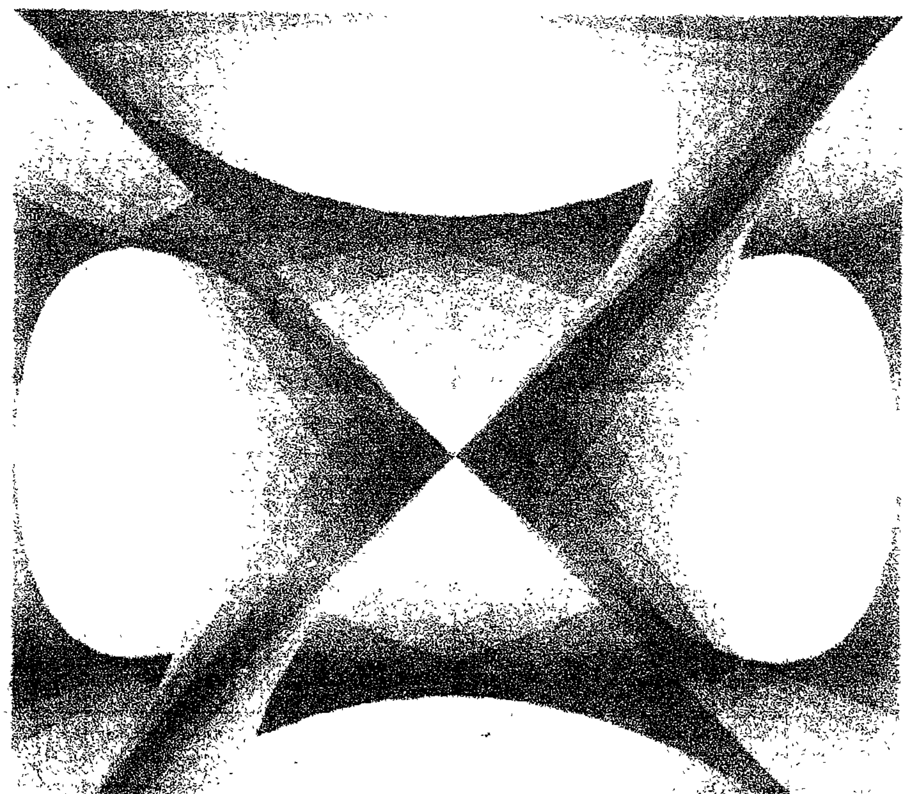
Symmetry: Culture and Science

Symmetry and Information

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

Volume 8, Number 2, 1997



Symmetry Culture and Science
Vol. 8, No 2, 215-221, 1997

SYMMETRY: CULTURE AND SCIENCE

SYMMETRY AND SYMMETRY-BREAKING BETWEEN SUPPLIERS AND CONSUMERS IN NATURAL ECOSYSTEMS

Yoshinori Takahara[1)] and Nobuaki Ono[2)]

Address. [1)]Department of BioEngineering, Nagaoka University of Technology, Nagaoka 940-21, Japan, E-mail· mick@voscc nagaokaut.ac.jp, [2)]Ichinoseki National Technical College, Ichinoseki 021, Japan; E-mail: nono@ichinoseki.ac.jp

Abstract: *Each individual organism appearing in natural ecosystems serves as a consumer of trophic energy towards the upstream of trophic flow, and similarly as a supplier towards the downstream. Evolutionary dynamics of trophic flow makes each individual organism symmetric in the classification of its functional role between consuming and supplying trophic energy. Evolutionary dynamics is functionally symmetric and individualistic, while structurally symmetry-breaking in the genesis of evolutionary novelties. In contrast, ecological dynamics is structurally symmetric at the climax maintaining a fixed structure of food webs that could remain collectively stable there unless disturbed otherwise. The disparity between the functional symmetry and the structural symmetry-breaking latent in evolutionary dynamics is due to asynchonicity between consuming and supplying trophic energy at each individual organism. Generative information latent in evolutionary dynamics resides in the asynchronicity.*

1. INTRODUCTION

Evolutionary dynamics requires its own symmetric property in order to identify it as such. Identification of whatever dynamics is based upon the underlying symmetric operations. Unless such symmetric operations keeping the dynamics invariant are available, there would be no dynamics to be identified. For instance, evolutionary dynamics can be described in terms of trophic levels. Each level serves as a consumer of trophic energy towards the upstream of trophic flow, and as a supplier towards the downstream. Even the top predators serve as a supplier towards decomposers at the lowest level, while serving as a consumer towards the adjacent lower levels. Such a symmetric usage of the terms of suppliers and consumers would not require any preconception on how evolution would proceed (Takahara and Ono, 1997). Precisely for this reason, the functional symmetry between consuming and supplying trophic energy could provide itself with an unbiased framework for describing an evolutionary dynamics. Such a functional symmetry applies even to each individual organism at each trophic level since each individual remains as a functional unit in evolution. Evolutionary dynamics is thus functionally symmetric and individualistic.

However, the functional symmetry between consuming and supplying trophic energy at each trophic level does not give rise to the structural symmetry between suppliers and consumers. Ecological structures have been varied with evolutionary time. The network of food webs has come to vary with evolution (Ono and Takahara, 1997). This observation reminds us that a proper description of evolutionary dynamics requires to derive structural symmetry-breakings from a functional symmetry.

Of course, there is an ecological dynamics which can maintain a structurally stable network of food webs at the ecological climax (Margalef, 1968). The structurally stable network remains invariant against certain operations, otherwise no identification of such a structure could be available. Ecological dynamics destined to approach an ecological climax in one form or another is structurally symmetric and collective. An instance of the structural stability of ecological dynamics is seen in the endogenous capacity of a natural food web protecting itself against invaders from the outside to a certain extent.

Symmetry properties are by all means necessary for describing whatever dynamics. One can however recognize the difference of symmetry properties between evolutionary dynamics and ecological one. Nonetheless, each of evolutionary and ecological dynamics represents a specific aspect of the underlying unitary dynamics (Matsuno, 1989). It is thus required to see how the functional symmetry in evolution could come to relate to structural symmetries and symmetry-breakings observed in natural ecosystems.

2. AN EXAMPLE

Functional symmetry between consuming and supplying trophic energy conceived in whatever phase of evolutionary processes is not structurally symmetric. Although each individual organism serves as a consumer towards the upstream of trophic energy and as a supplier towards the downstream, consuming and supplying trophic energy are not synchronized in time (Matsuno, 1995). These two are incontrovertibly operative, but at most in an asynchonous manner. The top predators in an ecosystem may present themselves as a supplier of trophic energy towards decomposers only after their death, whereas they consume preys while they are alive. The present temporal asynchronicity of the functional symmetry makes evolutionary dynamics unique compared to ecological dynamics, in the latter of which all the ecological participants are declared to share one and the same structure in a synchronous manner. This is rather a matter of definition, since the presence of a structure is claimed to be temporal. Otherwise, dynamics having no prior structures would have to be called for.

Evolutionary dynamics just happens to be such a case. It requires a form of functional symmetry for the sake of guaranteeing its descriptive integrity, while it does not assume any preferred structures in advance for the sake of allowing for the emergence of novel structures in evolutionary time. At issue is how to accommodate the functional symmetry between consuming and supplying tropic energy to the asynchronicity between the two.

The asynchronicity between consuming and supplying trophic energy can be classified into at least two categories; one is consumer domination, and the other is supplier domination (Takahara and Ono, 1997). Consumer domination makes consumers causative in varying the inter-level trophic flow, while supplier domination makes suppliers causative. This classification suggests that a possible origination of chemolithoautotrophs in a heated Arcean ocean (Kandler, 1993) could point to supplier domination in the vicinity of the origin of life on the primitive earth. Supplier domination however could not last indefinitely.

Accumulation of organic materials in the lithosphere could invite the emergence of anaerobic bacteria that could consume the trophic energy stored in the debris of chemolithoautotrophs. Photosynthetic bacteria could also be consumers of carbon dioxide in the atmosphere. What could have been specific to micro-organisms inhabiting the primitive earth is a persistent emergence of consumers of new types which could squeeze trophic energy from the then available products from biological activities. Emergence of aerobic bacteria just happened to be such a case in that aerobes could extract trophic energy from hydrocarbons through respiration as utilizing oxygen molecules that are products of photosynthesis.

Circulation of trophic energy among photosynthetic bacteria, anaerobes and aerobes can be structurized in the form of a network of trophic flow. However, such a structurization varies with evolution (Matsuno and Ono, 1996).

3. STRUCTURIZATION OF ASYNCHRONICITY

Evolutionary process following the origin of life could have been a material manifestation of the reflexive interplay between consuming and supplying trophic energy, since the material components circulate indefinitely in the network. In particular, the absence of global synchronization between consuming and supplying trophic energy makes evolutionary processes to proceed in locally asynchronous time (Matsuno, 1996).

Appraisal of locally asynchronous time now provides evolutionary processes with a unique characteristic. Those global notions as fitness and its landscape specified in globally synchronous time (Dawkins, 1978) should be taken to be derivatives from local dynamics proceeding in locally asynchronous time. Even natural selection would be no exception in referring to globally synchronous time when it is understood as a quality conferred upon a global context (Sober, 1984). At issue is how time can be moved and structurized.

What is significant to locally asynchronous time is the constant generation of a signal inducing the subsequent action while reacting to the preceding signal. Successive alternation between action and reaction through constantly generating the signal for action is in fact autocatalytic in the respect of generating the signals of a similar kind (Ulanowicz, 1996). Autocatalysis is actually a material embodiment of the transference of locally asynchronous time into globally synchronous one in a structurized manner (Matsuno, 1996; Rössler, 1987; Leydesdorff, 1994).

4. INFORMATION IN LOCALLY ASYNCHRONOUS TIME

Material capacity of rendering preceding products to be a signal for subsequent production underlies autocatalysis (Matsuno, 1989). The present conglomeration of material production and signaling makes autocatalysis to be informational. Although contingent generation and communication of a signal and the determinate material production thereupon are simply incommensurable with each other, it is information that serves as a mediator connecting contingency to determinacy. On the other hand, however, any signal for autocatalysis has made itself embodied in a material form. The material aspect of a signal now raises a question on how some material products could serve as a signal, but others do not (Salthe, 1993). The underlying theme is the material context in which signals could be generated.

Occurrence of a signal is antithetical to mechanistic dynamics in which every degree of freedom in motion can be specified and determinate at any moment. Insofar as the number of the total degrees of freedom in motion remains fixed, the mechanistic stipulation could prevail simply by declaring identification of the relevant boundary conditions. There would be no room for a signal resulting in a contingent action to intervene. In contrast, if degrees of freedom in motion remain indefinite through, for instance, their degeneracy, a production yielding either association or dissociation of degrees of freedom among those identified in the record could generate a signal. There is no mechanistic stipulation prescribing how and when degrees of freedom in motion could further be associated or dissociated.

Although the global synchronism in the record specifies each degree of freedom involved in the finished movement because the degrees of freedom are defined as those objects whose every detail can be identified in a globally consistent manner, locally asynchronous time on the scene does not have such a global identifiability. Even if the notion of degrees of freedom is useful and valuable in other respects, communication dynamics connecting contingency in the making to determinacy in the record is set free from observing the constancy of degrees of freedom. Signal of material origin just refers to the material capacity of either associating or dissociating degrees of freedom in locally asynchronous time.

5. CONSUMING AND SUPPLYING AS A COMMUNICATION

Autocatalysis is a material pattern and form of associating degrees of freedom more closely than being dissociated due to enhancing material accumulation having a similar functional characteristic (Matsuno, 1978). Rather, autocatalysis is one specific mode of enhancing material association grounded upon the capacity of taking in material resources. It is in fact a manifestation of two fundamental attributes of matter, inertia and signal, in the manner that both could be visible at the same time. Compared to mechanics addressing inertial bodies, autocatalysis is a mode of communication dynamics acting on the signal producing a signal of a similar production characteristic successively. Consuming and supplying trophic energy serve as signals inducing similar activities in a successive manner. This autocatalysis is certainly a communication proceeding in locally asynchronous time.

Evolutionary processes found themselves upon the communication dynamics of constantly generating signals inducing subsequent actions. Evolution thus perceived is internally caused in letting an indigenously generated signal be a causative factor for action in the participating material bodies in the form of consuming and supplying trophic energy. Internal causation in evolution is unquestionably materialistic and physical in locally asynchronous time. Nonetheless, such internal cause cannot externally be identified because the causation proceeds in locally asynchronous time. Internal communication does not survive in the finished record. What can be identified in the record is necessarily manifested in globally synchronous time that preserves the global consistency among those identified. Although it is structurized in the record, the pattern of consuming and supplying trophic energy in locally asynchronous time is communicative internally and information-generative.

6. LOCALLY ASYNCHRONOUS TIME AND CLOCKS

Internal causation in evolution is in the transference from locally asynchronous to globally synchronous time. Autocatalysis as a prototypic evolutionary dynamics can yield evolutionary variations in the difference between the signals successively generated. Mutations certainly exhibit a consequence of such internal causation. In particular, the presence of molecular clocks manifesting the stochastic regularity in generating point mutations indicates that the transference from locally asynchronous to globally synchronous time has a regular stochastic pattern on an evolutionary time scale. An evolutionary sequence of autocatalytic signals being capable of generating their derivatives of a similar characteristic could establish a similarity even in making evolutionary variations.

The rate of mutations as a stochastic parameter characterizing the generator of evolutionary variations is an example of exhibiting a sustaining similarity over the sequence of autocatalytic signaling. Availability of molecular clocks witnesses the likelihood of a sustaining similarity in making evolutionary variations. What is more, constancy in the rate of mutations could also serve as a cause for establishing a hierarchy of the rates themselves, because the hierarchy provides a homeostatic stability in the rates even if perturbations that could disturb them may intervene.

Evolutionary constancy as exemplified in the presence of molecular clocks is in fact a characteristic of a globally synchronous time resulting from locally asynchronous time in action. Such a constancy in globally synchronous time exhibits a distinct contrast to natural selection as a global characteristic of evolutionary variations. Although the contrast between constancy and variations in globally synchronous time has historically been referred to as a dichotomy between genotype and phenotype, it may invite a serious conceptual conflict if both are taken to proceed in the same globally synchronous time. The difficulty could have been most serious at the point of establishing the effective separation between genotype and phenotype, since the underlying dynamics has been one and the same in time that is global. The separation between evolutionary constancy and variations, that is between genotype and phenotype, could be at most epistemological in the sense of being dependent upon the perspective. What one concerns at this point is whether such a separation of epistemological origin could survive in time. At issue is again the role of time.

That globally synchronous time remains legitimate only in the finished record reminds us that it is an artifact at the best. But, the global synchronism of an object in globally synchronous time, that is vertical in time there, is instrumental in securing a constant and invariant character of the object. In contrast, the global synchronism of the participants in locally asynchronous time, that is skewed in time there, is necessarily incomplete in constantly supplying a signal anticipating the succeeding actions. Natural selection ascribed to the skewed synchronism in locally asynchronous time, while being global, is generative compared to evolutionary constancy in the rates of mutation perceived in globally synchronous time. Recognition of locally asynchronous time underlying evolutionary dynamics clarifies that natural selection upholds the evolutionary emergence of constancy and a hierarchy of the rates of mutation. Consequence of the operation of natural selection is a self-organization in that the skewed synchronism in locally asynchronous time constantly generates signals anticipating the succeeding actions internally. In contrast to the self-organization in globally synchronous time

(Kauffman, 1993), natural selection is about self-organization in locally asynchronous time.

7. CONCLUDING REMARKS

Natural selection perceived as a skewed synchronism in locally asynchronous time is also a factor for moving time itself. When it is conceived solely in globally synchronous time, natural selection could be mechanistic as being moved with the flow of time. In fact, whether natural selection could be mechanistic or self-organizing for the sake of the self depends upon how time is moved. If time is taken to be globally synchronous without allowing any intervening intermediaries, whatever operates in time comes to be moved by time. Natural selection could be no exception. Globally synchronous time cannot be moved by others because there is nothing more global that could subordinate it. Final causality is legitimately dismissed in globally synchronous time. Only its mechanistic counterpart survives there. On the other hand, however, once it is duly recognized that locally asynchronous time is moved by a material signal for the sake of fulfilling the global synchronism, natural selection can be more than what mechanistic stipulation could prescribe. Natural selection as a principle bringing about a unity of experiences is locally final in fulfilling the global synchronism in a skewed manner.

This perspective opens a new vista such that the dichotomy of consuming and supplying trophic energy at each individual organism in natural ecosystems enables us to confront how to accommodate symmetries to symmetry-breakings in evolution. A key is within each individual organism behaving both as a consumer and a supplier in locally asynchronous time.

The authors wish to acknowledge helpful discussion with Koichiro Matsuno.

REFERENCES

Dawkins, R. (1978) *The Selfish Gene*, Oxford University Press, Oxford UK.

Depew, D. J., and Weber, B. H. (1994) *Darwinism Evolving*, Bradford/MIT Press, Cambridge Mass.

Kandler, O. (1993) The early diversification of life. In: *Early Life on Earth* (Bergtson, S., ed.) Nobel Symposium 84, Columbia University Press, New York, pp. 53-66.

Kauffman, S. A. (1993) *The Origin of Order. Self-Organization and Selection in Evolution*, Oxford University Press, New York.

Leydesdorff, L. (1994) Uncertainty and the communication of time, *System Research*, **11**, 31-51.

Margalef, R (1968) *Perspective in Ecological Theory*, University of Chicago Press, Chicago Illinois.

Matsuno, K. (1978) Evolution of dissipative system· a theoretical basis of Margalef's principle on ecosystem, *Journal of Theoretical Biology*, **70**, 23-31.

Matsuno, K. (1989) *Protobiology: Physical Basis of Biology*, CRC Press, Boca Raton Florida.

Matsuno, K. (1995) Consumer power as the major evolutionary force, *Journal of Theoretical Biology*, **173**, 137-145.

Matsuno, K (1996) Internalist stance and the physics of information. *BioSystems* **38**, 111-118.

Matsuno, K., and Ono, N. (1996) How many trophic levels are there? *Journal of Theoretical Biology*, **180**, 105-109.

Ono, N., and Takahara, Y. (1997) Ubiquity of omnivores in natural ecosystems, *BioSystems*, in press.

Rössler, O. E. (1987) Endophysics, In: Casti, J. L., and Karlquist, A. (eds.) *Real Brains, Artificial Minds*, New York: North Holland, pp. 25-46.

Salthe, S. N. (1993) *Development and Evolution: Complexity and Change in Biology*, Bradford/MIT Press, Cambridge Mass.

Sober, E. (1984) *The Nature of Selection – Evolutionary Theory in Philosophical Focus*, University of Chicago Press, Chicago Illinois

Takahara, Y., and Ono, N. (1997) Interplay of causation between suppliers and consumers in evolutionary trophic dynamics, *BioSystems*, in press.

Ulanowicz, R. E. (1996) Ecosystem development: symmetry arising? *Symmetry: Science & Culture*, 7, 321-334