PHYLLOTAXIS

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Leaves are commonly arranged on the plant stem according to a pattern. If the pattern is "whorled," several leaves arise from the same node, at intervals along the stem. If the pattern is "distichous," the arrangement is two-ranked. However, the most common pattern of arrangement is "spiral."

The most accurate method for studying plant phyllotaxis is by transecting the apical bud and making observations on the cross-section. When one examines such a cross-section, the most striking feature to meet the eye is the spiral appearance of the arrangement of leaf primordia. It has been found that there is a definite, heritable spiral appearance of the arrangement of leaf primordia. It has been found that there is a definite, heritable spiral arrangement which can be designated (in most cases) by two numbers: the number of spirals which turn in one direction, and the number which turn in the other (these curves are called "parastichies"). The intersections of these two spiral systems delineate "quasi-squares," within which are found the leaf primordia (2, 4, 40).

In an overwhelming number of species (434 species in the Angiospermae and 44 species in the Gymnospermae were found by T. Fujita in 1938) the parastichy numbers fall in the Fibonacci Sequence, the most common pairs of numbers being 2:3 and 3:5 (see Appendix) (40). When the parastichy numbers do not fall in the Fibonacci Sequence, they regularly fall into one of the other summation series (see Appendix, footnote).

It has also been found by investigators in the field (2, 14, 40) that the angle between adjacent leaf primordia is, in a convincing number of cases, approximately $137^{\circ}30'$. This is variously called the "ideal angle," the "divergence angle," and the "Limitdivergenz." This angle can be obtained mathematically by applying the limiting value of the Fibonacci Sequence u_n/u_{n+1}:

$$360^{\circ} - (0.6180)(360^{\circ}) = 137^{\circ}30'.$$

Phyllotaxis has been a field of interest for centuries. Since 1900 several theories have been offered as explanation of some of the phenomena of phyllotaxis. Some experimentation has been done to determine the effect of environment or mechanical damage on phyllotaxis (6, 11, 21, 25, 42); and some X-ray and chemical effects on the development of leaf arrangement have been noted (17, 20, 22, 23). However, after 1920 very little has been published on this subject; perhaps the feeling is that there are so many more fruitful and less "mysterious" areas of botanical interest, that this one is best left alone. Also, the subject seems to lie more properly in the realm of biophysics, which is a relatively new field.

The spiral arrangement discussed in (1) above is not peculiar to plants. It is also found in the shells of foraminifera (4), nautili, and other animals. It is the opinion of Church (4, p. 48) that the factor common to both plants and the foraminifera is "the building of new units one at a time, — and it thus appears that this is the essential factor behind all such presentation of Fibonacci relations, to all time."

Church also feels that the Fibonacci phyllotaxis is phylogenetically primitive (4, p. 13).

> "...very admirable spiral arrangements, in which Fibonacci symmetry may be distinctly traced, obtain in the case of many of the more massive Brown Seaweeds (Phaeophyceae-Fucoideae), in the orientation of the more or less frondose or leaf-like lateral ramuli; leaving little doubt that the phyllotaxis-mechanism is, in fact, a still older function of the axis of marine types of vegetation, and that the presentation of such phenomena, even in a more elaborated and special form, can be but the continuation and amplification of factors of marine phytobenthon; and that it is to the sea that one must look for the origin and primary intention of this remarkable relation." (4, pp. 37-38)

There seems to be little doubt that the primary mechanism responsible for Fibonacci phyllotaxy is genetic in nature, rather than being a function of growth conditions such as availability of, and need for, illumination. In the words of Church,

> "It can only be concluded that the plant is somehow biased from the first in favour of members arranged one by one in a Fibonacci sequence; and the suggestion immediately offers that this may be in some way the expression of the inheritance of the equipment of a preceding phase and the solution of a much older problem." (4, p. 53)

I suggest that, by a consideration of a type of order and symmetry so basic to living matter, one may perhaps gain some insight into the problem of the origin of that order.

Editorial Comment: A mimeographed 46 entry annotated bibliography is available on request from the Fibonacci Association. Send requests directly to Brother U. Alfred, St. Mary's College, California 94575.

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CORRECTIONS: Volume 2, Number 3

In the poem "A Digit Muses" by Brother U. Alfred, page 210, we wish to say "oh pshaw, no phi!" since PHI was omitted from the end of the sixth line.

Page 204: The symbol ϕ was omitted from the numerator of the last displayed equation. The numerator is, of course, $\phi(x)$.

CORRECTIONS: Volume 2, Number 4

Page 290: Title should have π in the blank after the second word in the title and the eighth displayed equation should have a + and a - respectively in the blanks between the second and third terms and the third and fourth terms.

Page 281: Missing symbol in the first displayed equation is, of course, a summation symbol.

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