XVI. "On the Leaf-arrangement of the Crowberry (*Empetrum nigrum*)." By HUBERT AIRY, M.A., M.D. Communicated by CHARLES DARWIN, M.A., F.R.S. Received May 8, 1876.

(Abstract.)

Pursuing the study of leaf-arrangement, the author finds that the crowberry of our moors (*Empetrum nigrum*) habitually exhibits a peculiar mode of variation in the arrangement of the leaves on different parts of the same twig. Out of fifty crowberry-twigs taken at random, only four (and these fragments) preserved the same arrangement throughout. In the remaining forty-six the leaf-arrangement was found to undergo a progressive change in ascending from the base of the twig to the summit—a change from a simpler order to others more complex. In general the basal order was that denoted by the fraction $\frac{2}{5}$; and this was found to pass most frequently into $\frac{2}{7}$, which in turn was found to pass into $\frac{2}{9}$, with or without an intermediate set of whorls of 4: $\frac{2}{9}$ generally passed into whorls of 5, sometimes into $\frac{2}{11}$, which was the most complex arrangement that was met with in this plant. The following is a list of the transitions found in the fifty specimens:—

Transition	from	$\frac{2}{5}$ (or $\frac{3}{8}$)	to $\frac{2}{7}$	occurred	22	times.
,,	,,	do. do.	,, $\frac{2}{9}$	,,	5	,,
,,	,,	do. do.	,, whorls of 5	,,	1	,,
,,	,,	whorls of 3	,, $\frac{2}{7}$	,,	2	,,
,,	,,	$\frac{2}{7}$	,, whorls of 4	,,	10	,,
,,	,,	$\frac{2}{7}$	,, *a**	,,	2	,,
,,	,,	$\frac{2}{7}$	,, $\frac{2}{9}$	,,	9	,,
,,	,,	whorls of 4	,, $\frac{2}{9}$	,,	5	,,
,,	,,	*a**	,, $\frac{2}{11}$	,,	1	,,
,,	,,	$\frac{2}{9}$	,, whorls of 5	,,	5	,,
,,	,,	$\frac{2}{9}$	,, $\frac{2}{11}$	,,	1	,,
,,	,,	whorls of 5	,, $\frac{2}{11}$	,,	1	,,
				Total	64	

* By *a* the author denotes a 4-, 6-, 10-ranked order, such as is found in heads of Dipsacaceæ.

In all these instances the striking peculiarity to be observed is that the arrangement passes from an order belonging to one phyllotactic series (*e.g.* from the order $\frac{2}{5}$ in the primary series $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, &c.) to an order belonging to another phyllotactic series (*e. g.* to the order $\frac{3}{7}$ in the secondary series $\frac{1}{3}$, $\frac{1}{4}$, $\frac{2}{7}$, &c.), and that this is a phenomenon which could not result from uniform vertical condensation of the lower arrangement; whereas in other plants the ordinary transition is from one order to another of the *same* series (*e.g.* from $\frac{2}{5}$ to $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, &c.), and is such as *would* result from uniform vertical condensation of the lower arrangement (as the author has shown in a paper read before the Royal Society on the 30th April, 1874: see Proc. vol. xxii. p. 298).

In order to examine the mode in which the above transitions were effected, the author constructed an instrument (described below) by means of which he obtained diagrams, pricked on paper, of the leaf-arrangement of the fifty specimens. On comparison of these diagrams it was found that, in every case where the details could be traced, a gradual dislocation (so to speak) took place between two adjacent spirals belonging to one of the two sets of spirals with least angular divergence, whereby the other set became deranged and gave rise to new sets having different numbers. Thus the transition from the arrangement $\frac{2}{5}$ (in which the spirals of least angular divergence are 2 in one direction and 3 in the other) to the arrangement $\frac{3}{7}$ (in which those spirals are 3 in one direction and 4 in the other) was effected by an apparent slip between two of the 3 spirals, whereby the 2 spirals became deranged and helped to form a new set of 4 spirals, which with the old persistent set of 3 formed the spirals of least angular divergence in the new arrangement $\frac{3}{7}$, while a new primary spiral arose, turning in an opposite direction to the old. (A diagram is required to make this clear.) In all these transitions the change of order is brought about not by any agency affecting all parts of the system uniformly all round the axis, but by a disturbance of the relative position of leaves along one special spiral tract.

The variations described by the Rev. G. Henslow (Trans. Linn. Soc. vol. xxvi. p. 647) as occurring in the leaf-arrangement of *Helianthus tuberosus* appear to be similar in character to those of *Empetrum nigrum*, but much more limited in range. The author has met with a few other instances of the same kind in other plants.

It is noteworthy, in the above transitions, that the primary spiral of the basal order is lost at the first change and gives place to a new one turning in the opposite direction, which, again, is replaced by another at the next change: in fact, in the crowberry, no rank or set of ranks is found to possess enduring value, but all are liable to derangement. They appear to be only the *local result of the geometrical conditions of mutual accommodation of contiguous leaves under mutual pressure* (*which brings with it the common need of economy of space*) *in the bud.*

This principle the author has before enunciated, with regard to the more common forms of leaf-arrangement, in the paper above referred to (Proceedings of the Royal Society, 1874, vol. xxii. p. 298, &c.), and in a "Note on Variation of Leaf-arrangement," read before the British Association at Belfast in August 1874 (see Rep. Brit. Assoc. 1874, Trans. Sect. p. 128).

Having there drawn attention to two ways in which modification of leaf-arrangement appears mainly to have been brought about—namely, (1) *direct variation of number of vertical leaf-ranks*, producing the fundamental orders of different phyllotactic series, and (2) *subsequent variation of degree of uniform condensation*, effecting transition between different orders of the *same* series—he now shows (3), from examination of the crowberry, that transition between different orders of *different* series is brought about apparently by means of unequal condensation resulting in *spiral dislocation* between adjacent secondary ranks.

The instrument ("taxigraph") used in this research consists of a twig-holder which rotates in fixed bearings, the twig being held in the axis of rotation under a framed lens which slides on fixed guides parallel to the twig. Thus the angular position of any leaf is observed by aid of the rotation of the twig-holder, and the vertical position by aid of the sliding motion of the lens. The sliding motion of the lens is conveyed by cords and pulleys to a light frame carrying a strip of paper beneath the platform, which is the base of the instrument; and the rotary motion of the twig-holder is made, by aid of cords and pulleys, to draw a sliding pin-holder to and fro along a slit in the platform at right angles to the direction of motion of the strip of paper below. The pin, in any position of the slider along the slit, is made to pierce the strip of paper on pressing a lever. Every leaf on the twig is thus observed, and a corresponding pin-prick made in the paper. The longitudinal position of any pin-prick shows the vertical position of the leaf, and the lateral position of the pin-prick shows the angular position of the leaf. The whole figure represents the leaf-arrangement of the twig in radial projection, and is bounded laterally by two vertical lines corresponding to one and the same vertical line on the twig. By enlargement of the lateral dimension the arrangement is shown relatively foreshortened.

The author suggests modifications of this instrument by which it could be adapted to other forms of stem or twig; *e.g.* by causing the paper to rotate under the sliding pin-holder, and by giving the lens a quadrantal motion, it would be adapted to flat or conical systems such as the heads of Compositæ.

The paper was accompanied by the original fifty specimens (less one, lost), and by the fifty "taxigrams" obtained from them: two of these were especially referred to in illustration of the paper. The instrument used was also exhibited.