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THE SYMMETRY OF LIVING BEINGS
I. THE DECREASE IN SYMMETRIES AND EVOLUTION

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Abstract

It seems to be a general property of nature that the (atomic and cellular) organizing of matter resp. anti-matter can only take place of particles of a single kind of helicity.

The asymmetry of components does not mean that the living beings (the composition) are (is) also unambiguously asymmetrical.

The main manifestation of the onto- and phylogeny is: the decrease in symmetries, the formation of the evolutional series of symmetry states. The complete asymmetry, however, means decline, stagnancy, because a higher organization can only be achieved by cells (forms) that have preserved their symmetry.

The cause of the formation of helix symmetries is the damage to cylinder symmetries. The helix is a new, stable state of the linear formation, the manifestation of the cylinder symmetry at a higher level.

In the living world, Fibonacci's series is followed by every helix symmetry, because this takes the arrangement 1+1, the most ancient cylinder symmetry, as its starting point.

Are living beings asymmetrical?

The laws of nature are approximately symmetrical. Nevertheless, in the living world we find several instances of asymmetry. Looking at ourselves in the mirror the heart of our reflected image beats on the right side. Were the symmetry of reflection full then people of the same number should live with hearts on the right and left sides. Similarly, the right- and left-handers should amount to the same number.

The shells of most snail species, living in our days, are whorled to the right. A distinction, like this, may often be met with in the vegetable kingdom as well: e.g., the hop-vine ramps on the hop-pole to the left but the stalk of bean has a winding to the right. We do not know any bean or hop species, among which we could find stalks winding to right and to left in the same number. However, not the morphological asymmetry of the organs but the molecular asymmetry is considered as the main argument for the universal asymmetry of the living world. The living beings are built only of one of the possible two stereoisomers.

These facts are well-known. The question is, however, whether we can draw the conclusion from them that living beings are unambiguously asymmetrical. We are of this opinion.

In physics, symmetries have an outstanding significance. In biology, however,

an undeservedly low attention has been payed to them. In connection with the raised question, I take it important to discuss the following subjects:
(1) The concept of symmetry, the principles of symmetry in nature,
(2) The main manisfestation of evolution, decrease in symmetries and increase in co-ordination,
(3) *Helix* symmetries in the living world.

1. The concept of symmetry, the principles of symmetry in nature

In art and science people have always been attracted by the perfect things or by those damageable only a little. In our environment, symmetry generally means geometrical regularity. It may be seen, therefore, justified for answering the question, "what symmetry is," to set out first from geometry. According to the definition of the mathematician Weyl: Something is symmetrical if it can be subjected to a certain operation and after performing this operation it remains the same as before.

The main characteristics of the performable operations or, by another name, symmetry-transformations are: turning round in space, shifting in space and time, on the other hand: reflecting.

1.1. Continuous transformation

Turning round and shifting are also named continuous transformation because starting out of a position, we can get with any small steps into the wanted new position.

The most symmetrical spacial form is the sphere because it may have in its centre innumerable axes, passing through, and turning round it remains the same as it was earlier.

The cylinder has already no more than one axis, round which it can be turned in any degree and, after turning we shall see it the same as before.

The symmetrical tranformations of the square are poorer. It can be turned unchanged at a plane by 90, 180, and 270 degrees. And round the four bisecting axes at the plane we don't observe any change only in case of a turning by 180 degrees.

An entirely regular pentapetalous flower is even less symmetrical than the square. If it is turned round the sole axis in its centre, there will only be four cases — the removal by 72, 144, 216, 288 degrees — when the petals get into a position that is undistinguishable from the original position.

We find, of course, also some "bodies" in nature that — in case of a spatial turning — being pushed in a direction — pass into themselves. Taking into consideration the shift, as well, the symmetry of the highest degree is shown by gases (homogeneous isotropic systems). In the system all points, all directions are equivalent, sphere-symmetrical.

In crystals, all points are also equivalent but there are already some distinguished directions (axes), too, along which the crystals, shifted by one or more rows of atoms, are found unchanged. The crystals are homogeneous, anisotropic systems.

In the vegetable kingdom, the carbohydrate polymers consist only of one of the two possible isomers, the "right-hand" D-glucose. In the starch and cellulose hemicrystals we find some axes, along which all "points" are equivalent. This is a nice example that symmetrical structures can be created even from asymmetrical molecules, at a higher level of organization.

If we consider the cell as an elementary unit, then a homogeneous cell filament, a cell plate is also symmetrical. If we shift a linear series of cells like this in the field of sight of the microscope by one or more cells along the longitudinal axis, the, new picture remains exactly the same as the former one was.

1.2. Space reflection is the symmetry of the right and left

Reflection is a geometrical forming (transformation), in the course of which distances remain unchanged. Reflection is also named discrete symmetry because the transformation — in contrast to the continuous space — time symmetries — can only be performed in a single step.

The discrete symmetry transformation may be: space reflection, time reflection and filling reflection (transposition of matter — antimatter). The fundamental characteristics of reflection is that if the operation is performed successively, two times the initial position returns.

The image of a point P reflected on the system of co-ordinates yz be P'. The transformation means in the co-ordinates of the point the following:

$$x' = -x, y' = y, z' = z$$

After reflecting on plane, the reflected image of formations entirely agrees with the original one. The bisecting plane of the sphere, cube, cylinder, square, etc. is, at the same time, a reflecting plane, as well. The reflected image of several symmetrical molecules (e.g., H_2O, CH_4) can be turned so that it covers the original molecule. These "bodies" have no "right-hand(and'left-hand" varieties.

The image of point P° reflecting the origo of the system of co-ordinates is P. But at the reflection referring to the origo, we get the following change:

$$X^0 = -x, y^0 = -y^0, z = -z$$

At reflecting on the origo, the reflected image of a system of "right-hand" spinning will be of "left-hand" spinning. The right-left symmetry, therefore, means that the physical laws are independent of the choice of a system of co-ordinates.

The spatial reflection is the symmetry of nature because "every" formation has a reflected image, as well. In the mirror, of the right-hand a left-hand helix and of the right hand a left hand helix is formed. The right-hand and left-hand formations — apart from the single property that they cannot cover each other — are equivalent from every point of view.

By the spatial reflection a recent common characteristic of symmetry-principles is shown: symmetry is always connected with the fact that some quantity cannot be measured. We cannot distinguish "right" from "left" because these concepts are connected with each other and are not absolute distinctions like e.g. white and black.

The most strange in the whole is that a microbe can perfectly distinguish the right-hand and left-hand aminoacids and sugars. On the other hand, a researcher would in vain take pains to look for some quantitative signs in the teeth of a man, with which it would be possible to separate those of right hand from those of left hand. It would similarly be a hopeless research task to demonstrate that the quantitative relations, the physical and chemical properties on the right side of the leaves of a tree are different from those on the left side.

2. The main manifestation of evolution, decrease in symmetries and increase in co-ordination

In the development of individuals and species, apart from the spatial organization, the dimension of time is extremely important as well. It is worth while investigating into how the degree of symmetry and arrangement during the onto- and phylogeneses changes.

The decrease in symmetry (violation of symmetry) does not mean a full lack of symmetry but only that the number of available operations causing no change (symmetry-transformation) is lower and lower. It follows from this that the concrete symmetry states show a sequence of development, the most ancient formation being the sphere. The symmetry of highest degree is shown by a homogeneous isotropic body, and its arrangement is close to zero.

2. 1. The most symmetric cell of the living world is the zygote

The zygote has potentially all (geometrical, inner, and isotope-spin) symmetries, (MARÓTI, 1979). The animal zygote has — depending on the quantity of yolk and its localization — more than one type, but they correspond to one another that their shapes are roundish or ovoid.

It is frequent that the distribution of yolk in the zygote is uniform (isolecital). In this case, the first axis of division may be optional, as compared with the longitudinal axis of the zygote, "sphere-symmetrical". If the distribution of yolk is not uniform, then in one yolk a rich (vegetative) and in another a poor (animal) pole will be formed. The first (cylinder—symmetrical) axis of division of the zygotes, like these, corresponds to the animo-vegetative axis.

The second axis of division (furrow) is generally perpendicular to the first axis. The four-celled pro-embryo has a symmetry plane of two equal axes (a bilateral cylindrical symmetry of equal axes).

All cells of the two- or four-celled dividing zygote are almost equivalent. If the cells are separated from one another (polyembryonia), identical twins will be born.

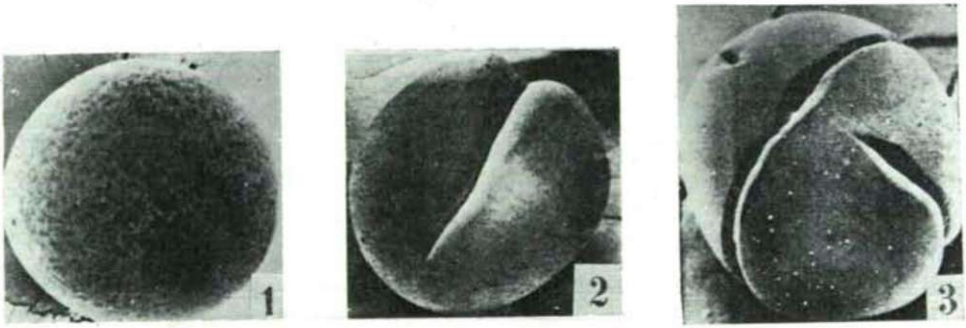


Fig. 1. Merogenesis of the fertilized zygote of frog *(Rana pipiens)*. 1) Unimpregnated ovum; 2) The first cell division in about 2.5hours after the fertilization; 3) The second merogenesis in about1 hour after the first merogenesis. (According to KESSEL & SHIH 1976).

The first divisions of the zygote take place in a rapid succession: the primitive "cell plate", consisting of four cells, will soon be organized into a sphere-symmetrical colony of cells, then into a cell-plate (endoderm). The endoderms of two dimensions take up the form of a sphere, tube and cyst of three dimensions in the course of gastrulation.

The essence of the development of the embryo is the continuous movement in the direction of the decrease in symmetry. At its formation, every cell of the endoderm is of identical value. The migration and three-dimensional arrangement of cells, the formation of the inductive material currents in the right place (in a certain tissue) and in a definite time damage the original (cylindrical and shifting) symmetries. The gastrula gets into a new state of symmetry. Its organizing centre and the foci of the gene will be right and left symmetrical.

2.2. Placing of the heart on the left and right-handedness

YANG (1959) mentioned in his Nobel-report that the physical laws are right and left symmetrical, but in the living world there are considerable differences between right and left sides. "Our heart takes, for instance, place on the left." (Lee and Yang 1956, 1957).

FEYMAN (1969) went even farther and said humorously: If you meet in the cosmic space a space ship arriving from a distant world and the astronaut offers his left hand, you should be careful — he may consist of antimatter!

The possibility is interesting, but we are of the opinion that symmetry should be looked for here, on the Earth, situated this side of the mirror — and not in the anti-man of left hand and right heart.

The heart in human embryo develops from two separate colonies (in the third week of the foetal life). The so-called primitive cardiac tube is symmetrical and takes place in the medial line of the embryo, before the intestinal canal. It has two parts: the venous sinus, the primitive atrium, the primitive heart ventricle, and the arteriectasis.

In the early phase of the embryonal development — similarly to the heart of full-grown fishes — the venous and arterial vascular systems are also symmetrical. Four main (right upper and lower, as well as left upper and lower) veins transport blood into the venous sinus of the cardiac tube. The arterial system also forms initially equivalent aortas on the right and left.

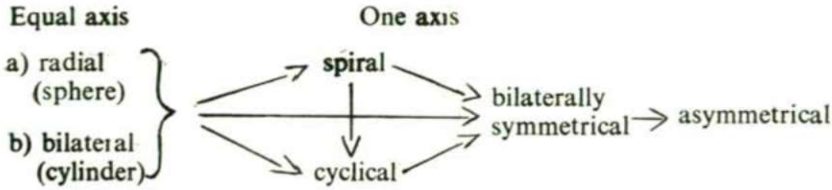
In the course of development, the heart is placed on the left side, and only the left-side main branch of the main aorta survives.

In case of man, we may say of every so-called "asymmetrical" organ that it was originally symmetrical and became asymmetrical only in the course of ontogeny.

Righthandedness is also a result of development. It has supposedly been elicited by the shifting of the heart to the left and by education, as well as doing the work in a standing position.

2.3. Damaging to symmetries in the course of phylogeny

It is shown by countless examples of the living world that phylogeny is also characterized by serial damages of symmetry, by the transition from symmetrical into less symmetrical forms:



The tendency of change in symmetries can be observed in the evolution of families and species of the phyla of Protozoa, Mollusca, Pteridophyta, and Angiospermae, etc.

In the taxonomic tree-like evolution, the trunk of the "tree" symbolizes the changes connecting the (vertical) evolutionary levels (atom, molecule, macro-molecule, prokaryota cell, eukaryota cell, the phyla, classes of Metazoa, etc.). Ant its "horizontally" ramifying branches indicate the unfolding of the given level of organization. In the phylogeny of matter only stable "fermions" of a long living time can take part.

In the course of evolution countless perfect qualities, "inventions" are created but only the forms can get to a higher level of organization that pereserved their symmetry, became less specialized. The "trunk" of the taxonomic tree is more symmetrical than its "branches". The branches are cul-de-sacs, dead-end streets from the point of view of the taxonomic tree-like evolution. Of mammals man is the most symmetrical species.

The damage in symmetry is not frontal, it does not occur by affecting every organ. It can be observed first of all in isolated organs (heart, liver, snail shell, stalk and root of plants, etc.). (MARÓTI, 1969, 1979).

3. Helix symmetries in the living world

The living nature — from Foraminiferae to snails, from phyllotaxes to flowers — is full of always changing and always returning spiral structures. DNA, Watson-Crick's double helix (1957) is the straight continuation of the helix structure of the single-spun protein given by PAULING—COREY (1951). And both are the prominently valuable products of a nearly one thousand years old idea.

The mathematical bases of phyllotaxy go back till FIBONACCI, alias LEONARDO PISANO (1170—1250) mentions the series 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144 ..., any member of which is equal to the sum of the preceding two, in his work, published in 1202, entitled Liber Abaci.

Many interesting mathematical properties of the series have been discovered, but its most important characteristic feature — found about 700 years later — is that it describes the regularity of side-formations in the helix. Apart from the phyllotaxy and flower structures, the regularities of Fibonacci's series are shown by the spiral structure of proteins, as well.

The helix-model proved to be useful particularly in the research of macromolecules but it leaves fundamental problems without response.

On the one hand, it has no adequate explanation for the deeper cause of the formation of the helix symmetries. On the other hand, it is not known, either, why just Fibonacci's series is followed by every helix-like structure.

3.1. The helix is a new stable state of linear formations becoming unstable

A helix can only be covered with itself by the joint application of two transformations (planar turning and shifting along its longitudinal axis). Only the determined combinations of these two operations show a helix symmetry.

Here arises the question, as well, how the helix formations are created.

In our opinion, helix is the manifestation of the cylinder symmetry at a higher level. The condition of equilibrium of the cylinder-symmetrical linear formations becomes unstable as a result of the one-way gravitation (or of another inner or outer parameter), the initial cylinder-symmetry becomes damaged (TÉL, 1979). The new stable state of equilibrium, the helix, has already more stable conditions, and the mutual relation of these conditions corresponds to the original symmetry.

To the spatial self-organization of the "one-dimension" formation, i.e. to the stability of helix, there often contribute some secondary forces, as well.

The cause of the frequent twisting of plants is that they develop in a fixed way in the gravitational field of force. Perpendicularly to the equipotential surface (soil), the gravitational field of force means for them a distinct direction and they grow, therefore, round this fixed direction as round an axis.

As long as the deviation of the shoot apex from the perpendicular axis is small, the state of the cylinder-symmetrical equilibrium survives. But the state of the shoot apex becomes unstable if it, as a result of its inner structure and of the environmental effects, considerably deviates from the perpendicular equilibrium. The shoot apex had initially two symmetry planes but, as a result of shooting, its symmetry decreased. And, as a result of fluctuations and support, the shoot gets into the state of a new stable equilibrium, a helix-symmetric liane stalk is formed.

The direction of twisting takes shape spotaneously but, in the course of the evolution of species the right or left direction may genetically be fixed. It is shown by the genetic analysis of the water snail Limnaea that the direction of twisting is a maternal inheritance (BOYCOTT and DIVER 1923). It seems general that the direction of twisting of the zygote (or meristem) is determined by the polarity of the matrix of the cytoplasm. In the exclusive fixation of some direction the effect of a unidirectional force is important. In case of snail species, the shells of which have no distinct "upper and down" directions, the right-side and left-side shells equally occur. When the tendrils of plants catch at a thing, the right-hand helix became a left-hand one.

3.2. Hidden mirror-symmetry in the phyllotaxis

We may consider as one of the forms of the damage in the cylinder symmetry the helix-like location of the side formations, as well, on the almost cylinder symmetrical stalks.

The leaf arrangements: 1/2, 1/3, 2/5, etc., established on the basis of old observations, are too idealized. In case of alternate phyllotaxes, the leaves above one another cannot be connected with a straight line. There are no real orthostichons, even the superposed leaves twist slightly, form a helix (spirals).

The helix-like (spiral) arrangement of the side organs can be studied well: on the pine-cones, on the flowers of the fossil angiosperms, on amenta on the position of the fruit of the plants of capitula, etc. BÉRCZI (1976) demonstrated that if we pushed phyllotaxes on the stalks nearer together, we got an arrangement, like in case of pine-cones.

By shrinking the stalk, the symmetry of phyllotaxis may be transformed into cone-symmetry (Table 1).

Table 1

Phyllotaxis	Number of helices twisting to the right and to the left
1/2	1+1
1/3	1+2
2/5	2+3
3/8	3+5
5/13	5+8
8/21	8+13

Phyllotaxes that can be expressed with fractions of higher number than 5/13 can only be observed with difficulty. In inflorescence, however, the number of helices in the flower and fruit is frequent from (8+13) till (89+144).

In the Botanical Garden of the Attila József University in Szeged, we have studied the localization of side organs on a number of plants:

Table 2

Species	Number of helices twisting to right an to left	
Juniperus sabina L.	pine-cone	1+1
Picea glauca VASS.	pine cone	3+5
Picea abies (L.) KARST	pine-cone	5+8
Pinus silvestris L.	pine-cone	5+8
Magnolia sp.	fruit	3+5 5+8
Corylus avellana L.	amentum	5+8
Carya sp.	fruit	8+13
Helianthus annuus L.	inflorescence	34+55 55+89 89+144

In addition, we have observed innumerable other plants, as well, but apart from the 1+1, the number of "spirals", twisting to the right and to the left, agreed in no case in the same "pine-cone." This unambiguously means the lack of mirror symmetry. But where is then the hidden symmetry, established in the title?

If we take a good look at the many hundred pine-cones of the same tree, it turns out that in the half of pine-cones five helices run to the right and eight to the left, and

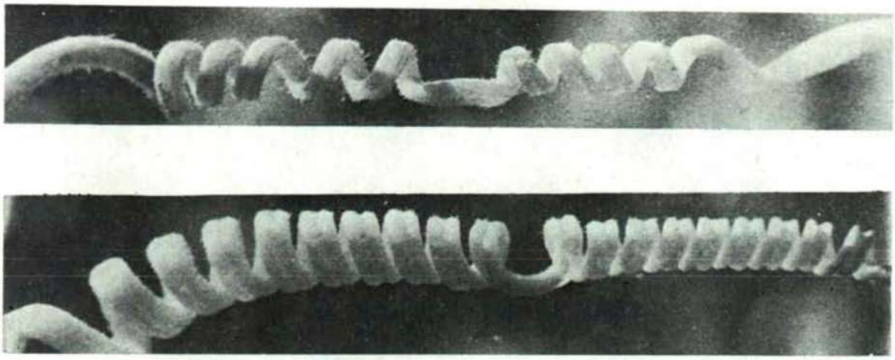


Fig. 2. Branch tendrils of the vegetable marrow *(Cucurbita)*. After clutching, as a result of the power impulses in two directions, the right-hand helix became left hand helix resp. vice versa. (Original).

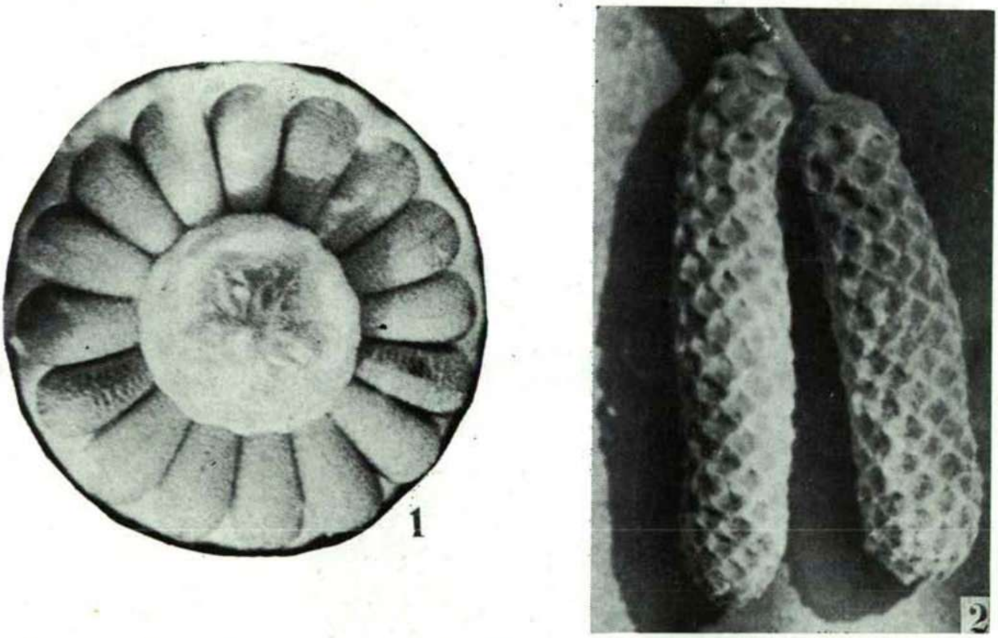


Fig. 3. 1) The "mallow" fruit of the hollyhock *(Atlhaea rosea)*. The capsule is of radial symmetry- and splits up into part-fruits; 2) The hazel *(Corylus avellana)* has mirror symmetric amenta with stamina and 5+8 and 8+5 helices. (Original).

in the other half, five run to the left and eight to the right. At Kiszombor, we have observed approximately 1000 sunflowers (various hybrids), as well, and the symmetry of stocks showed a similar distribution. This is the "wonder" of nature, compensating the damage to symmetry in this way.

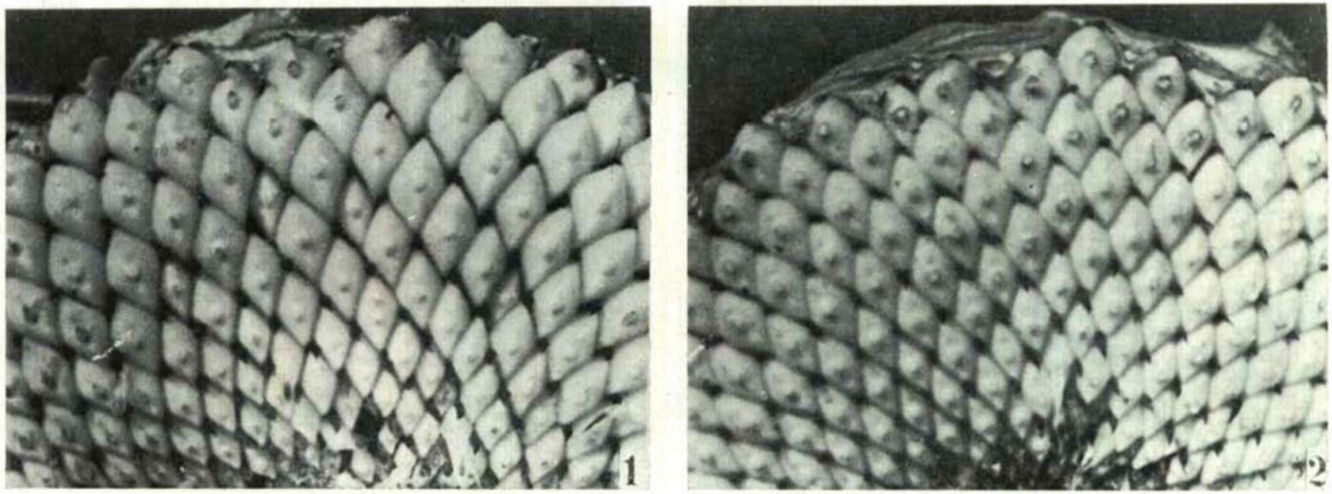


Fig. 4. Arrangement of the uniseed achenia of the sun-floewer on the "plate". 1) There are running 34 helices to the left, 55 helices to the right;
The numbers of fruit-helices are 34 to the right, 55 to the left. The two "plates" originate from one root. The mirror-symmetrical individuals of 89 + 144 helices are frequent. (Original).

3.3. Why does nature distinguish Fibonacci's numbers?

Helix-symmetries could be satisfied with other arrangements as well. Nevertheless, in nature only leaf arrangements, sporophyll, flower- and fruit-helices occur that can be characterized with Fibonacci's numbers. How does nature select? And what principle is realized in Fibonacci's series?

Before answering the questions, we should outline — according to BÉRCZI (1976) — the arrangement of helices.

We number the megasporophylls in two uniform pine-cones of $3+5$ helices. In imagination, we "uncoil" the helices of scales and place them side by side. At first, we present the five helices, running to the left from one of the pine-cones, then the three "helices" running to the right from the other (Fig. 5). For simplification, we draw the forms of scales as rhombi. We get two broad bands. In one of these, the scales form five, in the other three part-bands (helices).

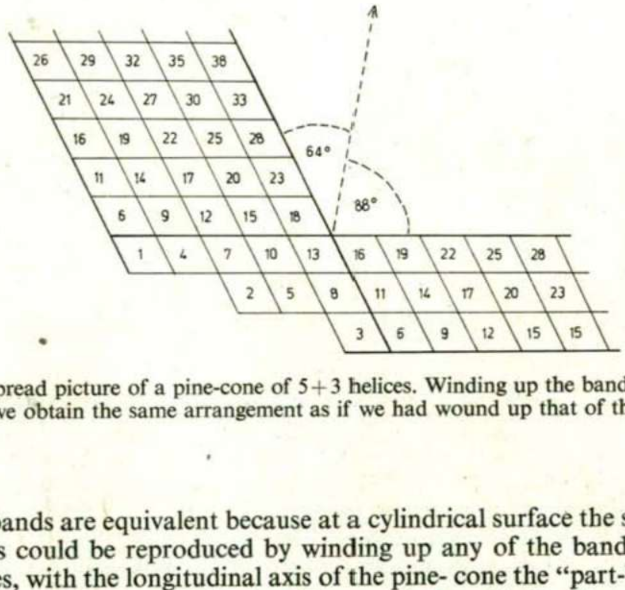


Fig. 5. The outspread picture of a pine-cone of $5+3$ helices. Winding up the band of five helices to the left, we obtain the same arrangement as if we had wound up that of three helices to the right.

The two bands are equivalent because at a cylindrical surface the same pine-cone of $5+3$ helices could be reproduced by winding up any of the bands. In the band with five helices, with the longitudinal axis of the pine- cone the "part-bands" enclose an angle of about 64 degrees, and in the ribbon with three "helices" an angle of about 88 degrees.

If we draw the "band pair" of the first four members of Fibonacci's series on one another, we may observe the rule of the shifting of helices in the bands of identical breadth (Table 3).

This is the band model of phyllotaxes 1/2, 1/3, 2/5, and 3/8, transformed into pine-cone symmetry, according to BÉRCZI (1976). The helices winding to the right and to the left form two equivalent "bands". The numbers of helices (part-bands), apart from band-pair $1+1$, differ from one another. In nature, the reflection-symmetrical pair of every band-pair is also realized.

Table 3

Phyllotaxis	Band pairs								Number of helices winding to the right and to the left
1/2			5				5		1+1
			4				4		
			3				3		
			2				2		
			1				1		
		8	9				5		
		6	7				4		
1/3		4	5				3		2+1
		2	3				2		
			1				1		
		6	9			13	11	9	
		4	7			10	8	6	
2/5		2	5			7	5	3	2+3
			3			4	2		
			1			1			
	19	22	25	28	31	19	14	9	
	14	17	20	23	26	16	11	6	
	9	12	15	18	21	13	8	3	
3/9	4	7	10	13	16	10	5		5+3
		2	5	8	11	7	2		
				3	6	4			
					1	1			

The bands of identical breadth $\binom{2}{2}$ and $\binom{3}{3}$, lying over one another, differ from each other to such an extent that in the band of a broader band-pair (1/3 and 3/8) the part-bands are shifted by the distance of a lamella more than in the band of narrower band-pairs (BÉRCZI, 1976).

This shifting can be observed in the bands of identical breadth (helices), lying over each other. In this way, with the shifting operation of the part-bands, known in nature — starting from the simplest band-pair 1+1 — the helix symmetry, characterized by Fibonacci's numbers, can be built up.

By shifting the part-bands, we can build up another helix-symmetrical family of a band-pair of a different starting (e.g., of a helix 4+5). This, however, does not occur in nature because it does not contain the band-pair 1+1. In other words, Fibonacci's series is followed by every helix symmetry in nature bacause this started from the most ancient cylinder symmetry, the arrangement 1+1. In fact, in the ontogeny of plants the damage to the cylinder symmetry of phyllotaxy 1/2 can very often be observed.

The universality of the helix (shifting) symmetry is further deepened in us by the helix structure of protein, as well, which similarly returns to Fibonacci's series (ERNST, 1970).

Recently the spatial arrangement of Watson-Crick's known right-handed DNA double helix was queried by more than one paper CRICK et al. (1979). Of the new suggestions, the models of FODLEY et al. (1976) and SASISEKHARAN et al (1977, 1978) are entirely symmetrical. In their opinion, the two strands of DNA do not wind round each other but they coil up on opposite sides, on a cylinder-jacket, forming a so-called side-by-side (SBS) structure. Symmetry is also increased that in the strands, sequence parts, winding to the right and to the left, keep alternating.

It is difficult to submit the DNA model to a thorough searching criticism. At any rate, in the anti-parallel directedness of the two strands the restitution of a higher-level symmetry manifests itself. The SBS symmetric structure is, therefore, for us very improbable.

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