Why is a Flower Five-Petaled?

Yutaka NISHIYAMA

[Summary]

This paper examines why many flowers are five-petaled through the use of a five-petaled model that draws insights from the location of cell clusters at a shoot apex, rather than by way of the Fibonacci sequence or the golden ratio as in the past. The conclusion drawn is that flowers are most likely to be five-petaled, followed by six-petaled; four petals are unstable and almost no flower can be seven-petaled.

[Keywords] flower, plant, cell, petal, leaf, pentagon, Fullerene

1. Many Five-petaled Flowers

I am deeply interested in pentagonal forms in the natural world. A hexagon, as seen in bee's nests or snow crystals, is mathematically explained, but no clear explanation is made about a pentagon.

Echinodermata such as sea urchins, starfish and sea cucumbers are five-actinomorphic with a bony plate on the skin and a unique water-vascular system. In other words, they are pentagonal and rotationally symmetrical. The arm of a starfish has strong regeneration power as indicated by the fact that one of its five arms can regenerate immediately. Even more surprising is the fact that one arm can regenerate the remaining

four arms[1]. Is something that determines five arms strongly coded for in DNA?

Using a compass or ruler, a regular pentagon cannot be drawn as easily as a regular triangle, tetragon or hexagon. Although we can draw a regular pentagon with a protractor, by way of a 360-degree central angle which is divided into five, starfish do not use a compass or ruler, nor have mathematical knowledge. How can such a primitive aquatic creature draw a regular pentagon so easily?

"Five," as seen in sea urchins and starfish, is also observed in plants. Flicking through the *"Illustrated Guide to Plants* (*Shokubutsu no Zukan*)*"* (Shogakukan), many five-petaled flowers are found: spring flowers such as cyclamen, pansy, gypsophila, ume (Japanese apricot), cherry, azalea and peach, summer flowers such as morning glory, bellbind and oleander; as well as autumn flowers such as cotton rose, balloon flower, gillyflower and gentian produce five-petal flowers. Farm products such as watermelon, melon, pear and apple also have five petals.

Having said that, there are also exceptions—a calla with one petal, an iris with three petals, daphne, dogwood and fragrant olive with four petals, and lily, narcissus and orchid with six petals.

As for the one-petaled and four-petaled flowers among these exceptions, some theory says that what looks like a petal is actually a sepal. Firstly, a calla belongs to the arum family, and what appears to be a white petal is a bract with small flowers on a thick axis inside. Calla's bract is sometimes called a spathe, as it looks like the halo or flames often seen in the Buddha statues. Secondly, with respect to four-petaled flowers, a daphne, spring flower, has four sepals, not petals. The same thing applies to the autumn flower of fragrant olive with yellow blossoms.

2. Trimerous, Tetramerous and Pentamerous Flowers

The *"Makino's New Illustrated Flora of Japan, Revised and Supplemented* (*Kaitei Zoho, Makino, Shin Nihon Shokubutsu Zukan*)*"* by Tomitaro Makino (Hokuryukan) neatly classifies all plants according to kingdom, division, class, order, family, genus and species[2]. The book specifies the number of sepals, petals, stamens and pistils of all the families. A flower diagram shows the pattern of locations and distributions of these to aid people easily understand the structure of a flower.

The classification of trimerous, tetramerous and pentamerous flowers is based on a flower's components. If flowers have three (or a multiple of that number) sepals, petals, stamens and pistils, they are called trimerous flowers. Many monocotyledons such as lily, iris and spiderwort belong to this category. Similarly, flowers with four (or a multiple of that number) components, such as Japanese laurel and evening primrose, are tetramerous, and those with five (or a multiple of that number), such as azalea and morning glory, are pentamerous.

Flowers that belong to the same family have the same number of petals. All you have to do in order to know the number of petals of plants is research at a family level. The result of such research is described below. The spermatophyte division, subject of the research, has 219 families. The division is divided into the gymnosperm subdivision (13 families) and the angiosperm subdivision (206 families). The gymnosperm subdivision has no sepal or petal, and is classified as zero-petaled. The angiosperm subdivision branches off the monocotyledon class (35 families) and the dicotyledon class (171 families). The monocotyledon class includes the iris family and the lily family, and many families in the class are three-petaled and six-petaled (trimerous). They have no sepal, and

are counted by tepals. The dicotyledon class is split into the choripetalae subclass (125 families) and the gamopetalae subclass (46 families). Many families in the choripetalae subclass are five-petaled (pentamerous) like the rose family, mallow family and violet family, or four-petaled (tetramerous) like the mustard family and dogwood family. The gamopetalae subclass that includes the heath family and morning-glory family has many five-petaled (pentamerous) families.

Table 1 categorizes the 219 families in the spermatophyte division according to the number of petals. Table 2 picks up the part from three-petaled to six-petaled. Families with no petal are included as long as the number of sepals or bracts can be counted. As a result, it is found that the largest number of families is five-petaled and that five-petaled flowers belong to the dicotyledon class, the angiosperm subdivision, which is an advanced plant community from the perspective of the evolution theory.

Table 1 Classification by Number of Petals (All)

Number of petals	Number of families	Percentage
0	38	17.4%
1	2	0.9%
2	6	2.7%
3	13	5.9%
4	38	17.4%
5	84	38.4%
6	24	11.0%
More	7	3.2%
Unknown	7	3.2%
Total	219	100.0%

Table 2 Classification by Number of Petals (3-6 petals)

Number of petals	Number of families	Percentage
3	13	8.2%
4	38	23.9%
5	84	52.8%
6	24	15.1%
Total	159	100.0%

3. Chrysanthemum also Five-petaled

We are familiar with chrysanthemums. According to the *"Illustrated Guide to Plants* (*Shokubutsu no Zukan*)" (Shogakukan), the aster family accounts for the largest share of 9%, with its 135 species among the total of 1,495 species. The representative species of the aster family are a dandelion in spring, sunflower in summer and cosmos in autumn. I had mechanically classified the aster family as multi-petaled (seven or more), but it actually is five-petaled.

A flower of the aster family consists of a ray flower and a tubular flower, the latter surrounded by the former. The ray flower is a coalescent five-petaled flower. That is, the four of the five original petals had been degenerated with one ray petal remaining. The tubular flower at the center is an aggregate flower with hundreds of condensed small flowers.

Cosmos looks like an eight petal flower but these eight petals are actually eight flowers. You can find this by looking at cosmos' tubular flowers at a park through a magnifying glass with a power between 10 and 15. Each one of densely located small flowers splits into five at the edge. Its appearance is similar to the flower of a balloon flower, and obviously

five-petaled.

The flower of a tare in the legume family is tubular at the bottom, and divided into five at the edge. One flag petal, two wing petals and two keel petals of the five petals constitute the corolla (whole of petals). The flowers of the legume family, mint family and violet family are symmetrical if horizontally observed. Such a flower is called a zygomorphic flower. In any case, they are five-petaled.

The okra, which is edible, has the shape of a regular pentagon. It is also called America neri in Japan, and belongs to the mallow family, the Hibiscus manihot genus (Abelmoscus). The mallow family belongs to the mallow order (Malvales), the choripetalae subclass, the dicotyledon class, the angiosperm subdivision, and it is pentamerous. Its sepals, petals and stamens can be found from outside, but its ovary cannot. This ovary has to do with the pentagonal shape of okra's fruit. The ovary located below the pistil is divided into five cells, which makes the fruit pentagonal. The cross-section of the fruit of a pear shows a pentagon like okra. A pear belongs to the rose family, which is pentamerous.

4. What is a flower?

Let's get an idea about what is a flower in shape, in reference to the *"Plant Morphology* (*Shokubutsu Keitai-gak*)" by Noboru Hara (Asakura Shoten)[3]. A plant's organs are the root, stem and leaf. The root is an underground part of a plant body, which exists to support the plant, and absorbs water and inorganic salts. Stems are an aboveground part of the plant body designed to support the plant, and disseminate matter. Leaves regularly line up around a stem, and carry out photosynthesis with their flat shape. A plant, through its leaves, actively provides oxygen in exchange for carbon dioxide from outside, and transpires.

A unit consisting of a stem and leaves regularly arranged around the stem is called a shoot in botany. One example of a shoot is a branch. An inflorescence, a bud and the growth is develops and extends from it are also considered as a shoot.

Many plant flowers consist of sepals, petals, stamens and a pistil, which is formed by one to several carpels, equivalent to leaves, sticking to one another. A sepal, petal or stamen is also regarded as a modified leaf. Therefore, a flower can be considered as a metamorphosed short stem and variations of leaves regularly surrounding it (FIG. 1).

A flower, from the perspective of botany, is an organ that produces a fruit and seed. In other words, a flower is ultimately an organ for a descendent from a seed. In this sense, a flower is called a reproduction

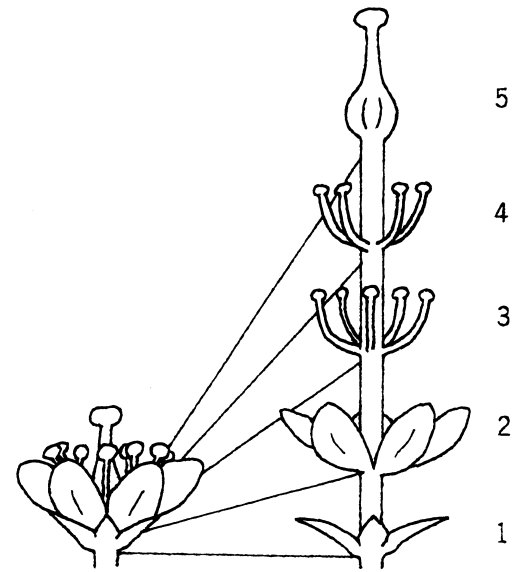

FIG. 1 A flower as a Shoot (1. sepal, 2. petal, 3. and 4. stamen, 5. pistil). This figure is originally taken from Hara's article[3] and modified by myself.

organ.

Some mechanism to determine a five-petaled characteristic may exist in a pollen. From such a standpoint, I looked at the picture of pollen taken with a scanning electron microscope in the *"Compendium of Modern Botany, Vol. 7 (Gendai Seibutsu-gaku Taikei, Di 7 Kan)"* (Nakayama Shoten). Although, various forms of pollen are observed, some of which are spherical like fertilized eggs and the morulae of a sea urchin or starfish, no sign of anything that might decide "five" is observed. The next candidate is a seed, in which the origins of only a cotyledon, plumule and radicle, in other words, leaf, bud and root are found with no sign of flower. The growth of a plant has two stages, and a flower is formed during the second phase growth, which indicates that the shape of a flower is not determined yet.

5. Spiral Phyllotaxis and Fibonacci Sequence

A rafflesia of the tropical rain forest in Sumatra, the largest flower in the world, is five-petaled. I saw a documentary TV program on how its flower blooms; I had thought that one petal was followed by a petal next to it when the flower bloomed, but the picture showed that the next petal was skipped and every other petal opens in the first round and that the second round completed the blooming of the five-petaled flower. Such an order in flower blooming is confirmed by peeling and observing the petals of a blossom bud pulled off a plant of the tea family.

The order of petal opening is similar to that of leaf arrangement, which is explained later (spiral phyllotaxis). This suggests that a flower consists of metamorphosed leaves with a very shortened stem. By the way, the leaf primordium theory about a flower was originally advocated by Goethe in 1790. This theory is correct on the whole, although it

also contains an error in the sense that a leaf bud and a flower bud are different and that all the leaves do not become flowers.

The role of leaves is photosynthesis. Sunlight must be made most of in photosynthesis, and leaves are arranged so that the shade of a leaf on other leaves is avoided as possible as it can. There are four such arrangements (FIG. 2). The first one is called opposite, with two leaves at the same height of a stem. The second one is alternate, with leaves alternately arranged at different levels of a stem. The third arrangement is verticillate, with three leaves at the same height of a stem. The last one is called spiral, with three leaves at different heights of a stem. When there are many leaves, a spiral arrangement can reduce shades most effectively. The arrangement of leaves is called phyllotaxis and a spiral leaf arrangement is called spiral phyllotaxis.

An alternate leaf arrangement and a spiral phyllotaxis are further classified by the divergence. The divergence is an angle formed by the two lines on the sectional view of a leaf arrangement, the one line to connect a stem and the center of a leaf and the other to connect a stem and the center of another leaf immediately above (or below). When the divergence is, for example, one of 144-degrees, the leaf arrangement is called a two-fifths leaf arrangement because 144-degrees is two-fifths of 360-degrees. Many types of leaf arrangements exist, such as a half, one-third, two-fifths and three-eighths ones. It can be considered that the numerator and denominator reflect the numbers of spirals and leaves in the spirals respectively. For example, three-eighths leaf arrangement implies that there are eight leaves in three spirals.

These leaf arrangements of plants can be explained by way of the Fibonacci sequence. The Fibonacci sequence, which is taught in mathematics at high schools, derives from botanical studies, and is a sequence