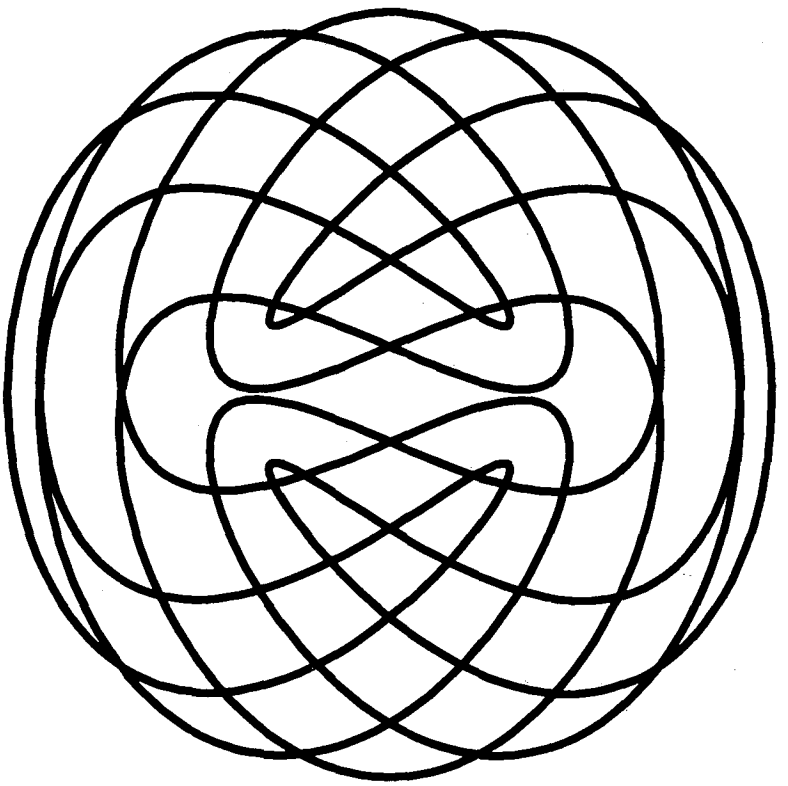
Symmetry: Culture and Science

Mindprints, footprints literacy, and culture

The Quarterly of the
International Society for the
Interdisciplinary Study of Symmetry
(ISIS-Symmetry)

Volume 9, Number 1, 1998



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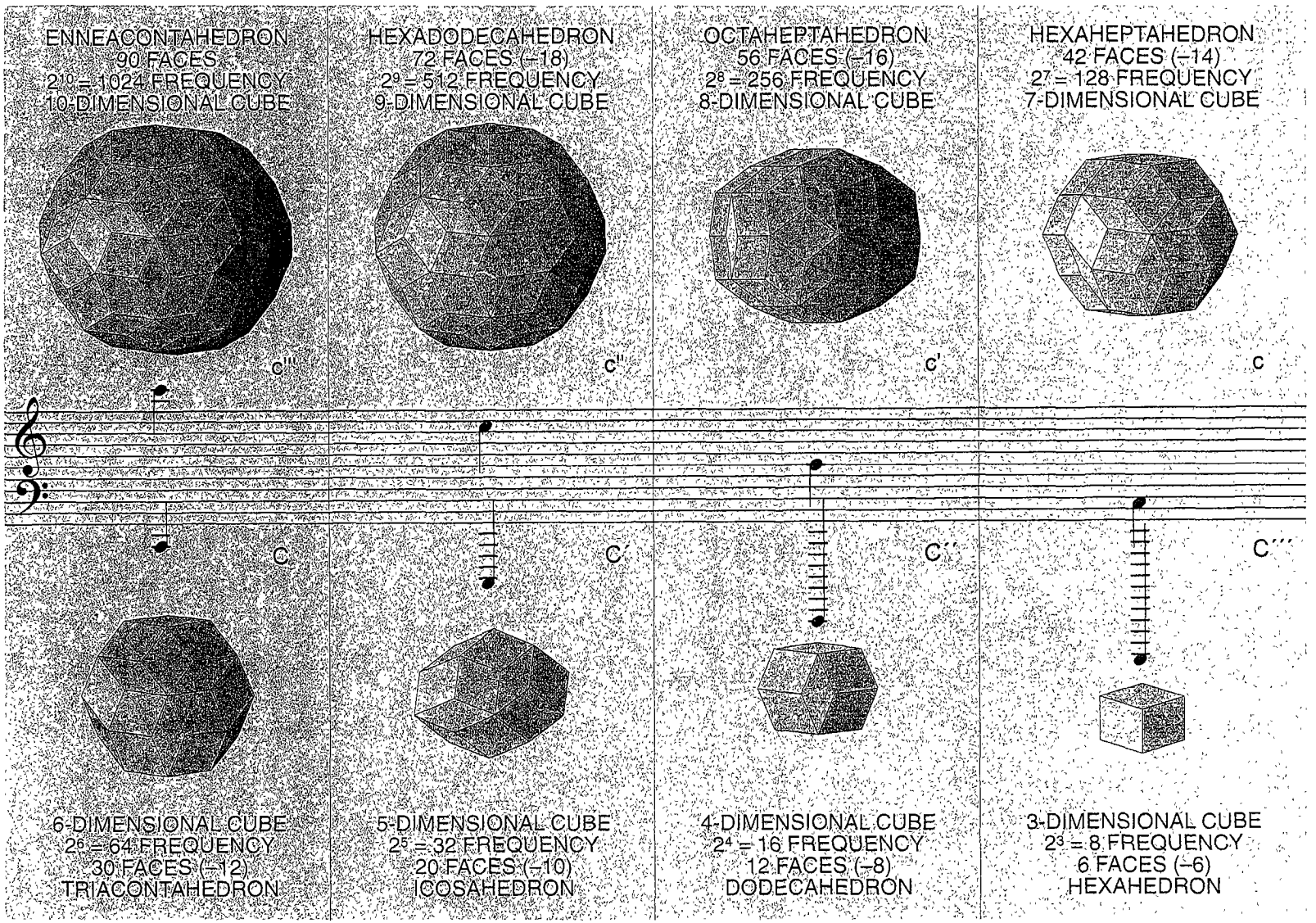
ENNEACONTAHEDRON
90 FACES
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HEXADODECAHEDRON
72 FACES (–18)
2^9 = 512 FREQUENCY
9-DIMENSIONAL CUBE
c''
OCTAHEPTAHEDRON
56 FACES (–16)
2^8 = 256 FREQUENCY
8-DIMENSIONAL CUBE
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HEXAHEPTAHEDRON
42 FACES (–14)
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6-DIMENSIONAL CUBE
2^6 = 64 FREQUENCY
30 FACES (–12)
TRIACONTAHEDRON
5-DIMENSIONAL CUBE
2^5 = 32 FREQUENCY
20 FACES (–10)
ICOSAHEDRON
4-DIMENSIONAL CUBE
2^4 = 16 FREQUENCY
12 FACES (–8)
DODECAHEDRON
3-DIMENSIONAL CUBE
2^3 = 8 FREQUENCY
6 FACES (–6)
HEXAHEDRON

Idea and drawings by Naoki Yoshimoto, 1994
Mathemusic compiled by Caspar Schwabe, 2000

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Symmetry: Culture and Science

The Quarterly of the
International Society for the
Interdisciplinary Study of Symmetry
(ISIS-Symmetry)

Temporarily edited by the *curatory* of the International Symmetry Foundation
Published by the *International Symmetry Foundation*

Volume 9, Number 1, 1-112, 1998

SPECIAL ISSUE:

MINDPRINTS, FOOTPRINTS LITERACY, AND THE ORIGINS OF CULTURE

CONTENTS

SYMMETRY: CULTURE AND SCIENCE is *edited* by the Board of the International Society for the Interdisciplinary Study of Symmetry (ISIS-Symmetry), and *published* by the International Symmetry Foundation. The views expressed are those of individual authors, and not necessarily shared by the Society or the editors.

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Subscription:

Annual membership fee of the Society:
Benefactors, US$780.00;
Ordinary Members, US$78.00 (includes the subscription to the quarterly),
Student Members, US$63.00 (includes the subscription to the quarterly);
Institutional Members, please contact the Secretary General.

Annual subscription rate for *non-members*: US$100.00.

Make checks payable to *ISIS-Symmetry* and mail to G. Darvas, Secretary General, or transfer to the following account number: ISIS-Symmetry, International Symmetry Foundation, *10300002-50400004-21004015*, Hungarian Foreign Trade Bank, Budapest, Szt. István tér 11, H-1821 Hungary; Swift: MKKB HU HB.

ISSN 0865-4824

Cover layout: Günter Schmitz.
Image on the front cover: A piece of *Pend-Art*: "Fruit",
images on the back cover: A piece of *Pend-Art*: "Tulip", and "Cat-curve", all the 3 by Gábor Gévay.
Ambigram on the back cover: Douglas R. Hofstadter.

24850 Akaprint Kft. F. v.. Freier László

Symmetry: Culture and Science
Vol. 9, No. 1, 3-46, 1998

SYMMETRY: ART AND SCIENCE

FOOTPRINTS LITERACY: THE ORIGINS OF ART AND PRELUDE TO SCIENCE

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Fields of interest Philosophy of Culture, Art, Aesthetics, (Systems Theory, Paleoanthropology, Tool Making) *Publications*: (1992) The Complementarity of Art and Design, In: *Emerging Visions: Contemporary Approaches to the Aesthetic Process*, edited by G. C Cupchik and J László. Cambridge: Cambridge University Press, pp 64-83; (1996) Symmetry: The Connectivity Principle of Art, *Symmetry: Culture and Science*, 7, 1, 27-50; (1997a) Figurative Art Versus Abstract Art: Levels of Connectivity, In *Emotion, Creativity, & Art*, ed by L. Dorfman, C. Martindale, D. Leontiev, G Cupchik, V Petrov, & P. Machotka. Perm: Perm Cultural Institute, pp 134-152, with G. C. Cupchik (1998) Perceiving Hierarchical Structures in Nonrepresentational Paintings, *Empirical Studies of the Arts*, 16 (1) 59-70; (In press) Narrative Thinking in a Structure Oriented Culture, Due to appear in *SPIEL* - [Special Issue], *Siegener Periodicum zur Internationalen Empirischen Literaturwisessenschaft* Universität - Gesamthochschule Siegen.

Shows: Artonomy· Systemic Art, National Library Gallery (Jerusalem, 1974); *The Fourth International Congress and Exhibition of ISIS-Symmetry*, Technion I.I.T, Haifa, Israel, September 1998.

Abstract: *Art is a far too complex cultural phenomenon to have been invented ex-nihilo. However, no adequate explanation has so far been given regarding the graphic and cognitive skills which preceded prehistoric art, and made its actual emergence possible. This essay proposes that prehistoric art was preceded by a more primitive kind of pictorial literacy, namely footprints literacy. The obvious attribute common to many early prehistoric paintings and footprints is that both represent their subjects by*

contour and negative. A deeper analysis of these two kinds of visual literacy reveals many other common attributes: connectivity-differentiation, classification, abstraction, generalization, signification, visual class-names, symmetry-asymmetry, schematization, complementarity, induction, deduction, hypothetical thinking and others. Thus, it is probable that footprints are the proto-symbols from which figurative art evolved. It is striking that the same attributes which appear in footprints literacy and in art, appear much later as basic attributes of modern science, but at a much higher level of sophistication. Possibly, these three domains represent successive stages of noetic evolution. Probably, this finding points to fundamental cognitive attributes or "mindprints" that are basic not only to these areas, but to human intelligence itself and probably to all other phases of Being. Pointing out the origins of art might be a substantial contribution to the lifting of the veil from the most fundamental attributes of art since its very beginnings. This may provide a new key to the delineation of the demarcation lines between art and non-art, which seems to be the problem that haunts modern art.

> *The problem 'Which comes first, the hypothesis (H) or the observation (O)', is soluble; as is the problem, 'Which comes first, the hen (H) or the egg(O)'. The reply to the latter is, 'An earlier kind of egg'; to the former, 'An earlier kind of hypothesis'.*
>
> Karl R. Popper (1969, p.47)

> *In the beginning was my end,...*
> *...in my end is my beginning.*
>
> T. S. Eliot, East Coker

1 IN THE BEGINNING WAS THE END

In recent decades the consciousness has become increasingly established, that modernism has indeed failed and that in our century art has rached a dead end. Aestheticians, historians and not a few art critics explicitly maintain this, albeit at differing levels of decisiveness, and in the light of analyses at varying levels of sophistication. (Appleyard, 1984; Avital, 1996, 1997a, 1997b, Avital, in press; Belting, 1987; Field, 1970; Fuller, 1982; Gablik, 1984; Habermas, 1985; Lang, 1984; Ripley, 1969; Wolfe, 1975, and others.) On the one hand, it is doubtful whether it can still be

denied, that art is in a paradigmatic crisis which is the inevitable result of the fact that in the name of unlimited creative freedom in the twentieth century, the demarcation lines between art and non-art have been completely breached. On the other hand, art theory at all levels has not to this day provided a clear way of distinguishing between art and non-art. From this arises the central idea of this essay, that an attempt has to be made to uncover the sources of art, and to understand what its attributes were at the earliest stages, before it underwent so many transformations, and served so many functions in the course of tens of thousands of years. The uncovering of the basic attributes of art at its very sources can in any case help us today to distinguish art from non-art. This idea indeed seems promising, but on turning to an examination of the known theories of the origins of art, it is found that they contribute nothing to such an understanding. For this reason, an attempt is made in this essay to propose a more adequate theory of the origins of art which both has wide implications regarding culture as a whole, and furthermore places in a new light the profound connection between art and science.

In another paper entitled: *The Origins of Art: An Archaeological or Philosophical Problem?* (under review)–three theories have been examined regarding the origins of art: Breuil's imitation theory (Breuil, 1981), Gombrich's projection theory (Gombrich, 1962) and Davis' mark–thing confusion theory (Davis, 1986a). These theories differ in their points of departure and in their degree of elaboration, but equally failed to fulfill the three basic requirements that must be met by an adequate theory of the origins of art: 1. The three theories failed to explain the graphical and cognitive evolutionary stages that must have preceded the emergence of pictorial representation. 2. None of them contributes anything to our understanding of the attributes of art, and these theories therefore cannot help us in solving the central problem of art today, which is the problem of demarcation between art and non-art. 3. None of these theories teaches us anything about the structure of the intelligence of the human beings who created pictorial representation, and therefore none of them helps us towards understanding the deep cognitive structures common to art and to other branches of culture all of which are in the end products of the same intelligence. This being so, a completely different theory is needed, that on the one hand will meet the requirements that have been established here concerning theories intended to explain the origins of art, and on the other hand will be free of the fallacies and inconsistencies which have been exposed in the above mentioned theories. An alternative theory to those must first and foremost single out the activity or cognitive capacity that was the stage preparatory to prehistoric art. Such capacity would have to be of a much earlier origin than prehistoric art, and

probably earlier than tool making as well. This cognitive capacity would have to be common to all hunters everywhere and at every period, and would thus explain the fact that very similar representational systems appeared in all hunting societies. In what follows I shall try to show that this capacity is *footprints literacy.*

Not a few archaeologists and anthropologists have of course noticed the fact that footprints and handprints are among the earliest subjects of prehistoric art, and that it is therefore possible to connect these pictures with the *graphical origins* of image making. (Breuil, Leroi-Gourhan, Delluc and Delluc, and others.) It must be stressed that these scholars deal *exclusively with the graphical aspect* of footprints as a possible origin, to one degree or another, of image making; and in this respect the present article makes no claim to innovation. What is new in this essay is firstly, the argument that image making has two kinds of origins: graphical origins, and cognitive origins, between which there is a profound connection. Secondly, an attempt is made here to show that the *cognitive mechanisms* required for the reading of footprints, which are a much more fundamental stratum than the graphical stratum, are basically the same cognitive mechanisms as those required for image making, and are also the same cognitive mechanisms as those that are identifiable in modern scientific activity. That is to say, there is here an attempt to point out a certain noetic evolution, the manifest beginnings of which can already be clearly identified in footprints literacy. For this reason it is quite certain that this is one of the likeliest and most important (although not the only) origins of image making, not only graphically speaking but also, and mainly, cognitively speaking. The graphical and cognitive components of image making cannot be independent of one another, but it is clear that the cognitive component is the one that conditions the graphical component and in fact makes its existence possible, just as certain cognitive properties condition the very existence and functioning of our language and thinking. This being so, it is of at least as much importance to examine the cognitive properties involved here, as it is to understand the graphical evolution of image making. Art historians and archaeologists either ignore completely the cognitive attributes which must have been a precondition for the emerging of image making, or totally deny the need–or even the existence–of such attributes (Davis, 1986a). However, in the light of the analysis of Davis's theory presented in the above mentioned paper, it is absolutely clear that the fact that scholars do not deal with the cognitive properties required for image making or deny their necessity, does not mean that they do not assume them implicitly. For this reason a cognitive approach, even a speculative one, to the problem of the origins of art is no less legitimate than the empiricist and behaviorist approaches, granted that it provides us with insights that enhance our understanding of the origins of art, its nature and the nature of the intelligence that created it. Art is a phenomenon that is not only too

complex for it to have had only a single origin, but it is also too complex for any specific approach to suffice for the understanding of its origins.

The alternative theory to be put forward here regarding the origins of art is actually a considerable broadening and deepening of the projection theory. But the concern here is not with the projection of contents such as fears and desires, as assumed by Gombrich, but the projection of structural or organizational principles of mind. According to Gombrich, whose point of departure is basically cognitive, projection is only another word for classification (Gombrich, 1962, 89). Ironically, it transpires that if we were to make a thoroughgoing examination of what cognitive attributes were required in order to classify, then we would arrive more or less at the same list of attributes as that implicitly assumed by his opponent (Davis, 1986a), who sets out from a behaviorist standpoint. But Gombrich did not ask what cognitive attributes were latent in the image we project, nor did he ask what attributes were required in order that one could classify, just as Davis did not ask what attributes were required in order that one could recognize similarities between things or marks. The attributes assumed implicitly by both are the attributes that I have called "mindprints". These unique attributes, which will be briefly discussed below, seem to be the meta-structures of the complementarity of mind and reality. However, the archaeology of mind is not necessarily an archaeological problem. Before we approach the main discussion, which shows how these mindprints appear at the deepest level of footprints literacy, image making, and most probably in science and all branches of culture, we shall first review several basic aspects of footprints literacy that make this phenomenon the point of departure for the alternative theory.

2 FOOTPRINTS LITERACY: THE EGG THAT PRECEDED THE HEN

Human beings learn to utter sounds before they are able to speak, and learn to read words before they are able to write them. To the same extent human beings also learn to read a picture before they are able to draw. The fact that a person is capable of reading does not imply that he can write, but if he is capable of writing it can safely be assumed that he can read as well, since writing includes reading as a prior condition, but not the contrary. That is to say, writing is a skill of a higher level of order than reading and it is therefore natural that it always appears at a later stage than reading. From this it is clear that *human beings must have known how to read something very like pictures before they were able to draw pictures*! If this is indeed so, what pictures did the hunters read

before there were pictures? The answer is written on the ground: they read marks that were a kind of 'natural drawing' outlined on the ground without intention or awareness on the part of those who 'drew' them; these were the footprints of animals and human beings. As we shall see, it is almost certain that hominids were already able to read footprints some four million years ago. It seems very reasonable to assume that for the early hunters, as for trackers of all times, footprints were graphic indications, substitutions or even representations of the creatures that produced them, and this is therefore probably the beginning of symbolization and of the capacity of reading graphic representations. If one of the essential attributes that characterize human consciousness is the capacity of thinking in marks related to hypothetical entities, then the reading of footprints is almost certainly the earliest expression of the ability of man to think referentially. On the other hand, some millions of years were needed before the hunters could generalize from the reading of these natural representations, to the 'writing' or drawing of footprints and handprints on the walls of caves and rock shelters (See Fig. 2.). After this, only a short while was needed for them to generalize from the depiction of hands and feet by the contours of those limbs, to the depiction of the prints of entire animals and men by the contours of their bodies. If image making is indeed a generalization of footprints literacy, it has to be shown that the footprint has the overwhelming majority of the most important attributes possessed by drawings, even if on a less developed level than drawing. Another aspect of the same matter that must be shown is, that the reading of footprints requires skills and cognitive abilities similar to those needed for the reading and use of pictorial symbols. In other words, it has to be shown that footprints are the *proto-symbols* from which the symbols of figurative art may have developed.

Hunters invented prehistoric art, and the hunter's chief skill is not killing but tracking; this is the ability to decipher the enormous plurality of marks that make up his environment. Footprints are one of the most important kinds of marks that the hunters of all times must have been acquainted with, for as a rule it is easier to find footprints than to find the animals that leave these footprints. Very great expertise in deciphering marks is a necessary condition for the hunter's existence both in securing food for himself and his family and furthermore not to become himself food for another animal. Marks based on the senses of hearing or smell are only very effective at a short distance from their source, and they are therefore efficient mainly for creatures that are sufficiently strong to be able to attack their prey without danger to themselves, such as the large predators; or sufficiently swift to flee quickly enough when sudden danger is revealed. But for man, who has neither of these advantages, and particularly when he had as yet no weapons at all, his only advantage was perhaps the ability to decipher a special kind of marks even

at a very great distance from the animal that left them: footprints. According to the type of footprints and their characteristics, the hunter could choose whether to ignore them, to rapidly reduce the distance between himself and the animal in order to make a kill, or to distance himself from it. The main difference between footprints and the other marks or indications such as all kinds of secretions, smells, sounds, etc., is that all of these are real entities with positive existence, and in most cases are an actual part of the animal that has become detached from it. By contrast, footprints derive from the absence of soil in an amount and of a shape that fits the foot of a particular animal. The footprint then, is not material but is the *pattern* of the foot that left it. A pattern is a kind of abstract indication of the animal, but not of a kind from which it is possible to generalize with the aid of one of the senses to the identification of the animal that left it, but only by means of very complex cognitive activity of the kind required for symbolic thinking. Munn describes an instructive example of a special integration of footprints literacy, drawing, and verbal thinking among present-day hunter-gatherers, the Walbiri in Central Australia: "Among the most prominent of the graphs that Walbiri draw in the sand are track prints of animals and birds and circle or circle-line notations referring to places and journeys... Footprints are impressed in the sand by holding the hand in various special positions; their production is a casual play activity in which men, women, and children may indulge." (Munn, 1973. 119). If footprints literacy is likely to be such a basic component in the thinking of contemporary hunter-gatherers, it may be supposed that among prehistoric hunter-gatherers, footprints literacy was almost certainly an even more basic component in their thinking, for they were chiefly visual thinkers, and only to a marginal degree verbal thinkers as well.

The identification of an animal by means of its footprints entails cognitive abilities that have a great deal in common with the capacities needed by the prehistoric draughtsman, and the capacities needed by the scientist today. In the three cases, footprints literacy, prehistoric image making and modern science, the same attributes are required, but at different levels, and these attributes can be identified for the first time in footprints literacy: connectivity, differentiation, grouping, classification, abstraction, generalization, thinking in visual universals or visual class-names which in this case are visual schemes of an object derived from its contours, pattern recognition: the identification of symmetries and transformations of those symmetries, complementarity of figure and ground, induction and deduction, construction of hypotheses and their empirical testing, thinking in terms of spatial order, in time and causality, the ability to reconstruct in the imagination and thought, hypothetical processes connected with the

behavior of the animal, et cetera. All this and more is required for a hunter to deduce which animal left the footprints. It is true that a similar cognitive activity is also present when trying to deduce what animal left particular droppings. But this activity is at a far lower level, for in this case a part of the animal itself is given, and therefore there are in this case far fewer possibilities of making a mistake in obtaining a correct solution. The awareness of the cognitive mechanisms involved in footprints literacy makes obligatory a theory of a level of conceptualization and abstraction that is quite high even today, when our thinking is much more conceptual than visual. It is therefore obvious that the cognitive mechanisms involved in footprints literacy among hunters of all times, are mostly unconscious. The same is true, not only concerning the prehistoric hunters who initiated image making and whose thinking was undoubtedly much more in visual (and other) terms than in verbal terms, but also with regard to image makers of all times. Now it is easier to show that the emergence of image making probably followed from generalization and elaboration of the principles of the visual thinking that had served hunters for millions of years before in footprints literacy and tool making.

3 CONTOUR IN PICTORIAL SYMBOLS AND FOOTPRINTS

It is quite easy to show that Breuil's imitation theory does not explain the origins of figurative painting, but his empirical findings are among the foundation stones of the study of prehistoric art, and they may also help us to put our finger on the origins of art. One of his most interesting findings was that the earliest prehistoric paintings were handprints, finger meanders, and sometimes also depictions of human or animal footprints (Breuil, 1952). From this finding, he concluded that the imitation of the footprints of animals and men is one of the sources of art because this is one of the first subjects they imitated. It must be noted that there is no agreement among archaeologists with regard to the time of the beginning of image making; nor with regard to the place where it began, nor regarding the aims it fulfilled, and it is therefore not to be wondered at, that there is no agreement on whether pictures of hands are indeed the earliest motif in prehistoric image making. On the other hand, nobody disagrees that this is one of the earliest motifs in prehistoric image making, and this is supported by many findings in Europe and elsewhere. Thus for example, handprints painted on a rock shelter in Kakadu National Park in Australia are dated by some archaeologists at 40,000 B.P. (before the present). Similarly, in the recently discovered Cosquer cave, the paintings of hands are estimated at 27,000 B.P., whereas the paintings of horses found there were produced only some 9000 years later. According to Delluc and Delluc (1981, 1984) the earliest paintings are mainly those depicting animals, female and phallus signs, and these

are estimated at around 30,000 B.P. The most important characteristic of the earliest image making is that the pictures are always *incomplete*. These authors suppose that the *simplification* of the representations is a kind of quasi-symbolization, and in this connection they propose the principle of *la partie pour le tout*. That is, the representation of the animal or the figure by means of a schematic representation of only a certain part of it. This principle seems very logical, inasmuch as it cannot be supposed that the first paintings already depicted figures in their entirety. According to the logic of this principle, it is correct to argue that a footprint, whether a natural footprint or a painted or engraved one, was for the hunter a kind of representation of the entire animal. Delluc and Delluc (1985) also mention many places in which footprints and partial footprints of animals have been preserved, and also sites in which marks have been painted or scored, that have in the past been interpreted as female marks; but they believe that these marks are more like footprints belonging mainly to predators, and sometimes also footprints of men and of birds. Paintings of footprints are found in stationary places and also upon moveable objects. Sometimes they did not engrave the whole footprint but were content with an engraving in the shape of a U or V. Their very logical conclusion was that the draughtsmen who produced these marks were Palaeolithic hunters, and that they created footprints of the animals and men that they customarily tracked. They displayed these creatures by means of simplification, schematization or geometrization of these figures. It seems to me that there is no contradiction between the supposition that pictures of hands are the earliest, and the supposition that pictures of parts of animals are the earliest, both because it is impossible to deny the possibility that the two subjects were coeval, and also because in both cases the whole is represented by its part. In what follows, I shall try to show that the drawings of handprints which are quasi-prints of hands on the wall, are the first generalization of footprints literacy, and therefore the link connecting footprints literacy with the symbol system of figurative art. We shall begin the comparison between footprints and painting with regard to two very simple attributes: representation by negative image and contour of the object, before we approach the deeper and more complex attributes that exist within the two phenomena.

It is no accident that hunters noticed the contours of footprints and afterwards generalized this principle to painting. Research today has discovered the high sensitivity of the brain to contours, and in fact this is the basic strategy of the visual cortex in constructing the image from the information received from the retina. New research points to the possibility that the brain stores the visual information in memory as a two-

dimensional picture and not a three-dimensional one (Bulthoff and Edelman 1992). The construction and storing of visual information by means of contours is of course very economical, especially when the concern is with visual information that requires a large amount of memory. Handprints fall into two groups: a minority of them were indeed done by imprinting with a hand that has previously been dipped in or smeared with pigment, in this way obtaining a positive image of the hand, but in most cases the handprints were produced by spraying paint over the hand which was pressed to the wall of the cave. In this way a picture was obtained which is the negative image of the hand, just as a footprint is the negative image of the foot that produced it. The negative in the picture is two-dimensional only, whereas in the footprint the negative is a three-dimensional configuration. But this difference is marginal in comparison with the common ground shared by the two phenomena and which is, that in both cases the configuration resulting by means of the negative traces a contour of the hand or foot. Depictions of feet painted by this method are to be found at many prehistoric sites, and sometimes even whole creatures were painted in the same way. (This subject is extensively discussed in all prehistoric art books, and there is no need to discuss it here. See for instance the now classic books: Breuil, 1952; Giedion, 1962; Leroi-Gourhan, undated). A generalization of the principle of representation by means of contour, not by spraying but in a much more economical way, can be seen in most early prehistoric paintings. Since even for super-hunters it was difficult to hold a whole mammoth pressed to the wall simply in order to obtain its contour by spraying, they drew the animals by first outlining the contour and afterwards scoring it and filling the incision with pigment. The history of the contour and what happened within it is more or less the history of art, and we shall not discuss it here. We shall mention only that in later stages the hunters gradually filled the area within the contour with color, partially at first and later on completely. At later stages a retreat took place in the opposite direction - towards greater and greater schematization which led in the end to the creation of writing. For this it was essential to renounce the principle of representation of the object by its contour, for the graphic marks no longer represented objects, but the sounds of speech. The generalization from the reading of given footprints of animals and human beings, to the deliberate depiction of 'prints' of images that we have regarding real or fictitious objects by means of their contours, was an invention of vital importance in the continued evolution of human culture. For the first drawings were already the beginning of the pictorial writing from which there developed, by a long evolutionary process, the syllabographic and alphabetic writing systems without which it would not have been possible to construct the conceptual hierarchies required for the creation of philosophy and science. The invention of prehistoric art signals a singular upward leap in the history

of man, since this was the first time that human beings produced an extension of the brain or memory and not of the hand; they transformed visual thinking from a private experience into a public one, for drawing is the 'speech' and also the documentation of visual thinking. That is to say, prehistoric painting is visual thinking exorcised of its privacy in the mind (eyes) of the beholder, to become communal and communicative, i.e. to become visual language. In this way, for the first time a means was created of storing information and human experience for subsequent generations, outside the skull. Only the invention of the computer in our time is equal to the invention of prehistoric art, in being the second extension of the brain created by man; although infinitely more powerful, it is doubtful whether it would have been possible without the first. In the last two sections we have seen in what sense footprints literacy is likely to explain the *graphical origins* of image making. In the next sections we shall see that footprints literacy is likely to explain its *cognitive origins* as well. Before we can examine other aspects that footprints and painting have in common, which are far less obvious than contour, but infinitely more important, it is necessary to explain even if very briefly the new key-term: *mindprints.* (For a more comprehensive presentation of this concept see Avital, 1997b.)

4 MIND, MINDPRINTS AND THE ORIGINS OF ART

One of the reasons for the fact that to this day we do not know what are the properties that really distinguish art from other domains, is that until today the basic question has not been studied: What were the cognitive attributes that were a precondition or necessary condition for the emergence of prehistoric art? The basic assumption of this essay is that all domains of culture and among them art, are different expressions of certain fundamental properties of human intelligence, or mind. This being so, the uncovering of these properties which are a priori in relation to the possibility of the emergence of art, is likely to enable us to anchor the nature of art in the nature of mind. This essay attempts to show that footprints literacy includes not only most basic aspects of the graphical sources of prehistoric art, but also most of the cognitive attributes without which it is impossible to paint or to read a painting. The cognitive precedence of footprints literacy in relation to art is on at least two levels: on one level, footprints literacy requires highly developed thinking in *images.* If footprints literacy indeed preceded tool-making, as I presume, then the visual thinking that developed within the context of footprints literacy also served the making of stone tools. This matter is understandable if we remember that thinking in images (which are a kind of proto-

symbols) is the necessary condition for the making of stone tools, for it is impossible to make any stone tool at all unless the maker has some preconceived image of the tool it is wished to make. It is reasonable to suppose that the thinking in images that developed within the context of footprints literacy and tool-making, was a stage preceding the capacity for thinking in images, which was a necessary condition for image making. Thinking in images is a necessary condition in these three domains, but it served different purposes: in footprints literacy the images serve the identification of the animals which created the footprints; in tool-making, the images were patterns or a kind of guiding plan for the design of tools; and in prehistoric art the images served the creation of a *system* of pictorial symbols which was mainly intended to preserve information and to give expression to the creative character or the open-endedness of human intelligence by means of a visual language. However, at a second level the cognitive attributes common to footprints literacy and painting are at a much deeper stratum and they possess, not a visual but a structural character. (These attributes are common to tools as well, but I shall discuss this matter in another essay.) I have called these attributes *mindprints*, seeing that for reasons extensively discussed in the history of philosophy, and other realms, all of the knowledge that we have is necessarily only some *interpretation,* and we shall therefore never be able to know what is Reality in itself; and we shall never be able to know what is the mind in itself, but only indications at the most: shadows and its "footprints" insofar as these are manifested in a way that organizes reality and the contents of consciousness. From the outset the main aim of mindprints theory was not to provide a new basis for epistemology and ontology as did most of the theories of categories put forward throughout the history of philosophy, but rather to try to point out the most basic properties of mind that appear in all paintings, and thereby to anchor the nature of art in the nature of mind. Together with this, the fact that these properties, which will be briefly discussed in what follows, appeared throughout perhaps millions of years in footprints literacy and in tool-making, and throughout tens of thousands of years in paintings, independently of place and time, perhaps hints at the possibility that these properties are not special to art alone, but to all domains of culture and perhaps even to all aspects and levels of Being. The idea of mindprints is discussed extensively in another essay (Avital, 1997b) and I shall therefore content myself here with only a minimal explanation to be clarified in the following paragraphs in discussing the appearance of most of these attributes in footprints literacy, in prehistoric painting and to some extent in science as well. So that the reader may already obtain at this stage a synoptic view of this issue, it is desirable to study the two comparative tables which appear at the end of this essay.

At this point I wish to propose a tentative table of mindprints:

1 Connectivity–Disconnectivity (Codis)
2 Open endedness–Closed endedness
3 Recursiveness–Singularity
4 Transformation–Invariance
5 Hierarchy–Randomness
6 Symmetry–Asymmetry
7 Negation–Affirmation (Double Negation)
8 Complementarity–Mutual Exclusiveness
9 Comparison - (No Comparison?) Imparison
Determinism–Indeterminism (Probability, Selection, Choice)

As already indicated, mindprints are probably the meta-structures of the complementarity of mind-reality. In other words, these special attributes are perhaps the structural bridge between mind and reality, or the structural interface of the complementarity of epistemology and ontology. I shall briefly indicate a few characteristics of mindprints so that in what follows it will be better understood in what manner these attributes are most fundamental in footprints literacy, and in art as well.

1. The most prominent characteristic of all of the mindprints is that every one of them is constituted from a pair of complementary opposites. That is, like yin–yang, every mindprint is an oxymoron comprising a pair of opposed attributes which generate a complementary unity. Thus for example, Connectivity–Disconnectivity does not indicate two attributes but rather a single attribute of a higher level having two opposing aspects one of which we call Connectivity and the other Disconnectivity. Since Western culture is much more influenced by Parmenides' law of contradiction than by Heraclitus' principle of complementary opposites, it is little wonder that in Western languages there are almost no concepts that are oxymorons like the Chinese concepts of Dao or yin–yang. Since Connectivity–Disconnectivity is a very central mindprint, I propose the term *Codis* for it, which comprises the combination of the connective prefix 'co' and the separative suffix 'dis'. It is easy to show that most of our cognitive activities such as: grouping, distinction, analysis, synthesis, classification, generalization, abstraction, symbolization and many other activities connected with organization, ordering, lawfulness and the like, are special cases of connectivity–disconnectiviy. It is moreover possible that this is a central mindprint not only on the noetic level but also in the biological, the social and the material world. It is likewise worth mentioning that almost

all of the mindprints have an entropic pole of a negentropic character, but there is always a certain predominance of the negentropic pole. Thus, for example, the pole of connectivity is more dominant than the pole of separation, for otherwise a material world, life and culture would not be possible.

2. Another prominent attribute of mindprints is that some of them are primary, or not derivable from other mindprints, while with regard to others it is clear that they are comprised of other mindprints. Thus it is, for example, easy to show that hierarchy–randomness and symmetry–asymmetry are composed from other mindprints whereas open-endedness—closed-endedness or connectivity–disconnectivity are not composed from other mindprints. Nevertheless, all of the mindprints assume explicitly or implicitly negation–affirmation (double negation), and for this reason this is perhaps the most basic mindprint of all. It is worth noting that the most complex mindprint is hierarchy–randomness, which includes most of the other mindprints, and for this reason several students of mind are unjustifiably tempted to reduce mind to hierarchical or systemic patterning (Bateson, 1979; Stamps, 1980, and others). Special importance for our subject attaches to Open-endedness—Closed-endedness, which together with Connectivity–Disconnectivity (Codis), Recursiveness–Singularity and Transformation–Invariance, generates attributes such as novelty, originality, creativity, metaphor, evolution, new orders, induction, extensivity, hypothetical thinking, etc. Another aspect of mindprints is that the products of the operation of some of them may accumulate, whereas the products of the operation of others do not accumulate. Thus for instance, the recursion of connectivity is likely to generate hierarchy, and recursion of separation is liable to break all connections and thereby to generate a state of randomness. By contrast, there is no accumulation in the case of recursion of negation, affirmation, comparison or complementarity.

3. In a certain sense, there is a non-rigid hierarchy among the mindprints, and in another sense there is no hierarchy among them, since almost certainly mindprints are all different aspects of a structuring meta-principle that is far more abstract and general than all of the mindprints mentioned in the foregoing. It would appear that our conceptual system will have to develop to a considerable degree in order for us to be able to understand a principle of such a level of abstraction, and perhaps it will remain forever beyond our grasp, for in a certain sense it is another name for a totality which is in principle beyond our grasp. However, the totality is an infinite system of nested hierarchies and therefore it is reasonable to suppose that the mindprints too are, in a manner not clear to me, holons in a system of inconceivable abstraction. In sum, I am sure that any understanding of mindprints I may have is at best very partial, and I can

only hope that in the future I may understand the idea a little better. At the same time, even the limited understanding I have of this concept has helped me to understand art more than all of the theories of art that I have read over many years, and I hope that the reader too will be able to derive benefit from this concept. (Again I emphasize that the exposition of the idea here is perhaps too concise, and that the reader who wishes to obtain a deeper understanding of the idea of mindprints is therefore recommended to study another essay which deals with it more extensively–Avital, 1997b.

Here a last debt must be paid to W. Davis whose theory I have criticized harshly in another paper (Avital, under review). The strongest argument of Davis against any kind of idealist or cognitivist view regarding the origins of art is that it assumes a priori capacities for the perception and creation of images and representations. His argument is that such a standpoint is built on a tautology and leads to an infinite regression, since the Idealist has to assume language 2 in order to explain language 1, and to assume language 3 in order to explain language 2, and so on ad infinitum (Davis, 1986a, 201). In the same discussion I tried to refute the first part of his argument, concerning the tautology supposedly present in the Idealist standpoint, but the argument of regression remained unanswered. Only now, after the schematic presentation of the idea of mindprints, is it perhaps possible to counter this argument as well. The answer to this argument is already to be found in a very concentrated form in the quotation from Karl Popper which appears at the head of this essay: Before the chicken, there was *a different kind of egg*. If we assume that in order to understand language 1, language 2 is necessary, and language 3 in order to understand language 2 and so on, as in Davis's argument, then we do indeed enter an infinite regression. However, this happens because we assume that the languages 1, 2, 3 are languages with content of the same type *and of the same level.* But if we accept Popper's insight, there is no need for us to be trapped in an infinite regression, since if the egg that precedes the chicken is a *structural system* such as the system of mindprints, which is likely to explain the language of content that is below it, then we need not be caught in an infinite regression. I suggest that mindprints are basic organizational patterns of mind that precede every language of content, whether visual or conceptual. Here Davis is likely to press with the demand: "And what preceded the mindprints?" My reply is that I simply do not know. But if there was something that preceded them, it was something different from them, and of a level of abstraction that is beyond my understanding. Then he may ask: "Have we not again entered an infinite regression?" and my reply is - perhaps, and perhaps not; for, if the mindprints or something like them are the highest patterns of mind-

reality, then there is in any case no regression; but we shall never know whether beyond them there are no higher levels of structuring. However, even if there is here the possibility of a regression, at least at this stage we do not know whither to retreat beyond the mindprints. Secondly, even if we accept the possibility that there is a regression, this is not necessarily a fault. Thus, for example, in fractal drawings, a kind of infinite regression can be generated by repeatedly zooming in, each time on a tiny part of the picture created by the preceding zoom-in, and each time we shall get the *same structure* despite the probable change of scaling and color. It may be that this is the situation with regard to the case of mindprints, but I cannot be sure. The logical conclusion of this argument is that mindprints as principles of organization of the mind precede, at least logically, not only all perception and cognition but life and matter itself, and are perhaps a precondition for their coming into being. The conclusion that intelligence and its mindprints, which are the structuring function from both the ontological and the epistemological point of view, precede what they structure, seems to me far less absurd than the paradoxical argument of the Behaviourist who does not think that he thinks.

The reader may rightly argue that if mindprints are cognitive meta-structures that are necessary in one measure or another for every cognitive activity and not only for art, then they cannot serve as a criterion for the purpose of distinguishing between art and non-art. The answer to this argument is very simple: It is true that mindprints are common, in one form or another and at various levels, to all branches of culture, since according to the view presented here, it may be that the highest goal of all branches of culture is to give explicit expression, to one degree or another and at different levels of abstraction, to mindprints or to intelligence. However, the disparity between the various branches of culture is in the different types of symbols by means of which each branch of culture expresses the mindprints in a particular stratum. Thus for example, it can be shown that on the one hand in figurative art and in science all of the mindprints are present, but they are manifested by means of symbol systems having very different attributes. The fact that the one field uses aesthetic symbols and the other conceptual and formal symbols, has profound implications for the level of connectedness and generalization that each field is capable of attaining: the measure of stratification that each field is likely to offer with regard to its subjects; the types of symmetry that each field requires for the description of reality; the types of transformation that each field can offer; the level of ambiguity and communicativity of each of the two symbol systems; and so on. However, beyond all these profound differences, the fact that the two fields are in the final analysis anchored in the same fundamental attributes of the mind is for me far more important, and also gives room for hope that in the future it may

be possible to greatly reduce the alienation of the "two cultures". In a sense–and this is no mere play on words–prehistoric art is prehistoric science. As against this, as we shall see at the end of this essay, in the modern art called "Non-representational" or "Abstract Art" there is not to be found any one of the mindprints that appear in figurative art, in footprints literacy and in science, and I therefore maintain that there is certainly room for doubt as to whether it is art at all. After this schematic presentation of the idea of mindprints, we shall now try to see how these mindprints and other cognitive attributes which are their derivatives, appear in figurative art and in the stage that preceded it–footprints literacy.

5 CONNECTIVITY–DISCONNECTIVITY (CODIS), CLASSIFICATION AND ABSTRACTION IN PICTORIAL SYMBOLS AND FOOTPRINTS

" In each and every case that which unifies is mind."

Aristotle, De Anima 430b.

In order to understand how footprints functioned for prehistoric hunters in a way similar to that in which symbols of all kinds function for us, we should recall some of the main attributes of symbols. All kinds of symbols, whether visual, verbal, formal or any other, have both special attributes, and attributes that are common to all types of symbols. The most basic attribute of every symbol and every image is a seemingly paradoxical one, namely: on the one hand every symbol connects all of the entities encompassed by it, but by this very fact the symbol also isolates and separates this class of entities from all others. That is to say, the fundamental attribute of every symbol is built on a dialectic or complementarity of *connectivity–disconnectivity* which I have tentatively called *codis* (Avital, 1997a). This double-edged property is probably one of the most basic mindprints, because in one way or another some other mindprints are derived from or depend upon it, and it is also multi-leveled. It appears on the material, the biological, and the noetic levels; it is therefore at the foundation of differentiation of any kind. From this basic mindprint, arise the most prominent attributes of our intelligence: abstraction and classification. It is true that there is connectivity on the material level, and also on the biological level, but noetic connectivity is higher than these two types, because it always generates classes of much higher levels. Since noetic connectivity exists mostly through symbols, the very symbolization generates an ascent of

connectivity in relation to the level of connectivity of the things for which we create the symbols. Cultural history is therefore to a great extent the history of the connectivity generated by means of the various symbol systems. It would seem that the fundamental attribute of this evolution is the continuous rise of the level of connectivity, and more precisely of the level of codis, i.e. the simultaneous connectivity–disconnectivity that every symbol system generates. It is easy to discern this phenomenon if we observe the levels of connectivity of the following symbol systems: verbal language, totemism, mythology, philosophy and science. However, all of these symbol systems are based on an increasingly efficient recycling of conceptual connectivity to ever higher levels. Science includes conceptual connectivity and also mathematical-logical or formal connectivity, which is the highest yet to have been generated. By contrast, the connectivity of pictorial symbols does not belong to this evolutionary continuity, but to the evolution of visual thinking. This type of thought preceded verbal thinking by hundreds of millions of years, for it has existed as long as vision, and vision is a mode of thinking. Visual connectivity exists in all kinds of visual thinking such as vision, dreams, imagining, and reaches its peak in footprints literacy, tool making and image making. Despite the fundamental difference between visual connectivity and conceptual connectivity, it is very probable that the first type served as the basis for the second, and that the second served as the basis for the next leap in the level of connectivity: formal connectivity. In order that it may be easier to see the connection between pictorial symbolization and footprints literacy, it is worthwhile noting here a number of properties of symbolization in general.

The attribute of connectivity–disconnectivity or codis is also at the base of the mechanism by means of which we create symbols of all kinds: abstraction. In every abstraction there are three components that act together simultaneously: we create a grouping of certain entities; secondly, we eliminate all of the specific attributes of each of these entities, and thirdly, we preserve only the most important of the attributes that are common to all of them. That is, we preserve under a certain class-name the common denominator which is an idealization and generalization of the attributes of these entities. The relation between the symbol and the object it denotes, is the relation between a type and a token or event, and a symbol is therefore an entity of at least one order higher than all those which it encompasses. Thus for example, the word 'dog' is a verbal symbol for all dogs that have been, are, or will be in the future. This label does not only connect all these dogs, but also distinguishes them from all other things. That is to say, symbols allow us to create differential groupings of various entities and thereby to classify, organize and order our world view. The same principle of differential grouping holds for pictorial symbols. As in the case of verbal and formal symbols, so

too are pictorial symbols constructed, by exactly the same processes of abstraction by means of which we generate the other types of symbol. So, for example, a prehistoric drawing of a horse does not describe some specific horse but is a pictorial class-name for all of the horses that have the attributes described in the drawing, and distinguishes all of these horses from all other living things. As in the creation of symbols of any type, here too we ignore very many aspects of all specific horses. But we preserve certain visual aspects that are common to most horses, such as the characteristic contour of a horse seen in profile, and this configuration becomes a pictorial label or connector for all horses of the same kind. In order to read the picture, it is essential that the reader be aware of most or all of the aspects of the horse that we have eliminated in the process of making the symbol for a horse. It will now be easier to see that the attributes of connectivity–disconnectivity, classification and abstraction that are present in every figurative picture and in all other kinds of symbol, are also present in footprints literacy.

Every hunter is a tracker, and every tracker is an expert at reading all kinds of footprints. Unlike the case of verbal or pictorial texts, footprints are not written but only read. But in exactly the way that the picture of a horse is a class-name for horses, so the type of footprint of the horse's hoof is for the hunter a visual class-name for *a* horse, even though it was created by the hoof of a specific horse. More precisely, if the footprint is that of a certain kind of horse, whose attributes such as age, sex, weight, characteristic manner of walking etc. are expressed in the type of footprint, then the footprint is a visual class-name or proto-symbol for all horses that possess these attributes. The relation between the footprint and the animal that created it is the relation between the type and its individual case. In a sense, the animal is a specific case of its footprint type, as every red apple is a specific case of a picture representing a red apple. Secondly, as in the reading of every symbol, footprints cannot be read without abstraction, since the tracker must reconstruct hypothetically the way in which the footprints were created. In this process, he knows that he must ignore most of the visual aspects associated with the animal that created the footprint, and treat the print as a formal common denominator characterizing the feet of all animals that are of the same kind, and have the attributes represented by the footprint. By generalization, the type of footprint represents for the hunter the whole animal even though in actuality it represents only a very small part of its body. The footprint is therefore a means of grouping, exactly like any verbal, formal or pictorial symbol; and every grouping requires abstraction since every grouping is made selectively and by classification, in the light of preconceived criteria of attributes. For the reading of footprints the tracker must have a kind of system of images or a

'theory', either explicit or implicit, about footprints. This visual preconception must include a general concept or image of the footprint as a sign left on the ground by a creature in certain circumstances. His visual vocabulary must include images for the footprints of different creatures, among them human beings. It is also essential that he have images of the footprints of these creatures at different ages and weights, with differing health and gait, and in different conditions of terrain and weather. That is to say, the reader of footprints must have a profound understanding of causality: between the fact of the gait of X and the formation of a footprint of the specific shape and attributes. He must also be able to estimate, according to the characteristics of the footprint, the time that has elapsed since the footprint was made, for there is no point in following stale footprints. By establishing the time, he must be able to estimate the distance between the maker of the footprints and himself. It is instructive that Kant, one of the greatest philosophers of all time, considered that the orders of space, time and causality were the most basic instruments of reason, and clearly these were the basic brain tools of the hunters of all time, even before there was verbal language. The prehistoric tracker-hunter had, then, an extremely complex visual or imaginative theory of footprints as a condition of survival. This theory included a system of images of different levels of connectivity and generalization and as in every symbol system, in footprints literacy too there is stratification of the system of images from the general to the specific. It has already been noted that every symbol is a connector - whether the symbol be a word, number, equation, law of nature, figurative picture, or footprint. Each of the different kinds of symbol and sign connects in a way special to the type. The question is in what way a footprint connects between living beings whose feet have the same pattern. The answer to this question brings us to the next set of mindprints common to figurative art and to footprints: symmetry–asymmetry.

6 SYMMETRY–ASYMMETRY, TRANSFORMATION AND COMPLEMENTARITY IN PICTORIAL SYMBOLS AND FOOTPRINTS

One of the most basic attributes of symbols is the actual duality of the symbol and the symbolized. In principle, the symbol differs from the symbolized and is not dependent upon the latter for its existence, since symbols can denote entities that are not perceptual–fictitious or hypothetical entities. In most symbol systems the connection between the symbol and the symbolized is fundamentally a convention which becomes entrenched through the use of the symbols, as with all linguistic and formal symbol systems. In figurative art too, there is in principle a duality of the symbol and the

symbolized, only that here the connection between the two is not the outcome of convention and habit, but is *inherent.* This internal linkage between the figurative symbol and the object symbolized by it, springs from the fact that the symbol in this case is built on a certain symmetry between the two. It is easy to ascertain this fact by looking at some of the very earliest pictures: those of handprints. Since these were created by blowing a spray of paint over the hand, it cannot be denied that there is symmetry between the shape of the hand and the shape of the negative image produced by the spraying. The principle of symmetry between symbol and symbolized is also preserved in the more complex pictures produced not by spraying but by drawing the contour of the depicted animal. Besides figurative painting, the only area in which an inherent connection of this kind is to be found between the sign and the signified is that of footprints. Since all footprints are produced by the imprint of the foot on the ground, it cannot be denied that there is symmetry between the form of the foot and the shape of the footprint it created. It is an instructive fact that in footprints and in handprints the configuration is of the same type: symmetry that is a mirror image or reflective transformation of the shape of the object that produced the footprint or the picture. It is this transformation that produces the duality between the symbolized and the picture, or between the sign and the signified in the case of footprints. However, it also exemplifies a much more general principle: that there is no symbolization or signification without transformation of one sort or another, and this principle is already evidenced for the first time in a quite advanced manner in footprints literacy. The fact that figurative art and footprints are based on a certain symmetry between the object and the symbol or the sign that represents it, is of great importance on at least two levels: firstly, it is this fact that makes figurative art readable at all periods and in all places, even tens of thousands of years after it was produced, as with the very earliest prehistoric art. We can evaluate better the universal readability of figurative art, if we bear in mind that contemporary 'abstract art', founded precisely on the breaking and negation of this symmetry, cannot be read by anyone, including the artists who created it. This symmetry is also the factor that makes footprints readable not only to the skilled tracker who read them soon after they were made, but to us as well. This is actually so even when footprints were made millions of years ago and have been preserved only because of special conditions and circumstances, as in the case of the footprints left by hominids and animals at Laetoli in northern Tansania (Leakey, 1987). These tracks were produced some 3.5 million years ago at least, and one of these tracks is especially relevant to the topic of footprints literacy, because it seems to have been produced as the result of a certain hominid treading exactly in the footprints of another hominid with larger feet who walked before

him. The result is a double track such that there is superimposition of the smaller footprints of the second subject upon the larger footprints of the first subject. Here it should be mentioned that indeed most researchers believe that there is in fact superimposition of the small footprint upon the larger one, but there are others who do not accept this interpretation and maintain that it is only a single footprint. In my analysis I shall take as my point of departure the assumption accepted by most, that there is superimposition of two footprints here. According to research by L.M. Robbins it is impossible to walk in someone else's footprints by chance, and her conclusion is therefore that the second subject deliberately walked in the footprints of the first (Robbins, 1987). Nevertheless, the fact that the second hominid trod exactly in the footprints of the man in front of him, does not mean that he read those signs *as footprints* and therefore, even if that is very likely, it is impossible to maintain with certainty that hominids could already read footprints 3.5 million years ago. What supports the hypothesis that the second hominid could apparently read footprints is the fact that both for the purpose of identification of the marks or prints in front of him as the *same type* of visual patterns, and for him to be able to step exactly and consistently in those prints, he must have had the capacity of pattern recognition at a complex level that actually includes almost all of the cognitive attributes required for the reading of footprints: connectivity, discrimination, selection, abstraction, classification and generalization: this hominid must have had some latent understanding of symmetry–asymmetry, inclusion–exclusion, transformation–invariance, complementarity of ground and figure, hypothetical thinking, comparison, recursiveness, causality, and others. But we cannot infer from his treading in the man's footprints that he had any understanding of the reference relation between a mark and the thing it indicates, which is necessary for the reading of footprints, but unnecessary for treading in the same kind of pattern. However, if the supposition is correct, it has of course weighty implications regarding the cognitive structures of these hominids, and one of them is the startling resemblance between their mode of thinking and our mode of thinking today, despite the fact that their brain was only about half the size of ours. That is, although their thinking was mostly visual and ours is mostly verbal, we share the same mindprints. If this is true, then we should begin to think of our remote ancestors as visual sages rather than as non-verbal savages.

Figure 1: Trail of hominid footprints fossilized in volcanic ash. This 70 metre trail was found by Mary Leakey's expedition in Laetoli, Tanzania in 1978. The trail probably belongs to *Australopithecus afarensis* and dates from 3.7 to 3.0 million years ago. (Photo by John Reader, reproduced here by his kind permission.)

Figure 2. *Negative hand and dots, Pech Merle.* (Photo by Jean Vertut, reproduced here by kind permission of Yvonne Vertut.)

This matter obviously raises the question whether the primates too are capable of reading footprints. Indeed, this question has bothered me for many years, whereas I have found in the literature no direct reference to the matter at all. Mary Leakey mentions the possibility that the footprints at Laetoli were created by a process similar to that by which chimpanzees and gorillas customarily play the game called 'Follow the leader' (Leakey, 1981, 1987). On this subject she relied upon Schaller (1963), but he does not say anywhere in his book that the gorillas step each *within the footprints* of the one in front. Of course the fact that in this game they walk "in the steps of the leader's" does not mean that they pay any attention to the footprints, especially since they usually live in places where there is abundant and tall grass, so that there is little exposed soil upon which footprints can be seen. Furthermore, in this game they are so close to one another that they have no need to look for the one in front of them, and this game therefore provides no proof for footprints literacy among apes.

Nevertheless, even if someone were to prove that they customarily trod in exactly the same place as the subject in front of them, this would still not constitute evidence that they *read* the graphical pattern in the soil as *footprints* of the subject walking in front. As we have already seen, in order to read the signs on the ground as footprints, many and highly complex cognitive mechanisms are required. So far as I know, there is still no proof that primates are capable, or incapable, of reading footprints. My feeling is that chimpanzees almost certainly can read footprints, for there are experiments carried out in completely different contexts, from which it can be deduced that they indeed have at least a considerable part of the cognitive qualifications required for reading footprints. Nevertheless, anyone who attempts to examine this matter empirically will have to expect very difficult methodological problems. As a matter of fact, a few years ago I canceled at the last moment an experiment I was to have carried out at the Ramat Gan Safari Park in Israel, using two young chimpanzees, with the aim of putting to the test their capacity to read footprints. The chief reason for this cancellation was, that I found no way of proving that they were reading the marks as *footprints*. That is to say, I might have succeeded in teaching them to distinguish between their keeper's footprints, which it was intended should lead to boxes containing bananas, and my own, which were larger and would have led to empty boxes; but I could find no way of proving that they saw the prints of their keeper's feet or my own as transformations of the shape of a foot, and not as visual marks that could as well have been triangles and circles or any other two objects. Another, more amusing but diverting, problem was that the two chimpanzees

were very young and most of the time preferred to hug and kiss their motherly young keeper than to cooperate in any game.

Cognitive evolution is not the central issue of this essay, but it is important at this stage only to indicate the possibility that footprints literacy is a much earlier human achievement than we tend to think. Secondly, the symmetry between the symbol and the symbolized in figurative art, like that between the footprint and the foot, is precisely the means of connection unique to art and to footprints. Indeed, art and footprints differ in this from all other kinds of symbols. That is to say, symbolization produces grouping and classification of things, and this requires abstraction, analysis and synthesis of the aspects and attributes common to the objects grouped under the same symbol. The symbols make the connectivity between the members of the class in different ways: a verbal symbol such as 'bull' tells us nothing about the common attributes of the entities that belong to the class 'bulls'; and if we wish to know what the attributes of a bull are, we have to refer to our own knowledge and memory. By contrast, the pictorial symbol representing a bull represents explicitly the most basic visual attributes of all bulls. That is to say, what is special in the mode of connectivity of the pictorial symbol is that this connectivity is achieved by displaying a particular figurative common denominator of the class of bulls it describes . This visual common denominator is a particular symmetry or isomorphism present among all bulls connected by the symbol, but the same symmetry is also *preserved concisely in the symbol itself*! We find the same characteristic in footprints as well: there is symmetry between the shape of the feet of all bulls of a certain kind, and the same symmetry is also preserved, albeit reversed, in every footprint that one of these bulls leaves on the ground. Each footprint is therefore a means both of connection and of classification for all living creatures that possess a foot that fits or is symmetrical with a given footprint. We have seen that in footprints and in figurative art, symmetry is the connecting principle (Avital, 1996). Since this principle of connection by symmetry must have appeared in footprints literacy long before it appeared in art, it is highly probable that in art this principle is a generalization and elaboration of the same principle found in footprints literacy. The strength of the connection by symmetry, can be seen from the fact that in early hunting civilizations, and even those of them that still exist today, the connection between the animal and its footprints, or between the handprint or footprint and the person they belong to, is an iconic connection between the footprint and the *whole* animal or person, and not only his foot or hand. This connection is in fact so strong that members of these cultures tend to confuse the two: such a footprint or picture might represent the creature it belongs to, but is more often a substitute for the creature. Thus, for instance, the Mehinaku tribe which lives on the banks of the Xingu River, a tributary of the Amazon, has a tragi-

comic story about a man whose sweetheart ran away from him, and who looked for her in vain. "All he could find was her footprint, and he had sex with that." (Gregor 1985).

It has already been noted that connectivity–disconnectivity or codis, is one of the most basic mindprints in the hierarchy of mindprints, and it is thus already clear that symmetry–asymmetry is a certain variant of codis. It is therefore not surprising that connectivity in general, and connection by symmetry in particular, are among the cornerstones of human intelligence and culture. These characteristics appear not only in the reading of footprints and art, but in different forms in all symbol systems. So for example, pictures and footprints connect bulls in a similar way to that in which the equations of Newton connect the stars: in both cases the connection is made by symmetries, except that in the first case the symmetry is figurative, and in the second case it is formal and relational. In a paper the starting point of which is symmetry in biology, Gregory Bateson maintains that symmetry is the connecting pattern, and he explains: "The *pattern which connects* is a meta-pattern. It is a pattern of patterns. It is that meta-pattern which defines the vast generalization that indeed *it is pattern which connects.*" (Bateson, 1978. His emphases.) This fine insight of Bateson's helps us to a more profound understanding of art and footprints: figurative painting is a system of pictorial or visual universals. However, since every such symbol and each of its sub-symbols is built upon a particular symmetry in relation to the part of the body it depicts, painting is thus a *hierarchy of symmetries.* A painting is therefore a system of connecting patterns, and the whole picture is a meta-pattern connecting all of these patterns and all of the objects it describes. Because of this attribute, footprints and pictures do not belong to the same level of being as all objects, but they are a priori at least one level higher than the world of objects. Footprints and pictures, like words, concepts, numbers, equations, models and theories, belong to the world of ideas or patterns and not to the world of objects; they are of the kind of mindstuff that makes possible the complementarity of mind and reality. Complementarity is another fundamental attribute of footprints and figurative pictures.

Footprints are marked by the contours of the lack of soil, following the inclusion relationships between foot and Mother Earth. Like every inclusion relationship, the relationship between the foot and the footprint is one of yin and yang; it is a relationship of *complementarity.* This relationship is also present in the graphic structure of the footprint as mark. Thus it is impossible to read a footprint without the background upon which it exists, for the footprint is a gestalt or complementary unity of figure-ground.

However, this gestalt is constructed from a complementarity of symmetry and asymmetry together. For on the one hand, the pattern of the footprint is symmetrical to the foot; but on the other hand, the ground which surrounds the footprint and which is an inseparable part of it, is asymmetrical to the foot. The fact that we are much more aware of the pattern of the footprint from its outer boundaries inward, does not mean that the space surrounding the pattern of the footprint from its outer boundaries and outward is irrelevant or less important to the reading of the footprint. In a way, footprints literacy requires that the tracker-hunter should be able to think in paradoxical terms: he must be capable of identifying the unity of a thing and its opposite; or the complementarity of *symmetry–asymmetry*, and not only symmetry. In a sense the symmetry between the pattern of the foot and the reversed pattern of the footprint is derived from the complementarity of the two patterns. That is to say, the pattern that connects is a symmetry that includes both the symmetry and its complementarity, asymmetry. We observed this paradoxical attribute in codis, which is built upon the complementarity of connectivity–disconnectivity. We also find the same complementarity of figure-ground explicitly, in prehistoric paintings of handprints and footprints in which the contours of those parts were generated by spraying. In a less explicit form we can observe this complementarity in the generalization of this principle to pictures based upon contour, whether emphasized as in early paintings, or deliberately blurred as in later paintings. That is to say, no figurative picture is possible without the integration of the principle of complementarity into its structure. It is possible that the complementarity–mutual exclusiveness that is revealed in both the reading of footprints and in art is indeed one of the cornerstones of human intelligence and perhaps even of Being at all levels. Tens of thousands of years after the emergence of painting and in a completely different context, Lao Tzu in China, and Heraclitus in Greece assumed complementarity as a cornerstone of their philosophies, and in our century Niels Bohr did the same in physics. When he argued that light is a wave phenomenon and a particle phenomenon at one and the same time, he was thinking in the terms of a real hunter; except that he was a hunter-tracker of 'little thoughts' rather than of little animals. In a sense, footprints literacy and general systems theory are two ends of the same issue; the first deals with the symmetry between graphic patterns and various animals, and the second, which is a meta-theory, deals with the symmetry between the various symmetries upon which are based the main areas of knowledge created by man. Totemism, art, mythology, philosophy and science are only intermediate links between these two poles, and all of them assume symmetries of one sort or another as the foundation for the connections and distinctions that they create.

7 HYPOTHETICAL THINKING AND COMPARISON IN FOOTPRINTS LITERACY AND PICTORIAL SYMBOLS

In a sense, footprints literacy is a mode of visual knowledge in which there is reading but not writing; art is a type of visual knowledge that records visual thinking; philosophy is a type of conceptual knowledge that sometimes requires and sometimes rejects visual knowledge, and science is a type of knowledge that integrates visual, conceptual and formal thinking. However, all modes of knowledge and even the simplest perception, are theory-dependent, and therefore all modes of knowledge are also hypothesis-dependent (Popper, 1982, Gregory, 1980). This stems from the fact that every theory, whether explicit or implicit, is a system of connections regarding certain entities, and a hypothesis is the mechanism by means of which we try tentatively to extend the system of connections of the theory, from the known to the unfamiliar and unknown. From the very fact that the theory is a system of connections, it follows that the theory also dictates the types of hypotheses that can be derived from it. Hypothetical thinking is, then, the expression of the inductive dimension, the metaphorical-creative drive of human intelligence which is a derivative of the Open-endedness–Closed-endedness mindprint. In other words, hypothetical thinking is an expression of open–endedness, which is a more basic and general attribute that is revealed in matter, in life and in intelligence. Hence the poetic flavor of every creative process: whether it be artistic, philosophic, scientific, technological or any other. We shall now see that hypothetical thinking already existed on a quite high level in footprints literacy, many years before art, philosophy and science were created.

The reading of footprints is impossible without highly developed hypothetical thinking, since in that situation the animal that produced the footprints is not present, and the hunter-tracker has only a graphic indication of its existence. As a rule, hypothetical thinking is required only in those cases in which there is more than one possible cause or explanation for a certain phenomenon, and in the case of the reading of footprints many possible 'causes', or feet of living creatures, could be the origin of the footprints. Hypothetical thinking is a very complex kind of thinking, involving several cognitive activities, among them the capacity of making a *comparison* between a given sign that the tracker sees on the ground and preconceived images that he sees in his mind's eye. In fact there is no difference in principle between the reading of footprints and any scientific observation. In both cases we assume tentatively that a given empirical phenomenon is a special case of a much wider system of connections formulated in a

system of images or symbols. The difference between the two cases is mainly in the level of connectivity and generality of the theories to which the empirical phenomenon is compared either in footprints literacy or in science. The process of comparison between a perceptual datum and images, like the comparison between an object and a class-name, is one of the basic characteristics of consciousness and a precondition for all kinds of knowledge and all thinking processes, and therefore Comparison–Imparison seems to be a mindprint. To what extent comparison is a basic matter in thinking processes, can be seen in hypothetical thinking particularly, which is impossible without comparison and is therefore eventually a derivative of it. From this point of view there is no difference between visual thinking and conceptual or formal thinking. In all of these cases, the hypothesis is the process in which a comparison is made between two entities, images, concepts etc., that are of two levels of order and produced at different times. Hypothetical thinking therefore always has a temporal aspect which is perhaps mainly the comparison of states of consciousness or knowledge at different times: usually, the past and the present. Occasionally this comparison also has implications for the future, and the hypothesis then has predictive value. In that case there are at least three possibilities. Either a certain entity is given and the symbol or class-name is looked for, of which the entity is a special case; as for example when an unknown animal is discovered and it has to be characterized as to the genus and species to which it belongs. Or on the contrary, when a new symbol or class-name is created on one level of generality or another, and the particulars are searched for that are special cases of that class; as for example when for theoretical reasons the conclusion is reached that there must be a particle x, and only then is an active search initiated for a particle that has the attributes defined in advance. The third possibility is a special variant of the first, and is the case when a certain symbol is given and the super-symbol is looked for of which it is a sub-symbol. Footprints literacy is precisely an example of this. That is, a given footprint constitutes a sub-symbol that indicates the foot of a certain animal, and the tracker's problem is to search his imagination for a particular image of an animal, such that the footprint is a sub-symbol of it. In the three cases we make a comparison of the entities from the two levels with regard to the measure of symmetry and asymmetry in their attributes. Comparison is always followed by affirmation or denial regarding the identity or level of variance between the compared entities and comparison is therefore always intertwined with another mindprint : negation–affirmation. Eventually comparison is an attempt at the *tentative connection* of the two or more entities which are not from the same level. Failure to find a concordance between the entities from the two levels is liable to shake the theory, or lead to the creation of a theory that proposes a new and more coherent system of connections.

The footprint temporarily preserves the pattern of the complement that produced it, and the footprint is thereby a way of coding or mapping the foot that produced it. The hunter-tracker is a gifted expert in solving jigsaw-puzzles; he knows how to decode the mark imprinted in the soil, by means of an educated guess at the foot whose shape is complementary to the pattern of the footprint he is reading. In this process the tracker is searching his brain for the pattern of the foot which is the opposite, or mirror image, of the pattern he sees on the ground. Moreover, for the purpose of connecting the given footprint and a foot of the specific kind that fits it, the tracker must compare the given footprint with the store of images of other footprints that he has in his memory, and he must also compare the shape of this footprint with the store of images of feet that he has in his memory. By a very subtle process of elimination he must select from this enormous plurality the type of foot that according to his best judgment is the most symmetrical or closest fit to the shape of the footprint. This choice is always accompanied by some level of uncertainty, and it constitutes only a hypothesis until data from reality confirm or disprove it. His hypothesis becomes a certain fact only if the tracks lead him to the animal that he expected or predicted would be the cause of the creation of the footprints. In the hunter's world, much more than in the academic world, the survival of the hunter-tracker is totally dependent upon the degree of precision of his hypotheses. Hypothetical thinking thus serves knowledge or survival, which are in a profound sense one and the same. We shall now see how hypothetical thinking is also at the foundation of figurative art.

Like the reading of footprints, the reading of a picture requires a complex hierarchy of hypotheses that classifies it according to many and varied classes and categories. The most important hypotheses of the observer regarding a picture are those by means of which he identifies the phenomenon before him *as a picture*, and the significance of that specific picture. That is, the observer's main hypotheses relate to the validity and relevance of the manner of *reading or decoding* of the pictorial symbol system in the picture. As the correct reading of the footprint is the most important aspect and the only point of treating the footprint as a sign, so the existence in principle of the possibility of a correct reading of the symbols in a picture is the main point of figurative art. In the case of footprints there is no possibility of the creator of the footprints making a mistake in the 'writing' of the footprint signs, and only the reader of the footprints could make a mistaken reading. However, for a correct reading of a picture to be possible, it is essential that the artist make no important mistake in drawing the signs of the picture. We recall that prehistoric art is the record of visual thinking, and that pictorial

representation is the only means of turning it from a private experience into a public language. It seems that the main aim and the highest test of prehistoric art was *communication* between the creator of the visual message and the readers of that message. As in other cases of communication, here too one of the essential conditions for its occurrence is that the creator of the symbols and their reader have common expectations and hypotheses as to the correct way of reading or decoding the pictorial symbols. Unlike the case of footprints, the symbols of art are not a phenomenon produced automatically by some creature, but the *achievement* of the constructor of the symbols, involving abstraction and generalization in relation to the symbolized entities. When man first drew a bison, he created the symmetry between the contour of the animal and the animal itself. For this purpose he chose a certain aspect of the animal in relation to which he created a symmetrical pattern. The basic hypothesis of the creator of the symbol is that others too would be able to recognize the symmetry he had discovered, chosen, created or evoked. The expression preferred here by the reader depends of course upon his epistemological standpoint. Again, as in reading the footprints of a bison, in reading a figurative painting depicting a bison, the reader has to compare the symbols he sees with images that he has of animals in general, and of bisons in particular, in order to read the picture as the depiction of a bison. This subtle process of elimination is only likely to lead finally to the correct reading if the reader and the artist have common hypotheses concerning pictorial representation in general, and the pictorial representation of bisons in particular. The fact that for tens of thousands of years human beings represented things in a similar way, and the fact that we have no difficulty in reading figurative pictures from all periods and places, at least on an elementary level, is the firmest evidence that visual connectivity is indeed fundamentally universal. Therefore our hypotheses regarding the interpretation or correct reading of its products are also similar. We saw that one of the most important aspects of footprints literacy is hypothetical thinking, and this factor is present in the construction and reading of figurative symbols. But in figurative art much more complex hypothetical thinking is required than in the reading of footprints. This matter brings us to a short discussion of the differences between footprints and pictures.

8 THE DIFFERENCE: HIERARCHY AND OPEN-ENDEDNESS

In supporting as far as possible the argument that footprints literacy is the most probable generative source of art, so far only those aspects and attributes have been highlighted that are similar or identical in the two domains. However, now that this matter has been sufficiently established, the most important differences should be pointed out between

these two types of literacy, which constitute two stages in the evolution of human culture. As we shall see, the main attributes that distinguish these two types of literacy, are to a large extent the attributes which distinguish a proto-symbolic phenomenon from a true *symbol system.* This difference is evidenced in two very basic attributes that are strongly connected: the one is the very great gap between the levels of connectivity of these two stages, the clearest indication of which is the extent of *stratification* of the class of signs or symbols in each of the two domains. The other attribute is the measure of *open-endedness* of each of these two classes of signs. We shall briefly detail these differences. As already mentioned, the complementarity of connectivity–disconnectivity or briefly codis, is one of the most basic attributes of being and becoming and also of noetic reality at all levels. Codis has an evolutionary dimension but there are two opposed but complementary trends within it: one has a negentropic or synthetic character, while the other has an entropic or analytic character. On the one hand connectivity develops by means of the recycling in time of previous connections to new and ever higher levels of connectivity. That is to say, throughout evolution connectivity is in a certain sense recursive or turned upon itself. The result of this process is that reality in all its manifestations has many strata or deep nesting, which generates a *hierarchical structure.* On the other hand, a simultaneous and opposite process of *recursive* disconnectivity is present, which at a certain limit generates random or chaotic states of affairs. Hierarchic order and random order are then two complementary orders. They are the two poles of the same process, and they arise from the special dynamic of the evolution of codis. The dynamic dimension of this evolution arises from two mindprints, which are also oxymorons: recursiveness–singularity; and open-endedness–closed-endedness, in both of which the tendencies of connectivity and openness are stronger than the tendencies of separation and stagnation. And indeed, already in prehistoric art, as in the physical, biological and noetic world, we find the dialectic of hierarchy and randomness, or a dialectic of order and disorder.

Every figurative picture is a hierarchical system of symbols that are systemic entities or pictorial holons, but at the same time there are present in such a picture very many elements that are arbitrary, and others that are completely random. However, the connective aspect of the picture is far more dominant than the separative, otherwise it would have no symbolic function whatsoever. Every symbol in such a picture is at the same time a pictorial holon or organization sub-symbols of lower levels of order, and in most cases is itself also a sub-symbol of another symbol from a higher level. The systemic structure of figurative symbols is what makes possible the construction of high

level symbols by the synthesis, recurrence or nesting of different symbols. By means of the combination of symbols of different levels it is possible to construct pictorial texts, and thereby to broaden and heighten the system of connections we wish to describe. The limits of combinations of figurative symbols are determined only by the limits of our imagination and visualization. Because of the inter-relatedness of figurative symbols, their meaning is conditioned by the nature of their connection with other symbols. That is, as with verbal symbols, the meaning of pictorial symbols too is a systemic meaning. Thus for example, a picture of a bull contains sub-symbols for head, legs, tail, etc. The sub-symbol for an eye contains a sub-symbol for the pupil and so on, in accordance with the degree of detail in the picture. In other words, a figurative painting may comprise a very deep nesting of pictorial symbols of various levels of complexity. It is also possible to draw a man throwing a spear at a bull, and we then have a pictorial text which describes a hunting scene. On the other hand, we can also draw a symbol comprised of the synthesis of the symbol for a man holding a spear who has from his waist downward the body of a bull, and we then have a metaphorical use of the former symbols. We may summarize, then: a picture can be 'written' and also read, and pictorial systems can be constructed on different levels of complexity and stratification. We also recall that the artist constructs the symbols by choosing or creating the symmetry by which he depicts the animal. Moreover, by means of these symbols pictorial metaphors can also be constructed and this is the creative, developmental and open-ended foundation of art. In what follows, we shall see that these attributes are almost entirely absent in footprints literacy.

As opposed to pictorial symbols, footprints are not invented and not written; they can only be read as signs when they are created as a by-product of animal and human walking. Footprints are to a great extent of an intermediary nature: they possess certain characteristics of objects, and some characteristics of visual signs, but only at an elementary level. On the one hand, each footprint as a sign is totally independent of other footprints, and cannot be combined with other footprints. The class of all footprints, therefore, like all object-classes, is a class of discrete signs and not a system of symbols. On the other hand, for the hunter-tracker footprints serve as pictorial representations of the feet of animals, and indirectly as a representation of the whole animal as well. However, this mode of representation has two great shortcomings.

The first great shortcoming of footprints as signs is the impossibility of forming any combination. In those cases in which there are more than one type of footprint in the same place, the proximity of one type of footprint to another type does not itself generate a new sign that contains or unifies the significance of the two, and they always

remain discrete signs rather than *nested* signs. That is to say that like traffic signs, different footprints cannot be combined in order to create a new sign or statement on a higher level that includes the different footprints. It is thus not possible to create a hierarchy of signs by the combination of signs of this sort. At the most, it is a very shallow unstratified system like a polymer chain; this is a class of signs all of whose members are of the same level of order, although each sign has minimal stratification. Thus for example, the footprint of a deer includes two similar sub-signs, and the footprint of a tiger includes five sub-signs four of which are very similar; but it is not possible to combine the footprint of a deer with the footprint of a tiger in order to generate a new sign. In footprints literacy there is no recursiveness of old connections to higher levels of connectivity, and thus no accumulation of knowledge likely to generate meta-concepts. There is no meaning to a synthesis or a dividing up of footprints, and therefore there can also be no syntax or connective principle between footprints. Hence there is no stratification of all possible footprints, and no hierarchy of footprints as signs.

The second great shortcoming of footprints as signs is that no metaphorization of them is possible: the use of a particular footprint cannot be extended in order to indicate something else. The footprint of a deer of a particular kind indicates deer of that kind alone, in all places and at all times so long as deer of that kind exist. The vocabulary of footprints literacy is of course limited only to animals that leave footprints, so that we have only footprints of animals that walk on the surface of the earth. We have no footprints of fish, nor of most birds, and there are certainly no footprints of fictitious or hypothetical creatures. Every type of footprint is *closed-ended*, and therefore no creativity is possible in footprints literacy, and as a type of knowledge it is almost completely lacking in any degree of open-endedness. It is thus clear why for so many ages knowledge in this domain was completely static and lacking any possibility of development. Moreover, with the passing of time the domain dwindled, since many kinds of animal became extinct, and the existential need for footprints literacy decreased. Since human intelligence is open-ended, the way to overcome the shortcomings of footprints literacy was only through the radical transformation of footprints into *pictures* of hands and feet! Prehistoric art is the superior metaphorization of footprints literacy. Image making solved completely the shortcomings of footprints literacy, and the way was thereby opened to the continued evolution of culture. Art had its shortcomings too, and these were solved by writing. For that is the rule: in all types of evolution, later stages tend to be more sophisticated than those stages from which they

developed, since they represent solutions to at least some of the shortcomings of the preceding stages. Here lies the profound connection between knowledge and survival.

9 SHADOW, REFLECTION, AND THE ORIGINS OF ART

Throughout the whole discussion thus far, it has been maintained that footprints literacy is the most probable origin of art, because, among other reasons, we see here the beginning of very sophisticated thinking processes utilizing figurative symmetries between sign and signified. On the face of it, it could be argued that there are other origins of thinking by graphical symmetries and that they are perhaps the origin of art–such as *shadow*, and *reflection* in water, which also exhibit visual symmetries of figures and objects. It is indeed highly probable that these two phenomena, which we shall discuss only very briefly here, made a very important contribution to the development of thinking by visual symmetries. Nevertheless it would appear probable that their contribution to the realization of art is secondary in the case of the shadow, and marginal in the case of the reflection.

Firstly, shadow and reflection are inseparable from the figure or object that generated them, and there is thus no clear duality here between sign and signified, and in most early cultures the shadow, for example, is perceived as a totally integral part of the body or being of its owner. In certain cultures this matter is so clear that a threat to one's shadow is considered a threat to the person himself, and is sufficient cause for battle. Because of the unique linkage between shadow or reflection and a specific person or object, these two phenomena are unlikely to have been the origin of the most important attribute of all symbolization and also of symbols in art. This is, that the symbols are class-names for classes of unlimited extent, and not the representations of specific entities. This problem does not hold in the case of footprints, of course. Secondly, if the origin of art had been reflection, it is unlikely that the earliest pictures would have depicted mostly hands and feet–mostly as negative images–and parts of animals in contour. If the shadow had been the main origin of art, it is likely that the first pictures would have represented silhouettes of the whole body and not only silhouettes of the hand or parts of animals; for there was full cognizance of the appearance of the shadow of a whole person and animals, both in sunlight and in firelight. We know that the mastery of fire has existed for some seven hundred and fifty thousand years at least, so that for hundreds of thousands of years human beings saw 'shadow shows' every evening by the light of the fires outside their rock shelters and caves. It is true that there are pictures of hands made by imprinting so that the hand is seen as a positive image like a

shadow, but these are a minority compared with the majority of pictures of hands and feet depicted, like footprints, as negative images. Secondly, if the shadow had been the origin of art, the image makers would not have been content with drawing the contour of the figures, and it is unlikely that they were economizing in black color, which they had in abundance from their fires. True, at much later stages of prehistoric art, images resembling shadows are found, and images lengthened like shadows, as may be seen in Bushman paintings, for example; but this phenomenon is very recent compared with the first pictures, which were based upon negative and contour. Thirdly, as we have seen, one of the most important attributes of figurative symbols is their hypothetical aspect. In the case of the reflection, this aspect is minimal since a reflection is perceived either as linked to an entirely specific entity, or as an independently existing entity. In the two cases, not much hypothetical thinking is required, since there was no duality here between a sign and a signified object or being. By and large, this argument holds in the case of the shadow as well, although in this case more hypothetical thinking is required, since the shadow supplies far fewer details of the object to which it is connected than does the reflection of the same object. Despite these reservations regarding the supposition that reflection and shadow are the direct origins of art, it is very likely that these phenomena had a very important influence upon the development of thinking by visual symmetries. That is to say, the visual thinking that was entailed in reading shadows and reflections included several cognitive mechanisms that were displayed in a far more sophisticated manner in footprints literacy and in image making. Perhaps it was here that human beings learned for the first time the possibility that an object is liable to have two different modes, one of which is concrete in the full meaning of the word, and the second somehow elusive. It is likely that they recognized the great similarity between the two modes of the object and learned to connect them. Again, in this duality there is a certain measure of preparation for the generation of abstraction entailed in the duality between sign and signified. It is possible that the skill of millions of years in identifying shadows and reflections served as a preparatory stage for thinking in symmetry in the context of footprints, which is infinitely more sophisticated; and it is therefore very probable that this skill made an indirect contribution to the emergence of image making.

10 SUMMARY AND IMPLICATIONS FOR PRESENT AND FUTURE ART

"In my end is my beginning."

Mary, Queen of Scots

We have seen that apart from hierarchy and open-endedness, which are present in footprints literacy to only a minimal degree, all of the other important attributes of art are present to a considerable extent in footprints literacy as well. (See two Summary Tables at the end of this essay.) These common mindprints and their derivative attributes are: connectivity–disconnectivity, classification, grouping, differentiation, abstraction, generalization, reference or symbolization, thinking in visual universals, thinking in symmetry–asymmetry, hierarchies of symmetries and transformations of symmetries, idealization or schematization, complementarity, induction and deduction, hypothetical thinking, comparison, and many more attributes that have not been discussed in this essay. Thinking in terms of spatial order and causality are present in the two domains, but in footprints literacy it is much more developed than in art. Thinking in terms of temporal order, which is very fundamental to footprints literacy, is quite absent in figurative art. Thousands of years after the emergence of image making, thinking in terms of spatial and temporal order, and causality, became the basis of science, and with them all the attributes mentioned above. All of these attributes were present in footprints literacy long before the appearance of figurative art, and it is thus very likely that the generalization and elaboration of the attributes and skills already present in footprints literacy, were the origin of art. In other words, footprints literacy and prehistoric art are two modes of visual knowledge on two different levels, but one served as the basis for the emergence of the other. It is therefore highly probable that footprints literacy is the origin of art, not only from a graphical point of view, as we have seen, but also from the cognitive point of view. Similarly, it is easy to see that basically the same attributes are present in scientific thinking too, albeit at a higher level than in footprints literacy and figurative art. In a non-trivial sense the early tracker-hunter was also the early scientist, and the modern scientist is a tracker-hunter of a new kind. Indeed the modern scientist has qualities in common with those of the early hunter, but with very important additions. In addition to visual thinking, the modern scientist has also two new modes of thinking: highly developed conceptual thinking and formal-relational thinking, which his predecessor did not possess. In the two new modes of thinking, we find the same attributes that we found in visual thinking, except that here they appear at a much higher level. These two new levels of thinking are free of the main

shortcomings of visual thinking, which by its nature is confined to the world of appearances and to subjects that can be visualized. However, these two new levels of connectivity are built on the foundation of the visual connectivity that preceded them by millions of years. In other words, the visual knowledge that was first evidenced in footprints literacy and later in art, was also the cognitive basis upon which all of the other symbol systems were constructed, though they served other, more sophisticated, modes of knowledge.

To sum up

- Footprints, then, function in a similar way to pictorial symbols, and a track is a pictorial text. This is usually a quite monotonous text, but occasionally it tells the story of life and death. The hunters transferred that story with dedication, delicately and with endless care, from the animal track prints to the walls in the darkest depths of the caves, so that it would not be erased by the rain and the wind. In their vision they implicitly understood that the prints of things have a different existence from that of the things themselves: that symbols are the connecting link between matter and mind; that symbols bring things into being, and that things persist for only as long as the symbols exist. They understood that symbols, like the gods, exist in a time that is slower than the time in which things exist, and thus always survive them. In the process of the generation of footprints, life touched matter and created the first proto-symbols, or the first link connecting matter, life and intelligence. These footprints seem to be the first stage of art. Moreover, all our forms of literacy are ultimately a transformation on one level or another of footprints literacy, which was almost certainly the first type of literacy that human beings ever developed.

The reader may have noticed that throughout this essay only figurative art has been dealt with and not 'abstract' or 'nonrepresentational' art. This avoidance was of course deliberate and requires an explanation, however short and unsatisfying. It is not very difficult to see that *not one* of the long list of mindprints and their derivative attributes indicated here as being common to footprints literacy, figurative art and modern science, is present in what is called 'abstract art' (Avital, 1996, 1997a). This fact, strange in itself, should arouse many doubts about modern art. The long list of mindprints and their derivative attributes which have been discussed in the previous sections, is in fact a sketch of the demarcation lines between art and non-art; for these attributes appear only in figurative art and footprints literacy, but not in the art called 'non-representational art', of which abstract art is only a part. That is, if something does not look like a duck, does

not swim or fly like a duck, does not quack or waddle like a duck, perhaps it is not a duck. Indeed, in order to prove conclusively that not one of the mindprints and their derivative attributes appears in abstract art, an essay of much wider scope is required. In the meantime, it is suggested that the reader study the two summary tables at the end of this essay.

To put it bluntly, my main argument is, that what is called 'abstract art' is not art at all, and not a new kind of art, but the debris of the old art. In fact it can be shown that the only attribute common to figurative art and 'abstract art' is the fact that 'abstract art' is a perceptual phenomenon too. But the fact that something is perceptual is hardly a sufficient condition for it to qualify as art. It does not follow from all this that figurative art is the only possible art, or that figurative art has to be returned to, something that is anyway impossible. But 'abstract art' is a necessary intermediate stage; a stage of breaking the structures of the old paradigm of art, so that we may build a totally new type of artistic paradigm. As briefly as possible, I shall only point out that the figurative paradigm was content oriented and static, whereas the new paradigm will be structural or systemic, and dynamic (Avital, in press). The first depicted explicitly the contents of consciousness, and contained implicitly the structures of mind. By contrast, in the new paradigm a radical reversal will take place: it will depict explicitly and dynamically the ordering structures of the mind, or mindprints, and the contents will become implicit. In the new art there will again be the same basic attributes or mindprints that we saw in footprints literacy and in figurative art, but at a much higher level (The full exposition of the new paradigm, which I have called Artonomy, and its applications to painting, sculpture, music and movement, will be presented in a book largely completed, and entitled: Artonomy: The Dark Side of Realism). In fact, in this new art the differences between art and science are largely dissolved because, in a profound sense, the subject of both is one and the same: the explicit expression or manifestation of the mindprints. I am obliged to content myself with this vague generalization, since any explanation of it would go far beyond the bounds of this essay.

Table 1 - Comparative Table of Mindprints and Derived Attributes in Footprints Literacy, Figurative Art, Science and Abstract Art.

Mindprints and Derived Attributes	**Footprints Literacy**	**Figurative Art**	**Science**	**Abstract Art**
Connectivity - Disconnectivity CODIS	Footprints as graphical connectors	Connectivity Present at higher level: pictorial connectivity	Connectivity Present at the highest level: conceptual and formal connectivity	Connectivity: Material and perceptual *only*.
Classification: Differential Grouping	*Classification of certain animals*	*Classifies all visual entities*	*Classifies all kinds of entities*	*No classification*
Abstraction	*Present*	*Present at higher level*	*Present at the highest level*	*None*
Generalization	*Present*	*Present at higher level*	*Present at the highest level*	*None*
Symbols	*Footprints are* Proto-symbols	*Figurative symbol system*	*Conceptual and formal symbol systems*	*NO symbols. Mostly perceptual phenomena.*
Universals	*footprints as Visual universals*	*Pictorial symbols are visual universals*	*Conceptual and formal universals*	*None*
Symbolization: Reference relation	*Sign/signified*	*Pictorial symbol system*	*Conceptual and formal symbol systems*	*None*
Preconceived theory or image	*Preconceived images of footprints*	*Preconceived images of many kinds*	*Preconceived theory and images*	*Usually none; also not essential*
Hypothetical thinking: tentative extension of connections	*Footprints Lit.. impossible without Hypothetical thinking*	*Present at higher level*	*Present at the highest level*	*Minimal*
SYMMETRY - ASYMMETRY	Footprints are figurative symmetries	Hierarchy of figurative symmetries	Formal and conceptual symmetries	Total symmetry or Total asymmetry. Geometrical sym.
Symmetry as connecting principle: common denominator of class represented	*Connects only certain classes of animals*	*Painting: System of connecting patterns*	*Connects real and hypothetical entities at all levels*	*Aesthetic phenomena: No meta-patterns*
TRANSFORM-ATION — INVARIANCE	Reflective transformation of foot and footprint	Reflection transformation and others	Various kinds of transformations	None, hence there is no symbolization
COMPLEMENT-ARITY– MUTUAL EXCLUSIVENESS	Complementar -ity of figure and ground	Complementarity of figure and ground	Conceptual and formal complementarity	Not essential
COMPARISON - (no-comparison?) IMPARISON	Comparison of footprints and images	Comparison of objects, Images & pictorial symbols	Comparison of phenomena and theory	Seldom

Table 2.- Attributes Differentiating Footprints Literacy from Figurative Art, Science and Abstract Art

Mindprints and Derived Attributes	**Footprints literacy**	**Figurative Art**	**Science**	**Abstract Art**
HIERARCHY - RANDOMNESS: Stratification	Limited, discrete set of signs. No combinations. Poor stratification	Elaborate pictorial hierarchy	Highly developed hierarchy	None or very meager hierarchy
Dialectics of hierarchy and randomness, order-disorder	*Low levels of hierarchy and randomness*	*Fairly high levels of hierarchy and randomness*	*Very high levels of hierarchy and randomness*	*No necessary recursiveness of connections - distinctions*
RECURSIVENESS - SINGULARITY. Recycling of connections and distinctions	Minimal recursiveness of connections and distinctions	High recursiveness or nesting of connections and distinctions	Very rich recursiveness, or very deep nesting of connections and distinctions	Very shallow nesting. recursiveness not necessary, mostly: 'One-offs'
OPEN-ENDEDNESS – CLOSED-ENDEDNESS - (CE)	Every sign is closed-ended	Symbol - style open-endedness (OE)	Open-endedness on theoretical level.	No dialectics of OE-CE
Creativity and Metaphorization	*No creativity or metaphorization*	*Creativity and metaphorization*	*Creativity and metaphorization*	*Creativity present but no metaphorization*
DETERMINISM-INDETERMINISM and Choice	Totally deterministic	Determinism, choice and arbitrariness	Determinism, choice and arbitrariness	Mostly arbitrariness
***Causality, Spatial* and *Temporal* Orders**	All necessary	Only Causality and spatial order.	All necessary	None are necessary
Syntax, connecting principles between signs or symbols	Elementary connecting principles between signs	Elaborate pictorial syntax	Elaborate formal, conceptual and visual connecting principles	Idiosyncratic, or arbitrary connecting guidelines
Semantics	Discrete meaning of signs or marks	Systemic meaning; mutual dependence of symbols	Systemic meaning; mutual dependence of symbols	No inter-subjective semantics, no interdependence of esthetic entities
Readability	Read only	Read-write	Read-write	No read, no write
Knowledge	Static/fossilized knowledge	Accumulative - non-developing knowledge	Accumulative and developing knowledge	No knowledge, private experiences
Number of symbols/signs	Finite	Unlimited	Unlimited	No symbols and no signs

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Symmetry: Culture and Science
Vol. 9, No. 1, 47-76, 1998

MINDPRINTS: THE STRUCTURAL SHADOWS OF MIND-REALITY?

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Abstract: *The point of departure for this essay was the question: What are the cognitive attributes without which the prehistoric image maker could not have begun to create painting? The aim of the search for these a priori attributes was an attempt to anchor the nature of art in attributes of the mind and thereby to uncover an Archimedean fulcrum for tracing lines of demarcation between art and non-art, which have become completely blurred in our century. The search has revealed some ten unique attributes all of which are epistemological and ontological oxymorons, or metastructures of the complementarity of mind and reality such as: Connectivity–Disconnectivity, Hierarchy–Randomness, Symmetry–Asymmetry and others. While the point of departure of this study was art, it may be that its results also have implications for the understanding of science and the other areas of culture, for these attributes which I have called "mindprints" appear to be common to all products of the mind. One may say with some boldness that these attributes are perhaps common to all levels of Being: the material, biological and noetic levels; but they are manifested by different means and at different levels of abstraction and generalization. If the mindprints are common to all branches of culture as is proposed here, it may be that this can serve as the structural basis for a particularly coherent transdisciplinary approach.*

> *"...the soul is analogous to the hand; for as the hand is a tool of tools,*
> *so the mind is the form of forms.."*

Aristotle, De anima 432a

In the beginning God created Mindprints,
and they have been doing the rest ever since.

Throughout the twentieth century not a few theoreticians and artists have maintained that modernism has failed and that art has reached its end or at least has reached a dead end. This deep scepticism arose from the great perplexity created with the rejection of the paradigm of figurative art, without the creation of another paradigm in its place. The unavoidable result of this situation is the complete blurring of the demarcation lines between art and non-art. For this reason the need for a new and truly reliable Archimedean fulcrum that would make it possible to distinguish between art and pseudo-art became an essential need for the very continuation of the existence of art as a relevant branch of culture. A search that has continued over tens of years for an adequate answer to this problem has led me to many and various channels, some of which I have already reported upon in other essays, and others which I shall report upon in the future. But among those particularly worth mentioning are two directions of exploration which appear on the face of it to be opposed, but are in actual fact complementary: on the one hand, the search for the graphic and cognitive sources that *preceded* art and made possible its actual emergence some 40,000 years ago, in the hope that in this embryonic stage it may be possibe to identify more easily the most basic attributes of art from its first beginning. On the other hand, this study revealed the need for a cognitive understanding of the *a priori conditions* necessary for a person to read or create a figurative picture at any time: in the prehistoric era, or today. The attempt to understand these a priori conditions led perhaps serendipitously to a new understanding of the mind and the way in which its basic patterns are manifested in the products of culture.

I have summed up the research regarding the sources of art in two essays (Avital, under review, and Avital ,1997c, Footprints Literacy... is to be published in this journal.) The second aspect of the research, which is of a purely theoretical nature and deals with the a priori conditions of art, is given very briefly in the present essay. While the point of departure was art, its results and conclusions may have implications which pass far beyond art itself and touch upon all areas of culture regardless of time and place, since like art, all are various products of the human mind. The central rationale of this essay is the attempt to reach a newer and more adequate understanding of the nature of visual art by anchoring it to the nature of mind itself. It is hoped that this may be achieved through an understanding of the way in which some of the basic attributes of mind already became manifest in the very earliest origins of art, which seem to be footprints literacy. This skill seems to have preceded prehistoric art by about 4 million years (Avital, 1997c, Footprints Literacy...). According to this understanding, art is an expression or embodiment of certain basic attributes of mind, by means of the

composition of aesthetic elements such as color, form etc. I have called these basic attributes "mindprints". These metastructures are fundamental attributes of mind and reality such as connectivity, complementarity, open-endedness, recursiveness, hierarchy, transformation, symmetry, *and their complementary opposites*. In the following, I shall try to give only a brief explanation of them, since a more complete explanation of the concept and its implications for other fields would require a far wider framework than this essay. In a minimal sense, mindprints are fundamental properties or attributes of human intelligence, or the interfaces between mind and reality. In a broader sense, it appears that mindprints are common to all levels of Being, and are therefore epistemological and ontological oxymorons, or metastructures of the complementarity of mind and reality. In other words, mindprints are the bridge between epistemology and ontology. Thus, when scientists such as Einstein and many others, observe with awe and wonderment the sublime concord between theory and nature they are really experiencing the grace of crossing this bridge. Many experience the same feeling when observing a great work of art. In both cases we unconsciously recognize in nature or art, as in a mirror, the mindprints which bind our mind and reality into a complementary unity. Indeed, the fact that science can make such remarkably accurate predictions, or the fact that we can easily read prehistoric paintings done eons ago, is probably the best evidence that mind and reality must have something fundamental in common, or that they are two aspects of a complementarity. In a sense, mind is reality folded upon itself, i.e. a reflective, and sometimes conscious reality. Thus consciousness is a node in the lacework of mind-reality. Regarded in this spirit, reality is a shadow of mind, and hence there should be at least partial correlation or symmetry between the "two". This is also true regarding products of mind such as art and science.

The reader may already have sensed the high degree of ambiguity of the concept "mind" and be wondering if what is meant is mind in the human context, or Mind in a total or metaphysical sense, such as the concept has for Hegel, or as it has in the Greek terms Logos or Nous, and the like. I subscribe to the view, and more precisely to the belief, that the human mind is a special case of Mind or Intelligence in the total sense and that these two meanings of "mind" are therefore, at least to some extent, symmetrical, inasmuch as they have similar basic attributes. Nevertheless, these two kinds of "mind" are different inasmuch as the one constructs our private and cultural world, while the other constructs the human mind, as well as reality and all that is in it. However, for the purpose of our discussion, it makes no difference at all in which of the two meanings the concept of mind is understood, and it should therefore be emphasized that the

characterization of art, or the establishing of its demarcation lines with the aid of mindprints, does not necessarily entail the commitment to perceiving Mind as a total and metaphysical entity; but rather is it possible to regard mindprints as hypothetical and very basic principles of organization of the human intelligence or mind. The problem is, that a paradox of no mean proportions is concealed here: how is it possible to indicate basic attributes of mind when the possibility of our knowledge regarding "mind" - whether in the human context or, even more, "Mind" in its total meaning - is in principle extremely limited? This problem has been discussed at length and from various angles throughout the history of philosophy and science, and there is no need to enlarge upon it, and I shall therefore briefly indicate only a few of the reasons for the impossibility of really knowing what Mind is in any sense, and why we must be satisfied with far less.

Firstly, language is in a way constructed like a multidimensional web in the form of a mountain chain with peaks of various heights. Concepts receive their significance in this multidimensional hierarchy as nodes in our conceptual system. When we understand a certain concept, we usually achieve this in relation to the concepts or nodes above it and including it, as well as to the concepts that are below it and included by it, and also through the language game of the concept within the entire linguistic system. But conceptual understanding is particularly difficult when one attempts to understand such unique meta-concepts as "Mind", "Being", "Reality", and "God", which are among the apexes of our conceptual system. These concepts can have only partial significance, since we have no concepts higher than them, and they can therefore only be understood in the light of concepts that are beneath them - through those that are contained by them, and not through any by which they are contained, since none such exist. In other words, such concepts are never sufficiently clear, since every such concept is the name of an ultimate meta-reference beyond which there is no meta-reference or concept of a higher logical type that would *give it* a truly full significance or characterization. These concepts indicate the highest limits of abstraction, generalization or induction that our thought is capable of achieving by means of our symbol system. These meta-concepts delineate the boundary between discursive thought and the domain of mysticism. Secondly, one of the main conclusions of philosophy since Kant, is that any knowledge that we may obtain is the outcome of some interpretation of our own. It follows that it is impossible really to know what that non-physical entity is that we call mind, just as we cannot know what is the thing-in-itself that we interpret as a physical or phenomenal entity. By stretching not too grossly Heisenberg's principle of uncertainty, which in a certain sense is itself a derivative of Kantian philosophy, it may be said that uncertainty exists not only with regard to physical measurement, but even more so when we try to

understand the mind, since here an attempt is being made to measure both the measurer and the measured. Thirdly, a difficulty entailed in every attempt at understanding mind follows from the limitation in principle, of reflexive thought trying to understand itself, or mind itself. Every understanding of this sort is in principle only partial, and every attempt to deny this leads to a paradox similar to that of the great antinomy of Russell regarding the impossibility of a class including itself as a member (Russell, 1985). Furthermore, even the scientists who reduce mind to brain, in most cases acknowledge that it is very doubtful whether our brain is ever likely to understand itself completely. On the other hand, if Mind is considered in its all-embracing sense, one immediately encounters the old problem that a finite consciousness cannot understand infinite mind, but can at most *intuit* it, as the mystics maintain. If the mind is beyond our reach, what can we nevertheless know about it?

Outside my window, about 2 kilometers away, lies the last valley before the steep ascent to Jerusalem from the west. At the edge of this valley is the village of Beit Zayit where the fossilized footprints were discovered, of a dinosaur that passed there tens of millions of years ago. We do not know, and never will, what the dinosaur that walked there really looked like, but through an examination of the structure of the footprints it is possible to deduce *at least* some of the characteristics of its body, which turned to dust long ago. An example that is far more recent and closer to our origins, is the path of fossilized footprints of three hominids, an adult male, a smaller man or child, and a female, that were preserved for about 3.6 million years in Laetoli in northern Tanzania, (Leakey 1981, Leakey and Harris, 1987). Again, we do not, and never will, know exactly what these hominids looked like, but from the structure of their footprints, the scientists reached instructive conclusions as to their height, their gait and the fact that they walked upright! In another paper (Avital, 1997c, Footprints Literacy...) I have shown that from the unique pattern of those footprints one can derive remarkable conclusions regarding their *cognitive* capacities. In the opinion of most scholars, there is superimposition of the footprints of the smaller male within those of the adult male; if this is indeed so, it has staggering implications regarding the cognitive structure of these hominids. That is, although these hominids did not yet have language, and despite the fact that their brain size was only about half of ours, they must have shared the same basic cognitive structures that we have. Obviously their thinking was visual rather than verbal, but we must assume that they applied similar fundamental structuring principles which I have called "mindprints", for otherwise it is quite impossible to explain the most striking aspect of those footprints, which is the fact that the smaller male trod

deliberately and precisely *into* the footprints of the male adult that walked ahead of him. By analogy with these examples, I would say that mind is like the Tibetan Yeti, the mythical being which nobody claims to have sighted, but whose footprints many assert that they have seen in the snows of the Himalayas. Similarly, I subscribe to the opinion of many who have affirmed that we shall never know what mind really is. But I believe that it is perhaps possible to learn something not trivial about mind itself from some of the attributes of its *products*; these properties or "mindprints" are as it were prints of the mind which produced them.

In the history of philosophy, and especially since Kant, several attempts have been made to map the basic categories or parameters of mind. Their main aim was to provide a satisfactory explanation for the possibility of knowledge and thereby to reduce the skepticism aroused by Hume's philosophy. This was attempted by means of a new characterization of the relations between mind and reality, while bringing out the autonomous and primary aspects which the mind has with regard to the subjects of knowledge of all kinds. In the light of the inevitable limitations we have with regard to the possibility of knowing what mind is, it is clear that every characterization of it by means of these or other categories is itself necessarily limited, and is a *particular interpretation* which cannot exhaust the subject, even when it is the thought of a great philosopher. This can be seen very well in the fact that every philosopher who has proposed a theory of categories, has begun by harshly criticizing his predecessor's theory of categories, without being thereby prevented from adopting part of it. It goes without saying that the orientation of these philosophers has been mainly epistemological and ontological. This being so, and despite the extreme rigor of these attempts, they hardly help us at all to an understanding of the nature of art.

I therefore wish to emphasize that I make no pretense at all of proposing a theory of categories, and certainly not a complete theory such as was attempted by Kant, Hegel, Whitehead and others–something which is anyway far beyond my capability, but to try first and foremost to identify *at least some* of the most basic attributes that are shared by all works of figurative art from its beginning and up to this day, and without which no figurative painting would be possible. The integration of these common attributes in paintings throughout tens of thousands of years was not "out of the blue"; their origin lay rather in the attributes of the minds of the artists who produced them in all periods of time, and which must have existed long before the emergence of art itself. If such attributes can indeed be identified, then the very fact of their extreme continuity, transcending time, place and cultures, perhaps suggests the possibility that they are not

attributes peculiar to art alone. They are basic mindtools which must also have been manifest in the stages that preceded art, and constituted a preparatory stage for it, as in footprints literacy and tool making. Again, if these attributes are indeed so fundamental, then it must be expected that they will appear in other areas of culture as well, since they are after all products of the same mind. A study of these mindprints suggests a more far-reaching possibility: namely, that these same mindprints exist not only at all levels of the human-noetic plane, but also at all levels in nature, and are therefore perhaps the morphological shadows of Mind, Reality, God, or Nature–everyone having his preferred name for the totality of Being. After many years of searching, the possibility of understanding art by anchoring it in the nature of mind seems to me, at least, to be a last resort in meeting the imperative need for an understanding of what art is. For in the light of the chaotic situation that characterizes art today, and in the light of the fact that aesthetics and the history of art have not succeeded in drawing clear demarcation lines of art, then without a new understanding making possible the distinction of art from non-art, there is little point in continuing to produce art, and it may be regarded as a closed chapter in the history of our culture.

The list of mindprints given below is not derived from any particular general theory or meta-principle, but from the question: *What are the cognitive attributes without which the prehistoric image-maker could not have begun to create painting?* A prolonged examination of mindprints has led me to think it possible that these attributes are not special to art alone, but are rather at the base of all branches of culture, and perhaps also at the base of Being at all levels. Nevertheless, the main aim was and is to understand art within a far wider context than that of art itself, but the reader is therefore by no means obliged to accept the implications of the mindprints beyond their application in art. It goes without saying that this list is neither exhaustive nor exclusive, but is merely the list of those properties of the mind that I have perhaps identified in the search for the attributes that anchor art in mind or intelligence, which are for me synonymous. Bateson (1980) and Waddington (1977) also attempted to characterize fundamental properties of the mind, but the starting point for them both was mainly scientific, with the emphasis on biology. Some of the attributes that they mention are similar to those which I have found, and some are different. R. Sheldrake (1981), who proposed the interesting hypothesis of Formative Causation, also set out from a mainly biological standpoint. His idea of morphogenetic fields is in several ways analogous to the idea of mindprints, and is in many ways very different from it. The main difference is that Sheldrake assumes the existence of an infinite number of morphogenetic fields: a special one for

each entity in the universe - for each particle, for each combination of particles, for each plant and for each living thing. In doing this, he in fact assumes double and parallel worlds: the one a formative hierarchy and the other a material hierarchy. Despite the great sympathy that I have for his motivation, I believe that one should follow in the steps of William of Ockham and prefer hypotheses that make do with as few assumptions as possible. As we shall see in what follows, the number of mindprints that I tentatively assume is ten, and it may even be possible to reduce this number by conceiving some mindprints in terms of others. Nevertheless, because of the considerations I have pointed out in connection with the limitation in principle of our knowledge of the mind, any list or table of the basic properties of the mind is necessarily partial, and will always be so. I only hope that others will add to and reduce it according to a more coherent and adequate understanding than my own. The drawback of a short explanation of such a complex subject is that it is inevitably very condensed. However, on the credit side it may be said that a certain roughness is sometimes the earmark of innovation. I therefore suggest that the reader should not give up or become confused by the prodigality of concepts that appear in the explanation that follows. It is my hope that the mindprints concept will be clearer in the paragraphs that follow as a result of the short explanation of the way in which they appear in art. (However, this concept will certainly be clearer if the reader cares to read my other papers, each of which deals specifically with a single mindprint or a combination of several. Avital, 1997c, Footprints Literacy...; 1996, 1997a).

At this point I wish to propose a tentative table of mindprints:

1. Connectivity–Disconnectivity (Codis)
2. Open endedness–Closed endedness
3. Recursiveness (Nesting)–Singularity
4. Transformation–Invariance
5. Hierarchy–Randomness
6. Symmetry–Asymmetry
7. Negation–Affirmation (Double Negation)
8. Complementarity–Mutual Exclusiveness
9. Comparison–(No Comparison ?) Imparison
10. Determinism–Indeterminism (Probability, Selection, Choice).

In order to reduce this tentative explanation of mindprints as far as possible to essentials, I shall content myself with pointing out a few of their characteristics, and dealing with

only some of the mindprints. After that, I shall briefly explain how it is possible by their means to distinguish between painting and pseudo-painting.

1. The first obvious characteristic of the mindprints is that almost all of them are in a sense paradoxical concepts, or *oxymorons* . That is, they indicate a thing and its opposite at one and the same time. This fact makes them particularly difficult both to discover and to understand, since in the Western world we are all still enslaved by the logic of the Greeks, the fundamental law of which is the law of contradiction. It is for this reason hard for us to think in terms that are constructed upon an Eastern or Heraclitean world view that sees the complementarity of opposites as the nature of things, and sometimes sees paradox as the earmark of non-trivial truth. It is therefore not by chance that in Western languages there are (so far as I know) no concepts such as the Chinese concept of Dao which explicitly indicates the complementary unity of opposing tendencies: Yin-Yang. Thus for example, the mindprint *Connectivity–Disconnectivity* is not intended to indicate two attributes but *one*, of which connectivity and disconnectivity are two aspects or poles. Simply put, it may be said that every connection is made against a background of a state of disconnectivity, and every separation is made against the background of some connectivity. In the absence of a suitable word, I have called this attribute *Codis* ('co': collective prefix; 'dis': separative prefix.). Most of those of our cognitive attributes that deal with connectivity and disconnectivity are derived from this mindprint, for example: grouping, differentiation, classification, generalization, abstraction, inclusion and exclusion, symbolization or coding-decoding, synthesis and analysis, etc. Likewise, all order, organization and regularity or lawfulness that we can comprehend are modes of connectivity-disconnectivity, and it is at the base of all our perceptions of unity and plurality, whether religious, artistic, philosophical or scientific. In order to bring out the uniqueness of Codis it is worth mentioning that Aristotle, Hume, Kant and others already stressed the unifying capacity of the mind. For Kant this is even the most important property of the understanding: "Combination does not, however, lie in the objects, and cannot be borrowed from them... On the contrary, it is an affair of the understanding alone, which itself is nothing but the faculty of combining *a priori*, and of bringing the manifold of given representations under the unity of apperception. The principle of apperception is the highest principle in the whole sphere of human knowledge." (Kant, 1787 B, pp.134-135.) But in this there is a concealed assumption, namely that there is no need for a special a priori capacity in order to understand or create the "manifold of given representations" as such, since plurality is "given". The

concept of Codis evidences a different understanding of the mind, in that it does not only connect and create the awareness of unity, but is at the same time also that which separates and creates the awareness of plurality. That is to say, these two attributes of unity and non-unity or diversity, are two complements or poles of *the same function* of the mind or of the same mindprint. These two attributes are the two ends of the same Ouroboros - the tail-eating serpent. Indeed, Codis is perhaps the pattern that underlies every image or concept of Ouroboros. This mindprint is also the most important characteristic of every symbol system - pictorial, verbal or formal, because all symbols are different modes of Connectivity–Disconnectivity. That is, the fundamental function of all symbols of all kinds is the same: every symbol connects or groups certain entities into a certain class, but at the same time it also separates those entities from all other entities. Thus Connectivity–Disconnectivity is the foundation of all classifications. It goes without saying that Connectivity–Disconnectivity or Codis is one of the most basic mindprints of Being at all levels: material, biological, social and noetic.

2. It is not hard to see that some of the mindprints are more basic than others, in that some are primary and not derivable from others, whereas some are derivable from the integration of other mindprints. Thus, for example, Codis is undoubtedly one of the most basic of all, and cannot be derived from any combination of other mindprints. Nor is negation derived from any other mindprint, but its complement, affirmation, is generated by a recursion of negation itself. Furthermore, *Open endedness–Closed endedness is not derived from other mindprints, but when it is combined with Codis* and *Recursiveness–Singularity* and with *Transformation–Invariance*, attributes are generated such as creativity, metaphor, evolution, new orders, induction, extensivity, hypothetical thinking, etc., all of which involve one form or another of recycling and transformation of earlier connections, in a reorganization which is usually of a higher level. This being so, creativity is immanent to the world; evolution is the natural parallel of metaphor in human creation. This integration of mindprints generates the dynamic and evolutionary dimension of Being at all levels, for Transformation–Invariance and Open-endedness–Closed-endedness are the melody of intelligence, being and becoming, life and decay, connectivity and disconnectivity–material or other. In the dialectic of Open-endedness–Closed-endedness, the pole of Open-endedness is the stronger, in the way that in the dialectic of Connectivity-Disconnectivity the pole or tendency of Connectivity is stronger than that of Disconnectivity, and in the dialectic of *Hierarchy–Randomness*, the pole of Hierarchy is more dominant than that of Randomness. In other words, the negentropic pole of mindprints is always more dominant than the entropic, for otherwise this world would have come to an end long

ago. (The fact that Hegel did not realize that mind is forever open-ended is in my opinion the main drawback of his conception of mind.)

Unlike mindprints such as Open-endedness–Closed-endedness, Codis, Complementarity and others, Hierarchy–Randomness is a mindprint created by the integration of other mindprints: recursion of the pole of Connectivity creates Hierarchy, whereas recursion of the pole of Disconnectivity creates a cumulative breaking of connections until at a certain stage a state of randomness or chaos is created, but only up to a certain limit of disorder, in which the tendency reverts to the other pole of the mindprint; and then new connectedness, hierarchy or order is spontaneously generated. Here there is latent perhaps one of the most extraordinary and complex properties of some mindprints which has a Daoist character. According to Daoism whenever Yin is overdeveloped to some extreme, then Yang will evolve and vice versa. Thus, in a sense, mindprints theory is expanded Daoism but in a structuralist key. And indeed extreme connectivity such as a black hole leads in the end to evaporation or dissolution. Malignant cancer, which is a form of extreme local connectivity within the organism, leads in the end to the disintegration both of the organism and of itself. Dictatorship frequently ends in anarchy, and anarchy frequently invites dictatorship, until it is learned that democracy is the most reasonable compromise. According to the big bang theory, the Universe began with the transformation into a state of radiation, of a singular point in which the entire mass of the Universe was concentrated - that is to say, a transformation from a state of total connectivity to total diffusion; at the same time levels of connectivity began to come into being which continuously developed into elementary particles, atoms and increasingly large combinations of them. Academism in art reached stagnation because it created excessively rigid connective principles for pictorial representation. According to the reasoning proposed here regarding these matters, this rigid connectivity had to lead to the splendid explosion of Impressionism, but in its wake no new and more flexible connecting principles were created, but rather the anarchy that reigns in the twentieth century, which in the end will lead to the need for the creation of a new kind of connectivity, more complex and abstract, in the art of the future.

Hierarchy and Randomness are, then, almost certainly two poles of a single phenomenon. Indeed, hierarchical structure (which always contains random aspects, except in formal systems) is the commonest ordering principle in nature at all levels. That is, Connectivity–Disconnectivity or Codis is probably the most basic mindprint, but Hierarchy–Randomness is certainly the most *complex* mindprint. Actually it includes

most of the other mindprints: Connectivity–Disconnectivity (Codis), Open-endedness–Closed-endedness, Recursiveness (Nesting)–Singularity, Transformation–Invariance, Symmetry–Asymmetry, Complementarity–Mutual Exclusiveness, and it probably includes all of the other mindprints too. This to some extent explains a fairly common misunderstanding among great scholars such as Bateson, Koestler and other students of General System Theory who explicitly or implicitly tended to reduce mind to hierarchy or systemic structure. (However, this issue is of great complexity and will be elaborated far more thoroughly in another essay.) It can likewise be shown that Symmetry–Asymmetry is basically a product of other mindprints. Thus all symmetries and asymmetries are modes of Connectivity–Disconnectivity, but additional mindprints are also involved such as Transformation–Invariance, and Complementarity. In those cases where there is also recursion, as in figurative art or biological and other phenomema, there may also be a hierarchy of Symmetries–Asymmetries.

5. Another characteristic of mindprints is that regarding some, there may be an accumulation of the products of the operations of the mindprint, while with regard to others there is no such accumulation. Thus for example, it is clear that in Codis, Symmetry–Asymmetry and Hierarchy–Randomness, there can be an accumulation of the products of these mindprints; but there is not, and cannot be, accumulation in the cases of Negation, Comparison, Complementarity and others. That is to say, in this regard it appears that mindprints fall into two types of organizational principle. For those mindprints that have an accumulative effect there is in any case also an evolutionary dimension. It may be said a little simplistically, that the history of the world is to a great extent the evolution of Connectivity–Disconnectivity – beginning at the material level, through the biological and up to the social and noetic level. As the level of connectivity increases, so it connects more things, but by fewer means. Every word or equation has a greater potential of connectivity than that of the things it connects, even though it is constructed from only a minute number of signs. In other words, the more noetic connectivity increases, so is more manifest intelligence and less matter involved, and vice versa.

I have some doubt regarding the generalization that *all* mindprints are constituted from pairs of *complementary* attributes, especially since at least in the case of "comparison" I do not know whether it has no complement, or whether it has and I have not found it; or whether there is no necessity for every mindprint to have a complement. The mindprint of Comparison is the mechanism of comparison between entities with regard *to identity and difference,* which accompanies every perceptual or cognitive activity, whether

conscious or unconscious, at least among human beings and animals (and it is not impossible that an analogous mechanism is also present at the level of matter), so that this is a basic mindprint and not some derived or marginal attribute. However, I do not find a completely satisfactory complement of it, unless we accept the negation of Comparison–*No-comparison* , or Imparison - as the complement of Comparison (I am indebted to D. Nagy and J. G. Harries for suggesting this term as a possible alternative to "no-comparison"). Moreover, there is a little nested paradox here: it is impossible to perform Imparison consciously because any such act necessarily involves Comparison, which is its opposite. Here I am still groping in the dark.

It is reasonable to assume that all of the mindprints *act together*, but that not all of them act to the same extent in every situation. I am inclined to think that all of the mindprints are particularizations of a single complex principle, but again, because of its totality it probably remains forever beyond our grasp and can be only partially understood. On the one hand, it is clear that in a certain sense there is a hierarchy among the mindprints, and I am therefore inclined to think that they are all subject to some meta-principle, as though the mindprints were a kind of fingerprints which are an organic part of the handprint. On the other hand, I have not found the handprint or hierarchic structure that comprises all of the mindprints. This being so, there is no necessary hierarchic significance to the order in which the mindprints are presented in the table above. It is likewise easy to see that some of the mindprints possess an internal hierarchy; thus, for example, it is clear that there are very many levels of Connectivity–Disconnectivity: material, biological, social, noetic and others, and in each of these types there are many levels of Connectivity–Disconnectivity. That is to say, the totality is an infinite system of nested hierarchies. I am sure that my understanding of mindprints is very partial, and I can only hope that in the future I may understand the idea a little better. Nevertheless, this concept has helped me to understand art (and many other things), much more than has all the literature on art and aesthetics that I have read over many years. I therefore hope that the reader too will profit from the attempt at understanding this concept by applying it to his/her field of interest, be what it may, even though at this stage it is far from being presented in a polished manner.

Having noted a number of their basic attributes, we shall see how mindprints appear in a particularly simple prehistoric picture such as, for instance, the contour drawing of an ibex, deer, ox or any other animal, to be found in every book dealing with prehistoric art. If painting and all branches of culture are indeed different embodiments of basic

structures of mind, then the very appearance or non-appearance of these attributes in the products of art may serve as a criterion for the distinction between art and pseudo-art. Clearly the appearance of one or several mindprints does not suffice to distinguish between art and non-art. But if all of them appear, then it is definitely likely that we have before us a work of art. At the same time, the mere appearance of mindprints does not establish in any measure the *quality* of the work, but rather does it establish that it belongs or does not belong to the category of art objects. In like manner, if we say that lettuce is a food, we do not thereby commit ourselves to its degree of nutrient value, which is a completely different matter.

a. Connectivity–Disconnectivity – CODIS

I have discussed this mindprint thoroughly in a separate essay (Avital, 1997a) and shall therefore content myself with only a brief characterization. The reader should, then, imagine a prehistoric contour drawing of a deer, for example. This drawing does not represent a particular deer, but is a pictorial class-name for all deer which share the visual characteristics denoted by the picture. It is in other words a pictorial universal just like the verbal universal "deer". As such, this picture *connects* all deer of the particular kind represented by the painting, but at the same time, it *separates* this class of deer from all other animals and all other entities in the world. In every figurative work there are at one and the same time at least three levels of connectivity: material, perceptual and symbolic. By contrast, in socalled "abstract" art there is only connectivity at the material and perceptual levels, just as with any object and any phenomenal entity, but it never has connectivity at the symbolic level. In the light of this, one should see in the difference in the levels of connectivity a prime difference distinguishing art from pseudo-art.

b. Complementarity–Mutual Exclusiveness

It has to be emphasized that complementarity is manifested not only in every mindprint but also in the products of culture. Thus for example, it was only in our century that Niels Bohr discovered the tremendous importance for science of the idea of complementarity, but this mindprint was implicit as an necessary condition for the possibility of art from its beginning 40,000 years ago, and it was implicit millions of years before that as a necessary condition for the possibility of reading footprints. In both instances it is impossible to detect the figure on the ground or on the wall without

the background which is its complementary aspect. Furthermore, since the symbols in every figurative painting consist in inclusion relations, or in a relation of nesting at various levels, thus in every figurative painting nested levels of complementarity are also present. As against this, in abstract art there is no necessity at all for complementarity between figure and ground, nor for nested levels of complementarity, for here there is the possibility of a uniform background with no figure within it as in monochrome paintings, or paintings in which the surfeit of colour causes us to see them as a more or less uniform surface. On the other hand, the very existence of an abstract painting, or any other object, cannot be distinguished without the background in which the painting itself is found, so that complementarity is a necessary condition for perception. Since complementarity is a necessary condition in every figurative painting but not within an abstract painting, it may be that this mindprint can serve as one of the factors that distinguish art from pseudo-art.

c. Open endedness–Closed endedness

The dialectic of Open-endedness – Closed-endedness is the source of all creativity and all metaphorization on the cultural plane; it is the root of existence and evolution in the biological world, and this dialectic can be seen on the cosmological level as well. Thus, the existence of every organism is absolutely finite, but with certain changes it continues its existence in its offspring. Similarly, the duration of the existence of every star is finite, but from the cosmic dust that remains after its disintegration other stars are created. The dialectic of Open-endedness – Closed-endedness also characterizes all types of symbol, whether verbal or pictorial. Symbols are as it might be special vessels, the inner space of which possesses a qualitative and not quantitative character, so that they are thus unlimited in their interior space, but have an outward facing partition. Thus for example the symbol "deer" whether verbal or pictorial, applies to every deer there was in the past, is in the present or will be in the future, and the symbol is thus open-ended. Every symbol has the attribute of extensivity which is a characterization of open-endedness, and therefore the symbol "deer" applies to every deer regardless of its age, size and special characters, unless it is of importance to us to create a sub-class having special characters, in which case a separate symbol is created for it. On the other hand, there has to be a limit to the measure of application of the symbol, for otherwise it will not be efficient for the classification of entities, and this fact indicates its closed-endedness. This dialectical duality of Open-endedness – Closed-endedness is present in every figurative painting without exception, but is not present in socalled "abstract"

painting. Paintings of this kind do not include symbols but patches of colour and shapes which we may interpret in any way we please as in a Rorshach test, and therefore there is in these works only the dimension of unlimited open-endedness. However, without limitation they have no value from a cultural point of view, for the supreme function of symbols is precisely to create finite coordinates and boundaries within the infinity that enfolds us. By contrast, when the matter of discussion is a non-representational work consisting of some common object taken out of its useful context and transferred to a museum – such as Duchamp's urinal – there is no open-endedness at all but only closed-endedness; that is, symbols and objects belong to different levels of reality, and symbols are always of a higher level than objects, because symbols are the precondition for the existence and meaning of objects. Hence, the introduction of an object into a museum can never transform it from an object into a symbol. Here again, there is not the complete mindprint, Open-endedness – Closed-endedness, which includes the dialectic of both of them. On the other hand, a socalled abstract painting such as an Yves Klein monochrome has only open-endedness but no closed-endedness, since there are no limitations to its possible interpretations. Since in every figurative work of art there is always the dialectic of Open-endedness – Closed-endedness, and in non-figurative art we find only one of the poles of this mindprint, it seems that Open-endedness – Closed-endedness can be one of the parameters that differentiate between art and non-art.

d. Recursiveness (Nesting)–Singularity, Hierarchy–Randomness:

Connectivity–Disconnectiviy or Codis is not sufficient for the creation of order, nor is it an ordering principle such as hierarchy, without which there can be no life or intelligence. Basically, hierarchy is recursive or nested Codis. In other words, hierarchy is an embedded oxymoron comprising connections and disconnections (Codis) at various levels of order. That is, hierarchy is connectivity turned upon itself or more precisely; it is connectivity folded upon *simpler* versions of itself and thereby gradually creating more and more complex versions of itself. In this process the earlier versions are not overruled or canceled, but are preserved and embedded as "intermediate stable stages" (Simon, 1962) or holons (Koestler, 1967, 1978) by their nesting in the new and more complex versions. Through such a process a *systemic* connection is generated between all stages and levels of the connectivity. However–since there is no connection without separation–simultaneously with the recursion of connections there is also a recursion of separations or disconnectivities, which at a certain limit create disorder or

randomness. Thus hierarchy, and its opposite and complementary pole–anti-hierarchy or randomness–are the two poles of the same mindprint.

Hierarchy and recursion are inseparable because both are founded on nesting. The more detailed a figurative painting, the deeper is its nesting of symbols or structures within each other; and the deeper its recursive structure. The structure or hierarchic order in a figurative painting is the result of *inclusion relationships*, nesting, or self-embedding which exist between all the symbols of the painting, all of which are included by its background. That is to say, every figurative painting without exception is a hierarchic system of pictorial symbols. However, different figurative paintings are likely to have completely different levels of stratification. Thus for example, in a typical Vermeer painting there is far greater detail than in a prehistoric painting of a deer, and for this reason the degree of stratification in a Vermeer painting such as "The Milkmaid" is immeasurably more developed, and therefore contains more levels of organization, than any prehistoric painting. By contrast, it can be shown that in non-figurative paintings the degree of stratification is always negligible or extremely small, for, since in this art there is no symbol system, there are inevitably no recursive processes or nesting, but rather repetitions; however this is not enough for the creation of levels of order. Thus for example all monochrome paintings are utterly lacking stratification. Similarly, despite the large difference in the number of colours in minimalist and abstract expressionist paintings, this does not alter the fact that in both the degree of stratification is minute, because the degree of stratification is not determined by the number of elements but rather by the manner of their organization. A further important aspect present here is the fact that in every figurative painting there is always present at the same time a dialectic of hierarchy and randomness. By contrast, in works called "abstract" this dialectic need not necessarily be present at all, and many of these works are quite good examples of random organizations almost entirely devoid of any hierarchical patterning. Another aspect of this matter is the fact that figurative painting has from the beginning and until this day served as a means of presenting *the order in the world.* This attribute is what makes it above all a branch of culture, for all branches of culture are different ways of expressing the order that is in the world, either as an actual, a hypothetic, or an imaginary phenomenon. This is possible because its hierarchic structure is an ordering relation and it is symmetrical to one degree or another, to the order we see in the phenomenal world. Since non-figurative painting lacks hierarchy it inevitably lacks an ordering relation and cannot therefore represent any extensive order whatsoever. This point may be summed up by arguing that

recursiveness, hierarchy and their derivative attributes are factors that distinguish art from pseudo-art.

e. Symmetry–Asymmetry.

All kinds of Symmetry–Asymmetry are modes of Connectivity–Disconnectivity, but symmetry also includes other mindprints such as Transformation–Invariance, some kind of recurrence which is a special case of Recursiveness–Singularity, Complementarity–Mutual exclusiveness and perhaps other mindprints as well. It is possible that all kinds of Connectivity–Disconnectivity include, at least in a minimal sense, Symmetry–Asymmetry as well, in the sense that there can be no connectivity without some kind of interface or common denominator, which may be either literal or metaphorical. Nevertheless, symmetry cannot be reduced to connectivity because there are numerous kinds of symmetries besides the one inherent to connectivity. As noted before, the most basic function of symbols is at one and the same time connectivity and differentiation. But symbols of different types serve this function in different ways. This difference is especially noticeable in the special way in which pictorial symbols connect and differentiate the entities they symbolize, in contrast to the way in which verbal and formal symbol systems connect their entities (Avital 1996). The special connectivity of figurative art is based upon maintaining a *certain symmetry of a relative nature* between the object and the symbol that denotes it. This symmetry is a structural common denominator of the class of entities connected by that symmetry. Thus for example, the contour depicting a deer is the graphical common denominator between all members of the class of deer. In this sense, symmetry is a connecting pattern in art as in science. Therefore the annulment of this symmetry from visual non-representational art, exactly like the annulment of hierarchy or any other mindprint from this art, has far-reaching implications for the cognitive functioning of modern art. This matter is especially relevant to "abstract art", which completely abrogates symmetry or similarity between symbol and symbolized as a principle of representation, thereby losing the cognitive function of Connectivity–Disconnectivity that has been so central to figurative art throughout the whole of its history. The breakdown of symmetry as the connectivity principle of art, is at the very root of the breakdown of art itself in our century, and it can therefore safely be assumed that in the future paradigm of art Symmetry–Asymmetry will be restored, without however reverting to figurative symmetry, but rather to Symmetry–Asymmetry of a much higher level of abstraction. This seems to be inevitable because, like all mindprints, the complementarity of Symmetry–Asymmetry,

is one of the most basic means of organization of mind or Being in all of its manifestations: on the material, the biological, and the noetic level, of which art is one sub-aspect.

f. Transformation-Invariance:

Transformation is the melody of matter, life and intelligence. It is the magical bridge between Being and Becoming. For Heraclitus change and transformation was the only truth, and invariance was illusory. For Parmenides transformation was sheer illusion and only invariance was the truth. For Plato transformation was the earmark of the phenomenal world, which for him was an intermediate reality between the realm of illusion and the world of Forms or Ideas, which is invariant and the only eternal truth. In Plato's conception there is thus room for both poles of this mindprint, but he did not see them as complementary opposites. Modern science has clearly opted for the Heraclitean view which perceives reality as dynamic and transformational. However, at the same time, science posits a number of invariants such as levels of organization or hierarchy, symmetry, transformation and others, as well as their complementary opposites. Indeed, the central and as yet unproven supposition of this essay is that the list of mindprints I have indicated is almost certainly a partial inventory of the invariants that are common to all branches of culture, and science among them. There are evidently many kinds of transformation: some are common to all levels of Being, some are unique to each level. The concept of transformation is too wide for discussion here, and I shall therefore focus only upon a few of its aspects that are relevant to symbolization, of which art is a special case.

Transformation–Invariance is not only inherent to all kinds of Symmetry–Asymmetry, but is also the precondition of all perceptual and cognitive activity. The reason for this is, that all mental or cognitive activity involves interpretation, and interpretation involves some kind of coding-decoding, signification or symbolization, which is impossible without transformations of various kinds. While the necessity of transformation is self-evident in the physical and biological domains, it is less apparent in the cognitive context. Thus, the creation of pictorial symbols involves spatial and temporal transformations: from three to two dimensions, and from faster to slower time. The first kind of transformation is self-evident, but the second is less obvious. Time is not a uniform phenomenon but rather is it an immense hierarchy of times which includes within it several hierarchies of kinds of time characterized by different levels of rate of

change (Fraser, 1975; Stamps, 1980). Thus for example, the rate of change in the physical world is much faster than in the noetic world. On the other hand, in each of these two domains a hierarchy is present, of rates of difference. By a broadening of this idea, it may be said that in drawing a house, a flower or a horse, the very creation of a symbol for one or all of them together, performs simultaneously two kinds of transformation: on the one hand, the transformation is made of a three-dimensional entity into its two-dimensional image, and furthermore it is removed from physical time to noetic time, which is much slower or characterized by a much lower rate of change. It is as if we had trapped or frozen a bubble from a world in which change takes place at a rapid pace, into a world in which change takes place at a far slower pace. Notwithstanding, despite these two transformations, a drawing representing (for instance) a horse, does not represent a particular horse, but constitutes a pictorial universal that can indicate any horse. This fact indicates the *invariant* and complementary aspect of transformation. In other words, there is present in figurative art a duality of descriptive vs. described processes, and there is a vast gap between the rates of change and levels of complexity in the two processes. However, the two processes are complementary and are connected by transformation and symmetry. That is, a basic function of pictorial symbolization is the preservation of information by translating or transforming a faster to a slower process, or by creating a slower process which denotes the symbolized process or entity. Thus, information is preserved by increasing connectivity. Connectivity is then in inverse relation to difference, and decelleration in time is a kind of freezing of the object as an image or concept. In most cases (but not always) intelligibility is also achieved by shifts to lower levels of difference, i.e. slower time or higher connectivity. As we shall see in the following, in the case of conceptual and formal symbolization the dynamics of Symbol vs. Symbolized is far more complex.

As already stated, when we construct a representation of a phenomenon it is necessary to move to a slower time than that of the symbolized phenomenon. But when attempting to represent a totally conceptual and highly abstract entity, such as "God" for example, it may be that we then pass to a level of change much more rapid than that of the matter symbolized since according to the monotheistic view, for instance, God does not exist in time and in any case has no variance! On the other hand, our concept of God, however abstract this may be, will include some measure of difference since we are unable to think otherwise. A less extreme case would be when we try to represent a mindprint like Symmetry–Asymmetry. For this we shall have to pass from the low level of difference at which the meta-patterns of the mind exist, to a higher level of difference, in order that

the concept shall have sense within our conceptual system. Two more examples: A close childhood friend whom I have not seen for many years has remained in my imagination in the same state, a kind of freezing in time of the image, and if I were to meet him in the street I might very well not recognize him. By contrast, when I draw a circle, there is no passage into a slower time than that in which geometrical ideas exist, but on the contrary: we pass from a low level of difference in which these ideas are present in our thought, to a much higher level of difference in order that the concept of the circle should receive actuality in the phenomenal world. The conclusion to be drawn from all that has been said is, that our consciousness exists only *within a certain range* of levels of difference. That is to say, in order that we may be able to function cognitively we move, in certain cases, into a time that is slower than that of the subject of symbolization, while in other cases we move into a more rapid time.

Unlike the case of figurative art, in abstract art there is no symbolization and therefore no transformation–neither spatial nor temporal. There are neither descriptive nor described processes. The work in this case is time-dependent only in a physical sense, as with any perceptual object. There are no shifts or transformations up or down the hierarchy of time and there is therefore no symbolization, no preservation of information and no intelligibility. It has also no invariant aspect, because one may interpret it in any way desired. In the light of these profound differences between figurative art and abstract art, it is reasonable to suppose that Transformation–Invariance, like the other mindprints, is one of the parameters that may distinguish art from pseudo-art.

g. Determinism–Indeterminism (Probablility, Selection, Choice)

Determinism in its classic formulation, as with Laplace and others, assumed a total causal connectivity between all events at all levels of Being, and therefore saw in selection and in free choice only illusion. Spinoza, Hume, Darwin and others saw in the assumption of the existence of chance an admission of our ignorance with regard to the causality of things. In a less extreme formulation, as with Descartes, absolute determinism exists only in the material world but not in the spiritual world, and not with regard to God. Modern physics learned to understand what had already been understood thousands of years earlier in the mythologies of Egypt, Greece, Iran and India: that there is no complete determinism, but two opposed tendencies of order and disorder. The difference is that modern physics, like Daoism, sees in these two tendencies opposed but complementary tendencies, whereas the mythologies saw in them opposed

forces that were not dependent upon one another. In complete opposition to the mechanistic view which is fundamentally classical determinism, Prigogine argues that matter is not passive but is characterized by *spontaneous* activity (Prigogine, 1984, p.9). This means, that the physical world is an open-ended process and that therefore in principle our knowledge regarding material reality discloses only a probabilistic situation, and not an absolute one. From this follows the profound connection between Open-endedness–Closed-endeness and between Determinism–Indeterminism. The fallacy of determinism is in the end the assumption that in Being there is absolute connectivity without the opposite pole of disconnectivity. In other words, determinism is an expression of connectivity and closed-endedness, and indeterminism is an expression of disconnectivity and open-endedness. And indeed, as there is no absolute connectivity and no absolute diffusion as permanent states but rather for very brief durations as a stage within a broader process in which they change, so too there is no determinism or its opposite as absolute states, but rather only intermediate states of connections of different strengths . Moreover, creativity is one of the salient expressions of Open-endedness – Closed-endedness, and the fact that there exists continuous becoming and creativity in all aspects and at all levels of being is perhaps the best refutation of the deterministic view.

In culture, as in the physical and biological worlds, there are constraints of different kinds which constitute the deterministic aspect of the products of culture; but along with these constraints there are also indeterminism, open-endedness or one measure or another of degrees of freedom. The deterministic aspects are the factor making the products of culture inter-subjective; otherwise they would have no cultural value. On the other hand, along with these constraints there are also anti-deterministic factors such as the idiosyncracy, talent and the special point of view of the creators. Similarly, another contribution to this matter is the uniqueness of the consumers of culture and other factors such as arbitrariness and randomality, which are a dimension that accompanies every creative process and every interpretation of it. Basically the indeterministic aspect, which is largely subjective, becomes in particularly successful cases public property. However, in less successful cases it remains the property of the subject, and therefore irrelevant to culture. Thus for example the basic structure of all languages is hierarchical, but different languages interpret and map reality in different ways; the speakers of every language use it in different ways to one extent or another, and in every language different combinations of phonemes are used in order to denote the same things. Moreover poets, philosophers and scientists try persistently to extend language and renew it so as to match an existing or hypothetical reality. Similarly, every

figurative painting is a hierarchical symbol system depicting real or fictitious entities by means of a specific symmetry that enables us to identify the painted object. However, in every such painting there are, alongside structural, syntactic, material and other constraints, also not a few factors which contribute to the open-endedness both of painting as an artistic domain, and to the open-endedness of the painting as a specific work. Thus for instance the special use that, throughout the history of painting, every artist makes of colours and shapes; shades and configurations that occur by chance alongside those that are planned; the special interpretation which he gives to the symbols and to divergences of one kind or another from the figurative syntax; all of these and others contribute to the creativity, originality, renewal and richness of the art of painting. In abstract painting there is by contrast only an indeterministic, subjective or idiosyncratic element, but no deterministic inter-subjective element at all, so that it is very doubtful whether it is art. It may thus be said in conclusion that Determinism–Indeterminism is a mindprint in art and in every other area, and can therefore serve as one of the parameters for distinguishing between art and pseudo-art.

h. Negation–Double negation, Comparison–Imparison

Negation–Affirmation (or double negation) would appear to be the most basic mindprint, since negation is immanent in every mindprint in the sense that it is the necessary condition for the generation of complementarity in all mindprints. In other words, negation is what creates otherness, and in this case the reciprocal connection and opposition between the poles that form each of the mindprints. From a psychological viewpoint, we tend to think that affirmation is more basic than negation. But from a logical point of view, negation is more primary, for negation cannot be derived from affirmation, whereas affirmation can be derived from negation by means of double negation. At the same time, affirmation has no meaning without negation, and not the contrary, for the one always assumes the other and they are therefore complementary. Thus for instance, in a proposition such as: "This table is made of wood", we explicitly affirm that the table is made of wood but we implicitly deny the possibility that it is made of some other material. such as iron, for example. As against this, when we maintain that: "This table is not made of iron", we explicitly deny the possibility that the table is made of iron, but we implicitly affirm that there are other materials of which it may be made, such as wood or stone, for example.

Without negation no kind of thought is possible in any area, nor the most basic laws of thought such as the law of contradiction, and the law of the excluded middle, already formulated for the first time in the sixth century B.C., by Parmenides. In a wider sense, without negation no noetic activity would be possible–whether perceptual, instinctive, symbolic or emotional. Negation and double negation accompany all processes of thought at all levels, and every comparison and every state of consciousness. For there is no awareness without consciousness of difference, and there is no difference without negation. Explicitly or implicitly, negation and affirmation are inseparable from every proposition, judgment and predication. Without negation and double negation there is no meaning to truth and falsehood, and evidently no logic; there is no possibility of verification and refutation in any domain; there is no certainty and no uncertainty, and there can be no order, organization or orientation of any kind. Not only is epistemology impossible without negation and double negation, but neither is ontology possible without this mindprint. That is to say, there is no Being at all levels without its complementary opposite, nonbeing or nothingness. In both cases, in the noetic world and also in the material world, negation creates *otherness*: it splits unity and simplicity and thus creates diversity and complexity. Negation creates the complementary classes: thus the class of *"not-blue cars"* is the complementary class of the class of cars which are blue. Without negation there can be no inclusion-exclusion relations, classification, differentiation of any kind or individuation; there will be no process or entropy, no evolution or negentropy and no variance or time. However, without these there can be no intelligibility or coherent view of mind or reality. In short, eventually, negation grants the emergence of mind and reality.

The wonder of Creation is perhaps the wonder of the creation of negation. Everything else is derived from it. The first verses of Genesis describe the first distinctions that God made, which are also the creation of the first complementary pairs: heaven-earth, light-darkness, etc., but no distinction is possible without negation, and negation and double negation therefore preceded all distinctions that followed. For the same reason complementarity too, which was generated by negation, preceded the complementary pairs that were created. Actually, the first Asymmetry, which according to the Big Bang theory is the moment of creation, could not be without negation. In a humorous vein, one might suggest a different opening for the first chapter of the Bible: In the beginning God was very bored amidst Perfect Symmetry, in which absolutely nothing happened. Then accidentally He sighed, "Oh No!" This created the first Asymmetry, which brought into being the other mindprints... and the rest is History. In other words, there is no symmetry without asymmetry, and there is no asymmetry without negation, therefore

negation is a precondition for Symmetry–Asymmetry, and the same can be shown with regard to all the other mindprints. In a final regression, the negation of negation is perhaps what created Being, and this is perhaps the significance of the proposition that Being was created from nothingness. There is nothing new about this, since the idea already arose in the creation myths and in philosophy, in Western and Eastern cultures, and also in modern physics.

It is doubtful whether there has in the history of philosophy been an issue whose implications for the history of Western thought have been so decisive as in the case of the concept of negation, and mention should therefore be made in this case, of the context within which this issue first arose. It is perhaps not by chance that Heraclitus and Parmenides, who largely established the main channels of the development of Western philosophy, presented in a polarized manner two opposing world views, the essential difference between which was a different view of negation. Heraclitus does not appear to have discussed explicitly the problem of negation, but since the world view that he presented is constructed upon principles of transformation and complementarity, then implicitly negation and affirmation, and also being and non-being, must be two opposing but complementary aspects, as with all the other opposites. By contrast, in the view of Parmenides, opposites and complementarity are only an illusion connected to the Way of Seeming and not to the Way of Truth, whereas the problem of negation was the main axis in his philosophy, and his conclusions had a decisive influence upon the subsequent development of Greek philosophy.

For Parmenides there was no clear distiction between subject and predicate, and no distinction between negation and nonbeing, and therefore the negation in 'what is not' is not the negation of a specific attribute of the subject, but rather the negation of the existence of the subject. Another assumption of his, was that there exists an identity between the content of thought and the reality of the object of thought: "...for it is the same thing that can be thought and can be" (fr.3), and it is therefore impossible to think about 'what is not', or what does not exist. Thus in his explanation of the impossibility of the becoming of the One or of 'what is', out of what is not, he argues: " I shall not allow thee to say or think 'from what is not', for it is not to be said or thought that 'it is not'. (fr 8.6; the fragments are from Guthrie, 1965, p.14, 26.) But as a result of the identity between negation and non-being, and because of the absence of the distinction between predicate and subject, for Parmenides a double paradox was created: on the one hand he argued that it was impossible to think of 'what is not', but the greater part

of his philosophy deals with thinking about the negation of the possibility of thought regarding what, according to his conception, it is impossible to think about. On the other hand, in his opinion it is possible to think only about 'what is'. However, it is not possible to think anything regarding that utterly indifferentiated transcendent Unity, without introducing a multiplicity of words and predicates–something that is opposed to his own view. And indeed he too is obliged to characterize this unity mainly by way of negation, with the aid of a few predicates, for otherwise he could not have said or thought anything regarding that unity. Parmenides was aware of the fact that because of our essential need for names and words, which for him were only conventions that did not necessarily describe a true reality, it is then possible in actuality to think only about contents or subjects which he considered it impossible to think, and impossible to think about what he considered it possible to think.

The polar opposition between Heraclitus and Parmenides is not only with regard to negation, but also in that they emphasized in their philosophies the different poles of another mindprint: Complementarity–Mutual exclusiveness. Heraclitus emphasized complementarity and ignored the other pole, which is mutual exclusiveness, whereas Parmenides denied complementarity and emphasized only mutual exclusiveness. For this reason there can also be for him only total negation or only total affirmation of the content of consciousness, which is for him identical with the object of thought: that is, for Parmenides there can be only absolute negation with regard to the perceptual world, or absolute affirmation with regard to the One, and there is no possibility of his affirming one aspect and denying another aspect in one of these two worlds (Scolnicov, 1988, p.151.)

The conclusions of Parmenides concerning negation led for the first time to a distinction between phenomenal reality as an illusory reality, and transcendent reality which is true, but with no possibility of bridging the gap between the two. Indeed, the chief life work of Plato was the attempt to forge a compromise between the opposed world views of Heraclitus and Parmenides, and in particular to bridge the abyss created by Parmenides. The key to his solution lay in showing that negation does not relate to a thing, but to characterisitics or predicates which can be related to a thing, so that there is no problem of negative things (Plato. Sophist, 257-258.) Aristotle agreed with his opinion in the matter of the nature of negation, but he rejected the rest of the implications of the Platonic solution which created three worlds, of which he attributed to the phenomenal world an intermediate status of between 'what is' and 'what is not': between the true world of Ideas whose attributes are similar to those of the Parmenidean One, and the

world of illusion. On the one hand Plato's solution introduced multiplicity or negation into the world of unity of Parmenides, through the plurality of ideas, and on the other hand introduced unity into the world of diversity, since the objects in the world owe their existence to the fact that they partake of the Ideas or imitate them. Plato anchored the Ideas or Forms in the transcendent level, whereas Aristotle considered that they were immanent to the things themselves. This was the central point of disagreement between these two giants, and the subsequent history of philosophy up to Kant is to a great extent the continuation of the argument between them. The problem of negation in its wide sense was the point of departure for Parmenides, but the discussion of it and its derivatives laid the foundations for epistemology and ontology, metaphysics and logic; the complete separation of the perceptual and the conceptual and their relation to the possibility of knowledge; the assumption of rationality as the point of departure for philosophical method and as a criterion for reality itself, and other issues. Here it can be seen to what extent the problem of negation indeed determined the character of Western philosophy for more than two thousand years. (Scolnicov, 1988, p.162.)

On a superficial view it is hard to see in what way the Negation–Affirmation mindprint could have importance in relation to the problem of demarcation lines between art and non-art. However, on deeper inspection its importance is revealed at two levels: firstly, with regard to figurative art it is very easy to establish whether some thing belongs to figurative art or not. By contrast, in non-representational or abstract art, there is no way of *denying* some thing its inclusion in this art, and thus in principle *any thing* can be accepted as a work of art of this type. In other words, modern art is not skeptical, as many try to present it, but rather is it nihilistic and therefore in the end also self-nullifying: it negated figurative art but it has no alternative of equal value, let alone a better one. Secondly, one of the functions of negation is the creation of differentiation on different planes. Thus for example there is always in figurative art a differentiation between figure and ground, and likewise a rich and well distinguished system of symbols each of which serves as a pictorial class-name for certain entities. As against this, in abstract art negation is not necessary at all: there is no necessity at all for a distinction between figure and ground, and a picture may well contain only unity, with no differentiation at all, as occurs in monochrome paintings. In the light of all this, it is clear that the Negation–Affirmation mindprint may be one of the parameters for the distinction between art and pseudo-art.

I have some doubt as to whether Comparison–Imparison is indeed a mindprint in its own right, or whether it is not an internal organisation, or nested mindprint of other mindprints such as Negation–Affirmation. For, at least in the area of predication, propositions and judgments, no negation or affirmation is possible without comparison between at least two states of affairs regarding the extent of difference, resemblance or identity of the attribute or attributes one is attempting to negate or affirm in relation to some subject. Thus for example, according to the law of contradicition a proposition cannot be true and false at the same time. Or, two propositions, p and not-p, cannot both together be true. However, the law of contradicition is not meaningful without an explicit or implicit comparison between p and not-p. Negation and affirmation are, then, not possible without *comparison* between two opposing possibilities regarding the same matter and the rejection of one of these possibilities. Thus for instance, for a person to be able to maintain rightly or wrongly : "This painting is not by Vermeer", he must compare the observed characteristics of the given picture with the totality of characteristics that there would be in an authentic painting by Vermeer. In the light of the difference between the characteristics of the given painting and those of a typical Vermeer, he rejects the possibility that the given painting is indeed a painting by Vermeer. By contrast, when a person maintains: "This painting is by Vermeer", he compares the characteristics observed in the given painting with the totality of characteristics that there would be in a typical painting by Vermeer, and in the light of the great similarity or identity of the two classes of characterisitics he rejects the possibility that the given painting is not by Vermeer. That is to say, he affirms that the given picture is indeed a painting by Vermeer. We have seen, then, that at least within certain areas there is no negation without comparison. But comparison is not possible without negation, in the sense that there is no comparison without the perception of variance or duality between things or between two appearances of the same thing. Similarly, there is no point in the act of comparison if it is not accompanied by an affirmative, negative, or dubious decision regarding the degree of variance, the similarity or identity of the characteristic considered in the objects of the comparison. It would seem that in the epistemological realm at least, negation and double negation are conclusions from comparison. However, I am by no means certain that this is so in all domains. In this, as in other matters connected with mindprints, I am still groping in the dark, and hope to understand them better in the future.

To summarize:

In order to understand art as a product of the mind, it is necessary to understand the structural patterns or mindprints that the mind stamps upon all phases of Being: in the physical, the biological, and the noetic world, of which art is one aspect. Seen in this light, human culture, including art, is not antithetic to nature, as suggested by some anthropologists, but is in a profound sense the latest phase in the evolution of nature itself. In this phase, the main product is not matter or life, but the unfolding of intelligence itself and its structures, which are implicit in nature from its beginning. An adequate theory of the origins of art must therefore indicate at least the linkage of art with the tremendous process of the emergence of intelligence. Seen in this way the characterization of art cannot be another particular theoretical caprice to be lightly accepted or rejected. Rather such a characterization of art is needed that anchors it in the broadest possible context - to cosmology itself, which is the grand objectivation of mindprints. In fact, a characterization of art in this way is to my mind a direct derivative of the most sublime principle that science has yet discovered: the *anthropic cosmological principle* (Barrow and Tipler, 1986) according to which many of the extraordinary properties of the universe constitute a necessary condition for the existence of life and of an intelligent observer of that universe. Intelligence is according to this view a purpose of the universe, and on our tiny planet this purpose began to materialize explicitly through culture and the stages which preceded it: footprints literacy at least four million years ago; tool making some two and a half million years ago; through image making or prehistoric art some 40,000 years ago; and through language and all of its products, which crystallized at some time between the emerging of tool making and image making, and has been to this day the main bearer and propellant of cultural evolution. If the mindprints are indeed basic structures of the mind as argued here, then the real test of this idea will be whether people from domains different from art will also identify the mindprints that have been indicated here as meta-structures in their domains as well. If this in fact happens, then the mindprints theory may indeed be able to serve as the structural basis for a transdisciplinary view of culture, or as the basis for a philosophy of culture. It can be seen from this essay that Symmetry–Asymmetry is only one out of nine or ten other mindprints, and not the most essential of them. In the light of this, I hope that the Society for the Interdisciplinary Study of Symmetry (ISIS) will widen its platform to include the rest of the mindprints as well, or the general investigation of the basic patterns of the mind and the mutual relations between them.

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Symmetry: Culture and Science
Vol. 9, No. 1, 77-112, 1998

SYMMETRO-GRAPHY

SYMMETRY: A BIBLIOGRAPHY OF INTERDISCIPLINARY BOOKS[1]

University-textbooks, scholarly monographs, popular-scientific works

Dénes Nagy

This bibliography includes
- about 600 books, plus their additional editions, close to 1,000 items (collections of papers by different authors, abstracts and proceedings of meetings, booklets shorter than 50 pages, and manuscripts are not considered),
- on symmetry (they refer to this term or its derivatives, including antisymmetry, asymmetry, dissymmetry, *directly in their titles),*
- in 25 languages (Bulgarian, Catalan, Chinese, Czech, Danish, Dutch, English, French, German, Greek, Hungarian, Italian, Japanese, Lithuanian, Norwegian, Polish, Portuguese, Rumanian, Russian, Serbo-Croatian, Slovakian, Spanish, Swedish, Turkish, Ukrainian),
- from all of the continents (from Brazil to Mongolia, from Mexico to Australia, from Norway to Mozambique),
- with the full bibliographic description of each book (Bulgarian, Chinese, Greek, Japanese, Russian, and Ukrainian names and titles are romanized), and
- with translations of all book-titles that have no English versions.

The books are classified according to a system that was developed for this purpose. Since the "linear" classification of interdisciplinary books is impossible, there are cross-references among sections.

INTRODUCTION

As it is emphasized in the heading, all of the listed books are on symmetry (*antisymmetry, asymmetry, dissymmetry*, and other derivatives): they refer to this fact directly in their titles. Since the expression *symmetry* became an international word, its adapted versions, with minor phonetic changes, are available in many languages. In the case of Far Eastern books those are considered that use

- the Chinese term *duìchèn* (modern Mandarin reading, Pinyin [sound assembly] system of romanization; which is *tui ch'eng* according to the earlier Wade-Giles romanization)[2,3], or

[1] Originally published in *Visual Mathematics*, http://www.mi.sanu.ac.yu/vismath, http://members.tripod.com/vismath.
[2] Its adopted Korean version *tae-ch'ing* (McCune-Reischauer system of romanization).
[3] Its adopted Japanese version *taishou* (revised Hepburn system of romanization).

- the Japanese *shinmetorii* (the adopted international word, which development has no Chinese or Korean equivalent).

The cited Chinese term, which is written in two characters, is related to objects facing each other to form a pair (bilateral symmetry), but its meaning can be extended to the case of rotational symmetry. Still, it is more specific than the Western "symmetry". Perhaps this observation also contributed to the fact that in modern Japanese both terms are used: *taishou* (adopted from China and written in Sino-Japanese *kanji* characters) and *shinmetorii* (adopted from Western languages and written in the *katakana* phonetic syllabary).

Note the following important conventions:

(1) Books without reference to symmetry (or its derivatives) in the title → not listed.

Unfortunately there are many books of this category which deal with symmetry-related topics. Obviously, the exclusion of these books has some disadvantages, but

- it was necessary to limit the scopes of this bibliography,
- there are some good bibliographies on polyhedra, proportions, rhythm, tilings and patterns, respectively, which are available for further reference.

Bibliography of bibliographies (or comprehensive lists of references) of some symmetry-related fields

(a) Polyhedra

Cromwell, P. (1997) *Polyhedra, Cambridge* [England]: Cambridge University Press, pp. 416-438.

(b) Proportions in art and nature

Graf, H. (1958) *Bibliographie zum Problem der Proportionen: Literatur uber Proportionen, Mass und Zahl in Architektur, Bildender Kunst und Natur*, [*Bibliography for the Problem of Proportions: Literature on Proportions, Measure, and Number in Architecture, Fine Art, and Nature*, in German], Speyer [Germany]: Pfälzische Landesbibliothek, 96 pp.

* Also see the additions to this bibliography in the following book:

Wittkower, R. (1971) *Architectural Principles in the Age of Humanism*, New York: Norton, 1971, "Appendix 3: Bibliographical notes on the theory of proportion", 162-166.

Naredi-Rainer, P. von (1982) *Architektur und Harmonie: Zahl, Mass und Proportion in der abendländischen Baukunst*, [*Architecture and Harmony: Number, Measure and Proportion in Occidental Architecture*, in German], Köln: DuMont, "Bibliographie", 232-283.

(c) Rhythm

Winick, S. D. (1974) *Rhythm: An Annotated Bibliography*, Metuchen, New Jersey: Scarecrow Press, v + 157 pp.

(d) Tilings and patterns

Grünbaum, B. and Shephard, G. C. (1987) *Tilings and Patterns*, New York: Freeman, "References", pp. 653-694.

* Abridged ed., *Tilings and Patterns; An Introduction*, New York: Freeman, 1989, "References", 401-442. [The first seven chapters of the original book and the full list of references].

(2) In the case of translated books:

- There are books where the original titles refer to symmetry (or its derivatives), but the translated versions do not → in this case we still list the bibliographic data of the translated versions.
- There are books where the original titles do not refer to symmetry (or its derivatives), but the translated versions introduce this term → in this case we do not list the book and its translated versions.

In short, our decision is based on the author's original intention, not on the later view of the translators.

(3) Items shorter than 50 pages are also excluded. We plan, however, to publish further bibliographies on symmetry and related topics, covering not only university-textbooks, scholarly monographs, and popular-scientific books, but also collections of essays, proceedings, and other works.

International aspects

It is interesting to note that many references in this bibliography are not yet available in major computer catalogs, data banks, and electronic bookstores: they frequently miss older items and books written in languages that are not widely spoken at their centers. We think, however, that these works are also important. Often they include tables and illustrations that are easy to understand without reading the actual language. A beautiful example is Kumagai and Sawada textbook *Moyou to shinmetorii* (*Ornamental Patterns and Symmetry*, in Japanese) in Section 1.1.3. In addition to this, the data of translated books

- may help the international cooperation among interested scholars and instructors,
- may provide useful information to lecturers and students who visit particular countries and would like to refer to locally available works,
- may orient publishers and translators.

We observed in various cases that translators of books did not revise the list of references, just adopted it. This method led to such comic cases where, for example, an English book on symmetry (translated from German) refers not to the original version of papers and books in English, but to their later German translations. Should the reader learn German to follow the references? I also believe that even publishers did not realize some basic data on translated books that are available in our bibliography. The lack of information led to duplicating or even triplicating the same work. I have no different explanation of the surprizing fact that Hermann Weyl's book *Symmetry* (Princeton, 1952) has

- three different Spanish translations: (1) Buenos Aires, 1958; (2) Barcelona, 1974; (3) Madrid, 1990.
- three different Chinese translations (with see slightly different titles!): (1) Beijing [Peking], 1986; (2) Taibei [Taipei, Taiwan], (3) Shanghai.

These are not reprint editions of the same translation, but different interpretations of the book.

If a book has more than one translation, we list these in a chronological order (according to the first editions in the corresponding languages).

In those cases where the translated titles significantly differ from the original ones (or new subtitles are added), those "modified" titles are also translated into English. For example, Pagels' book *Perfect Symmetry: The Search for the Beginning of Time*, New York: Simon and Schuster, 1985; 2nd ed., New York: Bantam, 1991 became in Japanese *Toki no hajimari e no tabi: Taishousei no butsuri* [Journey to the Beginning of Time: The Physics of Symmetry],while, as a further twist, the second edition was translated as *Hoshi kara ginga e: Heesheru no niwa* [*From the Stars to the Milky Way: Herschel's Garden*]. There is no similar "problem" with the Italian and Portuguese translations of the same book. They follow more or less the original title and therefore these titles are not translated into English.

Concerning translated books, we give the possible "new" (transliterated) names of authors in those cases where these are important to locate the book in the corresponding language territory, e.g.,

- Sheikov, a Bulgarian author (in English transliterated form) became
- Scheikov in the German translation of his book,
- Sejkov in the Hungarian version.

Luckily there is no similar problem in Japan: most library catalogs list the Japanese translations of foreign books under the original names of authors.

The translation of terms is often a very difficult task. In some cases we added alternative expressions <interrupting the translated titles> or brief notes [in brackets at the end]. The related problems led to two case studies and related hypertext essays:

- objectology or object-design as possible English equivalents of the Japanese *monogaku*,
- *futaishou* as a possible Japanese equivalant of *dissymmetry* (lack of some elements of symmetry).

Some conventions used in this bibliography:

To keep the bibliography shorter, we adopted the following conventions:
- If a book is published in a series whose title is important to find some extra information about it, we give the series title after the actual title of the book (note that the title of the book is italicized, while the series title is not).
- For place of publication, only the first one is given, followed by the name of the state or country if any difficulty may occur in locating the corresponding city [and maybe some additional information in brackets, e.g., the new names of some places in the former U.S.S.R.].
- The names of publishers are given in short form, e.g., we have Springer instead of Springer Verlag. We use, however, the full names of publishers where the sort forms may lead to ambiguities, e.g., we should make clear that a book is published either by the Academy of Science of the U.S.S.R. (*Akademiya Nauk SSSR*) or by the Publishing House of the same institution (*Izdatel'stvo Akademii Nauk SSSR*).
- In the case of parallel editions, we refer to both publishers.
- Reprint, paperback, and new editions are also listed; these are marked by asterisk (*).
- Translations are listed in new paragraphs; these are marked by dash (-).
- In some cases there are brief notes after the books [in brackets].
- We use the conventional transliteration of Cyrillic words [sometimes giving alternative versions of names in brackets].
- In the case of the transliteration of Japanese names and titles, we use the system preferred by most wordprocessors and some computerized data banks where, e.g., instead *ô* and *û*, we have *ou* and *uu* (without diacritical symbols!), respectively. We do not introduce, however, this style in case of "Tokyo", because this city is known in this form, while the linguistically correct "*Toukyou*" would be very strange for most readers.

We use some standard abbreviations: *ed.* (edition or editor), *eds.* (editions), *ibid.* (ibidem, in the same place), *pp.* (pages), *trans.* (translation).

A request:
Of course this bibliography is not complete. We kindly ask our readers to report any missing item.

1 INTERDISCIPLINARY TEXTBOOKS AND TEACHING MATERIALS

The border line between textbooks and scholarly monographs is not always clear. We list here such books where there are some indications that the works are written (partly or fully) with educational purposes: these are texts, guides, problem-books, or other teaching materials. Since this intention is not always clear from the titles of books, we pay a special attention to subtitles, series titles, the detailed data of the publishers, and even remarks in the prefaces. In the case of some non-English books, not only the titles, but also other bibliographic data are translated into English. In the case of names of institutions I try to give the official translation <with remarks that give further information or alternative translations that are closer to the original>. Occasionally, there are notes that explain the intention of the author [these are in brackets at end of the item].

1.1 Interdisciplinary works in a broad sense

1.1 1 General introductions

- Science-technology and arts-humanities:

Bérczi, S. (1990) *Szimmetria és struktúraépítés*, [*Symmetry and Structure-Building*, in Hungarian], Egyetemi jegyzet [University Text], Budapest: Tankönyvkiadó, 260 pp. [Published for a course at the Eötvös Loránd University, Budapest].

* 2nd printing, ibid., 1991, 260 pp.

- Many fields of science:

Sivardière, J. (1995) *La Symétrie en mathématiques, physique et en chimie*, [*Symmetry in Mathematics, Physics, and Chemistry*, in French], Collection Grenoble Sciences, Grenoble: Presses Universitaires de Grenoble, 880 pp. [Each of the 48 chapters contains exercises].

- Philosophy of science:

There are some related booklets, but these are shorter than our limit of 50 pages. See, e.g.,

* Zemlyanskii, F. M. (1974) *Struktura i simmetriya: Materialy dlya spetskursa*, [*Structure and Symmetry: Materials for a Special Topic Course*, in Russian], Chelyabinsk [Russia]: Chelyabinskii gosudarstvennyi pedagogicheskii institut [Chelyabinsk State Teacher-Training Institute <College>], 40 pp.

Also see:

* Khakimov (1986) on systems and symmetry → Section 1 2.6

1.1.2 Specific scientific fields (with an outlook to arts)

Herfort, P. and Klotz, A. (1997) *Ornamente und Fraktale: Visualisierung von Symmetrie und Selbstähnlichkeit*, [*Ornaments and Fractals: Visualization of Symmetry and Self-Similarity*, in German], [Series] Vieweg Mathematik für Schüler und Studenten, Wiesbaden: Vieweg, xii + 273 pp., 1 computer disk (IBM PC).

Klemm, M (1982) *Symmetrien von Ornamenten und Kristallen*, [*Symmetries of Ornaments and Crystals*, in German], Hochschultext [University Text], Berlin: Springer, vi + 214 pp.

Roanes Macías, E and Roanes Lozano, E. (1993) *Simulación didáctica de los grupos de simetría en el arte hispano-musulmán*, [*Didactical Simulation of the Groups of Symmetry in the Spanish-Muslim Art*, in Spanish], Madrid: Pablo Montesino and Universidad Complutense, 63 pp., 1 computer disk (5 1/4 in.).

Also see:

* Povileiko (1970) on technology and design → Section 1 2.7,

* MacGillavry on Escher → Section 2 2.3

1.1.3 Arts and design (with an outlook to science)

Huff, W. S. (1967-77) *Symmetry: An Appreciation of its Presence in Man's Consciousness*, Parts 2-6, Designed by T. Gonda, Pittsburgh: [Privately Published], 93 pp. in various pagings. [This series of booklets was distributed in Northern America for those universities that have design programs; Part 1 is not published; the order of publishing: Part 4, 1967; Part 6, 1970; Part 5, 1971; Part 2, 1975; Part 3, 1977].

* Reprint ed., Parts 6, 4, 5, In: *Oppositions*, Nos. 3, 6, 10, New York: The Institute for Architecture and Urban Studies, 1974, 63-78; 1976, 69-83; 1977, 76-99.

Kumagai, S. and Sawada, Y. (1983) *Moyou to shinmetorii*, [*Ornamental Patterns and Symmetry*, in Japanese with tables in English and a bilingual index of terms], Nonoichi-machi, Ishikawa-ken: Kanazawa Kougyou Daigaku Shuppankyoku [Kanazawa Institute of Technology Press], v + 147 pp. [A visual approach to plane symmetry groups, including black-and-white and colored ones; coauthored by a professor of design and a professor of mathematics].

1.1.4 Philosophy (see the Philosophy of science)

1.2 More specialized works of a given field (with some interdisciplinary outlook)

1.2.1 Mathematics

Some works on mathematical education and teaching aids on elementary mathematics are considered, but kept in the subsection 1.2.1.1.

Alsina Catalá, C., Pérez Gómez, R., and Ruiz Garrido, C. (1989) *Simetría dinámica*, [*Dynamic Symmetry*, in Spanish], Matematicas: Cultura y aprendizaje, No. 13, Madrid: Síntesis, 143 pp. [The title refers to geometrical transformations, not to Hambidge's dynamic symmetry, cf., Section 3.4.2.1].

Armstrong, M. A. (1988) *Groups and Symmetry,* Undergraduate Texts in Mathematics, New York: Springer, xi + 186 pp.

Farmer, D. W. (1996) *Groups and Symmetry: A Guide to Discovering Mathematics*, Mathematical World, Vol. 5, Providence, Rhode Island: American Mathematical Society, viii + 102 pp.

Martin, G. E. (1982) *Transformation Geometry: An Introduction to Symmetry*, Undergraduate Texts in Mathematics, New York: Springer, xii + 237 pp.

* 2nd printing, corrected, ibid., 1987.

Morcillo Rubio, J. and García Pérez, V. (1989) *Teoría de grupos y simetría*, [*Theory of Groups and Symmetry*, in Spanish], Madrid: Universidad Nacional de Educación a Distancia, 74 pp.

* Reprint ed., ibid., 1991.

Takahashi, R. (1998) *Taishousei no suugaku: Mon'you no kikagaku to gunron*, [*The Mathematics of Symmetry: Geometry of Patterns and Group Theory*, in Japanese], Tokyo: Housou Daigaku [University of the Air <Broadcasting University>], 163 pp.

Tang, Y. Q. (1979) *Duìchènxìng yuánli: Youxiàn duìchènqúnde biaoxiàn ji qi qúnlùn yuánli*, [*Symmetry Principles: The Representation of Finite Symmetry Groups and Their Group-Theoretic Principles*, in Chinese], Beijing [Peking]: Kexué chuban shè [Science Publishing Company], iii + 284 pp. [Each chapter contains exercises; the English description of the book is available in Mathematical Reviews 1984, cf., 84e:20052].

Also see:

* Graduate textbooks → Section 1.3.

1.2.1.1 Mathematical education, elementary mathematics

Breiteig, T. (1978) *Symmetri og monster i planet*, [*Symmetry and Pattern in the Plane*, in Norwegian], Kristiansand [Norway]: Kristiansand laererhogskole [Kristiansand Teacher-College], 79 pp.

Crowe, D. (1986) *Symmetry, Rigid Motions, and Patterns*, Arlington, Massachusetts: COMAP [Consortium for Mathematics and its Applications], viii + 36 [+ 20] pp.

* Abbreviated version, The UMAP Journal, 3 (1987), 207-236.

Dienes, Z P. and Mezard, S. (1971) *Logica, insiemi e simmetria*, [*Logic, Sets and Symmetry*, in Italian], Paris: O.C.D.L., 63 pp.

Fey, J. T. and Lappan, G. (1997) *Kaleidoscopes, Hubcaps and Mirrors: Symmetry and Transformations*, Ed. by C. Anderson, White Plains, New York: Seymour Publications, 209 pp.

Kufner, A. (1982) *Symetrické funkce*, [*Symmetric Functions*, in Czech], Skola mladych matematiku [Series: School of Young Mathematicians], Praha [Prague]: Mlada frontá, 116 pp.

Rossevatn, K. M. (1998) *Dynamisk geometri i undervisning: Symmetri og rotasjon*, [*Dynamic Geometry in Teaching: Symmetry and Rotation*, in Norwegian], Kristiansand [Norway]: Institutt for matematiske fag, Hogskolen i Agder [Institute for the Mathematical Subject, College in Agder], 127 pp.

Rull Perez, F. (1987) *Estudio de las propiedades de simetría de los bordados y encajes en la región de Castilla y Leon*, [*Study of the Symmetry-Properties of the Embroideries and Laces in the Region of Castilla and Leon*, in Spanish], Valladolid: Instituto de Ciencias de la Educacion, Universidad de Valladolid, 80 pp.

Walser, H. (1998) *Symmetrie*, [*Symmetry*, in German], [Series] Einblicke in die Wissenschaft: Mathematik, Leipzig: Teubner, 106 pp.

There are many related booklets which are shorter than our limit of 50 pages. Illustrating the broad international interest in symmetry, we refer here to two items that was published in Fiji, a South Pacific island

country (population ca. 750,000), and Kiribati, a country of tropical islands and atolls (population ca. 70,000), respectively:

* *Symmetry*, Pupils' Pamphlet A18, [Suva, Fiji]: University of the South Pacific, 30 pp.

* *Symmetry*, Class 6, [Tarawa, Kiribati]: USP [University of the South Pacific] Kiribati Project, 28 pp.

1.2.2 Crystallography

Alvarez Pérez, A. and Briansó, J. L. (1983) *Los Sistemas crístalográficos y su simetría*, [*Crystallographic Systems and Their Symmetry*, in Spanish], Ballaterra: Universitat Autónoma de Barcelona.

Arenas Rosado, J. F. and Fernández Gómez, M. (1979) *Apuntes de teoría de grupos y simetría*, [*Lectures Notes on Theory of Groups and Symmetry*, in Spanish], Granada: Universidad, Facultad de Ciencias, Departamento de Química-Física, 518 leaves.

Bojarski, Z., Habla, H., and Surowiec, M. (1976) *Materialy do cwiczen z krystalografii*, [*Materials for Exercises in Crystallography*, in Polish],

* Zeszyt 3: *Symetria w morfologii kryształów, grupy punktowe*, [Booklet 3: *Symmetry in the Morphology of Crystals, Point Groups*, in Polish],

* Zeszyt 4: *Symetria w budowie wewnetrznej cial krystalicznych, grupy przestrzenne*, [*Symmetry in the Internal Structure of Crystalline Materials, Space Groups*, in Polish], Katowice [Poland]: Uniwersytet Slaski [University of Silesia], 48 + 51 pp. [The subtitles of Booklets 1, 2, and 5 do not refer to symmetry].

* Cf., Bojarski, Z., Habla, H., and Surowiec, M., *Materialy do nauki krystalografii*, [*Materials for the Science of Crystallography*, in Polish], Ed. by Z. Bojarski, Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 1986, 287 pp. [Some of the earlier materials are integrated here].

Dubov, P. L., Frank-Kamenetskii, V. A., and Shafranovskii, I. I. (1984-87)

* [1] *Klassicheskaya simmetriya*, [*Classical Symmetry*, in Russian],

* [2] *Obobshchennaya simmetriya*, [*Generalized Symmetry*, in Russian],

* [3] *Antisimmetriya*, [*Antisymmetry* <Black-and-White Symmetry>, in Russian],

* [4] *Tablitsy dlya samostoyatel'nykh zanyatii studentov pri izuchenii simmetrii kristallov: Fedorovskie gruppy kubicheskoi singonii*, [*Tables for Individual Work of Students for the Study of Symmetry of Crystals: Fedorov Groups* <Space Groups> of the Cubic System, in Russian],

Leningrad [now Sankt-Peterburg]: Leningradskii gosudarstvennyi universitet [Leningrad <St. Petersburg> State University], 85 + 73 + 78 + 34 pp. [In the case of [1] the order of authors is different: Frank-Kamenetskii, Dubov, Shafranovskii].

Hahn, T., ed. (1985) *International Tables for Crystallography*, Brief Teaching Edition of Vol. A: Space-Group Symmetry, Dordrecht [The Netherlands]: Reidel, viii + 119 pp.

* 2nd revised ed., ibid., 1988, viii + 119 pp.

* 3rd enlarged ed., Dordrecht [The Netherlands]: Kluwer, 1993, viii + 152 pp.

Harsch, G. and Schmidt, R. (1981) *Kristallgeometrie: Packungen und Symmetrie in Stereodarstellung*, [*Crystal-Geometry: Packings and Symmetry in Stereo-Representation*, in German], Arbeitsbücher Chemie, Frankfurt am Main: Diesterweg and Aarau [Switzerland]: Sauerländer, 120 pp.

Loub, J. (1987) *Krystalová struktura, symetrie a rentgenová difrakce: Urceno pro posluchace fakulty prirodovedecke*, [*Crystal Structure, Symmetry and X-Ray Diffraction: Intended for Students of the Faculty of Natural Science* <Faculty of Science>, in Czech], Praha [Prague]: Státní pedagogicke nakladatelství (SPN), 142 pp. [Published for Charles University].

Nedoma, J. (1984) *Elementy symetrii: Grupy punktowe*, [*Elements of Symmetry: Point-Groups*, in Polish], Kraków [Cracow]: Akademia Górniczo-Hutnicza [Academy <College> of Mining and Metallurgy], 198 pp.

Planelles Fuster, J. (1996) *Teoria de grups de simetria*, [*Theory of Groups of Symmetry*, in Catalan], Castelló [Castellón de la Plana]: Publicacions de la Universitat Jaume I, 162 pp.

Trzaska Durski, Z. (1983) *Symetria w krystalografii*, [*Symmetry in Crystallography*, in Polish], Warszawa: Wydawnictwo Politechniki Warszawskiej [Publishing House of the Warsaw Polytechnics <Warsaw University of Technology>], 165 pp.

1.2.3 Physics (other than crystallography)

Abiko, S. and Koide, S. (1987) *Butsurigaku: Enerugii, taishousei, entoropii*, [*Physics: Energy, Symmetry, Entropy*, in Japanese], Tokyo: Toukyou Kyougakusha, xii + 417 pp.

Schottenloher, M. (1993) *Geometrie und Symmetrie in der Physik: Leitmotiv der mathematischen Physik*, [*Geometry and Symmetry in Physics: Leitmotiv of Mathematical Physics*, in German], Vieweg-Lehrbuch mathematischen Physik, Wiesbaden: Vieweg, xxii + 408 pp.

Also see·

* Engineering, technology → Section 1.2.7,

* Graduate textbooks → Section 1.3

1.2.4 Chemistry (other than crystallography)

Borsdorf, R., Dietz, F., Leonhardt, G., and Reinhold, J. (1975) *Einführung in die Molekülsymmetrie: Ein Lehrprogramm für Hochschulen, Chemie Programm*, [*Introduction to Molecular Symmetry: A Course-Program for Universities, Chemistry Program*, in German], Taschentext, Weinheim [Germany]: VCH and Physik Verlag, 112 pp.

Dorain, P. B. (1965) *Symmetry in Inorganic Chemistry*, Reading, Massachusetts: Addison-Wesley, vi + 122 pp.

- Polish trans., *Symetria w chemii nieorganicznej*, Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 1968.

- Japanese trans., *Muki kagaku nyuumon: Taishousei to kouzou*, [*Introduction to Inorganic Chemistry: Symmetry and Structure*, in Japanese], Tokyo: Baifuukan, 1970, 183 pp.

- German trans., *Symmetrie und anorganische Strukturchemie: Lehrbuch für Chemiker, Physiker, Physikochemiker und Kristallographen ab 3. Semester*, [*Symmetry in Inorganic Structure-Chemistry: Textbook for Chemists, Physicists, Physico-Chemists and Crystallographers from the Third Semester*, in German], [Series] Uni-Text / Lehrprogram, Wiesbaden: Vieweg, 1972, 146 pp.

Fiser, J. (1976) *Uvod do molekulové symetrie: Urceno pro posluchace fakulty prirodovedecke*, [*Introduction to Molecular Symmetry: Intended for Students of the Faculty of Natural Science* <Faculty of Science>, in Czech], Praha [Prague]: Státní pedagogicke nakladatelství (SPN), 197 pp.

Fiser, J. (1980) *Uvod do molekulové symetrie: Aplikace teorie grup v chemii*, [*Introduction to Molecular Symmetry: Application of Theory of Group in Chemistry*, in Czech], Praha [Prague]: Státní nakladatelství technické literatury (SNTL), 287 pp.

Grodzicki, A. (1977) *Symetria czasteczek a ich widma oscylacyjne: Materialy do cwiczen ze spektroskopii molekularnej*, [*Symmetry of Particles and Their Vibrational Spectra: Materials for Exercises in Molecular Spectroscopy*, in Polish], Torun [Poland]: Uniwersytet Mikolaja Kopernika [Nicolas Copernicus University], 72 pp.

Grodzicki, A. (1988) *Symetria czasteczek a ich widma oscylacyjne: Skrypt dla studentów chemii, fizyki i biologii uniwersytetów*, [*Symmetry of Molecules and Their Vibrational Spectra: Lecture-Notes for Students of Chemistry, Physics, and Biology of Universtities*, in Polish], Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 87 pp.

Hollas, J. M. (1972) *Symmetry in Molecules*, Chapman and Hall Chemistry Textbook Series, London: Chapman and Hall, x + 218 pp.

- German trans., revised, *Symmetrie von Molekülen: Eine Einführung in die Anwendung von Symmetriebetrachtungen in der Chemie*, [*Symmetry in Molecules: An Introduction to the Application of Symmetry-Considerations in Chemistry*, in German], de Gruyter Lehrbuch, Berlin: de Gruyter, 1975, 232 pp.

Jaffé, H. H. and Orchin, M. (1965) *Symmetry in Chemistry*, New York: Wiley, x + 191 pp.

* Reprint ed., Huntington, New York: Krieger, 1977, x + 193 pp.

- Japanese trans., *Gunron nyuumon: Kagaku ni okeru taishou*, [*Introduction to Group Theory: Symmetry in Chemistry*, in Japanese], Tokyo: Toukyou Kagaku Doujin, 1966, 191 pp.

* Japanese reprint eds , ibid., 191 pp.

- Spanish trans., *Simetría en química*, Madrid: Alhambra, 1967, xi + 208 pp.

- German trans., *Symmetrie in der Chemie: Anwendung der Gruppentheorie auf chemische Probleme*, [*Symmetry in Chemistry: The Application of Group Theory for Chemical Problems*, in German], Heidelberg: Hüthig and Stuttgart. UTB (Uni-Taschenbucher), 1973, 186 pp.

- Russian trans., Dzhaffe, G. and Orchin, M., *Simmetriya v khimii*, Moskva: Mir, 1976.

Kettle, S. F. A. (1985) *Symmetry and Structure*, Chichester [England]: Wiley, x + 330 pp

* Paperback ed., ibid., 1989.

* Reprint ed., corrected, ibid., 1992.

* 2nd ed., *Symmetry and Structure: Readable Group Theory for Chemists*, Chichester [England]: Wiley, 1995, xii + 416 pp.

- German trans. of the 1st corrected ed., *Symmetrie und Struktur: Eine Einführung in die Gruppentheorie*, [*Symmetry and Structure: An Introduction to Group Theory*, in German], [Series] Teubner Studienbücher: Chemie, Stuttgart: Teubner, 1994, 393 pp.

Klasinc, L., Maksic, Z., and Trinajstic, N. (1979) *Simetrija molekula*, [*Symmetry of Molecules*, in Serbo-Croatian], Zagreb: Skolska knjiga, viii + 131 pp.

Kober, F. (1983) *Symmetrie der Moleküle*, [*Symmetry of Molecules*, in German], Studienbücher Chemie, Frankfurt am Main: Diesterweg and Aarau [Switzerland]: Sauerländer, vi + 217 pp.

Kuzma, M. (1991) *Symetria polimerów: Wlasnosci fizyczne*, [*Symmetry of Polymers: Physical Properties*, in Polish], Rzeszów: Wyzsza Szkola Pedagogiczna w Rzeszówie [Teacher-Training College in Rzeszów], 224 pp.

Nakazaki, M. (1969) *Bunshi no katachi to taishou: Sono hyouji hou*, [*Form and Symmetry of Molecules: Their Representation Rules*, in Japanese], Tokyo: Nankoudou, vi + 278 pp.

* Reprint ed., ibid., 1973, vi + 278 pp.

Nakazaki, M. (1973) *Bunshi no taishou to gunron*, [*Symmetry of Molecules and Group Theory*, in Japanese], Tokyo: Toukyou Kagaku Doujin, vi + 260 pp.

* Reprint eds., ibid., vi + 260 pp.

Nakazaki, M. (1975) *Ritai kagaku 1: Taishou o chuushin ni*, [*Stereochemistry 1: Symmetry in the Focus*, in Japanese], Tokyo: Toukyou Kagaku Doujin, vi + 346 pp.

Nakazaki, M. (1976) *Kagaku to taishousei: Gunron nyuumon*, [*Chemistry and Symmetry: Introduction to Group Theory*, in Japanese], Tokyo: Nankoudou, vi + 220 pp.

Papulov, Yu. G. (1979) *Simmetriya molekul: Uchebnoe posobie*, [*Symmetry of Molecules: A Textbook*, in Russian], Kalinin [now Tver', Russia]: Kalininskii gosudarstvennyi universitet [Kalinin <Tver> State University], 84 pp.

Papulov, Yu. G. (1988) *Simmetriya v khimii*, [*Symmetry in Chemistry*, in Russian], Kalinin [now Tver', Russia]: Kalininskii gosudarstvennyi universitet [Kalinin <Tver> State University], 83 pp.

Vincent, A. (1977) *Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications*, London: Wiley, 156 pp.

- Hungarian trans., *Molekuláris szimmetria és csoportelmélet: Programozott bevezetés a kémiai alkalmazásokba*, Budapest: Tankönyvkiadó, 1987, 183 pp.

Wolff, R. and Kober, F. (1977) *Symmetrie und Gruppentheorie in der Chemie*, [*Symmetry and Group Theory in Chemistry*, in German], Der Chemieunterricht [Chemistry Education], Jahrgang 8, Heft 1, Stuttgart: Klett, 83 pp.

Zorkii, P. M. (1986) *Simmetriya molekul i kristallicheskikh struktur*, [*Symmetry of Molecules and Crystalline Structures*, in Russian], Moskva: Izdatel'stvo Moskovskogo gosudarstvennogo universiteta [Publishing House of Moscow State University], 231 pp.

Zorkii, P. M. and Afonina, N. N. (1979) *Simmetriya molekul i kristallov*, [*Symmetry of Molecules and Crystals*, in Russian], Moskva: Izdatel'stvo Moskovskogo gosudarstvennogo universiteta [Publishing House of Moscow State University], 176 pp.

Note. Dorain (1965), Jaffé and Orchin (1965), and Kettle (1985), see above, were not published originally as textbooks. However, their German translations are in series of university textbooks.

1.2.4.1 Chemical reactions (orbital theory)

There are some guides, programmed texts, and problem books on orbital symmetry, which is useful to predict and explain certain types of reactions in inoragnic chemistry. However, this topic is more specialized and we keep all of the related books together in Section 3.2.1.2.

See there especially, Bellamy (1974), Entwistle (1972), Gilchrist and Storr (1972), Lehr and Marchand (1972), Orchin and Jaffé (1971b), and Sunjic (1979).

1.2.5 Biology

Hámori, J. (1996) *Agyi aszimmetriák*, [*Brain Asymmetries*, in Hungarian], Pécs [Hungary]: Janus Pannonius Tudományegyetem [Janus Pannonius University], 152 pp.

Also

* Grodzicki (1988) on spectroscopy → Section 1.2.4.

* Khakimov (1986) on symmetry in nature → Section 1.2.6.

1.2.6 Earth sciences

Khakimov, E. M. (1986) *Sistemno-simmetriinyi analiz ob'ektov prirody* (Posobie po spetskursu), [*Systemo-Symmetric Analysis of Objects of Nature* (Textbook for a Special Topic Course), in Russian], Kazan' [Russia]: Chelyabinskii gosudarstvennyi pedagogicheskii institut [Chelyabinsk State Teacher-Training Institute <College>], 95 pp. [Published for students of geologo-geographical disciplines, also recommended for students of biology and chemistry (cf., preface, p. 4), and those who are interested in the philosophical questions of science (cf., annotation, p. 2)].

1.2.7 Engineering, technology

Aksan, M. (1969) *Ucus dinamigi: Simetrik hareketler*, [*Aerodynamics: Symmetric Movements*, in Turkish], Istanbul Teknik Üniversitesi Kütüphanesi Sayi 777 [Istanbul Technical University's Library <Series of Books> No. 777], Istanbul: Istanbul Teknik Üniversitesi, 127 pp.

Grigorovskii, B. K. (1982) *Printsip simmetrii v zadachakh izmeritel'noi tekhniki* (Uchebnoe posobie), [*Symmetry Principle in Exercises of Measuring Technique* (Textbook), in Russian], Kuibyshev [Russia]: Aviatsionnyi institut [Aviation Institute <College>], 94 pp.

Povileiko, R. P. (1970) *Simmetriya v tekhnike* (Eksperimental'naya lektsiya dlya studentov konstruktorskikh spetsial'nostei mashinostroitel'nykh i priborostroitel'nykh fakul'tetov Novosibirskogo èlektrotekhnicheskogo instituta), [*Symmetry in Technology* (Experimental Lecture for Students Specialized in Design at the Faculties of Machine-Building and Instrument-Making of the Novosibirsk Institute <College> of Electrotechnology <Electrical Engineering>), in Russian], Novosibirsk [Russia]: Novosibirskii èlektrotekhnicheskii institut, 129 pp.

1.2.8 Arts and the Humanities

Goncharenko, S. S. (1993) *Zerkal'naya simmetriya v muzyke: Na materiale tvorchestva kompozitorov XIX i pervoi poloviny XX veka*, [*Mirror Symmetry in Music: On the Material of Works by Composers of the 19th and the First Half of the 20th century*, in Russian], Novosibirsk: Novosibirskaya gosudarstvennaya konservatoriya im. M. I. Glinki [Novosibirsk M. I. Glinka State Conservatoire <Conservatory named after M. I. Glinka>], 231 pp.

Markova, O. B. (1996) *Simmetricheskie kompozitsii liricheskogo stikhotvoreniya*, [*Symmetrical Compositions of Lyrical Poems*, in Russian], Almaty [Kazakhstan]: Zhibek Zholy, 94 pp. [Added note: A teaching aid for philological faculties of higher educational institutions].

1.3 Graduate textbooks: Mathematics and/or physics

Altarelli, G. (1969) *Symmetry Groups and Current Algebra*, Lectures delivered by G. Altarelli, Notes compiled by R. Garcia, H. Moreno, and E. Hinojosa, Mexico City: Centro de investigacion y estudios avanzados del Instituto politechnico nacional, iii + 157 pp.

Fuchs, J. (1997) *Symmetries, Lie Algebras and Representations: A Graduate Course for Physicists*, Cambridge Monographs on Mathematical Physics, Cambridge [England]: Cambridge University Press, xxi + 438 pp.

Joshua, S. J. (1991) *Symmetry Principles and Magnetic Symmetry in Solid State Physics*, Graduate Student Series in Physics, Bristol: Hilger, xii + 270 pp.

* Paparback ed., ibid.

Marsden, J E. and Ratiu, T. (1994) *Introduction to Mechanics and Symmetry: A Basic Exposition of Classical Mechanical Systems*, Texts in Applied Mathematics, Vol. 17, New York: Springer, xiv + 500 pp.

Sailer, K. (1994) *Szimmetriák sértése a kvantumelméletben: Speciális előadások*, [*Breaking of Symmetries in Quantum Theory: Special-Topic Lectures*, in Hungarian], Debrecen [Hungary]: Kossuth Lajos Tudományegyetem [Kossuth Lajos University], 170 pp.

Zamorzaev, A. M. and Palistrant, A. F. (1977) *Teoriya diskretnykh grupp simmetrii: Lektsii po spetskursu*, [*Theory of Discrete Symmetry Groups: Lectures for a Special Topic Course*, in Russian], Kishinev [Moldavskoi SSR, now Moldova]: Kishinevskii gosudarstvennyi universitet [Kishinev State University], 101 pp. [Mathematics, Mathematical Crystallography].

2 INTERDISCIPLINARY MONOGRAPHS AND POPULAR-SCIENTIFIC BOOKS

2.1 General works with systematic surveys

2.1.1 Pioneering works published until 1952 (when three books appeared independently by Jaskowski, Weyl, and Wolf and Kuhn)

These books have significant historic importance. In addition to these, all of them have materials that are still current. Students may survey them in seminar reports.

Jaeger, F. M. (1917) *Lectures on the Principle of Symmetry and its Applications in All Natural Sciences*, Amsterdam: Elsevier, xii + 333 pp.

* 2nd enlarged ed., ibid., 1920, xii + 348 pp.

- French trans., *Le Principe de symétrie et ses applications*, Paris: Gauthier-Villars, 1925, xv + 420 pp.

Jaskowski, S. (1952) *O symetrii w zdobnictwie i przyrodzie*, [*On Symmetry in Decorative Art and Nature*, in Polish], Warszawa: Panstwowe Zaklady Wydawnictw Szkolnych, 168 pp.

Niggli, P. (1941) *Von der Symmetrie und von den Baugesetzen der Kristalle*, [*On Symmetry and on the Building-Laws of Crystals*, in German], Die Gestalt, Heft 4, Leipzig: Akademische Verlagsgesellschaft, 64 pp.

Nicolle, J. (1950) *La Symétrie et ses applications*, [*Symmetry and its Applications*, in French], [With a preface by L. de Broglie], Paris: Michel, 182 pp.

- German trans., *Die Symmetrie und ihre Anwendungen*, Berlin: Deutscher Verlag der Wissenschaften, 1954, 172 pp.

Shubnikov, A. V. (1940) *Simmetriya (Zakony simmetrii i ih primenenie v nauke, tekhnike i prikladnom iskusstve)*, [*Symmetry (The Laws of Symmetry and Their Application in Science, Technology, and Applied Art)*, in Russian], Moskva: Izdatel'stvo Akademii Nauk SSSR, 176 pp. [Cf., Shubnikov and Koptsik (1972) in Section 2.1.2, which is published as the 2nd enlarged ed. of this; however, the volume of that book is about twice larger than this one, and thus we suggest to consider it as a separate item].

Vul'f [Wulff], G. V. (1908) *Simmetriya i ee proyavleniya v prirode*, [*Symmetry and its Manifestations in Nature*, in Russian], Moskva: Sytin, 134 pp.

* 2nd ed., Moskva: Izdatel'skii otdel narodnogo komissariata prosveshcheniya, 1919, 135 pp.

* Reprint ed., In: Vulf, Yu. [sic] V., *Izbrannye raboty po kristallofizike i kristallografii*, [*Selected Works on Crystalphysics and Crystallography*, in Russian], Moskva: Gosudarstvennoe izdatel'stvo tekhniko-teoreticheskoi literatury, 1952, 242-320. [Note that the author's first name was used in two different versions: Georgii and Yurii].

Weyl, H. (1952) *Symmetry*, Princeton, New Jersey: Princeton University Press, 168 pp [Based on a series of lectures given for a broad audience].

* Reprint and paperback eds., ibid., 168 pp.

- German trans. [authorized by Weyl], *Symmetrie*, [Series] Wissenschaft und Kultur, Band 11, [With a new preface by Weyl], Basel: Birkhäuser, 1955, 157 pp.

* German trans., 2nd ed., ibid., 1981, 157 pp.

- Japanese trans , *Shinmetorii: Bi to seimei no bunpou*, [*Symmetry: The Grammar of Beauty and Life*, in Japanese], Tokyo: Kinokuniya Shoten, 1957, ii + 165 pp. [With a commentary by H. Touyama, pp. 159-165].

* Japanese reprint ed , *Shinmetorii*, ibid., 1970, ii + 165 pp. [The earlier subtitle is not used; H. Touyama's commentary is revised, pp. 159-165]

* Japanese reprint eds. of the latter, ibid.

- Spanish trans., *La Simetría*, [Series] Colección Interciencia, 5, Buenos Aires: Nueva Vision, 1958, 132 pp.

* Spanish trans., other version, *La Simetría*, Barcelona: Promoción Cultural, 1974. [With an introduction by E. Bonet].

* Spanish trans., other version, *Simetría*, Madrid: McGraw-Hill, 1990, x + 130 pp.

- Polish trans., *Symetria*, Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 1960, 202 pp.

* Polish trans., 2nd corrected ed., *Symetria*, Klasycy Nauki [Series: Classics of Science], Warszawa: Prószynski i S-ka, 1997, 157 pp.

- Italian trans., *La simmetria*, Milano: Feltrinelli, 1962, 175 pp.

* Italian trans., 2nd ed., ibid., 1981, 173 pp.

- French trans., *Symétrie et mathématique moderne*, [*Symmetry and Modern Mathematics*, in French], Paris: Flammarion, 1964, 151 pp.

* French reprint eds., ibid.

- Rumanian trans., *Simetria*, Bucuresti: Editura Stiintifica, 1966, 184 pp.

- Russian trans., Veil', G., *Simmetriya*, Ed. by B. A. Rozenfel'd, Moskva: Nauka, 1968, 190 pp. [With a commentary by the editor, pp. 168-173, and two additonal articles in Russian: "Weyl and the concept of symmetry" by I. M. Yaglom [IAglom], pp. 5-32, and "Weyl and the metodological problems of science" by B. V. Biryukov, pp. 174-190; the cover design is based on M. C. Escher's Lizards].

- Bulgarian trans., Vail, Kh., *Simetriya*, Sofiya [Sofia]: Nauka i izkustvo, 1969, 215 pp. [Translated from English; additional materials translated from the Russian ed.: a part of the commentary, pp 167-169, and I. M. Yaglom's article, pp. 170-215].

- Hungarian trans., *Szimmetria*, Budapest: Gondolat, 1982, 226 pp. [With additonal articles by T. Nagy (physics), J. Kiss (biology), S. Bérczi (phyllotaxis, polyhedra), respectively].

- Chinese trans., *Duìchèn*, Beijing [Peking]: Shangwù, 1986, 116 pp.

* Chinese trans., other version, *Duìchèn: Meide kexué chanshù*, [*Symmetry: Explaining the Beauty of Science*, in Chinese], Táibei [Taipei, Taiwan]: Zhèngzhong, 1988, 151 pp.

* Chinese trans., other version, *Duìchènxìng*, Shanghai: Shanghai fanyì chuban gongsi, 1991, vi + 156 pp.

- Greek trans., *Summetría*, Athêna [Athens]: Trohalía, 1991, 188 pp.

Wolf, K. L. and Kuhn, D. (1952) *Gestalt und Symmetrie: Eine Systematik der symmetrischen Körper*, [*Gestalt and Symmetry: A Systematic Presentation of Symmetric Bodies*, in German], Tübingen: Niemeyer, 64 pp.

- Spanish trans., *Forma y simetría: Una sistemática de los cuerpos simétricos*, Buenos Aires: Editorial Universitaria de Buenos Aires, 1977, 55 pp.

Also see the following pre-1952 books:

* Shepard (1948) on pattern analysis → Section 2.2.2,
* Plehn (1911) on colored patterns → Section 2.2.3,
* Veen (1911) on the diamond → Section 3.2.2,
* Danver (1942) on astronomy → Section 3.2.4,
* Jocobsohn-Lask (1924) on biology → Section 3 3 1,
* Hay (1846) on basic design → Section 3.4.2,
* Schröder (1902) and Werker (1922) on music → Section 3 4.4,
* Anderson (1897) on physical education → Section 3.5,
* Gauze (1940) on asymmetry of the protoplasm → Section 4 2,
* Lautman (1946) on mathematical and physical symmetry and dissymetry → Section 4.3.

Also see the modern editions of classical works:

* Fedorov (1949), Fedorov (1971) on symmetry groups (collections of late 19th century works in Russian and in English, respectively) → Section 3.2 2,
* García, S. (1681/1991) on architecture → Section 3 4 2,
* Tímár (1979) on Durer's book on human proportions → Section 3 4 3.

2 1.2 Works published after 1952

Alsina i Català, C. [Alsina Catalá, C.] and Fortuny, J. M. (1988) *Fascinant simetria*, [*Fascinating Symmetry*, in Catalan], Barcelona: Fundació Caixa de Pensions, 71 pp. [Published for an exhibition at the Museu de la Ciència (Science Museum) in Barcelona].

- Spanish trans., *Fascinante simetría*, [*Fascinating Symmetry*, in Spanish], Barcelona: Fundación Caja de Pensiones, 1990, 71 pp

Genz, H. (1987) *Symmetrie - Bauplan der Natur*, [*Symmetry: Blueprint of Nature*, in German], München: Piper, 464 pp.

* 2nd revised ed., ibid., 1992, 464 pp.

Hahn, W. (1989) *Symmetrie als Entwicklungsprinzip in Natur und Kunst*, [in German with an English summary], [With a preface by R Riedl], Königstein [Germany]: Langewiesche, 320 pp. [Very many illustrations, including some color plates].

- English trans., enlarged, *Symmetry as a Developmental Principle in Nature and Art*, Singapore: World Scientific, 1998, xxi + 510 pp.

Hargittai, I. (1983) *Szimmetria egy kémikus szemével*, [in Hungarian], Budapest: Akadémiai Kiadó, 292 pp.

- English trans., enlarged, co-author Hargittai, M., *Symmetry through the Eyes of a Chemist*, Weinheim [Germany]: VCH, 1986, xii + 458 pp.

* English paperback ed., New York: VCH, 1987.

* English trans., 2nd ed , New York: Plenum Press, 1995, xii + 469 pp.

- Russian trans. of the first English ed., *Simmetriya glazami khimika*, Moscow: Mir, 1989, 494 pp.

Hargittai, I. and Hargittai, M. (1994) *Symmetry: A Unifying Concept*, Bolinas, California: Shelter Publications, xviii + 222 pp. [Many photographic illustrations].

* Reprint ed., ibid., 1996, xviii + 222 pp.

- German trans. *Symmetrie. Eine neue Art die Welt zu Sehen*, [*Symmetry: A New Way to See the World*, in German], Rowohlt Taschenbuch, 1998.

Hargittai, M. and Hargittai, I. (1989) *Fedezzuk föl a szimmetriát!*, [*Discover Symmetry!*, in Hungarian], Budapest: Tankönyvkiadó, 148 pp. [Popular-scientific, also for children].

- Swedish trans., *Upptack symmetri!*, Stockholm: Natur och Kultur, 1998, 144 pp.

Heilbronner, E. and Dunitz, J. (1992) *Reflections on Symmetry*: In Chemistry ... and Elsewhere, Weinheim [Germany]: VCH and Basel: Helvetica Chimica Acta, vi + 154 pp.

Lisicky, M. (1980) *Zivá symetria*, [*Living Symmetry*, in Slovakian], Bratislava [Czechoslovakia, now Slovakia]: Mladé letá [Popular-scientific, for children].

Mainzer, K. (1988) *Symmetrien der Natur Ein Handbuch zur Natur- und Wissenschaftsphilosophie*, Berlin: de Gruyter, xii + 739 pp.

- English trans., *Symmetries of Nature A Handbook for Philosophy of Nature and Science*, Berlin: de Gruyter, xiii + 681 pp.

Morita, M. (1980) *Taishousei genri: Busshitsu to uchuu o shihaisuru migi to hidari*, [*Symmetry Theory: Matter and Universe Ruled by Right and Left*, in Japanese], [Series] Blue Backs / Buruu bakkusu, B-420, Tokyo: Koudansha, 228 pp. [Popular-scientific].

Merle, P. (1955) *L'Homme, le rythme et la symétrie*, [*The Human, the Rhythm and the Symmetry*, in French], Paris: Expansion scientifique française, 254 pp.

Nicolle, J. (1955) *La Symétrie dans la nature et les travaux des hommes*, [*Symmetry in Nature and the Works of Humans*, in French], [With a preface by L. de Broglie], Paris: La Colombe, 136 pp.

Nicolle, J. (1957) *La Symétrie*, [*Symmetry*, in French], Que sais-je?, Le Point des connasissances actuelles, No. 743, Paris: Presses Universitaires de France, 116 pp.

* 2nd ed., ibid., 1965, 128 pp [Popular-scientific].

- Spanish trans., Simetría, Buenos Aires: Fabril.

Rohde, G M. (1982) *Simetria· generalidades sôbre simetria, geociências, biociências, ciências exatas, tecnologias e artes, filosofia*, [*Symmetry: Generalities Concerning Symmetry - Geosciences, Biosciences, Exact Sciences, Technics and Arts, Philosophy*, in Portuguese], Sao Paulo· Hemus, 191 pp.

Roman, T. (1963) *Simetria - prezentare matematica a unor fenomene din natura si arta*, [*Symmetry - Presenting the Mathematics of Certain Phenomena in Nature and Art*, in Rumanian], Bucuresti: Technica, 254 pp

Rosen, J. (1975) *Symmetry Discovered: Concepts and Applications in Nature and Science*, Cambridge [England]: Cambridge University Press, xi + 138 pp.

* Reprint ed., corrected, Mineola, New York: Dover, 1998, xiv + 152 pp.

- Japanese trans., *Shinmetorii o motomete*, Tokyo: Kinokuniya Shoten, 1977, 182 pp.

Rosen, J. (1983) *Symmetry Primer for Scientists*, New York: Wiley, xiv + 192 pp.

Rosen, J. (1995) *Symmetry in Science: An Introduction to the General Theory*, New York: Springer, xv + 213 pp.

Shafranovskii, I. I. (1968) *Simmetriya v prirode*, [*Symmetry in Nature*, in Russian], Leningrad [now Sankt-Peterburg]: Nedra, 184 pp.

* 2nd revised ed., ibid., 1985, 167 pp.

Sheikov, N. (1977) *Zhivot i simetriya*, [*Life and symmetry*, in Bulgarian], [Series] Biblioteka radar, Sofiya [Sofia]: Narodna mladezh, 169 pp.

* 2nd ed., ibid., 1986, 160 pp. [Popular-scientific].

- German trans., abridged and revised, Scheikov, N., *Leben und Symmetrie*, [Series] Akzent, Leipzig: Urania, 1982, 128 pp.

- Hungarian trans. of the German version, Sejkov, N., *Élet és szimmetria*, [Series] Gondolat zsebkönyvek, Budapest: Gondolat, 1987, 127 pp.

Shubnikov, A. V. and Koptsik, V. A. (1972) *Simmetriya v nauke i iskusstve*, [in Russian], Moskva: Nauka, 339 pp. [Cf., Shubnikov (1940) in 2.1.1 and the note there].

- English trans., *Symmetry in Science and Art*, New York: Plenum Press, 1974, xxv + 420 pp.

Stewart, I. and Golubitsky, M. (1992) *Fearful Symmetry: Is God a Geometer?*, Oxford: Blackwell, xix + 287 pp. [The main title of the book is a quote from W. Blake's poem *The Tyger* (1794); cf., Zee (1986) in Section 3.2.1, Reader and Croze (1977) in Section 3.3.1].

- German trans., *Denkt Gott Symmetrisch?: Das Ebenmass in Mathmematik und Natur*, [*Does God Think Symmetrically: Symmetry in Mathematics and Nature*, in German], Basel: Birkhäuser, 1993, 302 pp.

- Italian trans., *Terribili simmetrie: Dio e un geometra?*, [*Terrible Symmetries· Is God a Geometer?*, in Italian], Torino: Bollati Boringhieri, 1995, 341 pp.

- Japanese trans., *Taishousei no yabure ga sekai o tsukuru: Kami wa kikagaku o aishita ka*, [*The Breaking of Symmetry Creates the World: Does God Love Geometry?*, in Japanese], Tokyo: Hakuyousha, 1995, 346 pp.

- Spanish trans., *¿Es Dios un geómetra? Las simetrías de la naturaleza*, [*Is God a Geometer? The Symmetries of Nature*, in Spanish], Barceolona: Crítica, 1995, 311 pp

Tarasov, L. V. (1982) *Étot udivitel'no simmetrichnyi mir: Posobie dlya uchashchikhsya*, [*This Amazingly Symmetric World: Book for Pupils*, in Russian], Moskva: Prosveshchenie, 176 pp. [Popular-scientific].

- English trans., *This Amazingly Symmetric World*, Moscow: Mir, 1986, 164 pp

- German trans., Tarassow, L., *Symmetrie, Symmetrie!: Strukturprinzipien in Natur und Technik*, [*Symmetry, Symmetry!: Structure-Principles in Nature and Technology*, in German], Heidelberg: Spektrum, 1993, 235 pp.

Wade, D. (1993) *Crystal and Dragon: The Cosmic Dance of Symmetry and Chaos in Nature, Art and Consciousness*, Rochester, Vermont: Destiny Books, 287 pp.

* British version [with no reference to symmetry], *Crystal and Dragon: The Cosmic Two-Step*, Bideford [England]: Green Books, 1991, 287 pp.

Wolf, K. L. and Wolff, R. (1956) *Symmetrie: Versuch einer Anweisung zu gestalthaftem Sehen und sinnvollem Gestalten, systematisch dargestellt und an zahlreichen Beispielen erläutert*, 1. Textband, 2. Tafelband, [*Symmetry: An Attempt towards an Instruction in Seeing Gestalt and Meaningfully Creating Gestalt, Systematically Described and with Numerous Examples Explained*, 1. Text-Volume, 2. Plate-Volume, in German], Munster: Böhlau, viii + 139 and vi + 192 pp.

2.2 Works on pattern creation and pattern analysis

2.2.1 Pattern creation

Binkley, T. (1992) *Symmetry Studio: Computer-Aided Surface Design*, [Software created by T. Binkley and J. F. Simon, Jr], New York· Van Nostrand Reinhold, viii + 198 pp., 1 computer disk [Macintosh]

Field, M. and Golubitsky, M. (1992) *Symmetry in Chaos: A Search for Pattern in Mathematics, Art and Nature*, Oxford: Oxford University Press, xii + 218 pp.

- German trans., *Chaotische Symmetrien: Die Suche nach Mustern in Mathematik, Kunst und Natur*, Basel: Birkhäuser, 1993, 218 pp.

- French trans , *La Symétrie du chaos: A la recherche des liens entre mathématiques, art et nature*, Paris: Inter éditions, 1993, xii + 218 pp.

Gansweid, J. (1987) *Symmetrie und Gestaltung: Optische Bewegungseffekte entwickelt aus geometrischen Elementen*, [*Symmetry and Arrangement* <Creating Gestalt>*: Optical-Kinetical Effects Developed with Geometrical Elements*, in German], München: Callwey, 134 pp.

Kainuma, H. and Kainuma, Y. (1981) *Patchiwaaku to shinmetorii*, [*Patchwork and Symmetry*, in Japanese], Kasugai: Shinuma Yoshirou, 76 pp.

Lauwerier, H. (1995) *Symmetrie, kunst en computers*, [*Symmetry, Art and Computers*, in Dutch], Haarlem: Aramith, 120 pp., 1 compact disk.

McDowell, R. B. (1994) *Symmetry· A Design System for Quiltmakers*, Lafayette, California: C and T Publishers, 144 pp.

Waller, M. D. (1961) *Chladni Figures: A Study in Symmetry*, London: Bell, xxii + 163 pp. [Note: Visualization of sound waves - the sand pattern technique of Chladni (1756-1827) produces symmetric patterns on plates vibrated, for example, by a violin bow at their edges].

Also see:

* Herfort and Klotz (1997) → Section 1 1 2

2.2.2 Pattern analysis: comprehensive surveys

Jablan, S. V. (1984) *Teorija simetrije i ornament*, [in Serbo-Croatian], Beograd: APXAIA, 344 pp.

- English trans , revised, *Theory of Symmetry and Ornament*, Beograd· Matematicki institut, 1995, 331 pp.

Lauwerier, H. A. (1988) *Symmetrie: Regelmatige structuren in de kunst*, [*Symmetry: Regular Structures in Art*, in Dutch], Amsterdam: Aramith, 140 pp.

Lockwood, E. H. and Macmillan, R. H. (1978) *Geometric Symmetry*, Cambridge [England]: Cambridge University Press, x + 228 pp.

Müller, C. (1985) *Symmetrie und Ornament: Eine Analyse mathematischer Strukturen der darstellenden Kunst*, [*Symmetry and Ornament: An Analysis of Mathematical Structures in Representational Art*, in German], Opladen: Westdeutscher Verlag, 51 pp.

Shepard, A. O. (1948) *The Symmetry of Abstract Design with Special Reference to Ceramic Decoration*, Contributions to American Anthropology and History, Vol. 9, No.47, Washington, D.C.: Carnegie Institution of Washington, Publication No. 574, [Separate pamphlet in Vol. 9, paginated as 209-293].

Stevens, P. S. (1981) *Handbook of Regular Patterns: An Introduction to Symmetry in Two Dimensions*, Cambridge, Massachusetts· MIT Press, 400 pp.

* Paperback ed., ibid., 1981; Many new printings.

Washburn, D K. and Crowe, D. W. (1988) *Symmetries of Culture· Theory and Practice of Plane Pattern Analysis*, Seattle, Wash : University of Washington Press, x + 299 pp.

* Paperback ed., ibid., 1991

Also see:

* Bérczi (1990) → Section 1.1,
* Huff (1967-77, Parts 2-3), Kumagai and Sawada (1983) → Section 1.1.3,
* Crowe (1986), Roanes and Roanes (1993) → Section 1.2.1.1 and 1.1.2.
* Takahashi (1998) → Section 1 2 1,
* Jaskowski (1952), Shubnikov (1940) → Section 2.1.1,
* Shubnikov and Koptsik (1972), Wolf and Wolff (1956), and some other books → Section 2 1.2.

2.2.3 Pattern analysis: special fields

Abas, S. J. and Salman, A. S. (1995) *Symmetries of Islamic Geometrical Patterns*, [With forewords by M. Atiyah and A. Moustafa], Singapore: World Scientific, xxii + 396 pp, 16 color plates.

Bérczi, S. (1986-87) *Szimmetria és techné a magyar, avar és hanti díszítőművészetben*, [*Symmetry and technê in the Hungarian, Avar, and Hanti Ornamental Art*, in Hungarian], Budapest: Eötvös Loránd Tudományegyetem, Általános Technika Tanszék; Leuven, Belgium: Leuveni Katolikus Egyetem [Catholic University of Louvain], Collegium Hungaricum, 59 pp.

Gerdes, P. (1996) *Lunda Geometry: Designs, Polyominoes, Patterns, Symmetries*, Maputo, Mozambique: Universidade Pedagógica, 152 pp. [Lunda is a region of the North-Eastern part of Angola].

MacGillavry, C. H. (1965) *Symmetry Aspects of M. C. Escher's Periodic Drawings*, Utrecht: Oosthoek, [Published for the International Union of Crystallography], xi + 84 pp.

* 2nd ed., Utrecht: Bohn, Scheltema & Holkema, [Published for the International Union of Crystallography], 1976, xi + 84 pp.

* American reprint ed., *Fantasy and Symmetry: The Periodic Drawings of M. C. Escher*, New York: Abrams, 1976, xi + 84 pp.

- Japanese trans., *Esshaa: Shinmetorii no sekai*, [*Escher: The World of Symmetry*, in Japanese], [With an afterword by K. Fushimi (Husimi)], Tokyo: Saiensusha, 1981, 90 pp.

Otto, B. (1976) *Geometrische Ornamente auf anatolischer Keramik: Symmetrien frühester Schmuckformen im nahen Osten und in der Agäis*, [*Geometrical Ornaments on Anatolian Ceramics: Symmetries of the Earliest Decoration-Forms in the Near East and in the Aegean*, in German], Mainz am Rhein: von Zabern, xiii + 203 pp.

Plehn, A. L. (1911) *Farbensymmetrie und Farbenwechsel: Prinzipien deutscher und italienischer Farbverteilung*, [*Color-Symmetry and Color-Change: Principles of German and Italian Color-Distribution*, in German], Strassburg: Heitz, 90 pp.

Schattschneider, D. (1990) *Visions of Symmetry: Notebooks, Periodic Drawings, and Related Work of M. C. Escher*, New York: Freeman, xiv + 354 pp.

* Paperback ed., ibid, 1992

- Japanese trans., *Esshaa - hen'you no geijutsu: Shinmetori no hakken*, [*Escher - The Art of Transformation: The Discovery of Symmetry*, in Japanese], Tokyo: Nikkei Saiensusha, 1991, xiii + 370 pp.

- French trans., *Visions de la symétrie: Les Cahiers, les dessins périodiques et les oeuvres corrélatives de M. C. Escher*, Paris: Seuil, 1992, 368 pp.

- Italian trans., *Visioni della simmetria: I disegni periodici di M. C. Escher*, [*Visions of Symmetry: The Periodic Drawings of M. C. Escher*, in Italian], Bologna: Zanichelli, 1992, xiii + 354 pp.

Tarayan, Z R. (1989) *Simvoly simmetrii ornamenta v armianskom prikladnom iskusstve*, [*Symbols of Ornamental Symmetry in Armenian Applied Arts*, in Russian], Erevan, Armenia: Izdatel'stvo Akademii Nauk Armyanskoi SSR, 198 pp., 26 plates.

Washburn, D. K. (1977) *A Symmetry Analysis of Upper Gila Area Ceramic Design*, Papers of the Peabody Museum of Archaeology and Ethnology, Vol 68, Cambridge, Massachusetts: Harvard University Press, xiii + 193 pp. [The Gila River rises in Sierra Madre, New Mexico, U.S.A., and crosses to the Colorado River in Arizona].

Also see:

* Rull Perez (1987) → Section 1 2.1.1,

* Lucich (1987), Witherspoon and Peterson (1995) → Section 3.4.1.

3 MORE SPECIALIZED MONOGRAPHS WITH SOME INTERDISCIPLINARY OUTLOOK

It is difficult to make strict rules for selecting books of interdisciplinary interest. Sometimes works referring to a concrete discipline still have an interdisciplinary importance. For example, a book on crystallographic symmetry groups is useful not only for crystallographers, but also for people interested in solid state physics, crystalphysics, crystalchemistry, materials science, and, in some cases, even for designers. As a general principle: we consider those books that have some importance outside its primary discipline. Following this

principle, we include books related to mathematical- physical topics (e.g., theoretical mechanics, quantum theory, particle physics) although many of these books have a limited target among a group of mathematicians and physicists. We also list books on symmetries in various artistic fields, because these could be useful for artists of other fields and scholars who would like to illustrate scientific books with artistic examples. We also include books on dynamic symmetry in design, a proportion-system proposed by Jay Hambidge on the basis of his studies on Greek art, because we witnessed that some aspects of this topic are also interesting for mathematics students (despite the fact that it has less value for the originally targeted artists and art historians). We also list some old books of historic importance (cf., Section 2.1.1 and the references there). Indeed, we think that dealing with the history of the subject is relevant and advanced students may prepare related reports. Although we also include books written by historians of science on various aspects of symmetry (see Section 3.1), we suggest combining these with the original sources.

What types of books are not included? It is not easy to give strict rules, but here are some general conventions. We do not list books that use the term symmetry or its derivatives

- (1) as a metaphorical expression, e.g.,

Frye, N. (1947) *Fearful Symmetry: A Study of William Blake*, Princeton: Princeton University Press, 462 pp. [Here the main title is a quote from Blake's poem].

- (2) as an attribute in a specialized term of a discipline that are rarely used outside a particular field (e.g., symmetric space, symmetric logic).

Note that there are cases where a similar term has great importance in two or more field (e.g., asymmetric synthesis, a chemical process that also attracted the interest of biologists).

3.1 History and philosophy of science, cognitive science, psychology, general education

Altmann, S. L. (1992) *Icons and Symmetries*, Oxford: Clarendon Press and New York: Oxford University Press, xii + 104 pp. [History of mathematics and physics; three case-studies: (1) Oersted's paradox of the interaction between the magnetic needle and the electric current; (2) Hamilton's description of rotation by quaternions and the later development of related mathematical tools, (3) symmetry in the classification of energy levels in atoms and solids].

- Spanish trans., *Iconos y simetrías*, Zaragoza: Prensas Universitarias, 1994, 147 pp.

Burckhardt, J. J. (1988) *Die Symmetrie der Kristalle: Von René-Just Hauy zur kristallographischen Schule in Zurich*, [*The Symmetry of Crystals: From René-Just Hauy to the Crystallographic School in Zurich*, in German], Basel: Birkhäuser, 195 pp.

Chakravorty, K. R. (1977) *Science Based on Symmetry*, Calcutta: Firma KLM, xxi + ca. 500 pp. [Philosophy of science; Indian philosophy, religion, and mysticism].

Hommel, H. (1987) *Symmetrie im Spiegel der Antike*, [*Symmetry as Reflected in the Antiquity*, in German], Sitzungsberichte der Heidelberger Akademie der Wissenschaften, Philosophisch-Historische Klasse, Jahrgang 1986, Bericht 5, Hieldelberg: Winter, 59 pp.

Khvan, M. P. (1986) *Filosofskoe znachenie printsipa simmetrii v fizike elementarnykh chastits*, [*Philosophical Meaning of the Symmetry Principle in Particle Physics*, in Russian], Moskva: Izdatel'stvo Universiteta druzhba narodov, 199 pp.

Leyton, M. (1992) *Symmetry, Causality, Mind*, Cambridge, Massachusetts: MIT Press, vii + 630 pp. [Cognitive science; Case studies: perception, liguistics, art, and political prisoners].

Melandri, E. (1974) *L'analogia, la proporzione, la simmetria*, [*Analogy, Proportion, Symmetry*, in Italian], Scienze dell'uomo, Vol. 27, Milano: ISEDI, 185 pp. [Logic].

Piersa, H. (1990) *Symetria i jej funkcje poznawcze w fizyce*, [*Symmetry and its Congnitive Functions in Physics*, in Polish], Rozprawa habilitacyjna, Lublin, Poland: Wydawnictwo Katolickiego Uniwersytetu Lubelskiego (KUL), 257 pp.

Scholz, E. (1989) *Symmetrie, Gruppe, Dualität: Zur Beziehung zwischen theoretischer Mathematik und Anwendungen in Kristallographie und Baustatik des 19. Jahrhunderts*, [*Symmetry, Group, Duality· On the Connection between Theoretical Mathematics and Applications in Crystallography and Structural Design of the 19th Century*, in German], Basel: Birkhäuser and Berlin: Deutscher Verlag der Wissenschaften, 406 pp.

Slok, J. et al. (1975) *Symmetri i videnskaberne*, [*Symmetry and the Sciences*, in Danish], Det lærde Selskabs publikationsserie, Ny serie, Hæfte 7-8, Aarhus [Denmark]: Universitetsforlaget i Aarhus, 77 pp. [Philosophy

of science; note: we include this item because the title-page presents it as a book with multiple authors, although it can be also interpreted as a collection of papers].

Sodnomgombo, D. and Khvan, M. P. (1981) *Filosofiya i simmetriya*, [*Philosophy and Symmetry*, in Russian], Ulan Bator, Mongolia: Gosizdat, 206 pp. [Physics].

Tsalikídês, E. G. (1995) *Kosmikê armonía kai summetría dia mésou tês klassikês kai eukleídeiou geômetrías*, [*Cosmic Hamony and Symmetry by Means of Classical and Euclidean Geometry*, in Greek], Thessalonîkê [Thessaloniki]: Zêtê, 181 pp. [History of geometry].

Urmantsev, Yu. A. (1974) *Simmetriya prirody i priroda simmetrii* (Filosofskie i estestvennonauchnye aspekty), [*Symmetry of Nature and the Nature of Symmetry* (Philosophical and Scientific Aspects), in Russian], Moskva: Mysl', 229 pp. [Philosophy, Biology, System approach].

Van Fraassen, B. C. (1989) *Laws and Symmetry*, Oxford. Oxford University Press, xv + 395 pp. [Philosophy, Physics]

- French trans., *Lois et symétrie*, [Series] Mathesis, Paris: Vrin, 1994, 520 pp.

Yaglom [IAglom], I. M. (1988) *Felix Klein and Sophus Lie: Evolution of the Idea of Symmetry in the Nineteenth Century*, Boston: Birkhäuser, vii + 237 pp. [History of mathematics and physics].

Also see:

* Khakimov (1986) on philosophy of science ⟶ Section 1.2.6,
* Dienes and Mezard (1971) on logic ⟶ Section 1.2.1.1,
* Horwich (1987) on the philosophical problems of asymmetry in time ⟶ Section 4.3, and
* the pre-1952 works in the context of history of science ⟶ Section 2.1.1,
* the books on the philosophical aspects of symmetry vs. asymmetry ⟶ Section 4.1.

3.2 Exact sciences (mathematics, physics, and chemistry, including mathematical crystallography)

3.2.1 General works and popular-scientific books

Aneva, B. (1990) *Supersimetria: Matematichni metodi na teoretichnata fizika*, [*Supersymmetry: Mathematical Methods in Theoretical Physics*, in Bulgarian], [Series] Lektsii za mladi ucheni, Sofiya [Sofia]: Izdatelstvo na Bulgarskata akademiya na naukite, 82 pp

Arai, A. (1993) *Taishousei no suuri*, [*The Mathematical Principles of Symmetry*, in Japanese], Tokyo: Nihon Hyouronsha, v + 221 pp.

Bandou, M. (1996) *Butsuri to taishousei: kuouku kara shinka made*, [*Physics and Symmetry: From Quarks to Evolution*, in Japanese], Tokyo: Maruzen, viii + 182 pp.

Bunch, B. (1989) *Reality's Mirror: Exploring the Mathematics of Symmetry*, New York: Wiley, xi + 286 pp.

- Japanese trans., *Jitsuzai no kagami: Shinmetorii no sekai*, [Reality's Mirror: The World of Symmetry, in Japanese], Tokyo: Seidosha, 1994, 350 pp.

Elliott, J. P. and Dawber P. G. (1979) *Symmetry in Physics*, Vol. 1, Principles and Simple Applications, Vol. 2, Further Applications, London: Macmillan, xix + xviii + 557 pp. [Vol 1, pp. 1-280; Vol. 2, pp. 281-557].

* Reprint ed., corrected, ibid., 1984. [616 pp. in various pagings].

- Russian trans., Élliot, D. and Dober, P., *Simmetriya v fizike*, Tom 1, Osnovnye printsipy i prostye prilozheniya, Tom. 2, Dal'neishie prilozheniya, Moskva: Mir, 1983, 364 + 410 pp.

Feynman, R. P. (1997) *Six Not-So-Easy Pieces: Einstein's Relativity, Symmetry, and Space-Time*, [Originally prepared for publication by R. B. Leighton and M. Sands; New introduction by R Penrose], Reading, Massachusetts: Addison-Wesley, xxvii + 152 pp.

Gribbin, J. R. (1998) *In Search of SUSY: Supersymmetry, String and the Theory of Everything*, London: Penguin. [Physics, popular scientific].

* American reprint ed., *The Search for Superstrings, Symmetry, and the Theory of Everything*, Boston: Little Brown, 1999, x + 212 pp.

Holden, A. (1971) *Shapes, Space, and Symmetry*, New York: Columbia University Press, viii + 200 pp.

* Reprint ed., New York· Dover, 1991, 200 pp [Polyhedra].

- French trans., *Formes, espace et symétries: Construisez facielement vos solides*, [*Shapes, Space, and Symmetry: Build Your Solids*, in French], [Series] Les Distracts, Paris: Conception, édition, diffusion, information (CEDIC), 1977, 206 pp.

Holod, P. I. and Klimyk, A. U. (1992) *Matematychni osnovy teorii symetrii*, [*Mathematical Foundations of Theory of Symmetry*, in Ukrainian], Kiyiv [Kiev]: Naukova dumka, 366 pp.

Icke, V. (1995) *The Force of Symmetry*, Cambridge [England]: Cambridge University Press, xxi + 338 pp. [Physics, popular scientific].

* Paparback ed., ibid., 1995.

Kompaneets, A. S. (1978) *Simmetriya v mikro- i makromire*, [*Symmetry in the Micro- and the Macro-Worlds*, in Russian], Moskva: Nauka, 207 pp. [Popular-scientific].

Mozrzymas, J. (1992) *Ewolucja symetrii*, [*Evolution of Symmetry*, in Polish], Wroclaw: Uniwersytet Wroclawski, 96 pp. [Physics].

Pagels, H. R. (1985) *Perfect Symmetry: The Search for the Beginning of Time*, New York: Simon and Schuster, 390 pp.

* 2nd ed., New York: Bantam, 1991, 390 pp.

- Dutch trans. of the 1st ed., co-author Shilling, G., *Volmaakte symmetrie: Speurtocht naar de oorsprong van ruimte en tijd*, Amsterdam: Contact, 1988, 432 pp.

- Japanese trans. of the 1st ed., *Toki no hajimari e no tabi: Taishousei no butsuri*, [*Journey to the Beginning of Time: The Physics of Symmetry*, in Japanese], Tokyo: Chijin Shokan, 1989, 402 pp.

- Japanese trans. of the 2nd ed., *Hoshi kara ginga e: Heesheru no niwa*, [*From the Stars to the Milky Way: Herschel's Garden*, in Japanese], ibid., 1993, 262 pp.

- Portuguese trans. of the 1st ed., *Simetria perfeita*, Lisboa: Gradiva, 1990, 455 pp.

Raichev, P. P. (1974) *Simetriyata na atomniya svyat*, [*Symmetry of the Atomic World*, in Bulgarian], Sofiya [Sofia]: Nauka i izkustvo, 66 pp. [Popular-scientific].

Rychlewski, J. (1991) *Symetria przyczyn i skutków*, [*Symmetry of Causes and Effects*, in Polish], Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 156 pp. [Physics].

Salam, A. (1966) *Symmetry Concepts in Modern Physics: Iqbal Memorial Lectures*, Lahore, Pakistan: Atomic Energy Centre, 55 pp. [Later the author was awarded the Nobel Prize in Physics for symmetry-related works.]

Schmutzer, E. (1972) *Symmetrien und Erhaltungssätze der Physik*, [*Symmetries and Conservation Laws of Physics*, in German], Braunschweig: Vieweg and Berlin: Akademie-Verlag, 165 pp.

- Russian trans., Shmuttser, É., *Simmetrii i zakony sokhraneniya v fizike*, Moskva: Mir, 1974, 159 pp.

Todorov, I. (1985) *Fizika, geometriya, simetriya*, [*Physics, Geometry, Symmetry*, in Bulgarian], Sofiya [Sofia]: Narodna prosveta, 144 pp. [Five lectures given for a broad audience of physicists, mathematicians, and philosophers, 1971-1983].

Verheyen, H. (1996) *Symmetry Orbits*, Design Science Collection, Boston: Birkhäuser, vi + 236 pp. [Geometry, Crystallography].

Wigner, E. P. (1967) *Symmetries and Reflections: Scientific Essays*, Bloomington, Indiana: Indiana University Press, viii + 280 pp. [Physics, Philosophy; the author was awarded the Nobel Prize in Physics for symmetry-related works.].

* Reprint ed., Westport, Connecticut: Greenwood Press, 1978, viii + 280 pp.

- Russian trans., enlarged, Vigner, E. P., *Étyudi o simmetrii*, [*Etudes on Symmetry*, in Russian], Ed. by Ya. A. Smorodinskii, Moskva: Mir, 1971, 318 pp. [Added part: some related papers by Wigner].

- Hungarian trans, Wigner, J., *Szimmetriák és reflexiók*, Budapest: Gondolat, 1972, 355 pp. [The initial "J" refers to Jenó (Eugene, in English), which was Wigner's original given name in Hungary].

Yale, P. B. (1968) *Geometry and Symmetry*, Holden-Day Series in Mathematics, San Francisco: Holden-Day, xi + 288 pp.

* Reprint ed., New York. Dover, 1988.

Zee, A. (1986) *Fearful Symmetry: The Search for Beauty in Modern Physics*, New York: Macmillan, xiv + 322 pp. [Popular scientific; the main title of the book is a quote from Blake's poem The Tyger (1794); cf., Stewart and Golubitsky (1992) in Section 2.1.2, Reader and Croze (1977) in Section 3.3.1].

* Reprint ed., New York: Collier Books, 1989, xiv + 322 pp.

- Japanese trans., *Uchuu no dezain genri: Paritt, geeji, kuouku*, [*Design Principle of the Universe: Parity, Gauge, Quarks*, in Japanese], Tokyo: Hakuyousha, 1989, 438 pp.
- German trans., *Magische Symmetrie: Die Asthetik in der modernen Physik*, [*Magical Symmetry: The Aesthetics of Modern Physic*, in German], Frankfurt am Main: Insel, 1993, 360 pp.

Also see:

* the books on history and philosophy of mathematics and physics → Section 3.1.

3.2.2 Structure of matter - atomic or molecular level; applications of group theory

Mathematical-crystallographical works on colored symmetry and chemical books on orbital symmetry and the theory of chemical reactions are considered, but kept separately in subsections 3.2.1.1 and 3.2.1.2, respectively.

Altmann, S. L. (1991) *Band Theory of Solids: An Introduction from the Point of View of Symmetry*, Oxford: Clarendon Press and New York: Oxford University Press, xiv + 286 pp.

Alworth, W. L (1972) *Stereochemistry and its Application in Biochemistry: The Relation Between Substrate Symmetry and Biological Stereospecificity*, New York: Wiley, xi + 311 pp.

- Spanish trans., Estereoquímica y su aplicación en bioquímica: La relación entre la simetría del sustrato y la estereoespecificidad biológica, Madrid: Alhambra, 1980, xii + 376 pp.

Baggott, J. E. (1994) *Perfect Symmetry: The Accidental Discovery of Buckminsterfullerene*, Oxford: Oxford University Press., ix + 315 pp. [Buckminsterfullerene = a new form of (carbon) molecules that resemble Buckminster Fuller's dome-structures].

* Paparback ed., ibid., 1996. ix + 315 pp.

- Japanese trans., *Kyuukyoku no shinmetorii: Furaaren hakken monogatari*, [*Ultimate Symmetry: The Story of the Discovery of the Fullerene*, in Japanese], Tokyo: Hakuyousha, 1996, 364 pp.

Belger, M. and Ehrenberg, L. (1981) *Theorie und Anwendung der Symmetriegruppen*, [*Theory and Application of Symmetry Groups*, in German], Mathematik für Ingenieure, Naturwissenschaftler, Ökonomen und sonstige anwendungsorientierte Berufe, Band 23, Leipzig: Teubner 116 pp.
* 2nd revised ed., ibid., 1988, 116 pp.

Belov, N. V. (1986) *Ocherki po strukturnoi kristallografii i fedorovskim gruppam simmetrii*, [*Studies on Structural Crystallography and Fedorov Groups* <Space Groups> *of Symmetry*, in Russian], Compiled by I. M. Rumanova, G. A. Geguzina, and E. M. Dolivo-Dobrovolskaya, Ed. by E. G. Fesenko, Moskva: Nauka, 278 pp.

Bernal, I., Hamilton, W. C., and Ricci, J. S. (1972) *Symmetry: A Stereoscopic Guide for Chemists*, San Francisco: Freeman, viii + 180 pp.

Bhagavantam, S. (1966) *Crystal Symmetry and Physical Properties*, London: Academic Press, x + 230 pp.

Bir, G. L. and Pikus, G. E. (1972) *Simmetriya i deformatsionnye effekty v poluprovodnikakh*, [in Russian], Moskva: Nauka, 584 pp.

- English trans., *Symmetry and Strain-Induced Effects in Semiconductors*, [With a foreword by J. C. Hensel], New York: Wiley, 1974, x + 484 pp.

- Polish trans., *Symetria i odksztalcenia w polprzewodnikach*, [in Polish], Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 1977, 561 pp.

Birss, R. R. (1964) *Symmetry and Magnetism*, Series of Monographs on Selected Topics in Solid State Physics, Vol. 3, Amsterdam: North-Holland and New York: Interscience, xx + 252 pp.

Blaizot, J. P. and Toledano, J.-C. (1997) *Symétries et physique microscopique*, [*Symmetries and Microscopical Physics*, in French], Paris: Ellipses, xiii + 188 pp.

Boardman, A. D., O'Connor, D. E., and Young, P. A. (1973) *Symmetry and its Applications in Science*, New York: Wiley, xiii + 305 pp.

Bradley, C. J. and Cracknell, A. P. (1972) *The Mathematical Theory of Symmetry in Solids: Representation Theory for Point Groups and Space Groups*, Oxford: Clarendon Press, xii + 745 pp.

- Japanese trans. of a part, *Tengun to kuukangun no hyougen*, [*Representation of Point Groups and Space Groups*, in Japanese], Tokyo: Uchida Roukakuho Shinsha, 1975, 361 pp.

Bunker, P. R. (1979) *Molecular Symmetry and Spectroscopy*, New York: Academic Press, xv + 424 pp.
* 2nd ed., co-author Jensen, P., NRC Research Press, 1998.

- Russian trans. of the 1st ed., Banker, F. R., *Simmetriya molekul i molekulyarnaya spektroskopiya*, Moskva: Mir, 1981, 451 pp.

Burzlaff, H. and Zimmermann, H. (1977) *Kristallographie*, Band 1, Symmetrielehre, [Crystallography, Vol. 1, Symmetry-Theory, in German], Stuttgart: Thieme, xii + 275 pp.

Butler, P. H. (1981) *Point Group Symmetry Applications: Methods and Tables*, New York: Plenum Press, ix + 567 pp.

Carter, R. L. (1998) *Molecular Symmetry and Group Theory*, New York: Wiley, x + 299 pp.

Cracknell, A. P. (1975) *Magnetism in Crystalline Materials: Applications of the Theory of Groups of Cambiant Symmetry*, International Series of Monographs in Natural Philosophy, Vol. 72, Oxford: Pergamon Press, vii + 276 pp.

Dmitriev, I. S. (1976) *Simmetriya v mire molekul*, [in Russian], Leningrad [now Sankt-Peterburg]: Khimiya, 124 pp.

- Czech trans., Dmitrijev, I. S., *Symetrie ve svete molekul*, Praha [Prague]: Státní nakladatelství technické literatury (SNTL), 119 pp.

- English trans., Revised, *Symmetry in the World of Molecules*, Moscow: Mir, 1979, 147 pp.

- German trans., *Symmetrie in der Welt der Moleküle*, Leipzig: Deutscher Verlag für Grundstoffindustrie, 1987, 146 pp.

Donaldson, J. D. and Ross, S. D. (1972) *Symmetry and Stereochemistry*, New York: Halsted Press Division, Wiley, 234 pp.

* British reprint ed., London: Intertext Books, 1972, 234 pp.

Douglas, B. E. and Hollingsworth, C. A. (1985) *Symmetry in Bounding and Spectra: An Introduction*, San Diego: Academic Press, xii + 456 pp.

Evarestov, R. A. and Smirnov, V. P. (1993) *Site Symmetry in Crystals: Theory and Applications*, Springer Series in Solid-State Sciences, Vol. 108, Berlin: Springer, xi + 274 pp.

* 2nd ed., ibid., 1997, xiii + 280 pp.

Ezra, G. S. (1982) *Symmetry Properties of Molecules*, Lecture Notes in Chemistry, Vol. 28, Berlin: Springer, viii + 202 pp.

Fedorov, E. S. (1949) *Simmetriya i struktura kristallov: Osnovnye raboty*, [*Symmetry and Structure of Crystals: Basic Works*, in Russian], Ed. by A. V. Shubnikov and I. I. Shafranovskii, Klassiki nauki [Series], Moskva: Izdatel'stvo Akademii Nauk SSSR, 630 pp. [Basic works of late 19th century, including the discovery of the 230 crystallographic space groups].

- English trans. of the major part of this book in: Fedorov (1971).

Fedorov, E. S. (1971) *Symmetry of Crystals*, ACA Monograph, No. 7, New York: American Crystallographic Association, x + 315 pp. [Trans. of Fedorov (1949) except the biography and the bibliography of Fedorov; translated by D. Harker and K. Harker].

Fieck, G. (1982) *Symmetry of Polycentric Systems: The Polycentric Tensor Algebra for Molecules*, Lecture Notes in Physics, Vol. 167, Berlin: Springer, vi + 137 pp.

Flurry, R. L., Jr. (1980) *Symmetry Groups: Theory and Chemical Applications*, Englewood Cliffs, New Jersey: Prentice-Hall, xii + 356 pp.

- Russian trans., Flarri, R L., *Gruppy simmetrii: Teoriya i khimicheskie prilozheniya*, Moskva: Mir, 1983, 395 pp.

Franzen, H. F. (1994) *Physical Chemistry of Solids: Basic Principles of Symmetry and Stability of Crystalline Solids*, Advanced Series in Physical Chemistry, Vol. 1, Singapore: World Scientific, xiv + 280 pp.

Fricke, H. (1965) *Symmetrie als Schlüssel zum Verständnis der organishen Chemie*, [*Symmetry as a Key for Understanding Organic Chemistry*, in German], Praxis-Schriftenreihe, Abteilung Chemie, Band 14, Köln: Aulis, 65 pp.

Fujita, S. (1991) *Symmetry and Combinatorial Enumeration in Chemistry*, Berlin: Springer, ix + 368 pp.

Griffith, J. S. (1962) *The Irreducible Tensor Method for Molecular Symmetry Groups*, Prentice-Hall International Series in Chemistry, Englewood Cliffs, New Jersey: Prentice-Hall, 134 pp.

Hall, L H. (1969) *Group Theory and Symmetry in Chemistry*, New York: McGraw-Hill, xiii + 370 pp.

Harter, W. G. (1993) *Principles of Symmetry, Dynamics, and Spectroscopy*, New York: Wiley, xxii + 846 pp.

Hatfield, W E. and Parker, W. E. (1974) *Symmetry in Chemical Bonding and Structure*, Colombus, Ohio: Merrill, ix + 277 pp.

Ho, T.-L. (1995) *Symmetry: A Basis for Synthesis Design*, New York: Wiley, xv + 561 pp. [Chemistry].

Hochstrasser, R. M. (1966) *Molecular Aspects of Symmetry*, New York: Benjamin, xiii + 355 pp.

- Russian trans., Khokhshtrasser, R., *Molekulyarnye aspekty simmetrii*, Moskva: Mir, 1968, 384 pp.

Ivchenko, E. L. and Pikus, G. E. (1995) *Superlattices and Other Heterostructures: Symmetry and Optical Phenomena*, Springer Series in Solid-State Sciences, Vol 110, Berlin: Springer, xi+370 pp. [Semiconductors].

* 2nd ed., ibid , 1997, xiii + 382 pp.

Izyumov, Yu. A. and Syromyatnikov, V. N. (1984) *Fazovye perekhody i simmetriya kristallov*, [in Russian], Moskva: Nauka, 245 pp.

- English trans., enlarged, *Phase Transition and Crystal Symmetry*, Dordrecht [The Netherlands]: Kluwer, 1990, xx + 443 pp.

Knox, R. S. and Gold, A. (1964) *Symmetry in the Solid State*, New York: Benjamin, xii + 344 pp

- Russian trans., Noks, R. and Gold, A., *Simmetriya v tverdom tele*, Moskva: Mir, 1970, 424 pp.

Kocinski, J. (1983) *Theory of Symmetry Changes and Continuous Phase Transitions*, Amsterdam: Elsevier, viii + 283 pp

Ladd, M. F. C. (1989) *Symmetry in Molecules and Crystals*, Chichester [England]: Ellis Horwood and New York: Halsted Press, 274 pp.

Lax, M. J. (1974) *Symmetry Principles in Solid State and Molecular Physics*, New York: Wiley, 1974, xi + 499 pp.

Ludwig, W. and Falter, C. (1988) *Symmetries in Physics: Group Theory Applied to Physical Problems*, Springer Series in Solid-State Sciences, Vol. 64, Berlin: Springer, xi + 461 pp.
* 2nd enlarged ed., ibid., 1996, xiii + 473 pp.

McWeeny, R. (1963) Symmetry: *An Introduction to Group Theory and its Applications*, *The International Encyclopedia of Physical Chemistry and Chemical Physics*, Topic 1, Mathematical Techniques, Vol. 3, New York: Macmillan and Oxford: Pergamon Press, xiv + 248 pp.

Mead, C. A. (1974) *Symmetry and Chirality*, Topics in Current Chemistry, Vol. 49, Berlin: Springer, iv + 88 pp.

Meyer, A. (1981) *Symmetriebeziehungen zwischen Kristallstrukturen*, Bände 1-2, [*Symmetry-Relations between Crystal-Structures*, Vols. 1-2, in German], Bochum, Drei-Eck-Verlag, 264 + 164 pp.

Miller, W., Jr. (1972) *Symmetry Groups and Their Applications*, Pure and Applied Mathematics, Vol. 50, New York: Academic Press, x + 432 pp.

Muck, A. (1987) *Symetrie krystalu a vibracní spektra*, [*Symmmetry of Crystals and Vibrational Spectra*, in Czech], Praha [Prague]: Státní nakladatelství technické literatury (SNTL), 266 pp.

- Polish trans., *Symetria kryształów a widma oscylacyjne*, Warszawa: Wydawnictwa Naukowo-Techniczne, 1992, 282 pp.

Schonland, D. S. (1965) *Molecular Symmetry: An Introduction to Group Theory and its Uses in Chemistry*, London: Van Nostrand, xii + 298 pp.

- French trans., *La Symétrie moléculaire: Introduction à la théorie des groupes et à ses applications à la chimie*, Paris: Gauthiers-Villars, 1971, xii + 336 pp.

Senechal, M (1990) *Crystalline Symmetries: An Informal Mathematical Introduction*, Bristol: Hilger, xii + 137 pp.

Slater, J. C. (1965) *Symmetry and Energy Bands in Crystals*, New York: McGraw-Hill, xii + 563 pp.

* Reprint ed., corrected, New York: Dover, 1972, xii + 563 pp.

Steinborn, D. (1993) *Symmetrie und Struktur in der Chemie*, [*Symmetry and Structure in Chemistry*, in German], Weinheim [Germany]: VCH, xv + 435 pp.

Vainshtein, B. K. (1979) *Sovremennaya kristallografiya*, Tom 1: Simmetriya kristallov, Metody strukturnoi kristallografii, [in Russian], Moskva: Nauka, 383 pp.

English trans , *Modern Crystallography 1:* Symmetry of Crystals, Methods of Structural Crystallography, Springer Series in Solid-State Sciences, Vol. 15, Berlin: Springer, 1981, xvii + 399 pp.

* English trans., 2nd enlarged ed., *Modern Crystallography* 1: Fundamentals of Crystals: Symmetry and Methods of Structural Crystallography, ibid., 1996, xxi + 482 pp.

Veen, A. L W. E. van der (1911) *Physish en kristallografish onderzoek naar de symmetry van diamant*, [*Physical and Crystallographic Investigation into the Symmetry of Diamond*, in Dutch], Leiden: Stijthoff, 58 pp. + 3 stereoscopic tables. [The Dutch spelling is archaic: the modern version of "symmetry" is "symmetrie", etc.].

Zheludev, I. S. (1976) *Simmetriya i ee prilozheniya*, [*Symmetry and its Applications*, in Russian], Moskva: Atomizdat, 286 pp.

* 2nd enlarged ed., Moskva: Énergoizdat, 1983, 303 pp.

- Japanese trans. of the 1st ed., *Taishousei to sono ouyou*, Tokyo: Koudansha, 1979, 303 pp.

Zheludev, I. S. (1987) *Fizika kristallov i simmetriya*, [*Physics of Crystals and Symmetry*, in Russian], Moskva: Nauka, 187 pp.

- German trans., *Kristallphysik und Symmetrie*, Berlin: Akademie-Verlag, 224 pp.

Zhuvikin, G. V. and Hefferlin, R (1994) *Symmetry Principles for Periodic Systems of Molecules*, Collegedale, Tennessee: Southern College, 84 pp. + 2 charts.

Also see:

* Burckhardt (1988) on the history of crystallography ⟶ Section 3.1,
* Scholz, E. (1989) on the history of crystallographic groups ⟶ Section 3.1,
* many textbooks → Section 1 3

3.2.1.1 Colored symmetry (a mathematical method for describing physical properties of crystals)

Jaswon, M. A. and Rose, M. A (1983) *Crystal Symmetry: Theory of Colour Crystallography*, Chichester [England]: Ellis Horwood and New York: Halsted Press, 190 pp.

Koptsik, V. A. (1966) *Shubnikovskie gruppy: Spravochnik po simmetrii i fizicheskim svoistvam kristallicheskikh struktur*, [*Shubnikov Groups* <Black-and-White Groups>: *A Handbook on Symmetries and Physical Properties of Crystal-Structures*, in Russian], Moskva: Izdatel'stvo Moskovskogo universiteta, 723 pp

Loeb, A. L (1971) *Color and Symmetry*, Wiley Monographs in Crystallography, New York: Wiley, xiii + 179 pp.

* Reprint ed , Huntington, New York: Krieger, 1978, xiii + 179 pp.

Shubnikov, A. V. (1951) *Simmetriya i antisimmetriya konechnykh figur*, [*Symmetry and Antisymmetry of Finite Figures*, in Russian], Moskva: Izdatel'stvo Akademii Nauk SSSR, 172 pp. [Antisymmetry = black-and-white or two-colored symmetry].

- English trans. in: Shubnikov, Belov, et al. (1964).

Shubnikov, A. V., Belov, N. V., et al. (1964) *Colored Symmetry*, Ed. by W. T. Holser, New York: Macmillan and Oxford: Pergamon Press, xxv + 263 pp. [The first part is the translation of Shubnikov (1951), the second part is based on the works by Belov et al].

Zamorzaev, A. M. (1976) *Teoriya prostoi i kratnoi antisimmetrii*, [*Theory of Simple and Multiple Antisymmetry*, in Russian], Kishinev [Moldavskoi SSR, now Moldova]: Shtiintsa, 283 pp. [Antisymmetry = black-and-white symmetry].

Zamorzaev, A. M., Galyarskii, E. I. and Palistrant, A. F. (1978) *Tsvetnaya simmetriya, ee obobshcheniya i prilozheniya*, [*Colored Symmetry, its Generalizations and Applications*, in Russian], Kishinev [Moldavskoi SSR, now Moldova]: Shtiintsa, 275 pp.

Zamorzaev, A. M., Karpova, Yu. S., Lungu, A. P., and Palistrant, A. F. (1986) *P-simmetriya i ee dal'neishee razvitie*, [*P-Symmetry and its Further Development*, in Russian], Kishinev [Moldavskoi SSR, now Moldova]: Shtiintsa, 154 pp. [P-symmetry is the generalization of colored symmetry].

Also see:

* Kumagai and Sawada (1983) → Section 1.1.3,
* Dubov et al. (1984-87, Vol. 3) → Section 1.2 2,
* Zamorzaev and Palistrant (1977) → Section 1 3,
* Jaskowski (1952) → Section 2 1 1,
* Shubnikov and Koptsik (1972) → Section 2 1 2,
* Jablan (1984), Lockwood and Macmillan (1978), Washburn and Crowe (1988) → Section 2 2.2,
* MacGillavry (1965), Schattschneider (1990) → Section 2 2 3,
* Vainshtein (1979) → Section 3.2 2.

Most of these books also present artistic examples (ornamental art, Escher's drawings, etc.). In connection with a fully artistic approach to color and symmetry, without any reference to crystallographic groups, see

* Plehn (1911) → Section 2 2 3

3.2.1.2 Orbital symmetry and other symmetry principles in the theory of chemical reactions

Bellamy, A. J. (1974) *An Introduction to Conservation of Orbital Symmetry: A Programmed Text*, [Series] Longman Text, London: Longman, x + 77 pp.

- German trans., *Lehrprogram Orbitalsymmetrie*, [*Study-Program Orbital Symmetry*, in German], Weinhem [Germany]: Verlag Chemie, 1974, vi + 107 pp.

Entwistle, N. (1972) *Orbital Symmetry Correlations in Organic Chemistry: A Guide to the Woodward-Hoffman Rules*, New York: Van Nostrand Reinhold, vii + 62 pp.

Gilchrist, T. L and Storr, R. C. (1972) *Organic Reactions and Orbital Symmetry*, Cambridge Chemistry Texts, Cambridge [England]. Cambridge University Press, viii + 271 pp.

* 2nd ed., ibid., 1979, vii + 311 pp.

Halevi, E. A. (1992) *Orbital Symmetry and Reaction Mechanism: The OCAMS View*, Berlin: Springer, xxii + 310 pp. [OCAMS = Optical Correspondence Analysis in Maximum Symmetry].

Lehr, R. E. and Marchand, A P. (1972) *Orbital Symmetry: A Problem-Solving Approach*, New York: Academic Press, x + 190 pp.

* British version, London: Academic Press, x + 190 pp.

Orchin, M. and Jaffé, H. H. (1971) *Symmetry, Orbitals, and Spectra (S.O.S)*, New York: Wiley, xiii + 396 pp.

- Japanese trans., *Kagaku ketsugouron: Bunshi kidou to taishousei*, [*Chemical Bound-Rule: Molecule Orbitals and Symmetry*, in Japanese], Tokyo: Baifuukan, 1974, 373 pp.

Orchin, M. and Jaffé, H. H. (1971) *Supplement for Symmetry, Orbitals, and Spectra: Problems and Answers*, [With the help of G. Kuehnlenz and R. Ellis], New York: Wiley, vii + 220 pp.

Pearson, R. G. (1976) Symmetry Rules for Chemical Reactions: Orbital Topology and Elementary Processes, New York: Wiley, ix + 548 pp.

- Russian trans., Pirson, R., *Pravila simmetrii v khimicheskikh reaktsiyakh*, Moskva: Mir, 1979.

Schipper, P. E. (1994) *Symmetry and Topology in Chemical Reactivity*, Singapore: World Scientific, xii + 272 pp.

Sunjic, V. (1979) *Simetrija granicnih orbitala i reaktivnost u organskoj kemiji*, [Symmetry of Limited Orbitals and Reactivity in Organic Chemistry, in Serbo-Croatian], Zagreb: Skolska knjiga, 150 pp.

Woodward, R B. and Hoffman, R. (1970) *The Conservation of Orbital Symmetry*, Weinhem [Germany]: Verlag Chemie, 177 pp. [Later both authors were awarded the Nobel Prize in Chemistry for related works.]

- German trans., *Die Enthaltung der Orbitalsymmetrie*, Weinhem [Germany]: Verlag Chemie, 1972, 177 pp.

3.2.3 Structure of matter - subatomic level; applications of mathematical methods in quantum theory and particle physics

Coleman, S. (1985) *Aspects of Symmetry: Selected Erice Lectures of Sidney Coleman*, Cambridge [England]: Cambridge University Press, xiv + 402 pp. [Physics].

Dyson, F. J. (1966) *Symmetry Groups in Nuclear and Particle Physics: A Lecture-Note and Reprint Volume*, Mathematical Physics Monographs Series, New York: Benjamin, xii + 320 pp. ["Sequel to The Eightfold Way edited by Gell-Mann and Ne'eman"].

Froggatt, C. D. and Nielsen, H. B. (1991) *Origins of Symmetries*, Singapore: World Scientific, x + 581 pp. [pp. 191-581 reprinted papers]. [Physics].

Lopes, J. L. (1969) *Lectures on Symmetry*, [Series] Documents on Modern Physics, New York: Gordon and Breach, xi + 170 pp.

Ne'eman, Y. (1979) *Symétries jauges et variétés de groupe*, [*Gauge Symmetries and Group Manifolds*, in French], Montréal. Presses de l'Université de Montréal, 141 pp. [Mathematical physics].

3.2.4 Astronomy, astrophysics

Banhatti, D. G. (1998) *Bilateral Symmetry in Active Galaxies*, Amsterdam: North-Holland, 182 pp.

Danver, C. G. (1942) *A Morphological Investigation of Some Near Galaxies, with Regards to the Lengths and the Form of Their Arms, Their Inclinations and Their Symmetry Properties*, Lund [Sweden]: Observatory, 192 pp.

Mozrzymas, J. and Wolanski, A (1993) *Harmonia sfer niebieskich i muzyka abstrakcyjnych symetrii*, [*The Harmony of Heavenly Spheres and the Music of Abstract Symmetry*, in Polish], Wroclaw: Leopoldinum, 1993, 148 pp.

3.2.5 Other mathematical-physical questions, applied mathematics

3.2.5.1 Geometry and algebra

Böhm, J. and Quaisser, E. (1990) *Schönheit und Harmonie geometrischer Formen: Spharoformen und symmetrische Körper*, [*Beauty and Harmony of Geometrical Figures: Spherical Figures and Symmetric Bodies*, in German], Berlin: Akademie-Verlag, 123 + xx pp.

Boltyanskii, V. G. and Vilenkin, N. Ya. (1967) *Simmetriya v algebre*, [*Symmetry in Algebra*, in Russian], Moskva: Nauka, 282 pp.

Johnston, B. L. and Richman, F. (1997) *Numbers and Symmetry: An Introduction to Algebra*, Boca Raton, Florida: CRC Press, 260 pp.

Lander, E. S. (1983) *Symmetric Designs: An Algebraic Approach*, London Mathematical Society Lecture Note Series, Vol. 74, Cambridge [England]: Cambridge University Press, xii + 306 pp. [Combinatorial configurations].

Miles, R. E. (1995) *Symmetric Bends: How to Join Two Lengths of Cord*, K & E Series on Knots and Everything, Vol. 8., Singapore: World Scientific, xii + 163 pp. [Mathematical Knot Theory].

Robertson, S. A. (1984) *Polytopes and Symmetry*, London Mathematical Society Lecture Note Series, Vol. 90, Cambridge [England]: Cambridge University Press, xv + 112 pp. [Polytope = higher dimensional polyhedron].

3.2.5.2 Mathematical analysis, theoretical mechanics, nonlinear mathematics, and related questions

Field, M (1996) *Lectures on bifurcation, dynamics and symmetry*, Pitman Research Notes in Mathematics, Vol. 356, Harlow: Longman, 159 pp.

Gaeta, G. (1994) *Nonlinear Symmetries and Nonlinear Equations*, Mathematics and its Applications, Vol. 299, Dordrecht [The Netherlands]: Kluwer, xix + 258 pp.

Garcia, N. M. L. (1985) *Simetria e periodicidade*, [*Symmetry and Periodicity*, in Portuguese], Lisboa: ED, v + 214 [Mathematics].

Garrett, R. (1987) *Symmetry of Sailing: The Physics of Sailing for Yachtsmen*, London: Adlard Coles Nautical, x + 268 pp.

* Paperback ed., ibid., 1995, x + 268 pp.

* American ed., Dobbs Ferry, New York: Sheridan House, 1996, x + 268 pp.

- Italian trans., Fisica della vela: La simmetria tra aerodinamica e idrodinamica nel movimento di un'imbarcazione, [Physics of Sailing: The Symmetry in Aerodynamics and Hydrodynamics in the Movement of a Boat, in Italian], Bologna: Zanichelli, 1990, 416 pp.

Holmes, P., Lumley, J. L., Berkooz, G. (1996) *Turbulence, Coherent Structures, Dynamical Systems, and Symmetry*, Cambridge Monographs on Mechanics, Cambridge [England]: Cambridge University Press, xviii + 420 pp.

Kavanau, J. L. (1980) *Symmetry: An Analytical Tratment*, Los Angeles: Science Software Systems, ca. 800 pages in various pagings. [Analytic geometry].

Kavanau, J. L. (1982) *Curves and Symmetry*, Los Angeles: Science Software Systems. [Analytic geometry].

Marsden, J. E., Montgomery R., and Ratiu, T. (1990) *Reduction, Symmetry, and Phases in Mechanics*, Memoirs of the American Mathematical Society, No. 436, Providence, Rhode Island: American Mathematical Society, iv + 110 pp.

Mitropolskii, Yu A. and Lopatin, A. K. (1995) *Nonlinear Mechanics, Groups and Symmetry*, Mathematics and its Applications, Vol. 319, Dordrecht [The Netherlands]: Kluwer, ix + 377 pp.

Olver, P. J. (1995) *Equivalence, Invariants, and Symmetry*, Cambridge [England]: Cambridge University Press, xvi + 525 pp. [Mathematical physics].

Sattinger, D. H. (1983) *Branching in the Presence of Symmetry*, CBMS-NSF Regional Conference Series in Applied Mathematics, Vol. 40, Philadelphia: Society for Industrial and Applied Mathematics, vii + 73 pp.

Vanderbauwhede, A. (1982) *Local Bifurcation and Symmetry*, Research Notes in Mathematics, Vol. 75, Boston: Pitman, 350 pp.

Yamashita, J. (1996) *Hoteishiki to taishousei*, [*Equations and Symmetry*, in Japanese], [Series] Suugaku a no tabi, Vol. 1, Kyoto: Gendai Suugakusha, 448 pp. [Mathematics].

Also see:

* the books on broken symmetry and asymmetry in physics → Sections 4.1 and 4.3,

* Petukhov (1981) on biomechanics → Section 3.3.3

3.3 Descriptive sciences (life sciences, earth sciences) and mathematical models in economics, medicine, and technology

3.3.1 Life sciences (biology, medicine, and psychology)

Charnov, E. L. (1993) *Life History of Invariants: Some Explorations of Symmetry in Evolutionary Ecology*, Oxford Series in Ecology and Evolution, Oxford: Oxford University Press, xv + 167 pp.

Chubarov, V. A. (1994) *Simmetrii litsa i traditsionnaya kitaiskaya meditsina*, [*Symmetries of the Face and Traditional Chinese Medicine*, in Russian], Sankt-Peterburg: Mezhdunarodyi tsentr ekonomiki, nauki i tekhniki, 206 pp.

Dubrov, A. P. (1980) *Simmetriya funktsional'nykh protsessov*, [*Symmetry of Functional Processes*, in Russian], Moskva: Znanie, 64 pp. [Biology, Biophysics - with some challenging ideas].

Dubrov, A. P. (1987) *Simmetriya bioritmov i reaktivnosti*, [in Russian], Moskva: Meditsina.

- English trans., *Symmetry of Biorhythms and Reactivity*, New York: Gordon and Breach, 1989, ix + 268 pp. [Biology, Biophysics - with some challenging ideas].

Jocobsohn-Lask, L. (1924) *Die Kreuzung der Nervenbahnen und die bilaterale Symmetrie des tierischen Körpers*, [The Crossing of Neural Pathways and the Bilateral Symmetry of the Animal Body, in German], Abhandlungen aus der Neurologie, Psychiatrie, Psychologie und ihren Grenzgebieten, Heft 26, Berlin: Karger, 125 pp

Jungnitsch, G. (1984) *Vergleichende Untersuchung bei vollsinnigen und geburtsblinden Personen an einer Form der Symmetrietauschung*, [*Comparative Study with Fully Sensible and Blind from Birth Persons on a Form of Symmetry-Illusion*, in German], Psychologia Universalis, No. 45, Bodenheim [at Frankfurt am Main]: Hain, 1984, 244 pp.

Malakhov, A. A. (1965) *L5-simmetriya zhizni*, [*L5-Symmetry of Life*, in Russian], Sverdlovsk [Russia]: Sredne-Ural'skoe knizhnoe izdatel'stvo, 60 pp. [L5-symmetry = 5-fold rotational symmetry].

McCall, J. J. (1997) *Search, Symmetry, and Arbitrage: A Unified Approach to the Social and Biological Sciences*, Boulder, Colorado: Westview Press.

Reader, J. and Croze, H. (1977) *Pyramids of Life: Illuminations of Nature's Fearful Symmetry*, Philadelphia: Lippincott, 222 pp. [Zoology, Animal ecology; "fearful symmetry" is a quote from W. Blake's poem *The Tyger* (1794); cf., Stewart and Golubitsky (1992) in Section 2.1.2, Zee (1986) in Section 3.2.2].

* British ed., *Pyramids of Life: An Investigation of Nature's Fearful Symmetry*, London: Collins, 1977, 222 pp.

Sukhanov, V. B. (1968) *Obshchaya sistema simmetrichnoi lokomotsii nazemnykh pozvonochnykh i osobennosti peredvizheniya nizshikh tetrapod*, [in Russian], Leningrad [now Sankt-Peterburg]: Nauka, 227 pp.

- English trans., *General System of Symmetrical Locomotion of Terrestrial Vertebrates and Some Features of Movement of Lower Tetrapods*, New Delhi: Amerind, [Published for the Smithsonian Institution and the National Science Foundation, Washington, D.C.], 1974, vii + 274 pp.

Sulima, Yu. G. (1970) *Biosimmetricheskie i bioritmicheskie yavleniya i priznaki u sel'skohozyaistvennykh rastenii*, [*Biosymmetrical and Biorhythmical Phenomena and Characteristics of Agricultural Plants*, in Russian], Kishinev [Moldavskoi SSR, now Moldova]: Izdatel'stvo Akademii Nauk Moldavskoi SSR, 148 pp.

Also see:

* Stewart and Golubitsky (1992) on mathematics and biology → Section 2.1 2,
* Urmantsev (1974) on philosophy and biology → Section 3.1,
* Tímár (1979) on Dürer's book on human proportions → Section 3 4.3, and
* the books on asymmetry in biology → Section 4 2.

There is a survey-booklet on symmetry in biology which is shorter than our limit of 50 pages:

* Kasinov, V. B. (1971) *O simmetrii v biologii*, [*On Symmetry in Biology*, in Russian], Leningrad [now Sankt-Peterburg]: Nauka, 48 pp.

3 3.2 Earth sciences (mineralogy and geology)

De Michele, V (1972) *Crystals. Symmetry in the Mineral Kingdom*, London: Orbis Books, 80 pp.

Makagonov, E. P. (1991) *Simmetriya srostkov mineralnykh individov*, [*Symmetry of Systems of Single Minerals*, in Russian], Moskva: Nauka, 193 pp.

Shafranovskii, I I. and Plotnikov, L. M. (1975) *Simmetriya v geologii*, [*Symmetry in Geology*, in Russian], Leningrad [now Sankt-Peterburg]: Nedra, 144 pp.

Ufimtsev, G. F. (1991) *Gornye poiasa kontinentov i simmetriya rel'efa zemli*, [*Mountain Belts of Continents and Symmetry of the Relief of the Earth*, in Russian], Novosibirsk: Nauka, 168 pp.

Yushkin [IUshkin], N. P., Shafranovskii, I. I., and Yanulov [IAnulov], K. P. (1987) *Zakony simmetrii v mineralogii*, [*Laws of Symmetry in Mineralogy*, in Russian], Leningrad [now Sankt-Peterburg]: Nauka, 333 pp.

3.3.3 Mathematical models in economics, medicine, and technology

Bobrowski, L. (1987) *Dyskryminacja symetriczna w rozpoznawaniu obrazów: Teoria, algorytmy, zastosowania w komputerowym wspomaganiu diagnostyki medycznej*, [*Symmetric Discrimination in Recognition of Images: Theory, Algorithms, Application in Computer-Assisted Medical Diagnostics*, in Polish], Wroclaw: Ossolineum, 170 pp.

Kholodnyi, V. A. and Price, J. V. (1998) *Foreign Exchange Option Symmetry*, Singapore: World Scientific, xvii + 134 pp. [Mathematical economics].

Petukhov, S. V. (1981) *Biomekhanika, bionika i simmetriya*, [*Biomechanics, Bionics, and Symmetry*, in Russian], Moskva: Nauka, 238 pp.

Sato, R. and Ramachandran, R V. (1998) *Symmetry and Economic Invariance: An Introduction*, Research Monographs in Japan-U.S. Business and Economics, Boston: Kluwer, viii + 134 pp. [Mathematical economics].

Tamari, B. (1997) *Conservation and Symmetry Laws and Stabilization Programs in Economics*, Jerusalem: Ecometry, 58 pp. [Mathematical economics].

Also see the following books that deal with some aspects of symmetry in technology,

* Povileiko (1970) → Section 1 2 7,
* Grigorovskii (1982) → Section 1.2 7,
* Shubnikov (1940) → Section 2.1 1,
* Rohde (1982) → Section 2.1.2,
* Bérczi (1986-87) → Section 2.2.3.

3.4 Art and the humanities

3.4.1 Anthropology

Lucich, P. (1987) *Genealogical Symmetry: Rational Foundations of Australian Kinship*, Armidale, New South Wales: Light Stone Publications, xxxi + 684 pp.

Witherspoon, G. and Peterson, G. (1995) *Dynamic Symmetry and Holistic Asymmetry in Navajo and Western Art and Cosmology*, American Indian Studies, Vol. 5, New York: Lang, x + 191 pp.

Also see:

* the books on pattern analysis → Sections 2 2 2 and 2.2 3.

In connection with physical anthropology, see:

* Tímár (1979) on Dürer's book on human proportions → Section 3 4.3,
* Schneider (1973) on asymmetry of Greek heads in art → Section 3.4 3,
* Chubarov (1994) on symmetry of the face and traditional Chinese medicine → Section 3.3 1,
* Anderson (1897), Mentzer and Friedberg (1983), Starosta (1990) on symmetry and physical education → Sec 3.5.

3 4.2 Architecture and design

Note that books on Hambidge's dynamic symmetry are listed separately in the → subsection 3.4.2.1.
Bibliography:

Stocklas, K., ed., (1986) *Symmetrie und Asymmetrie in der Architektur*, [*Symmetry and Asymmetry in Architecture*, in German], [Series] IRB-Literaturauslese, Fachbibliographie, No. 1192, Stuttgart: IRB [Informationszentrum Raum und Bau, Fraunhofer Gesellschaft], 64 pp.

* Stocklas, K., ed., 2nd revised ed., ibid., 1989, 40 pp.

* Stocklas, K., ed., 3rd revised ed., ibid., 1992, 54 pp.

* Hezel, D., ed., 4th revised ed., ibid., 1995, 71 pp.

Baglivo, J. A. and Graver, J. E. (1983) *Incidence and Symmetry in Design and Architecture*, Cambridge [England]: Cambridge University Press, xi + 306 pp.

García, S. (1681/1991) *Compendio de architectura y simetría de los templos: Conforme a la medida del cuerpo humano, con algunas demostraziones de geometría, año de 1681*, [*Summary of Architecture and Symmetry of the Temples: In Accordance with the Measurement of the Human Body, with Some Geometrical Demonstrations, Year of 1681*, in Spanish], Valladolid: Colegio Oficial de Arquitectos, Vols. 1-2. [Including the facsimile reproduction of Manuscript 8884 of the Biblioteca Nacional, Madrid; here "simetría" means proportion].

* Spanish text ed., *Compendio de architectura y simetría de los templos*, Salamanca: Hijos de Francisco Nuñez, 1941, 145 pp.

* Mexican text ed., *Compendio de arquitectura y simetría de los templos*, Churubusco, Mexico: Escuela Nacional de Conservación, Restauración y Museografía, 1979, 650 pp.

Hay, D. R. (1846) *First Principles of Symmetrical Beauty*, Edinburgh: Blackwood, viii + 88 pp., 100 plates. [Symmetry is "the result of harmonic ratio of numbers"; plane figures the bases of all forms, curvilinear figures; applications: ornamental design, Greek architecture, vases, pottery, etc.].

Kalayan, H. (1988) *The Architectural Information through Symmetry*, Amman: Department of Antiquities, The Hashimite Kingdom of Jordan, 89 pp.

Kambartel, W. (1972) *Symmetrie und Schönheit: Über mogliche Voraussetzungen des neueren Kunstbewusstseins in der Architekturtheorie Claude Perraults*, [*Symmetry and Beauty: On Possible Prerequisites of the New Artistic Consciousness in the Theory of Architecture of Claude Perrault*, in German], München: Fink, 179 pp.

Kask, T. (1971) *Symmetrie und Regelmässigkeit: Französische Architektur im "Grand Siècle"*, [*Symmetry and Regularity: French Architecture in the "Grand Siècle"*, in German], Basel: Birkhäuser, 157 pp.

Kurokawa, M. (1998) *Hantaishou no monogaku*, [*Objects* <Objectology, Object-Design> *of Antisymmetry* <Dissymmetry>, in Japanese], Tokyo: TOTO Shuppan, 162 pp. [The author (p. 54) would like to refer to dissymmetry (the lack of some elements of symmetry), but, unfortunataly, adopts the term hantaishou (antisymmetry), which is an alternative expression for black-and-white symmetry. This usage of hantaishou came from the Japanese translation of the book La Dissymétrie by Caillois (1973), see it in Section 4.1 with an additional note on this problem.] [Objectology or Object-Design is our suggested equivalent of Kurakowa's term monogaku or, in other reading, butsugaku. This term is not a well-established in Japanese; it is coming from *mono* or *butsu* = thing, object, *-gaku* = learning, study, science, (as suffix) -ology. Obviously, the term *monogaku* is broader than product-design and industrial design since objects of fine art and architecture are also considered. This is the reason that we initiate the new expressions objectology or object-design]

Also see:

Antisymmetry, Shubnikov (1951) → Section 3.2.1 1

Note, Caillois (1973) Japan version, → Section 4 1

Meunié, L. (1968) *L'Architecture et la géométrie. Symétries et rythmes harmoniques*, [*Architecture and Geometry· Symmetries and Harmonic Rhythms*, in French], Paris: Vincent, Fréal, 93 pp.

Ressa A (1990) *Chiese barocche in Piemonte: Nella evoluzione delle figure planimetriche a simmetria centrale*, [*Baroque Churches in Piemonte· On the Development of the Layout-Figures in Central Symmetry*, in Italian], Roma: Quasar, 210 pp.

Ruiz de la Roza, J. A. (1987) *Traza y simetría de la arquitectura: En la antiguedad y medievo*, [*Design and Symmetry of Architecture: In the Antiquity and the Middle Ages*, in Spanish], Sevilla: Servicio de Publicaciones de la Universidad, 393 pp.

Smolina, N. I. (1990) *Traditsii simmetrii v arkhitekture*, [*Traditions of Symmetry in Architecture*, in Russian], Moskva: Stroiizdat, 343 pp.

Stocklas, K (1986) - see at the beginning of this section: Bibliography.

Szambien, W. (1986) *Symétrie, goût, caractère: Théorie et terminologie de l'architecture à l'âge classique, 1550-1800*, [*Symmetry, Taste, Character: Theory and Terminology of Architecture in the Age of Classicism, 1550-1800*, in French], Paris: Picard, 232 pp.

- Spanish trans., *Simetría, gusto, carácter. Teoría y terminología de la arquitectura en la época clásica (1550-1800)*, Madrid: Akal, 299 pp.

Also see:

* Huff, W. S. (1967-77) on basic design → Section 1 1 3,
* Povileiko, R. P. (1970) on industrial design → Section 1.2.7,
* Horst (1994) on garden art → Section 3 4.3

3.4.2.1 Design with dynamic symmetry (a system of proportions based on square roots of integers)

Note that these books represent a method of proportional analysis of art works that are outdated in some sense, but still provide interesting sources not only for some historians of art, but also for educators of mathematics.

Bairati, C. (1952) *La simmetria dinamica: Scienza ed arte nell'architettura classica*, [*Dynamic Symmetry: Science and Art in Classical Architecture*, in Italian], Milano: Editrice Poltecnica Tamburini, 100 pp.

Edwards, E B. (1967) *Pattern and Design with Dynamic Symmetry*, New York: Dover, xx + 122 pp. [Reprint of the book Dynamarhythmic Design, 1932].

Hambidge, J. (1920) *Dynamic Symmetry: The Greek Vase*, New Haven, Connecticut: Yale University Press, 161 pp.

* 2nd printing, ibid., 1931, 161 pp.
* Reprint of the original work in a luxury ed., Found Class Reprints.

Hambidge, J. (1923) *Dynamic Symmetry in Composition as Used by the Artists*, New York: Brentano, 83 pp.

* Reprint ed., ibid., 1927, 83 pp.
* Reprint ed., New Haven, Conn.: Yale University Press, 1948, 83 pp.

Hambidge, J. (1924) *The Parthenon and Other Greek Temples: Their Dynamic Symmetry*, [With a preface by L D. Caskey], New Haven, Connecticut: Yale University Press, xxii + 103 pp.

- French trans., *Le Parthénon et autres tenples grecs: Leur symétrie dynamique*, Marseille: Aurea Carmina, 1995, 130 pp.

Hambidge, J. (1926) *The Elements of Dynamic Symmetry*, New Haven, Connecticut: Yale University Press and New York: Brentano, xx + 140 pp.

* Reprint ed., New Haven, Conn.: Yale University Press, 1948, xvii + 133 pp.
* Reprint ed., New York: Dover, 1967, xvii + 133 pp.

Hambidge, J. (1932) *Practical Applications of Dynamic Symmetry*, Ed. by M. C. Hambidge, New Haven, Connecticut: Yale University Press and London: Milford and Oxford University Press, xviii + 109 pp.

* Reprint ed., New Haven, Connecticut: Yale University Press, 1942, xviii + 109 pp.
* Reprint ed., New York· Devin-Adair, 1960, xviii + 109 pp.

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3 4.3 Visual art (painting, sculpture, garden art)

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Also see:

* MacGillavry (1965) and Schattschneider (1990) on the graphic art of M C. Escher → Section 2 2.3,
* Witherspoon and Peterson (1995) on Navaho painting and its modern adaptation → Section 3.4 1,
* Kurokawa (1998) on dissymmetry in art → Section 3 4 2, and
* the books on dynamic symmetry → Section 3 4 2 1.

3.4.4 Music

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- Hungarian trans., *Szimmetria a zenében*, Kecskemét [Hungary]: Kodály Intézet, 1994, 165 pp.

- German trans , *Symmetrien in der Musik: Einführung in die musikalische Semantik*, Kecskemét [Hungary]: Kodály Institut and Wien· Universal Edition, 1995, 173 pp.

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* Reprint ed , Vaduz [Liechtenstein]: Sändig, 1973, 128 pp.

* Reprint ed., Walluf [at Wiesbaden, Germany]: Sandig, 1973, 128 pp.

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* Reprint ed., ibid., 1969, 356 pp.

* Reprint ed., Vaduz [Liechtenstein]: Sändig, 1984, 354 pp.

Also see:

* Goncharenko (1993) → Section 1.2.8.

3.4.5 Literature and linguistics

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* Markova (1996) → Section 1 2 8,

* the books on broken symmetry and asymmetry in linguistics, literature, and semiotics → Section 4.4.

3.5 Recreation, games, and sport

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Sveton, E. (1989) *Symetria: Súbor hier pre deti, mládež a dospelych*, [*Symmetry: A Set of Games for Children, Youth and Adults*, in Slovakian], Bratislava [Czechoslovakia, now Slovakia]· Slovenske pedagogické nakladatelstvo, 281 pp. + 2 attachments [Board games].

Also see:

* Garrett (1987) on the physics of sailing → Section 3 2 5 2.

There is a booklet on symmetry in chess which is shorter than our limit of 50 pages:

* Zavodny, Z (1991) *Symetrické pescove formace v centru*, [*Symmetric Pawn Formation in the Center*, in Czech], [Series] Sachove strategie, Frydek-Místek [Czechoslovakia, now Czech Republic]: Pliska, 47 pp.

4 INTERDISCIPLINARY BOOKS ON DISSYMMETRY, BROKEN SYMMETRY, ASYMMETRY (INCLUDING SYMMETRY VS. ASYMMETRY, ASYMMETRY OF BRAIN, AND ASYMMETRY OF TIME)

Note the differences between these concepts:

(1) dissymmetry is the lack of some elements of symmetry (cf., Pasteur's molecular dissymmetry: the lack of some elements of symmetry is necessary to have left- and right-handed molecules) or the small deviation from the perfect symmetry (cf., P. Curie's principle of dissymmetry),

(2) broken symmetry is the occasional violation of an existing or suspected symmetry (cf., Lee and Yang's broken symmetry in particle physics),

(3) asymmetry is the total lack of symmetry.

(In connection with antisymmetry, or black-and-white symmetry, in crystallography, cf., Shubnikov (1951) in Section 3.2.1.1.).

4.1 General

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- German trans., *Symmetriebrechung und Wahrnehmung: Beispiele aus der Erfahrungswelt*, [*Symmetry-Breaking and Perception· Examples from the Empirical World*, in German], [With a new preface by H. Haken], Braunschweig. Vieweg, 1990, x + 200 pp.

- English trans., *The Dynamics of Ambiguity*, [With a new preface by H. Haken], Berlin: Springer, 1992, xx + 170 pp.

- Japanese trans. of the English version, *"Aimaisa" no butsurigaku: Chitsujo to muchitsujo no adida o toraeru atarashi kokoromi*, [*The Physics of "Ambiguity": A New Trial to Grasp the Gap of Order and Disorder*, in Japanese], [With a new preface by K. Hushimi (Husimi)], [Series] Blue Backs / Buruu bakkusu, B-1159, Tokyo: Koudansha, 1997, 243 + 5 pp.

- Russian trans. of the English version, Kal'oti, D , *Ot vospriyatiya k mysli: O dinamike neodnoznachnogo i narusheniyakh simmetrii v nauke i iskusstve*, [*From Perception to Thought On Dynamics of Ambiguity and Violations of Symmetry in Science and Art*, in Russian], [With a new preface by I. Prigozhin (I. Prigogine) and an introduction and an afterword by V. A Koptsik], Moskva: Mir, 1998, 222 pp.

Caillois, R. (1973) *La Dissymétrie*, [*Dissymmetry*, in French], Paris: Gallimard, 90 pp.

* Cf., *Cohérences aventureuses; Au coeur du fantastique; La Dissymétrie: esthétique généralisée*, [*Adventurous Coherences; A Fantastic Heart; Dissymmetry: Generalized Aesthetics*, in French - three works in one volume], Idées, Vol. 359, New edition, Paris: Gallimard, 1976, 281 pp.

Gardner, M. (1964) *The Ambidextrous Universe. Left, Right, and the Fall of Parity*, New York· Basic Books, x + 294 pp. [Popular-scientific, see the reference to "asymmetry" in the subtitles of the 2nd and 3rd eds.].

* British reprint ed., London: Allen Lane, Penguin Press, 1967, 272 pp

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* 2nd revised ed., *The Ambidextrous Universe: Mirror Asymmetry and Time-Reversed Worlds*, New York: Scribner, 1979, 293 pp.

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* 3rd revised ed., *The New Ambidextrous Universe: Symmetry and Asymmetry from Mirror Reflections to Superstrings*, New York: Freeman, 1990, xiv + 392 pp.

* Paperback ed., ibid., 1991, xiv + 392 pp

- Japanese trans., *Hantaishou: Hidari to migi no benshouhou*, [*Antisymmetry* <Dissymmetry>: *The Dialectics of Left and Right*, in Japanese], Tokyo: Shisakusha, 1991, 152 pp. [The Japanese title Hantaishou (han- = anti-, against, opposite; taishou = symmetry), which is also adopted by Kurokawa (1998), see in Section 3.4.2, is unfortunate: its meaning is closer to the crystallographic term "antisymmetry" (black-and-white symmetry), cf., Shubnikov (1951) in Section 3.2.1.1. Since there is no well-estbalished Japanese term for dissymmetry in the given sense, I suggest a new Japanese expression: futaishou.].

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* Spanish trans. of the 3rd ed., *El universo ambidiestro: Simetrías y asimetrías en el cosmos*, [*Ambidextrous Cosmos: Symmetry and Asymmetry in the Cosmos*, in Spanish], Barcelona: Labor, 1993, 343 pp.
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- German trans. of the 1st ed , *Das gespiegelte Universum: Links, rechts und der Sturz der Parität*, [*The Mirrored Universe: Left, Right and the Fall of Parity*, in German], Braunschweig: Vieweg, 1967, 285 pp.

* German revised and enlarged ed., *Unsere gespiegelte Welt: Denksportaufgaben und Zaubertricks*, [*Our Mirrored World: Puzzle-Problems and Magic Tricks*, in German], Berlin: Ullstein, 1982, 344 pp.
  * German reprint ed., Berlin: Deutsche Buch-Gemeinschaft [with Austrian, German, and Swiss partners], 1984, 344 pp.

- Russian trans. of the 1st ed., *Étot pravyi, levyi mir*, [*This Right, Left World*, in Russian], Ed. by Ya. A. Smorodinskii, Moskva: Mir, 1967, 264 pp.

- Lithuanian trans. of the 1st ed., Vilnius: Mintis, 1969, 288 pp.

- Polish trans. of the 1st ed., *Zwierciadlany wszechswiat*, [*Mirrored Universe*, in Polish], [Series] Biblioteka problemów, No. 138, Warszawa: Panstwowe Wydawnictwo Naukowe (PWN), 1969, 354 pp.

Japanese trans. of the 1st ed., *Shizen ni okeru hidari to migi*, [*Left and Right in Nature*, in Japanese], Tokyo: Kinokuniya Shoten, 1971, 340 pp.

* Japanese reprint eds., ibid., 340 pp.

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- Italian trans. of the 2nd ed., *L' universo ambidestro: Nel mondo degli specchi, delle asimmetrie, delle inversioni temporali*, [*The Ambidextrous Universe: In the World of Mirrors, Asymmetries, Temporal Inversions*, in Italian], Bologna: Zanichelli, 1984, x + 245 pp.
  * Italian reprint ed., Novara: Mondadori-De Agostini, 1996, viii + 244 pp.

- French trans. of the 2nd ed., *L'Univers ambidextre: Les Miroirs de l'espace-temps*, [*The Ambidextrous Universe: The Mirrors of the Space-Time*, in French], Paris: Seuil, 1985, 357 pp.
  * French reprint ed , ibid., 1994, 357 pp.

- Dutch trans. of the 2nd ed., Revised, co-author Beekman, G., *Spiegelsymmetrie: Links en rechts in de natuur*, [*Mirror-Symmetry Left and Right in Nature*, in Dutch], Amsterdam: Aramith, 1986, 222 pp.

Genz, H and Decker, R. (1991) *Symmetrie und Symmetriebrechung in der Physik*, [*Symmetry and Symmetry-Breaking in Physics*, in German], Braunschweig: Vieweg, 376 pp.

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Sonin, A. S. (1987) *Postizhenie sovershenstva: Simmetriya, asimmetriya, dissimmetriya, antisimmetriya*, [*Comprehension of Perfectness: Symmetry, Asymmetry, Dissymmmetry, Antisymmetry*, in Russian], Moskva: Znanie, 203 pp.

Tayler, K. (1989) *Symmetry and Antisymmetry*, Cambridge [England]: Haslingfield Press, 111 pp. [Symmetry vs. antisymmetry = continuity vs. discontinuity, convergence vs. divergence, variance vs. invariance, etc. - this is not the usual crystallographic or mathematical meaning of antisymmetry].

Also see:

* Witherspoon and Peterson (1995) on symmetry and asymmetry in Navaho art and cosmology → Section 3.4 1,
* Stocklas (1986) on symmetry and asymmetry in architecture → Section 3.4 2,
* Kurokawa (1998) on dissymmetry in desing → Section 3 4 2,
* Mohr (1987) on fractured symmetry in his art works → Section 3.4 3

4.2 Chemistry and biology, including asymmetry of brain

Brain asymmetry - there are many related books that use other expressions (cerebral dominance, dual brain, hemispheric lateralization, split brain, etc.); in accordance with the principles of this bibliography, such items are not listed (their data are available in the bibliographies of the listed books).

Bibliography:

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Bradshaw, J. L. and Nettleton, N. C. (1983) *Human Cerebral Asymmetry*, Englewood Cliffs, New Jersey: Prentice-Hall, xvi + 335 pp.

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* 2nd revised ed., ibid., 1988, 237 pp.

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Depenchuk, N. P. (1963) *Simmetriya i asimmetriya v zhivoi prirode*, [*Symmetry and Asymmetry in Living Nature*, in Russian], Kiev: Izdatel'stvo Akademii Nauk Ukrainskoi SSR, 174 pp.

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Kizel', V. A. (1985) *Fizicheskie prichiny dissimmetrii zhivykh sistem*, [*Physical Causes of Dissymmetry of Living Systems*, in Russian], Moskva: Nauka, 118 pp.

Kuroda, R (1992) *Seimei sekai no hitaishousei: Shizen wa naze anbaransu ga suki ka*, [*Asymmetry of the Living World: Why Does Nature Like Imbalance?*, in Japanese], [Series] Chuukou shinsho, No. 1097, Tokyo: Chuuou Kouronsha, 216 pp. [Popular-scientific].
* Reprint ed., ibid., 1995.

Moller, A. P and Swaddle, J. P (1997) *Asymmetry, Developmental Stability, and Evolution*, Oxford: Oxford University Press, xi + 291 pp.

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Yanagisawa, K. (1997) *Sayuu o kimeru idenshi: Karada no hitaishousei wa neze shoujiru no ka*, [*The Gene Determines Left-Right: Why Does the Asymmetry of the Body Arise?*, in Japanese], Blue Backs / Buruu bakkusu, B-1155, Tokyo· Koudansha, 200 + vi pp. [Popular-scientific].

Also see:

* Hámori (1996) on brain asymmetries → Section 1 2.5,
* Schneider (1973) on asymmetry of Greek heads in art → Section 3 4 3,
* Starosta (1990) on symmetry and asymmetry in physical training → Section 3.5,
* Ivanov (1978) on the asymmetry of brain → Section 4.4.

4.2.1 Asymmetric synthesis

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Coppola, G. M. and Schuster, H. F. (1987) *Asymmetric Synthesis: Construction of Chiral Molecules Using Amino Acids*, New York: Wiley, xiii + 393 pp.

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* 2nd revised printing, Washington, D.C.: American Chemical Society, 1976, xii + 465 pp.

- Japanese trans., *Fusei gousei*, [*Asymmetric Synthesis*, in Japanese], Tokyo: Toukyou Kagaku Doujin, 1973, xi + 487 pp.

- Russian trans., Morrison, D. and Mosher, G., *Asimmetrichnye organicheskie reaktsii*, Ed. by E I Klabunovskii, Moskva: Mir, 1978.

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4.3 Mathematics and physics, including asymmetry of time

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* Paperback ed., ibid., 1977, xviii + 214 pp.

Japanese trans., *Jikan no butsurigaku: Sono hitaishousei*, [*The Physics of Time: Its Asymmetry*, in Japanese], Tokyo: Baifuukan, 1979, xiv + 219 pp

* Reprint ed , ibid , 1982, xiv + 219 pp.

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* Reprint ed., Redwood City, California: Addison-Wesley, 1989, xxiv + 326 pp.

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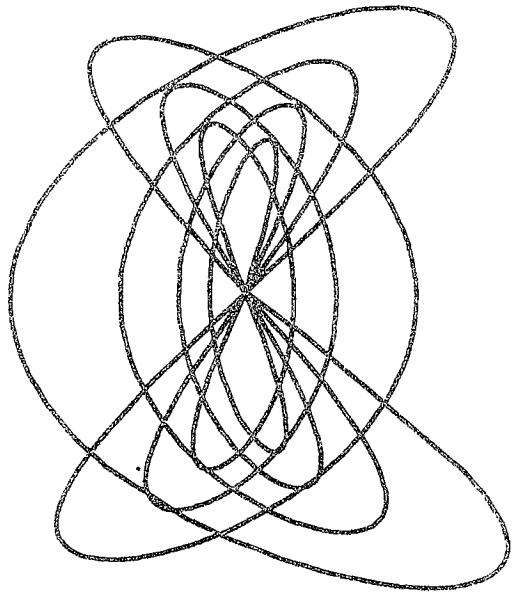

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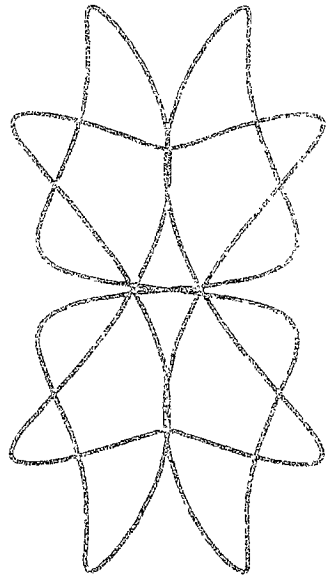

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