Symmetry: Culture and Science

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Natural and Artificial, 1

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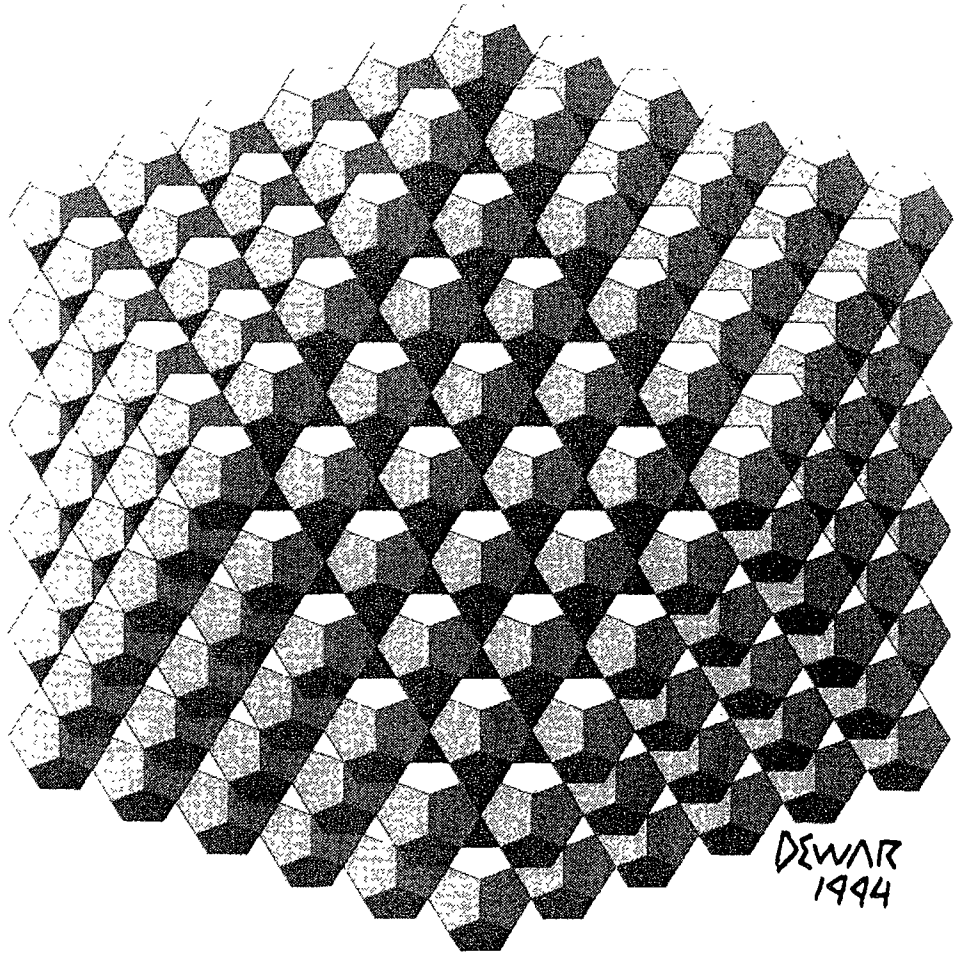

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ISIS-SYMMETRY: LOOKING FOR TRUTH AND BEAUTY

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In the last six years, *ISIS-Symmetry* became the center of a network bringing closer to each other scientists and artists, got active in over fifty countries, and is present at almost all of the World, the East and the West, all hemispheres, all cultural regions. A part of the participants of the Congress may remember my lecture at the Katachi U Symmetry symposium held in Japan last year, where I spoke about the dimensions of the mutual influences of the approaches to science and art in the East and the West, and in different cultures (Darvas, 1994). Then, in the heart of an Eastern culture, I concentrated on the Eastern origins of creativity. Let me concentrate now on the Western origins of our human creativity. Taking out of consideration the width of the uninhabited Atlantic Ocean, there are about equivalent distances of the lands of Europe and America, i.e., the lands of the traditional Western culture, to the East and to the West from the Congress venue. (Similar statement can be made for the North and South.) Thus, in a certain sense we are in the center of this specially considered region[1], and the feeling to be in a center (of anything) provides us with an illusion of comfort feeling. This follows from our world view. We own a world view since ancient times, what suggests us, that we presumably should live in a world, which is *perfect*. What perfect is, should enjoy a center, and be quasi-isotrop around this center. And one finds the world most beautiful and most quiet, when sees from the center, and finds it similar in each (or periodically repeated) directions.

This picture of the world can be demonstrated in science and art since the origins of any culture. One could mention the *mandala* in India, the *yin-yang* in China, the

[1] The boarders of this region have been changing, and so the center moved towards former peripheries during the recent history. Science and art historians demonstrate, that both cultural activities developed around the 'center' in all historical periods *more intensively*, or more precisely: *influentially*, than at the that time peripheries.


tomoe (the perhaps most widespread symbol in shrines) in Japan, etc., but let me concentrate now on the origins of the so called Western culture: the Mediterranean basin, having been its center about three thousand years ago.

Most of our ancient Mediterranean learned colleagues tried to find an as perfect model of the world as much it could be fitted to their experience about the reality. They were convinced, that our world *must be* perfect. One succeeded to describe the world really, if one reflected the nature in *true* statements and represented in *beautiful* compositions. *Truth* and *beauty*, they were the two criteria of the *perfectness*. The perfectness of the world could be treated like an axiom; there were the declines from this state what should have been explained by some reasons. Their strives to describe the perfectness culminated in the search for perfectness in the forms. Form meant different things in different (later so called) 'disciplines': (*a*) the perfectness of the statements in the logic, (*b*) the perfectness of the physical appearance in the geometry, and (*c*) the perfectness of the works of art. In the Hellenistic culture they were not separated. Soon later the first became associated with the racionality (science), the third one with the emotionality, impression (art), while the middle one more or less with both. This explains, why could it (*b*) save its bridging role (proportion, harmony, golden section, etc., ... *symmetry*) between sciences and arts during the centuries of separation (cf., D. Nagy's opening lecture at the first Congress of ISIS-Symmetry "Symmetry of Structure", Budapest, August 14, 1989). To follow this path, their search for the most perfect forms reached its climax in finding the so called five regular Platonic solids (not mentioning now the evidently most perfect body: the sphere), namely the tetrahedron, the cube, the octahedron, the dodecahedron and the icosahedron. The 'perfect' Greek 'forms' run an unprecedented career in the role played by them in the sciences (*a*) and the arts (*c*) since then.

The three golden centuries (6th to 3rd B.C.) of the Hellenic culture incorporated in a unique system all the achievements by the nations in the Mediterranean basin reached in the previous millennium. What worth more attention from our point of view, that this cumulative peak age coincided in the (later terms called) sciences and arts. According to the separated interpretation of the origin of science and the origin of art in the recent centuries, this fact would be not quite natural. In our interpretation we state: this happened not by chance.

Let us have a look to an other example. Perfect reflection of the world characterised not only the exact descriptions, like in the geometry, arithmetics, or astronomy. Description of the sky was exact, projected to (a) sphere(s), and the more phenomenological description of the Earth should have mirror the sky (cf., the Globe model, or at least the plate model). Geography, i.e., the physical

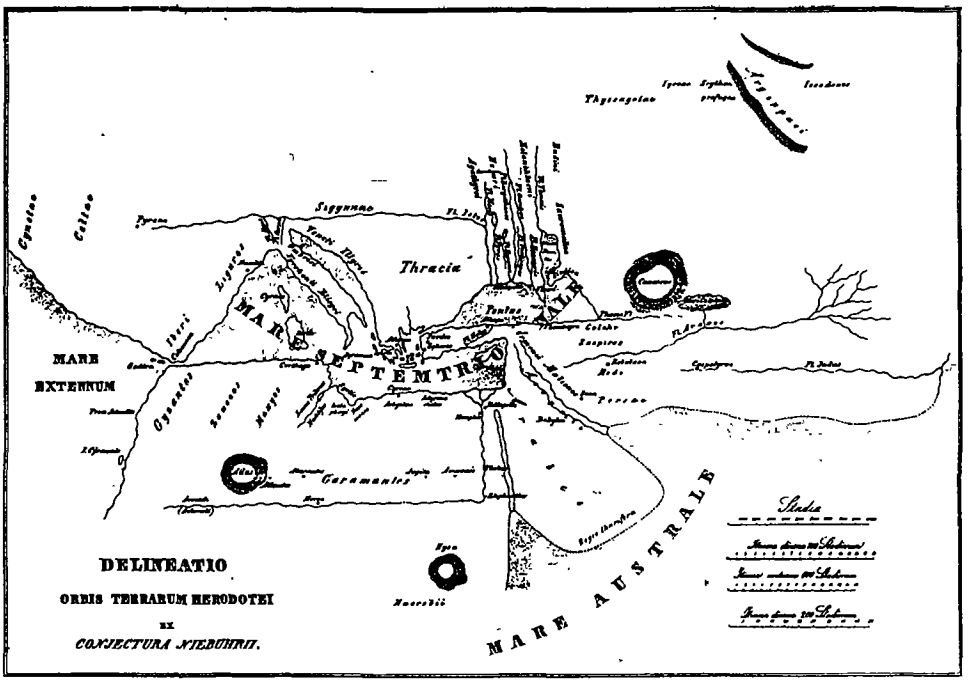
phenomenological description of the surface of the Earth must have followed this picture of the world. (We know, that practically it does not.)

Most of our knowledge about what ancient people knew about the Earth and its inhabitants originates from the historical books of Herodotos, where he summarises all what in his age was known in the Mediterranean basin about the that time known part of the world. Herodotos described not only the history of nations, and provided the geography where they lived, but reflected all the general world view of his age. He tried to describe the world as perfect, as he could imagine it, because according to his belief the Earth could be not less perfect than the sky above us. When he found facts, what did not coincide with the expectations about the perfectness of the world, he felt himself forced to give explanation for the differences. And explaining these contradictions he believed much strongly in the world view about the perfectness, than in the facts, what showed asymmetry on the surface of the Earth.

Please, try to imagine yourself in the role of our ancient colleague. Please, remember your works, when you had to evaluate experiments, systematise facts, summarise results, make conclusions in science, or plan an arrangement, polish art works; please, confess that you had a better feeling if you found a symmetric, more perfect final solution, than when the objects (*natural* or *artificial*) seemed to be more complicated, less ordered, asymmetric, i.e., less perfect. Psychoanalysts can confirm, that healthy human being's strive to symmetry, to perfectness belongs to our immense nature. So, do not feel ashamed, that you strived to symmetry in your decisions when confronting facts and explanations, planned objects and final formations. It is not against the truth and beauty, as long while the spiritual belief in the perfectness does not disguise the experimental facts or objects; in the contrary, our instinctive attraction to symmetry helps to find truth and beauty. (Thus, symmetry became a heuristic, methodological tool in our scientific and artistic creative work.)

So did Herodotos, too. His only mistake was, that overestimated the role of this heuristic tool, but presented us a wonderful fabulous picture of the world. He described the (known by him) world quasi mirror-symmetric to a West-East axis, placed in the middle of the Mediterranean sea, and quasi periodically symmetric when travelling parallel with the West-East axis. He described the Nile and the Danube as mirror symmetrically flowing two rivers. Both flowed, according to his picture, first from West to East, and then made a right angle turn towards each other and run into the same sea. In the case of the Nile, ancient people believed, that the Nile originated on the West in the Libyan desert, but in the case of the Danube, they knew, that it could not flow from the Pyrenes, because in this case it should cross the Rhine. Herodotos here preferred the belief in the symmetric, i.e., the perfect picture of the world against the experimental facts. For the sake of symmetry, he described, that following the bed of the Nile from East to the West in the Libyan desert, one found the oases in equivalent days walking distance

periodically (translational symmetry along the West-East axis). Of course, one did not find oases along the Danube. Because, he explained, there were more rains over the basin of the Danube. Moreover, the level of the water in the Danube was more equal during the year, while there were periodic floods, and droughts around the Nile. Terrible asymmetry, what should be explained, and he found the explanation. Summarising in short his flow of arguments: the Sun shines in a lower angle over the Danube than over the Nile, this is the reason, why the moisture is less in the hot Nile area and more in the cooler Danube basin. But, let us suppose, he speculates, the symmetric arrangement, that the Sun would shine from the North. Than the angle of the rays were higher over the Danube, and lower over the Nile, and in this case there were more rains in the Nile's basin and less over the Danube. So the same would happen with the Danube, as now in the case of the Nile and vice versa. Thus the postulate of the symmetric placement of the Sun over the 'symmetric center' of the known world, i.e., the Mediterranean sea, solved his problem of the disturbing asymmetry in the picture of the world.



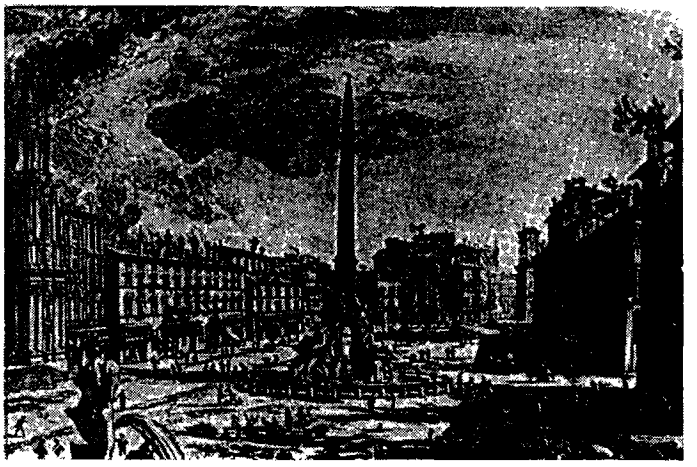
The example may be extreme, but strong enough to demonstrate, how the heuristic role of symmetry can influence the thinking of a scientist.

This picture of the World by Herodotos presented us another symmetry. Have a look at the symmetric picture of the Nile and the Danube. The birthplace and the scene of Earth-life of goddess *Isis* and the birthplace and headquarters of *ISIS-Symmetry* can be found symmetrically at the two rivers. The origins of the Western

culture (science and art) can be found almost symmetrically in the middle between them, somewhere along the axis of symmetry of the map. I choose the above example not by chance. This picture has a metaphorical, symbolical significance for us.

The cult of Isis did not ceased after the decline of the power of the Egyptian pharaohs and their national religion. The cult of Isis survived and lived further, not only in the Minoan and Hellenic cultures, but even in the Roman imperium. As it arrived from the Nile to the Appenin peninsula, the cult of Isis spread from there over the imperium, even to the Northern limes, the Danube, (and among others in Pannonia, where Aquincum saved the boarders of Rome at the place of the present Budapest, the birthplace and headquarters of ISIS-Symmetry).

It was also Italy, where the Renaissance of the Western culture emerged and spread about another thousand years later. Please, notice, that science and art prospered again in parallel. Moreover the greatest Renaissance personalities, like Leonardo, Dürer, etc., were as excellent creative representatives of science as of arts. The return to ancient masters moved symmetry in the foreground in the quattrocento (cf., the paper by D. Nagy at the present Congress). Even in the time of the accelerated separation of science and art after the Renaissance, the ancient roots and science-art interrelations did not ceased to motivate the most outstanding masterminds. See, e.g., Kepler's 'perfect' model of the celestial world (using Plato's perfect solids) (Kepler, 1696), combined with the music of the spheres (with reference to the Pythagoreans and Aristotle) (Kepler, 1619), or the topics of painters and sculptors of the baroque.[2]



Fontana di Quattro Fiumi (Piazza Navona, Roma). Fragment of the drawing by G. B. Piranesi, 18th c.

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[2] Later in the 20th century Hindemith composed the symphony *Harmonia Mundi* inspired by Kepler.

For example, one finds a symbolic sculpture in the heart of Rome, in the middle of the Piazza Navona: the Fontana di Quattro Fiumi (the Fountain of Four Rivers) by Lorenzo Bernini. A quadratic obelisk, surrounded by four symbolic figures looking to the four cardinal points. The figures symbolise four rivers: the North is represented by the Danube, and the South is represented by the Nile (while, for the completeness, the East by the Ganges and the West by the Rio de la Plata): The reincarnation of the symmetric picture of the world by Herodotos in the city where the cult of Isis survived for the longest time. Looking around that perfect composition there you feel yourself in the center of the world, and really, in the seventeenth century in certain symbolic cultural sense it was the center of the world, (to be moving towards the North-West in the next period).

The interweave of sciences and arts (the skill of truth and beauty) demonstrated itself also in the poetry. For illustration, let's quote from the Sonnet LIV by Shakespeare:

> "Oh, how much more doth beauteous seem
> By that sweet ornament which truth does give!"

The French R. de Piles (1708, p. 30) wrote on painting: "*Je trouve trois sortes de Vrai dans la Peinture: Le Vrai Simple, le Vrai Idéal et le Vrai Composé ou le Vrai Parfait.*" [There are three kinds of Truth in painting: Simple Truth, Ideal Truth and Complex or Perfect Truth.] According to Piles, the Simple Truth [...] is the simple and faithful imitation [...]; Ideal Truth is a selection of various perfections which are never to be found simultaneously [...]; while he gives not too much information about the third, which represents a combination of the other two but emphasises again the strive to perfectness and the artistic reflection of the truth.

At the same time, we cannot conceal, that these centuries provided a widely accpeted paradigm in the sciences according to which sciences must base only on the pure rationality, proving of truth, and keep far distance from the intuitive arts, influence of the beauty. (Cf., e.g., Kant's *Transcendental Logic* and *Transcendental Aesthetic.*)

Nevertheless, the human culture evolved; science and arts walked 'hand in hand' along the two banks of the widening river of the culture (cf. D. Nagy's lecture, 1989) looking at each other from a distance. *Science was searching for the truth, the arts for the beauty.* Open-minded intellectuals were looking for bridges.

The pillars of the bridge were found again and again in turning to the ancient culture, where science and arts, truth and beauty have not been separated yet. Let me quote from a well known poem by John Keats, the *Ode on a Grecian Urn.* He closes the ode with the following words:

> ""Beauty is truth, truth beauty," - that is all
> Ye know on earth, and all ye need to know."

(Vendler, 1983, pp. 114-115). These two lines tell everything about the unity of the culture. The inspiration to the whole ode and its summing up in the last two lines came from the Greek culture again. These words were not only a tool of poetic expression or a poen needed to close the poem. Keats attributed importance to this sentence, this can be verified in his correspondence after having written the ode (Rollins, 1958; cf. his letters to his friend B. Bailey[3] and to his brothers George and Tom in November and December 1817, the same year when D. Brewster patented his invention: the kaleidoscope), where he repeatedly analyses and explains this statement. The historians of literature devoted hundreds of pages to the analysis of this ode and these two lines. It is widely cited (even by the mathematician L. Fejes Tóth), but now let us add something to all of these. It is symmetry what most successfully combined the search for truth and beauty. Symmetry studies realized the dream of Keats to unify our knowledge.

Arthur Koestler[4] wrote in 1976 "that the artist and scientist do not inhabit separate universes, merely different regions of a continuous spectrum - a rainbow stretching from the infra-red of poetry to the ultra-violet of physics, with many intermediate ranges - such hybrid vocations as architecture, photography, chess playing, cooking, psychiatry, science fiction or the potter's craft. But to avoid oversimplification, after emphasising the affinities, I must briefly discuss the differences - some apparent, some real - between the opposite ends of the continuum. The most obvious difference seems to lie in the nature of the criteria by which we judge scientific and artistic achievement" (Koestler, 1978, p. 152). And what else are these criteria than those evaluating the attainment to the truth and the beauty? Look at his cited list: almost all or more are represented at this congress. Have a look at the faded contours on K. Kuchta's light installation at our exhibition: all the colours of the mentioned rainbow can be seen there from the infra-red "of poetry" to the ultra-violet "of physics", and the "intermediate ranges" of the "continuous spectrum" are represented symbolically by all of us, the participants of this congress and exhibition.

There are crossings in the paths followed by scientists and artists: when formulating a found scientific 'truth' the scientist strives to give a beautiful presentation, this makes his achievement easier acceptable for the peers, and when formulating an art-work's 'beauty' the artist strives to reflect truly the reality. It is attributed to H. Poincaré, that he was guided in unconscious groupings towards the happy combinations which yield new discoveries by the feeling of mathematical beauty, of

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[3] "I am certain of nothing but of the holiness of the Heart's affections and the truth of Imagination - What the imagination seizes as Beauty must be truth" p. 184.

[4] Arthur Koestler, was an outstanding writer of the twentieth century. His life and work was full with drastic turns. He was born in Hungary, then moved to Vienna, Berlin, Tel-Aviv, and Moscow, took part in the Spanish civil war, then lived in France, and after World War II in England, used to be a fan and enemy of the same ideology. His work did not miss the drastic turnovers too. So happened that in a period of his life this artist attracted to the sciences (to turn later against). We quote from his pro-science period.

the harmony of number, of forms, of geometric elegance. This is a true aesthetic feeling that all mathematicians know. It is told about Dirac, one of the greatest physicists of our century, that he went further in a pronouncement, according to which it is more important to have beauty in one's equations, than to have them fit to the experiment. Compare it with Herodotos' approach to draw the picture of the world!

Artists have also used to be guided by science motivated theories, the golden section, the geometry of perspective and foreshortening, the Renaissance masters' ultimate laws of perfect proportion, Cézanne's doctrine that all natural form can be reduced to spheres, cylinders, and cones; the reflection, repetition, counterpoint in the musical composition, the harmony of colours and the combination of usefulness, simplicity, beauty, and symmetry in the Bauhaus' principles, the inspiration of graphic artists and sculptors by geometric higher dimensions or by the quasicrystals, etc.

Mutual influences are evident between scientists and artists. This is possible, because beauty and truth are not fully dividable. Nevertheless, both parties act and are judged in the same social environment.

Returning to Koestler, he analyses the cited words of Keats in the following: "This is ... a touching profession of faith in the essential unity of the two cultures, artificially separated by the quirks in our educational and social system. In the unprejudiced mind, any original scientific discovery gives rise to aesthetic satisfaction, because the solution of a vexing problem creates harmony out of dissonance; and vice versa, the experience of beauty can only arise if the intellect endorses the validity of the operation - whatever its nature - designed to elicit the experience. Intellectual illumination and emotional catharsis are the twin rewards of the act of creation, and its re-creative echo in the beholder. The first constitutes the moment of truth, the *Aha* reaction, the second provides the *Ah...* reaction of the aesthetic experience. The two are complementary aspects of an indivisible process." (Koestler, 1978, p. 155.) (The Aha and the Ah... reactions, i.e., the scientific and the aesthetic cathartic sensation can be combined, visiting the AHA Gallery by C. Schwabe in Zürich, in the *Spiegelgasse*, which in English means 'Mirror Street'.)

In summary: we looked over the role of symmetry, as a form of appearance of the perfectness in the history of the Western culture. We followed this line since the picture of the world by the ancient Greeks, parallel with the cult of Isis, who borrowed her name to the Symmetry Society, from the ancient Egypt to Rome and further, and the parallel attempts of scientists and artists in their search for truth and beauty. We were looking for bridges between these separated intellectual activities, and concluded, by means of the poetry, that they are undividable. All who are present at the Congress and Exhibition of ISIS-Symmetry demonstrate with our interest and work that science is attributed also beauty, and arts bear also truth.

There is symmetry in their roles, and it is symmetry what can in the most appropriate way demonstrate the cross-fertilisation of science and arts.

Dear scientists and artists! Let symmetry help us to find mutually beauty and truth.

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THE 2,500-YEAR OLD TERM *SYMMETRY* IN SCIENCE AND ART AND ITS 'MISSING LINK' BETWEEN THE ANTIQUITY AND THE MODERN AGE

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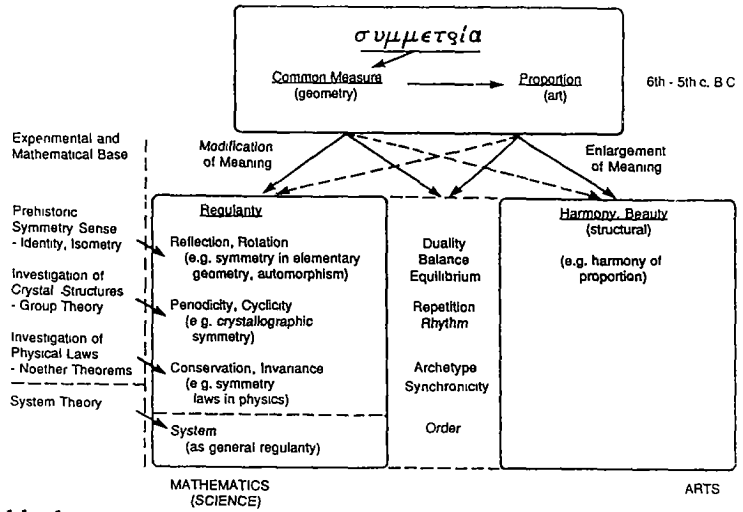
In an earlier survey we summarized the developments of the term *symmetry* in the antiquity and the modern age:



This table demonstrated the interdisciplinary aspects of symmetry. The fact that the term *symmetry* has roots in both science and art, as well as its modern meaning-family being broad enough, but still concrete, make this concept very useful to build 'interdisciplinary bridges' between various disciplines and to serve as a 'common language' between them. However, we should be very careful not to extend the meanings of symmetry without reasonable limits, which could lead to an empty concept: 'everything is symmetric'. We also suggested considering symmetry together with asymmetry and dissymmetry in the following framework:

symmetry (thesis) — asymmetry (antithesis)

dissymmetry (synthesis)
as a small violation of the perfect symmetry

This concept-triangle also inspires the introduction of some measures of symmetry. Group theory provided a very good mathematical tool to deal with perfect symmetries. With symmetry groups we may easily describe perfect geometric

figures or ideal crystal structures. The challenge is to extend our scope to the symmetries of real objects, which are obviously non-perfect ones (less symmetric than the perfect ones). We will return to this question later.

Our present goal is to extend the earlier historic survey on symmetry. While many works refer to the Greek origins of the term *symmetry*, its history from the 3rd century A.D. until the 16th century is ignored in the literature: no data are given from this period. Now we are glad to report that the 'missing link' is found. We also suggest having more comparative studies between the related Western and Eastern concepts, which was started at the symposium *Katachi U Symmetry* (Tsukuba Science City, 1994, cf., the forthcoming proceedings edited by Ogawa, Matsunari, Miura, and Nagy). Our historic survey also has an additional goal: to identify some problems for further studies. Let us first discuss the preliminaries of the 2,500-year history of the term *symmetry*, i.e., a period of many millions of years.

0 An intuitive symmetry-sense and an early level of conceptualization of symmetry in the animal world and in human prehistory

An intuitive symmetry-sense - thinking about the preference of both some specific proportions and regular shapes - can be detected at the earliest period of prehistory as it was reported at the First Congress of ISIS-Symmetry and was discussed in a paper in this journal (Toth). We may even argue that this symmetry-sense is earlier than mankind. Indeed, the experiments by Rensch in mid 1950s demonstrated that birds and monkeys prefer symmetric patterns against asymmetric ones. Dobzhansky in his monograph *Mankind Evolving* referred to these results as "protoaesthetic" phenomena. Sebeok discussed similar observations and claimed that there is a "prefigurement of art" at the animal level. He also initiated to extend semiotics, the science of signs, into this direction and to deal with zoosemiotics. There are various further studies about the ability of animals to differentiate between symmetric and non-symmetric shapes. Moreover experimental results indicate that some animals are able to conceptualize symmetry: for example pigeons discriminate symmetric forms from non-symmetric ones in a concept-like generalizing way (as Delius and Habers demonstrated in 1978; cf., Delius and Nowak in 1982). On the other hand the same research disproved two classical theories of symmetry recognition: this ability is based neither on the redundancy of symmetric patterns, nor the bilateral symmetry of the visual system. There were conjectures that an innate ability to recognize symmetry at the animal level is connected with searching for food with nearly symmetric shape, thinking here about various objects, from simple grains to prey-animals. Very recently the topic of symmetry in biology had a new breakthrough: biologists gathered evidence that symmetry considerations play a crucial role in mate-selection in case of such a diverse set of species as scorpionflies (Thornhill), common flies (Polak), barn swallows (Møller), zebra finches (Swadle and Cuthill), peafowls (Manning and Hartley), various primates (Manning and Chamberlain), and even humans (Thornhill and Gangestad, Grammer and Thornhill, Gangestad et al.). We think here about the careful investigation of the symmetry of ornamentation or body shape by animals and the preference of facial symmetry of humans, which often correlates with the symmetry of the whole body. The explanation of this tendency mobilized many biologists. There are some correlations between the symmetric shape and health of individual animals, thus symmetry may be a signal of such properties (high genetic quality, developmental stability, strong immune system, good parasite resistance, etc.; cf., Møller;

Thornhill and Gangestad). However, this topic went beyond traditional biology and lead to very different models in 1994 based on the simulation of the visual system by the modern techniques of neural networks: the preference of symmetry may also arise as a by-product of how image recognition works (Enquist and Arak; Johnstone). Of course these two types of theories do not definitely exclude each other: they could evolve together.

The lateralization (or asymmetry) of the brain is reflected on the left- and right-side of the face. A person with too perfectly symmetric face would lack to communicate his/her emotions. Note that contrary to the general belief, the lateralization of the brain is also detected at the animal level (Bianki).

From the symmetry sense of animals and the intuitive symmetry concept of prehistoric people there was a long path until the period when a group of people decided to form a related term. This step is always a very important one in the case of the higher level of conceptualization. In the following we will focus on this.

1 The Greek term *symmetria* and an outlook to the Hebrew *ketzev*, the Sanskrit *sammita*, and the Chinese/Japanese *xíng/katachi*

There are various theories about the birth of the Greek adjective *symmetros* and substantive *symmetria* (from *syn-* together, common + *metron* measure). Most works point to sculpture and aesthetics as the origin. In an earlier paper, however, we demonstrated that the Greek terms *symmetria* and *asymmetria* were formed with great probability by the Pythagoreans (6th-5th cc. B.C.) in a geometrical context, specifically in connection with the discovery that the side and the diagonal of a square are incommensurable in length (*asymmetros mêkei*). In case of this topic there was a great need for a new terminology. On the other hand, this terminology was adopted very quickly into aesthetical context:

Geometry		Art, Aesthetics
	adoption	
symmetria/asymmetria as commensurability/ incommensurability	⟶	*symmetria/asymmetria* as due proportion/ lack of proportion

Note that art in itself had no need for this new terminology because the existing Greek expressions could cover the basics of the theory of proportion, cf., *logos* (ratio) and *analogia* (equal in 'logos', i.e., proportion). The Pythagorean idea that beauty depends on *symmetria* was adopted by Plato (5th-4th cc. B.C) and Aristotle (4th c. B.C.). Following their works, *symmetria* became a main category of beauty. It is manifested in the following quote by Aristotle (*Metaphysica*, 1078 a 35 - b 1):

> The main species of beauty are orderly arrangement (*taxis*), proportion (*symmetria*), and limitation (*horismenon*), which are revealed in particular by mathematics.

Some of the Greek schools - especially the Sophists, Socrates and his pupils, and the Stoics - also realized that, beyond the objective and measurable aspects of beauty (*symmetria*), there area subjective elements, too. This lead to the

introduction of some other terms, including *eurythmia* (from *eu-* well + *rhythmos* proportion, arrangement) to differentiate the subjective proportions from the objective ones (*symmetria*). The originator of this term could be Socrates (5th c. B.C.), who did not write anything, but the term survived in a dialogue written by his pupil Xenophon (5th-4th cc. B.C.). Here the armorer Pistias discusses the advantage of his breast-plate with Socrates, concluding that it is (*Memorabilia*, 3, 10, 12):

> [...] well-proportioned (*eurythmos*) not absolutely, but in relation to the wearer. (Translation by E. C. Merchant).

Another account about *eurythmia* is due to the mathematician-physicist-engineer Hero (1st c. A.D.) who explained *eurythmia* as the modification of the objective proportions (*symmetria*) of a monumental statue by taking into consideration the optical illusions (*Definitiones*, 135, 13). Note that *eurythmia* also had another meaning associated with 'rhythmical movement', which survived until our age in movement art (cf., Dalcroze's *eurhythmics* and R. Steiner's *eurhythmy*). Another criticism against the emphasis of *symmetria* was given by Plotinus (3rd c. A.D.), who fully challenged its importance as a category of beauty. He explained that the too perfect *symmetria* is disturbing (cf., the 19th c. idea of dissymmetry). Note that modifying the objective *symmetria*, the average human proportions, with subjective elements when shaping our objects can be associated with the most recent methods of Computer Aided Design/Manufacture (CAD/CAM).

Parallel to this there were important developments in connection with the original geometrical meaning of *symmetria* by considering the case of commensurability in square. While the side and the diagonal of a square are incommensurable in length (*asymmetros mêkei*), these are commensurable in square (*symmetros dynamei*), since the ratio of the area of the squares drawn on these two line-segments is 1/2. This terminology is used by Plato (*Theaetetus*, 147d-148b) and later by Euclid (*Elements*, Book 10, Definitions 1-3). We should emphasize that figures with bilateral or rotational symmetry, including the five Platonic solids (regular polyhedra), appear never to have been associated with the Greek term *symmetria*. (Incidentally, Plato is not the discoverer of the Platonic solids, he just referred to earlier works, and Euclid's theory of regular polyhedra has some discrepancies, e.g., in the sense of his definition there would be more than five of them, as we discussed in an earlier paper).

May we refer here to a mostly ignored tradition of ancient mathematics; we suggest calling it *craftsman's mathematics*. Indeed, there were two basic traditions:

Craftsman's mathematics (Vitruvius) - - - - - ➔
Abstract mathematics (Euclid) ---------->

The first one is obviously the older one and contributed to the birth of abstract mathematics, which is well represented in Euclid's book. The older tradition is impressively represented in the geometry of Greek temples, theaters, and various other pieces of art. Just one comprehensive book survived through the ages that summarized some elements of this geometry: Vitruvius's *De architectura libri decem* (Ten Books [Chapters] on Architecture, in Latin, 1st c. B.C.). This work is a synthetic collection of architectural, aesthetical, geometrical, physical, and technical ideas. Vitruvius's approach is based on practice and not on Euclid. The book also has a great importance from the point of view of the term *symmetria*.

Vitruvius adopted the Greek word *symmetria* in Latin: this term and its derivatives appear 85 times in his book (considering the modern reconstruction of the text from various medieval manuscripts).

Let us also see the 'doubling' of the Greek terminology in Latin:

GREEK	LATIN	
	ADOPTION	TRANSLATION
συμμετρία [common measure, proportion]	*symmetria*	*commensus* (Vitruvius, 1st c. B.C.) *commensuratio* (Boethius, 5th-6th cc.)
ἀναλογία [proportion]	*analogia*	*proportio* (Cicero, 1st c. B.C.)

The translated terms remained closer to the original Greek meaning, while the adopted words became available for later generalizations or modifications. Note that after the decline of the Greek and Arabic mathematics, the scholars did not deal with questions of geometric commensurability, and when they started again they used, with a few exceptions, the Latin expression *commensuratio* and its derivatives. Thus, *symmetria* temporarily lost its importance in mathematics, and rather the aesthetical meaning was utilized. There is no doubt, however, that the translated *proportio* became much more popular than the adopted *symmetria*. We are aware of a very few ancient usages of the Latin word *symmetria* (Varro, 1st c. B.C.; Vitruvius, 1st c. B.C.; Plinius, 1st c. A.D.). We may even say that *symmetria* was not a well-established term in Ancient Latin since Plinius noted that "there is no Latin word for *symmetria*" (*non habet Latinum nomen symmetria*, see *Historia Naturalis*, Book 34, Chap. 19, Sec. 65). This is a good illustration of the fact that the adoption and translation of Greek terms was a complicated process and many ambiguities could occur. These confusions had a strong impact on the Medieval Latin terminology.

Vitruvius used all three terms *symmetria* (85 times), *proportio* (32 times), and *eurythmia* (4 times), moreover he tried to make some distinctions among them in building design (Book 6, Chap. 2, Sec. 5):
(1) as a first step of design, we should consider the general method of *symmetria* (as an aesthetic principle),
(2) then we should select the concrete proportions (as the practical realization of *symmetria*),
(3) finally we should adjust the proportions to counteract with the optical illusions and thus to have *eurythmia* (i.e., to restore the desired *symmetria* to the observer).
Basically, we have here the same idea of *eurythmia* that we discussed in Greek context.

In Hebrew there is no direct equivalent of the Greek *symmetria*. In modern Hebrew both *symmetry* and *proportion* are used in adopted form. However, there is an ancient Hebrew expression that has a similar history to that one of the Western *symmetria/symmetry*. This word is *ketzev*:
- In ancient times it was associated with measure of length (cf., *metron*) as the following quote demonstrates (about the sanctuary of King Solomon's Temple; I

Kings, 6:25): "The other cherub also measured ten cubits [about 4.5 m]; both cherubim had the same measure and the same form."
- Later it gained a modified meaning as 'rhythm' in music or poetry (cf., the similar meaning of the modern symmetry).

A further question is whether the Greek *symmetria* occurs in the Holy Scriptures. The *Old Testament* was translated into Greek by Jewish scholars in Egypt in the 3rd and 2nd centuries B. C. This translation is called *Septuagint* (from *septem* and *ginta*, i.e. 70) referring to a non-authentic story that 70, or 72, translators completed the work in 72 days. In the *Septuagint* the adjective *symmetros* occurs once (Jeremiah 22:14):

> I will build myself a great house (*oikov symmetron*) with spacious upper rooms [...].

In the *New Testament*, written in Greek, the word *symmetria* does not occur at all. In case of the later Latin translations of the *Old* and *New Testaments*, the situation is more complicated because there are many versions. Checking some concordances, it seems to us, that the Latin *symmetria* is not used in the Bible.

In the Indian culture the Sanskrit term *sammita* (from *sam-* together + *mita* measure) has very similar etymology to the Greek *symmetria*. Note, however, that this concept did not play such a role in mathematics or aesthetics as in Greece. On the other hand, the Indian culture also developed various ideas that are strongly connected with the modern concept of symmetry, but not yet with the ancient term *sammita*. See, for example, the abstract geometrical symbol-systems (*mandalas*, *yantras*, and *chakras*) that represent various forces and energies of the cosmos. An analysis of the importance of symmetry in the context of these Indian symbol-systems was given in this quarterly by Trivedi in 1990.

In the Chinese and Japanese cultures there is no term that would cover all of the meanings of the Western symmetry, rather a set of terms would do that. The closest term to the Western bilateral symmetry is the Chinese *duìchèn*, while the Japanese reading of it is *taishó*. However, this word has no association with common measure, proportion, invariance, and other meanings of symmetry. On the other hand, there is a concept that may play an interdisciplinary role similar to the Western symmetry. This concept is written with one character and should be read in Chinese as *xíng* and in Japanese as *katachi* (form, shape, figure). In connection with this, see the cited symposium *Katachi U Symmetry* (Tsukuba, 1994) and the related papers by Ogawa. Note that the Japanese culture has a strong preference for dissymmetry (cf., ikebana, garden art).

2 The 'missing link' in the Middle Ages

There are some well-documented cases for the use of the adopted versions of term *symmetria* in some languages from mid 16th century. However, it remained unclear in the literature, including historical-etymological dictionaries, what happened with this term after the 3rd century A.D., how it could survive, and when the Greek and Latin term was adopted by other languages. We tried to find the 'missing links' in this period of more than 1,200 years from both directions:

- to see the appearance of the term in the continuation of the Greek and Roman traditions after the 'golden age',
- to go backwards from the 16th century usages, considering their possible roots.

The decline of ancient Greece did not lead to the vanish of intellectual activity in the corresponding territory, although its intensity became much lower. There was a new progressive direction: the Greek Church Fathers continued to write works in Greek. Considering the meanings of *symmetria* in Greek patrological texts we may notice an interesting tendency (see the 161-volume *Patrologia Graeca*, edited by Migne in the 19th century, and Lampe's *Patristic Greek Lexicon*):
- until the 4th c. A.D.: due proportion (Clement of Alexandria, 2nd-3rd cc.; Basil of Caesarea, or St. Basil the Great, 4th c.; Athanasius, the Patriarch of Alexandria, 4th c. A.D.),
- from the 5th c. A.D.: keeping to the same measure, moderation, limit (Pseudo-Dionysius, 5th c.; Eulogius of Alexandria, 7th c.).

The latter set of meanings is a dead end for the word *symmetria*, because there are much better and simpler terms to refer to those. The disappearance of the interest in *symmetria* as 'due proportion' could have various reasons. The Christian beauty is associated with God: it is not geometric, but transcendent. The field of art where proportions play a crucial role, sculpture, had a very limited presence in the Byzantine culture. Even some inconoclastic periods could interrupt this interest. Note that the mentioned usages of *symmetria* are infrequent cases: we cannot speak about any systematic discussion in connection with this term. Consequently, we do not think that this Greek tradition was the source of the 16th century revitalization of the term *symmetria*, which happened in the Western part of Europe. Following the split between the Western and Eastern Christianity, the people in the West had even less knowledge about the works of Greek Church Fathers and later Greek authors.

Shifting to the culture of the Western part of Europe and to the Western Christianity, we face the problem that the Latin *symmetria* remained obscure even in the antiquity. This term did not become an important one for Augustinus, or St. Augustine (4th-5th cc.), who played a crucial role in formulating the bases of Western Christian aesthetics in Latin. He rather used the terms *convenientia* (harmony), *ordo* (order), *similitudo* (similarity) and *partium congruentia* (congruence of the parts). Where should we look for the Latin word *symmetria*? In Medieval Latin there was no relevant need for adopting the Greek word *symmetria*, because its meanings were covered by other Latin terms:
- *commensuratio* could refer to the Greek geometrical meaning (which topic was rarely considered until late Middle Ages, thus *commensuratio* was also used in some other senses, cf., Boethius, 5th-6th cc.; Thomas Aquinas, 13th c.),
- *proportio* (and some other terms, e.g., *convenientia, concinnitas, harmonia*) referred to the Greek aesthetical meaning.
Still we could locate the term *symmetria* in some peculiar places where the authors strongly followed ancient philosophical tracts (Boethius, Thomas Aquinas). On the other hand, these occasional and obviously secondary references to the Latin word *symmetria* could not initiate the later importance of this terminology.

Let us now see the period of 1,200 years from the other end. The 20-volume *Oxford English Dictionary* (Oxford, 1989) claims that the modern English expression

symmetry was adopted from French, where the term appeared in 1529. The listed earliest English usage, excluding one in an obscure physiological sense, is in the book by John Shute entitled *The First and Chief Groundes of Architecture* (London, 1563). The most comprehensive German dictionary the *Deutsches Wörterbuch*, published originally by the Grimm brothers, gives credit to J. Herold for introducing the corresponding word into German (1540). This dictionary also refers to the earliest usages of the word in other languages, the French one in 1529 and the English in 1563. According to the *Dizionario etimologico italiano* in five volumes (Firenze, 1975) the Italian term occurred in the 16th century. There is also a reference here to a French usage of 1530. None of these dictionaries give any further details in connection with the French work of 1529 (or 1530) where the word appeared, but using French dictionaries, we could determine that this is Geoffroy Tory's book *Champ fleury* (Paris, 1529). Thus, all pieces of information pointed to one direction: the Latin word *symmetria* was first adopted by Tory in his French book of 1529 and later it spread into other European languages. Tory's book has a long subtitle that refers to the art and science of the right proportion (*vraye proportio*) of Roman letters according to human bodies and faces, while the "flower garden" in the actual title is associated with the author's interest in floral ornamentation of books, including initial letters. We still could not see his motivation to revitalize the word *symmetria*. However, we conjectured that he could have some Italian influence because earlier he pursued artistic and grammatical studies in Rome and Bologna. The fact that the early French and English adoptions of the word were associated with human proportions and architecture, turned our interest to Vitruvius, as well as to the earliest known translations of his book, specifically to its Italian interpretations. We believe that this is the topic where there was a strong need to adopt the term *symmetria* into Italian and other languages: the Vitruvian term *symmetria* cannot be replaced by the derivatives of *proportio*, because he used both terms with a slight distinction. With this starting point we were able to disprove the earlier mentioned statement, hinted by many of the best known dictionaries, including the *Oxford English Dictionary*, that the Latin word *symmetry* was first adopted into French: we located earlier Italian adoptions of the term and could give a new picture about the 'hiding' and the reoccurrence of this term. Of course the works by Tory still have a great importance in the transmission of the Latin and Italian term.

Let us see this new reconstruction of the history of the term *symmetria* and its adoptions by other languages, also using some known results of the Vitruvius studies and the critical editions of some Renaissance manuscripts (Maltese, Scaglia):

(1) *Symmetria* survived in the tradition of copying and discussing ancient manuscripts, including the Vitruvian text, in medieval monasteries and later in circles of humanists.

(2) When some Italian artist-humanists also rediscovered the Vitruvian text at the beginning of the Renaissance, they prepared various Italian excerpts and commentaries - partly for their own use, partly for the new generation of artists-craftsmen who did not use Latin manuscripts any more - and they formed the Italian version of *symmetria*:

- Around 1450 Lorenzo Ghiberti, a famous goldsmith and sculptor, among others the creator of the *Gates of Paradise* for the doors of the Baptistery in Florence, translated some part of the Vitruvian text, which did not survive. However, there is

indirect evidence, via his grandson's notebook *Zibaldone* (Codice Banco Rari 228, Bibloteca Nazionale, Firenze), that he used the Italian equivalent of *symmetria*. Specifically, the notebook includes excerpts from Vitruvius where the Italian *simmetria* occurs three times in different orthographical versions: *simettrie*, *simettria*, and *simittri*.

- Around 1475, or at the latest in the 1480s, Francesco di Giorgio Martini, one of the polymaths of the Renaissance, wrote a comprehensive manuscript on various questions of architecture and engineering (cited usually as *Trattato I*), where he included sections from Vitruvius and used the term *simetria* three times.

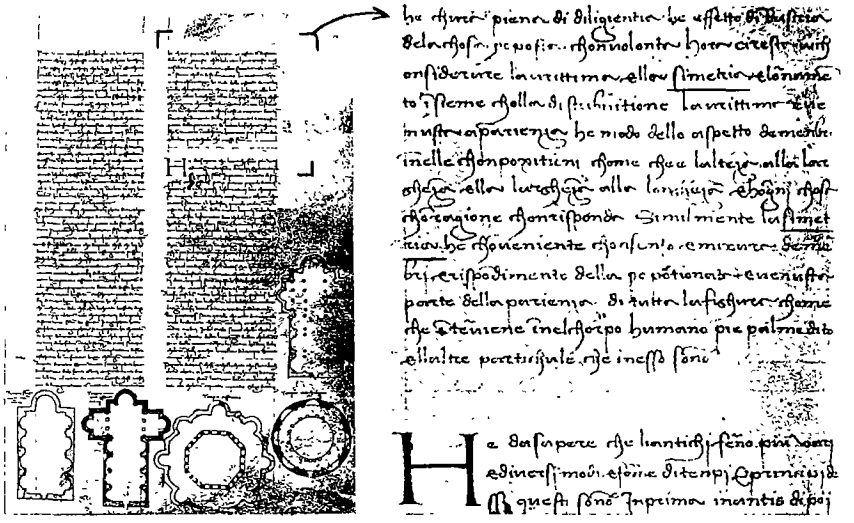


Figure 2: The Italian word *simetria* in Francesco di Giorgio Martini's *Trattato I* according to a survived manuscript-copy (Codice Saluzziano 148, folio 11 recto; Biblioteca Reale, Torino). Another copy of this work was owned by Leonardo da Vinci. The first usage is in the left column, line 16 from the bottom, the second and the third ones are in the right column, line 3 and lines 8-9 from the top, respectively (see the latter in enlarged form at the right where the word *simetria* is underlined by us). The first and the third usages are in translated quotes from Vitruvius, while the second one is in a comment by Francesco.

- Around 1485 the same Francesco di Giorgio Martini prepared an Italian translation of a large part of the Vitruvian text (Codice Magliabechiano II.1.141, Bibloteca Nazionale, Firenze), and here he used the term *simetria* as a well-established term 35 times.

- In 1521 Cesare Cesariano published his Italian translation of Vitruvius in Como, the first printed one in any language except Latin. Cesariano added many comments and figures to the translated text (interestingly his figure-captions are in Latin) and adopted the Latin word into Italian as *symmetria*, sometimes *symmetria*.

Still in the 16th century two further Italian translations were printed: by Barbaro (Venice, 1556) and Rusconi (Venice, 1590). The interest generated around Vitruvius is well represented by the fact that in 1542 the Vitruvian Academy was founded in Rome. Various Vitruvius translations appeared in other languages: in Spanish (excerpts only) by Diego de Sagredo, Madrid, 1542; in French by Martin, Paris, 1547; in German by Rivius, or Riff, in Nürnberg, 1548. The *Deutsches Wörterbuch* by the Grimm brothers lists Rivius's *symmetri* in his Vitruvius-translation as the second oldest example for the use of the German word, which is in modern form *Symmetrie*. Interestingly, the English attitude was different: no

translation of Vitruvius was issued until 1771, but, using manuscripts and other sources, they utilized the word *symmetry* in various theoretical works on architecture.

Note that this period was also marked with various geometric-artistic problems that are strongly related with the modern concept of symmetry, including Albrecht Dürer's book of 1525 (net models of some regular and semiregular polyhedra, close packing of circles, non-periodic tilings by pentagons). Periodic patterns, from Alhambra (14th c.) to various European churches and palaces, were widely used (the floor of the Chateau in St. Lye, South of Paris could inspire the systematic study of infinite black-and-white patterns with combinatorial methods by Truchet in 1704 and Douat in 1722). However, the term *symmetria* was not used in these contexts because the word had not yet gained such an understanding. Mathematically the word *symmetria* remained an 'empty niche', waiting for a more fortunate period...

3 The modern *symmetry*

The modern geometric meaning of *symmetry* was developed gradually. A possible explanation of the new understanding is the following:

proportion (commensurability) of areas [also see the term *symmetros dynamei*, i.e., commensurable in squares, which was used by Plato]	⟶	*two equivalent halves, left/right equivalence* (bilateral figures) *more equivalent parts, regularity of the parts* (e.g., rotational or translational ones)

Parallel to this, the meaning 'proportion' did not vanish, but became gradually less frequent. The process of modification was stronger in the context of national languages then in the rather conservative Latin. We found many early examples pointing to the direction of the new meaning, which are associated with the everyday life, including questions related to architecture.

The term *symmetria* also occurred in dictionaries, lexicons, and encyclopedias in various languages. In France this process was boosted by Claude Perrault, a leading zoologist and physiologist turned architect, who published a new French translation of Vitruvius where he added his own comments on the aesthetical role of *symmetria* (Paris, 1673). Thomas Corneille in his work entitled *Le Dictionnaire des arts et des sciences* (Paris, 1694) included the keyword "Symmetrie" and referred to Perrault (Vol. 2, p. 447). This short article also remarked that we may speak about "the correspondence (*le rapport*) that the right sides have with the left ones, the top ones with the bottom ones, and those of the front with those of the back". The clear scientific adoption of this new meaning of *symmetria* took place in geometry and crystallography, sometimes in the 18th century. We detected an interesting step during this process via the *Mathematisches Lexicon* by Christian Wolff (Leipzig, 1716), who is better known in connection with his later philosophical works. His short article "Symmetria, die Symmetrie" gives two interpretations of the term:
- the Vitruvian one as the proportion (*Verhältnis*) of the parts and the whole of a building, also referring to Perrault,

- a new one developed in French language which is based on *"die Ähnlichkeit der Seiten neben einem unähnlichen Mittel"* (the similarity of the sides at a non-similar center).
This article with a minor extension was adapted in the 64-volume German *Universal Lexicon* (Leipzig, 1732-1750), which is in some sense the first comprehensive encyclopedia in the Western culture. According to some accounts the first exact definition of the symmetry of geometric figures with mirror reflection was given by the French mathematician Legendary in his book *Eléments de Géométrie* published in Paris, 1794 (see, Tropfke, Burckhardt, cf., *Deutsches Wörterbuch*, Vol. 10, 1942, p. 1396).

The concept of symmetry in this new sense was quickly introduced into other fields and was generalized further:
- crystallography: Haüy's symmetry law (1815)
- chemistry: Pasteur's molecular dissymmetry (1848)
- physics: P. Curie's dissymmetry principle (1894)
- mathematical physics: Noether's theorems connecting symmetry transformations (invariances) and conservation laws (1918).

Symmetry became a major organizing principle in science: it helped to find all the possible cases, the exhaustive list, in various fields:
- kaleidoscope types (Brewster, Möbius, Hess, Fedorov),
- crystallographic space groups (Fedorov, Schoenflies),
- chemical isomers (van't Hoff, Fischer),
- elementary particles (Gell-Mann, Ne'eman).
A special importance of the exhaustive lists is the fact that in the most fields these included not only the experimentally known cases, but predicted new ones and thus inspired further studies. Similar lists and classifications are also useful in some fields of art and humanities, including
- ornamental arts (cf., Crowe and Washburn's survey),
- musicology (Graeser's reconstruction of Bach's *Kunst der Fuge*),
- architecture (March and Steadman).
Parallel to this, the importance of symmetry breaking was also discussed, especially in the contexts of particle physics, non-linear mathematics, and modern art.

The overspecialization in science lead to the desire of various interdisciplinary movements, including general systems theory, cybernetics (the science of communication and control in machines and animals), and others. After some time, however, these movements tried to become new disciplines: departments and institutes were founded. This institutionalization, as well as their too broad approach, led to the decline of these movements. In the framework of ISIS-Symmetry we suggest another approach: to make bridges between existing fields, instead of trying to shape a new discipline, as well as to help some concrete, but broad approaches in education and research.

At the beginning of this paper we referred to the work by Delius and Hebers that pigeons can conceptualize symmetry. Let us hope that we, human beings, can not only conceptualize symmetry, but also use it!

(The present paper is a brief summary of a longer paper with detailed references that will be published later in this quarterly.)