The Evolution of Organization

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A scientist must ask for what he really wants to know, and not for what he thinks he wants.

(W. Ross Ashby)

Organization expresses order. It ranges from no organization, thermodynamic equilibrium, to hierarchies of perfect form, symmetry, or interaction. How and why organization started and what causes its evolution over time are questions of utmost scientific and philosophical importance. Yet little is known about them, and what is considered to be known is mostly inferred from historical type observations and falls in the realm of experience or belief.

In recent years, simulation has been added as a tool to the study of organization. The interest so far has been centered around self-evolving, autopoietic organization [11], [21], [23], which is self-created and self-evolving during the simulation. The obvious advantage of the simulation approach is that different types of organization can be studied under various assumptions, experimental models and initial conditions and the time dimension shortened at will.

I should like to thank CISI and Robert Sultan for their generous support in providing me with all the computer time required to carry out the research described in this paper; without their support, this research could not have been carried out. I would also like to thank Claude Faucheux and James Lyons for their comments and criticisms, and useful suggestions concerning this paper.
This paper will describe research work in which hundreds of thousands of systems have been generated, through simulation, and their behaviour and characteristics recorded and studied. The objective has been the establishment of general rules about organization and the factors that cause its emergence and evolution. The work to be described differs from other simulation studies in that it uses stability as the main factor through which the existence, or continuation of organization is inferred. The advantage of doing this is that fewer assumptions are required about the nature of system elements and their interaction than by alternative approaches.

I. ORGANIZATION AND STABILITY

A system of \( m \) elements can be expressed as a vector differential equation of the form:

\[
dX/dt = f(X)
\]

where \( X \) is the \( m \)-dimensional state vector. An equilibrium state of (1) is a state \( \bar{X} \), such that \( f(\bar{X}) = 0 \). An equilibrium state is stable, asymptotically, if for any solution of (1) with arbitrary initial value \( X(0) \),

\[
\lim_{t \to \infty} |X(t) - \bar{X}| = 0
\]

Stability is a relative concept. A cup of water in a constant environment is unstable if it is viewed as a collection of molecules. Each molecule of water, taken as a separate system, however, is stable. Furthermore, each of the two atoms of hydrogen and the atom of oxygen are stable systems themselves.

A universe \( U_1 \) is at a state of thermodynamic equilibrium—maximum entropy—at some hierarchical level \( L_0 \), if it does not contain within its boundaries stable systems at a level above \( L_0 \). Such a universe is characterized by uniformity, maximum entropy, or complete disorder. It therefore exhibits zero organization at level \( L_0 \). Organization starts when some deviation from uniformity appears at \( L_0 \), that is when some stable system(s) emerge(s). The evolution of organization at the universe \( U_1 \) between levels \( L_0 \) and \( L_u \) (an upper hierarchical level), can be observed by following the appearance of stable system(s) within \( U_1 \), and tracing their evolution over time. For simplicity, all stable systems will be associated for a universe \( U_1 \), between the hierarchical levels \( L_0 \) and \( L_u \), unless otherwise specified.

Entropy is often used as a quantified measure of organization—see [5],[6] and [12]. It is usually defined as:

\[
H = -\sum_{i=1}^{N_1} p_i \log_2 p_i \quad (i = 1, 2, \ldots, N_1)
\]