

BROKEN SYMMETRIES IN SCIENCE AND ART

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Scientific values and artistic values are both pursued by man, and they are not extraneous to each other. The aim of this report is to explore the nature of the relationship between art and science, and suggest arguments supporting the thesis which asserts that art and science have a common meeting ground in symmetries, and especially at the point where symmetry is broken (1).

Symmetry is invariance under a transformation. Symmetry is indiscernibility of the transformation. Symmetry transformations are associated to the concepts of invariance or conservation, and therefore to the permanent significance of structures. Although it exists, so to speak, outside time, symmetry is nevertheless essential to a description of the fundamental characteristics of a structure.

By definition, symmetry implies the impossibility of perceiving or measuring differences in systems at equilibrium without provoking perceptible changes in the structure. To perceive and measure, to remove uncertainty and create information and knowledge, it is necessary to make choices. And each choice involves a loss of equilibrium, that is, a breaking of symmetry. Paradoxically, symmetry can be understood providing it is broken.

We, as living beings, and as such removed from thermodynamic equilibrium, form self-reproducing information systems. Consequently, not only is symmetry agreeable to us - associated to ecstatic, detached and passive contemplation - but so are broken symmetries - associated to an acquisition of information which is at the same time attentive, interested and active. As living beings we obey the laws of nature, and the mere following of these laws gives us satisfaction, or at least cause for serenity. Still, we find even greater gratification if we become attuned to nature to the point of making such laws our own, and being able therefore to understand and express them adequately. To understand and express the laws of nature, the artist-man and the scientist-man will each use his own instruments.

Perception is a fundamental instrument for the artist in his relationship with nature. It is the perceptive process which permits the artist to grasp the correlations which exist or may exist among forms, colors and sounds; once he has acquired these correlations, the artist filters them, subjectivizes them and transfers them in sculpture, on canvas or in music. His work will then be a stimulus for those who make use of it. And it will arouse emotions if this stimulus is created so as to resound on the observer's state of mind: a state of mind that has matured precisely because of a continuous exercising of the perceptive activity.

An essential instrument for the scientist in his

relationship with nature is measurement. It is measurement which enables the scientist to grasp the correlations that govern the formation of natural structures, eliminating superfluous details and revealing the functional aspects: once these correlations have been acquired, the scientist elaborates his theory or his model of reality. His work will then be a stimulus for the person who utilizes it: it will inspire consensus if it has been created so as to pass all the experimental tests to which the theory or the model lend themselves.

The perceptive process and the measuring process are therefore at the basis of creativity in art and in science, respectively. These processes however have one characteristic in common: both are completed only after a critical stage has been overcome. In the critical stage the subject who perceives or who, with the aid of an instrument, measures, enters into symbiosis, so to speak, with the object perceived or measured, and in this way he gathers its aesthetic or gnoseological value. This critical stage is characterized by a breaking of symmetry: it appears during every crisis taken as a choice, or as a transition between a before and an after, between a state in which I was not aware and a state in which I became aware, between a state in which I didn't know and one in which I know.

To clarify in what sense the breaking of symmetry is to be found at the point where art and science converge, think, for example, of a baroque fugue (2). Like the vast majority of musical compositions, the fugue is divided into a

succession of beats which, with translational symmetry, measure the time in equal steps. On these beats, all of the same length, the theme is developed and repeated, again with translational symmetry: a theme which, to follow itself, runs from itself along the score. And as it fades and reappears it evokes a rhythmic and periodic movement to which, just as in flight, a momentum (or a velocity) is associated, the value of which remains, on the average, constant in time. On the other hand, it's the melodic line of the theme which breaks the translational symmetry, and with its informative content modulates the meaning of the structure, which otherwise would be purely rhythmic. Passing from music to poetry, Montale comes to mind: 'If I think of poetry as an object, I believe that it was born from the need to add a vocal sound (word) to the beating of early tribal music (....). Also in the first Nibelung sagas and later in the romance epics, the true nature of poetry is sound.' (3). In poetry, it is sound that breaks the translational symmetry associated to the rhythm of the meter.

Other examples can be drawn from figurative art, especially from Greek vase painting.

But the example which most deserves our attention here is that reported in fig. 1, taken from Gestalt psychology. The reader who wishes to actively make use of this image may be led to discern an analogy (4) between the triggering of the 'chemical' bond resonance at the breaking of symmetry provoked by the 'charge transfer spectrum' during a

spectroscopic measurement (5), and the perception of the "structural" ambiguity of the information bit: information that is released at precisely the critical stage of the perceptive process or the measuring process. Having reached the critical stage, the structure loses its equilibrium, the inversion symmetry is broken and the center of symmetry disappears (1).

In conclusion, with the passing of classical determinism and the advent of quantum physics, the physics of cooperative phenomena (6) and irreversible thermodynamics of systems away from equilibrium (7), the concept of symmetry breaking is assuming ever greater importance in increasingly wide-ranging fields of applicability. It offers a unifying interpretation for the understanding of complex structures and phenomena of the scientific and the humanistic cultures.

Caption for fig. 1

Graphic condensation (by Franco Grignani). The wall common to both cubic moduli of the condensed structure (in the lower portion of the figure) behaves, during the perceptive process, rather like an electron in an hydrogen molecule does during a spectroscopic measurement, under the action of an electromagnetic field whose frequency matches the resonance or exchange integral. Both the dynamic perception of the gestaltic structure and the measurement of the resonance frequency between bond-symmetric and antibond-antisymmetric levels of the biatomic molecule which this structure resembles, take place at the onset of the dynamical instability which marks the disappearance of the center of symmetry.

Bibliographical References

- (1) G.Caglioti, *Simmetrie infrante nella scienza e nell' arte*, Clup, Milano, 1983. German language edition, Vieweg, 1988
- (2) G.Caglioti, *Finzione e realtà nelle simmetrie infrante*, in *AD, Architectural Digest*, Italian Edition, Giorgio Mondadori, Milano, (45) February 1985, 20-24
- (3) E.Montale, *Sulla Poesia*, Mondadori, Milano, 1970
- (4) G.Caglioti, *Risonanza del legame chimico e percezione dinamica dell' ambiguità*. *Chronache di chimica*. *Farmitalia's quarterly magazine* - Carlo Erba, (3), 3-7, January 1988

- (5) G. Herzberg, Molecular Spectra and Molecular Structure, I. Spectra of Diatomic Molecules, Van Nostrand Reinhold Co., New York, 1950
- (6) H.Haken, Sinergetica. Il segreto del successo della natura , Boringhieri, Torino, 1983
- (7) G.Nicolis, I.Prigogine, Self Organization in Non equilibrium Systems, Wiley, New York, 1977

