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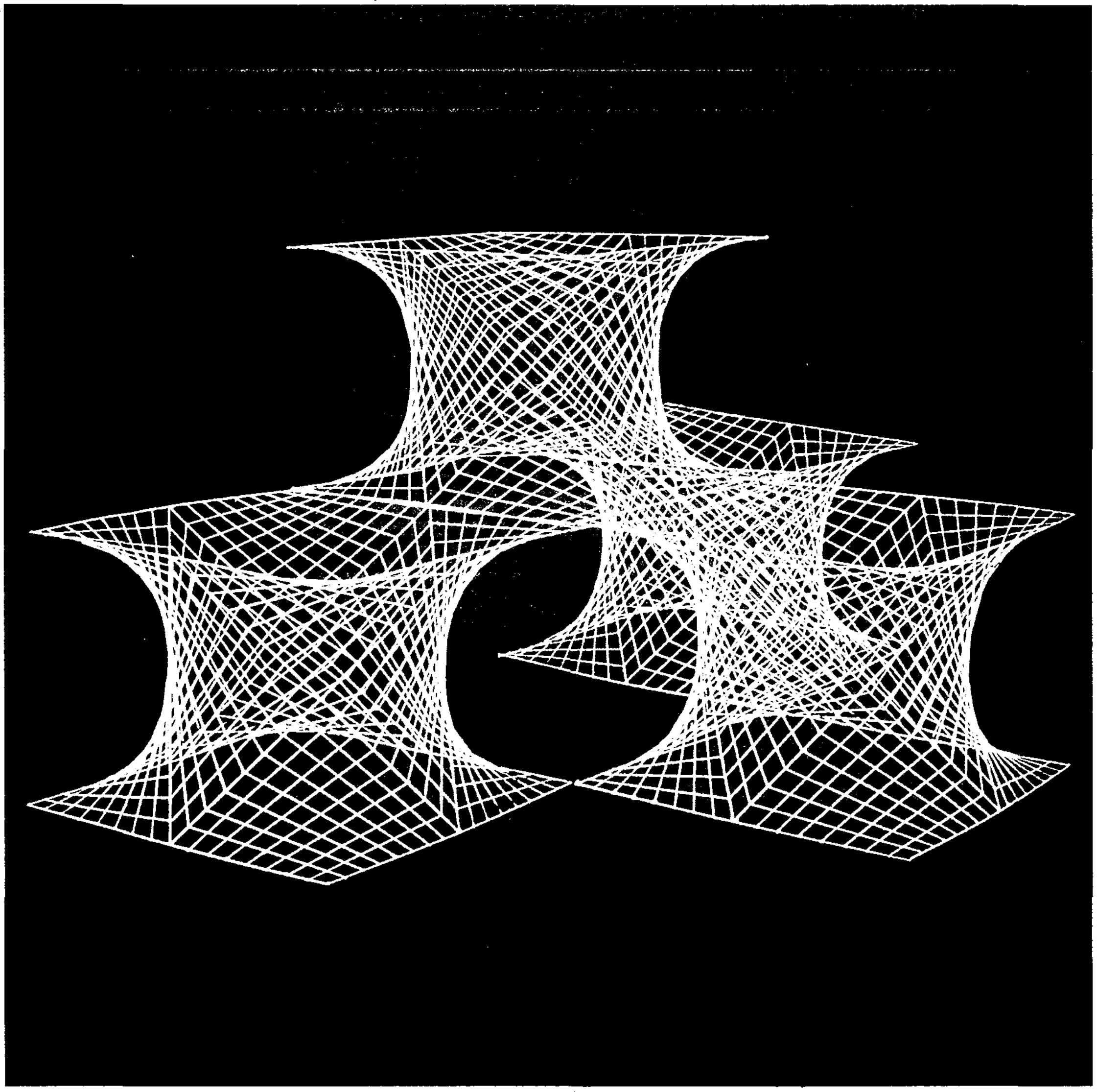

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LAWS OF SYMMETRY BREAKING

Closing plenary lecture

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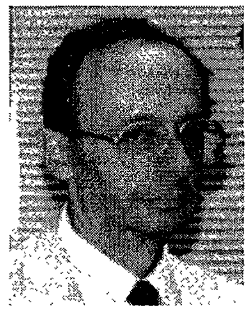

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Introduction

We came together at fourth time now. We are representing different fields of study, different kinds of the arts, different cultures. One could raise the question, what brings so many different scientists and artists together again and again? The answer seems very simple: it is the common interest in *symmetry*.

What is that? Well, one can quote definitions of symmetry, asymmetry, dissymmetry, etc. what *denote common concepts* and *common phenomena* in our everyday work, and form a *common platform for our communication* where we understand each other, and where we can *reveal useful information* to each other.

Nevertheless, the case is not so simple. Symmetry does not mean a branch of science or arts. This word denotes an interdisciplinary concept, a class of properties and phenomena. Its essence is in its interdisciplinary character. Symmetry and asymmetry, order and disorder appear in all of our fields of activity. So, the information we can convey, bears *practical value* for each other. Therefore, although there is no such discipline like "symmetrology", but there are common features, and we acknowledge mutually accepted values.

Thus, when we answered the first question, (what brings us together?), we found the *glue* (that was symmetry), but did not answer the question, *what is kept together by this glue*? Semantically, there can be two subjects of this last question. In epistemological sense, one of them are we, ourselves. The other is, in ontological sense, the "common object" of our studies.

Now the next question is, whether there exist common objects of studies, what do not form a discipline? In other words, one can raise the question: are there common principles or common laws what are guiding the symmetry studies conducted in all disciplines? Does this glue keep together (at least symbolically) an *ordered structure*, in which all of us have our quiet space, where we can maintain the privacy of our creative activity, and without which space the whole structure should collapse?

My answer is definite: yes.
Yes, there are general enough *common objects* of our studies (at least in philosophical terms).
Yes, there are *laws* (and not only principles) of symmetry/asymmetry.
Yes, these laws are *common*, irrespective of the discipline, where we are active.
Yes, there are *general* laws, what are glued by the phenomena of symmetry (to be more precise, of symmetry breaking).
Earlier or later any field of learning formulates its laws (this belongs to its identity). So do we now.

These are demonstrated in my paper.

Maybe the question seems too theoretical for some of you, it cannot be quite neutral for any of us after nearly a decade of work together: whether there are general laws guiding our activities; whether there can be formulated what is common in each other's work; how can we determine what is kept together by this glue called symmetry, asymmetry; what is exactly, which brings our achievements close together? I am convinced that the introduction of some general features in the field of symmetry studies makes our co-operation more conscious. The recent decades demonstrated that methods borrowed by the means of symmetry considerations from different disciplines and arts, led to new discoveries (cf., e.g., the quasicrystals, the fullerenes). What has worked on the level of intuition, may become part of the co-ordinated activity of scientists and artists in the future.

Philosophical background

Nature proved to be not always symmetric. Although basic laws could be formulated by the application of symmetry principles, most *new phenomena* appeared by certain distortion of symmetry. Therefore, it was *symmetry breaking* what led scientists to new discoveries. This is why P. Curie stated “dissymmetry makes the phenomenon”.

Symmetry plays several different roles in philosophical thought.

In *epistemology* it plays a heuristic role, since the mind often prefers symmetric solutions of problems from among alternatives. Not only prefers, even seeks for such solutions if there are available any such. Thus, symmetry performs a methodological function in the formulation of scientific knowledge. Many examples can be quoted when great discoverers' minds were led by symmetry principles.

The *ontological* basis of the importance of (dis)symmetry is that material reality indeed has both symmetry properties and symmetry breakings. It has been less realised that symmetry breaking plays important role in the *construction of the material world.* There is an order (of symmetry breakings), what can be traced along the evolution. These material properties and order should be reflected in the *laws of the nature.* They are the *laws of symmetry* and *symmetry breaking*.

Science and mathematical description looked for *order* and for the *linear phenomena* for many centuries, because those were so perfect and beautiful. Less attention was paid to *chaos*, *disordered structures* and *nonlinear phenomena.* The recent two decades turned the attention of scientists to the systematic description (and discovery of laws) of the latter.

Similar is the situation with the *phenomena of symmetry breaking.* We knew and phenomenologically described them. We knew, that they were present in any phenomenon of nature, and most new promising areas for a scientist could be identified by the study of dissymmetric phenomena. However, most works dealing with symmetry itself discussed symmetry and treated laws of symmetry (e.g., Rosen, 1995; van Fraassen, 1989; de Gortari, 1970). Many new transdisciplinary discoveries were made on the basis of the application of symmetry considerations (cf., the discovery of quasicrystals, fullerenes, in the recent two decades). Dissymmetry, and so symmetry breaking was left for the so called "puzzle solving" research (using this term after T. Kuhn, 1963). Making an order in symmetry breaking was a subject only within separated disciplines, like in particle physics and cosmology, as well as in some biological subdisciplines.

Now, we make an attempt to discuss the role of symmetry breaking at a philosophical level. *Laws of symmetry breaking* in a wide context will be formulated first.

The laws of ontological levels and symmetry breaking

(1) The law on the determining role of the lower levels.

(1a) Among two consecutive ($_{\text{a lower}}$ and $^{\text{an upper}}$) levels, the lower level potentially (but only potentially) possesses the characteristic type of interaction of the consecutive upper level; i.e., that the preceding lower level's types of interaction play the determining role in the development and existence of any level's characteristic interaction. However,

(1b) In the interrelation of two different ($^{\text{an upper}}$ and $_{\text{a lower}}$) levels, generally the upper level's structure affects actively the other, since

(1c) Any lower level material structure can reflect its environment only on its own (lower) quality and own level. Within that, the material structure of a lower level can reflect the material structures corresponding to the upper level's forms of material motion also only on its own (lower) level.

(The two statements in (1c) are not-certainly equivalent, because the given levels are determined *per definitionem* by their characteristic interaction and not by the corresponding form of material motion.) For example, any inanimate being can reflect an animal only as a physical object, and cannot reflect its biological properties; no animal can discern the social differences between human beings.

Since the relation of the two (${}_{\text{lower}}$ and ${}^{\text{upper}}$) levels are not symmetric, this law does not open the door to any reductionism. A reductionist approach would allow only the following kind of statement, viz., "among two consecutive levels, the lower level possesses the characteristic type of interaction of the consecutive upper level." But, according to our laws, (1a) limits the existence of the upper level's characteristic interaction at the lower levels to potentiality, while (1b) and (1c) together contradict any statement which denies the appearance of new qualities at the upper levels.

(2) The law of correspondence between the ontological levels and their potential symmetry properties.

(*2a*) Each qualitatively higher organisational form in the evolution of matter is marked by the loss of a certain symmetry property, and

(*2b*) Each loss of a potential symmetry property of matter traces a new material quality.

Consequently, the precondition of the development (in its relative totality) of a qualitatively new (material) level is the breaking of a certain symmetry (property), and at the same time, the condition of the continuance (existence) of the new level is to possess (new?) conserved properties. Therefore

(*2c*) Parallel with the appearance of new material qualities and new (higher) ontological levels, there appear also new symmetries.

(*2d*) These new symmetries qualitatively differ from those what existed at the previous (lower) levels and what have been broken at the given level. These new symmetries involve new conserved properties.

As a conclusion, the lower and higher ontological levels can be traced by a sequence of symmetry breakings, thus it can be formulated, that

(3) Each symmetry breaking leads to a higher organisational level of matter.

(4) Each higher organisational level of matter is - in a certain sense - less stable than the former one.

The latter statement needs some further explanation. This will be given in a detailed treatise by encountering examples for all the above four laws. Let's now mention only the decreasing self-reproducibility of the living organisms along phylogeny, or the decreasing forces keeping together the inanimate structures from the subatomic particles to the large molecules.

Some open problems

There are some further problems what arise in the interpretation of the above laws. Two of them are crucial. The first one concerns the so called level theories, what are formulated in the framework of philosophy, and what distinguish fundamental and particular levels. Without going into philosophical details, we mention, that generally there are distinguished three fundamental levels of the material world: inanimate nature, the organic world, and human society and thought, while there are further, particular levels *within* the respective fundamental levels. This is the point, where the next important group of concerns appear: what are the *differentia specifica* of a given level? What is the main concept, according to which one distinguishes the different levels? There are many candidate concepts for this role, e.g., interactions, forms of motion, order of magnitude relations (principle of 'nest of tables'), sequence of genetic evolution, degree of complexity, types of matter, space-time forms, structures. I choose from among them the characteristic *interactions*, because this works, and plays an equivalent role, both at the fundamental and non-fundamental levels. In short, one can speak about two types of level theories: a general one (in philosophy) and particular ones (in inanimate, the organic nature, and in human society). Particular level theories differ from each other *in the* three fundamental ontological spheres, nevertheless in their description and contents. At the same time they may have common features, e.g., all are particular theories concerning their width of validity, and all are based on an arrangement by a common concept, namely the *forms of interaction.* The clarification of these conceptual problems is necessary to understand the laws of symmetry breaking. One can put the question: Is unification of the different types of level theories possible? With certain limits, yes. For this reason, one should accept that all levels can be characterised by a given type of interaction, and they are submitted to the laws (1a-c). Any further detail belongs to the competency of the discipline studying the phenomena of the given level.

The detailed treatise of the mentioned two crucial problems are given in my philosophical works. I do not want to bore too long our interdisciplinary audience with special philosophical problems.

Levels and symmetry breakings

Is there a one-to-one correspondence between the *levels* and *symmetry properties broken* at the given level? One cannot give a definite answer yet, since it has not been studied thoroughly in all disciplines. However, all the available examples affirm the presumption. E.g., the stronger a basic physical interaction is, the more quantities are conserved, and with weakening the type of interaction, the number of symmetry breaking increases. That means also, that the weaker an interaction is, the greater number of material structures (particles) are affected by it, and their interactions are limited by fewer conservation laws. Strong interaction conserves all elementary particle quantities. In electromagnetic interaction Isospin is not conserved, but all the others are; in weak interaction Parity, Charge conjugation and others are not conserved, (however the combination of them with Time reversal (CPT) is conserved). Parity conservation is also violated in the so called united electroweak interaction. The antineutrinos play an important role in the electroweak interaction. These particles exist only in a right-handed chiral form. Antineutrinos are produced during beta decay, where the majority of the electrons produced simultaneously with the antineutrinos have a left-handed chirality (spin) (Ne'eman, 1986). The participants of the electroweak interaction are the electrons of the atom on the one side and the protons and neutrons of the nucleus on the other. From the chirality of the participants follows the chirality of the atoms, and the molecules built of them. This leads to the existence of the enantiomers in the organic molecules (e.g., glucose and fructose), then the L- and D-aminoacids. Proteins are built up (almost) exclusively from L-aminoacids, and therefore it is not by chance that RNA and DNA form only right-handed helixes. Is it surprising that living creations are chiral? All this follows from the electroweak interaction what distinguishes 'left' and 'right' by the charged weak currents and neutral weak currents (or in other words by W and Z forces) (Hegstrom and Kondepudi, 1990).

However, nature is not so·simple. Nature reproduces the dominance of left- or right-handedness at any new level by new properties. While left-handed DNA helixes are very rare, we find both left- and right-handed helixes among bacteria, plants, snails, etc. Nature produces again both kinds, although, by a spontaneous symmetry breaking their numbers are different.

The dominance of morphological asymmetry is becoming prevailing in the morphology at the more evolved animals (e.g., circulation system). Another symmetry: irreversibility (e.g., reproducibility of the organs) weakens during the evolution too. Nevertheless, the brain remains symmetric, even at mammals. A new, qualitative change (mutation) takes place, when the lateralisation of the brain starts. This makes possible the real right- and left-handedness, differentiation of the kinetic and the speech centres in the brain, and the separation of the emotional and rational, etc. functions. The loss of the symmetry of the brain is also a typical example of the violation of a symmetry, which did not exist 'always', only since one can speak of 'brain' or 'neural system' as a quality, as an organ of living organisms (2c-d).

Closing remarks

This treatment could not give a detailed philosophical analysis of the full problem. That was not the aim of this paper. Our goal was only to introduce the *laws of symmetry breaking*. We did not want to replace any evolution theory; these laws touch them only tangentially. It is important to note that none of the treated laws take stand on the debate of reductionism. We stressed, that they may be used as arguments by both parties - probably they can bring the parties closer to a decision - but in their presented form they do not fulfil a decisive function. This was also not the aim of this paper. The new features of this treatment were to link the level theories with the laws of symmetry breaking. Finally, what is most important at this forum: we have demonstrated that one can find common ground, based by its own specific laws, for hunters for symmetric/asymmetric phenomena in different disciplines.

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