motion of the wind at any point of its spiral track into two rectangular components (fig. 11), — one, along a radius toward the centre, *P R*, the centripetal component; the other, circular or tangential, *P T*. Only the first of these comes directly from the convectional circulation, already described as depending on the central warmth; and this one would never produce winds of devastating strength. The second, or tangential, arises first from the deflective force of the earth's turning. The higher the latitude, the less the friction at the bottom of the atmosphere, and the greater the distance from which the wind is derived, then the greater its right-handed departure from a radial path. Hence in a large storm at sea, where the friction is small, and the indraught has its source several hundred or even a thousand miles away from the centre of low pressure, the deflective tangential component becomes very considerable, and may, near the centre, outrank the centripetal.

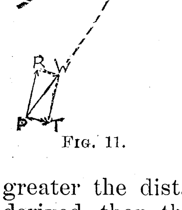

FIG. 11.

[1] See SCIENCE, i. 98.

But there is another and even more important cause of growth in the circular element of the wind's motion; namely, the increase of its rotary velocity as the radius of rotation decreases, in accordance with the law of the 'preservation of areas,' already mentioned. Let us suppose, that, when at a distance of five hundred miles from the centre, the inblowing wind has been turned to the right of its radial path by the earth's deflective force so as to have the moderate tangential or rotary velocity of one mile an hour; and, disregarding the further effects of deflection, let us consider the consequences of gradually drawing this mass of air towards the centre. The product of its radius and its rotary velocity must remain constant; and hence, as the radius is diminished, the velocity must increase, one quantity varying inversely as the other. The wind has no visible, material connection with the storm-centre; but it is slowly moving around that centre, under the control of central forces, derived from differences of temperature and pressure, that drive it inwards, or, in other words, shorten its radius of rotation: and consequently, when, in the case supposed, the radius has been diminished to five miles, the velocity must have been accelerated to one hundred miles an hour, — a violent hurricane-wind. The recognition of this important factor of the storm's strength is due to Ferrel (1856). The theoretical increase of velocity thus provided is never fully realized, for much motion is overcome by friction; but enough is preserved, especially in tropical storms, to give them the greatest share of their destructive strength. The total tangential component of the wind at any point must therefore be considered as the sum of the deflective and accelerative forces, minus the loss by friction. Near the storm-centre, where the velocity of the wind is very great, this tangential component is much greater than the centripetal, and the spiral path becomes almost circular; while the reverse relation holds for the outer part of the storm.

It will be easily understood, that a considerable centrifugal force will be developed by the rapid central rotations, as well as by the earth's deflective force; and, as a consequence, the centripetal force will be partly neutralized, and the winds will be held out from the centre. This must increase the depression already produced there by expansion and overflow; and, as a matter of fact, the low pressure of a storm-centre, especially in tropical latitudes, is chiefly the effect of this dynamic, and not of the earlier named static cause. But so long as the wind maintains its rapid motion, the additional depression is powerless to draw it towards the centre. Only when its velocity is decreased by friction does the barometric gradient, just before produced by the centrifugal force, urge the wind inwards to the middle of the storm. The additional gradient, therefore, represents potential energy, derived from the actual energy of the rotating winds, and all ready to be transformed into actual energy again, as soon as friction has destroyed some of the velocity of rotation.

The general interaction of the storm-forces may now be thus summarized: in obedience to a centripetal tendency, produced by differences of temperature or of pressure, or both, the air moves along the surface to the region of low pressure. On its way, the deflective force arising from the earth's rotation turns it continually to one side, and so gives it a more and more nearly circular path; and, in addition to this, its rotary velocity increases as much as its radius of rotation decreases: the tangential component of its spiral motion must therefore continually increase. With the increase of this component, and the decrease of the radius of rotation, the centrifugal force ($v^2 \div r$) must increase rapidly, and soon come to equal and counterbalance the original centripetal force, and at the same time greatly increase the barometric gradients. At this point the wind would blow in a circular path, were it not that friction with the sea or ground is continually consuming some of its velocity, and thus decreasing its centrifugal force, and allowing the potential energy of the steep barometric gradient to produce centripetal motion. This decreases its radius, and at once gives it new life, again to be partly destroyed and renewed as before. Absolutely circular motion can therefore never be attained, although it is approached very closely near the centre. At sea, where friction is small, and in tropical latitudes, where the strength of the storm is great, the wind is unable to reach the storm-centre; for, when the distance from the centre is reduced to only five or ten miles, the centrifugal force is so great, and the wind's course is so nearly circular, that it is carried aloft by the up-draught before it can enter noticeably farther: the central area is therefore left unprovided with violent winds, and is generally a comparative calm, known as the 'eye of the storm,' of which there will be more to say later. The general form of the storm-wind's spiral can be deduced from the preceding considerations. The angle between the tangential component and the actual path of the wind, which is called the inclination (fig. 11.), will vary with the relation of the circular and centripetal elements of the wind's motion; the tangent of the inclination will equal the radial divided by the tangential component: hence in the outer part of the storm the inclination will be large, and the wind will blow almost directly toward the storm-centre; but nearer the centre the inclination will become smaller and smaller, and the wind will blow in a more and more nearly circular path. It will also be understood, that the upper winds, less influenced by friction, will near the centre have a greater velocity and a less inclination than the lower ones. Moreover, the inward gradient which they produce will be effective and important in urging along the slower surface-winds, in a manner better illustrated in a tornado, where this action will be more fully described.

(To be continued.)

ON THE DEVELOPMENT OF TEETH IN THE LAMPREY.

THE teeth in the myxinoid fishes are quite different from those of other vertebrates, and have hitherto been supposed to belong in an entirely different category. Nothing has been known with regard to their development, except a brief statement as to their mode of succession in Petromyzon by Professor Owen, in his 'Odontography.'

The teeth of the lamprey are horny, and of simple conical shape, disposed concentrically in the dome-shaped mouth. Besides these, there are horny lingual and palatal teeth.

The kindness of my friend Professor Benecke of Königsberg, who sent me a number of lampreys at the end of their metamorphosis from Ammocoetes, has enabled me to follow out the development of these horny teeth with unexpected results; for, as far as the essential part of the process is concerned, it differs but slightly from the normal course of true dental development. There is first formed a low conical papilla of somewhat reticulate tissue, belonging to the mesoblast (*m.p.*), and continuous with the dermis, which in this, as in other vertebrates, is of mesoblastic origin. Over this papilla the epiblast which lines the cavity of the mouth becomes extremely thick, and consists of very numerous layers of cells. All of these layers can be continuously traced into the other epiblast of the mouth, as well as that of the external skin. In the stage here figured there may be seen, immediately overlying the mesoblastic papilla, a layer of epiblastic cells irregularly columnar and polygonal in shape (*e.o.*). These cells are the homologue of the