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THE APPLICATION OF AUTOPOIESIS IN SYSTEMS ANALYSIS: ARE AUTOPOIETIC SYSTEMS ALSO SOCIAL SYSTEMS?

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Autopoietic systems are "self-producing" systems. The concepts of the autopoietic nature of a system were developed by Varela *et al.*[8] based upon a living, biological, system. To illustrate the diversity of autopoiesis in its application to systems analysis, three systems (a eukaryotic cell, an osmotic precipitation membrane, and the human family) have been defined and analyzed using the six-point key, criteria, of Varela *et al.* Conclusions have been drawn as to the autopoietic nature of each system.

Varela *et al.*'s criteria as they have been applied to a biological (living) system can be applied to other systems (e.g., chemical, spontaneous social) that are not currently considered as "living" and this may have a profound effect on the way "living organization" is defined and/or viewed. The very question of autopoiesis in spontaneous social systems is irrelevant. Not only are spontaneous social systems autopoietic but a stronger relation exists where **"All autopoietic, and therefore all biological (living) systems, are social systems."**

INDEX TERMS: Artificial life, autopoiesis, living systems, osmotic growth, precipitation membranes, self-production, social systems, spontaneous social systems, synthetic biology, systems analysis.

SYSTEM DEFINITION, FRAMEWORKS, AND AUTOPOIESIS

A "system" has been simply defined and perhaps best expressed by Gaines[1] in his statement: "A system is what is distinguished as a system." This statement implies that the observer has a choice as to how to define the system that he intends to analyze. There is a wide variety of system types such as physical systems, chemical systems, biological systems, social systems, economic systems, logic systems, political systems, and others that may be described by an observer.

Each system mentioned above has an adjective associated with it that describes the type of things that are in the system. It is not the properties of the things that we, as systems scientists, are interested in. It is the properties that are independent of the specific nature of the things (independent of the things themselves) that are of interest. The concepts of "thinghood," properties dealing with the nature of the things, and "systemhood," properties dealing with concepts independent of the nature of things, have been introduced by Rosen[2] as terms for these concepts.

For an observer to be able to characterize the systemhood, the domain of inquiry in systems science, requires a conceptual framework. This framework will determine the types of systems that can be described and should lead to some specific criteria as to how the systems can be categorized. Several frameworks have been developed by Mesarovic and Takahara,[3] Wymore,[4] Zeigler[5,6] and Klir.[7] Within these frameworks different types of systems are categorized. One type of system is the "autopoietic" system. The formalism of this system has been introduced and defined by Varela, Maturana, and Uribe.[8] An example of how an autopoietic system is categorized within a conceptual framework has been given by Klir.[7] Within his GSPS (General Systems Problem Solver) framework Klir has described the autopoietic system as a rather unorthodox goal-oriented system. The goal is some kind of boundary, usually topological, that allows the observer to recognize a part of space as a unit. Klir views the autopoietic system in GSPS language as a metasystem of the form $MD = (T, \mathbf{D}, r)$.

Autopoietic systems are "self-producing" systems. The system itself (limited by its boundary) is such that by the existence of itself (its structures, processes, etc.) it produces itself. Thus it does not matter what the things are in the system only that whatever they are they produce themselves. The autopoietic nature of a system is within the domain of systems science, systemhood, since it is independent of the things, thinghood, in the system.

Another, and perhaps clearer, expression of an autopoietic system is a system (that which is being observed) that is generated through a closed organization of production processes such that the same organization of processes is generated through the interactions of its own products (components) and a boundary emerges as a result of the same constitutive processes. In other words, because of the system's operation the product is the system. The system is the realization of the autopoietic organization.

Varela *et al.*[8] have defined autopoietic organization as a unity by a network of productions of components which participate recursively in the same network of productions of components which produced these components and realize the network of productions as a unity in the space in which the components exist.

Zelený[9] states that the organization of components and component-producing processes is maintained invariant through the interaction and turnover of components. The invariance follows from the definition: if the organization (the relations between system processes) changes there would be a change in the system's identity class: its categorization. What changes is the system's structure (its particular manifestation in the given environment) and its parts. The nature of the components and their spatiotemporal relations (associated with "thinghood") are secondary to their organization (associated with "systemhood") and thus refer to the structure of the system. Thus the boundary is a structural manifestation of the system's underlying organization. The boundary is not the organization; it represents the structural realization, of the system, in a particular environment of components. In a physical environment this does not mean that the topological boundary is not conducive to, or even necessary for (by creating a favorable environment of components), the maintenance of an autopoietic organization. Both organization and structure are mutually interdependent.

The concepts of the autopoietic nature of a system were developed by Varela *et al.*[8] based upon a living (biological) system as a model of self-production. Yet self-production has the potential to mean and be interpreted many different ways by a variety of people. "Autopoiesis" has been coined (not translated) from Greek as a label for a clearly defined interpretation of "self-production." This phenomenon of self-production can be observed in living systems. A cell, a system that renews its macromolecular components thousands of times during its lifetime, maintains its identity, its cohesiveness, relative autonomy and distinctiveness, despite this turnover. This lasting unity and wholeness is called "autopoiesis." Zelený[9] presents an excellent overview of autopoiesis as a theory for living organization. But for a systems scientist to be able to use a theory, he must be able to look at his system and methodologically determine whether the theory applies to his system. To this end Varela *et al.* have developed a six-point key that provides the criteria for determining whether or not a system is autopoietically organized.

It is our intention to propose, demonstrate, and argue that Varela *et al.*'s criteria as they are applied to a biological (living) system can be applied to other systems that we *currently* do not consider "living," and that this may have a profound effect on the way we as scientists should view and/or define the phrase "living organization." We also intend to argue that the very question of autopoiesis of (or in) spontaneous social systems is not only irrelevant, but the very opposite is true. Not only are spontaneous social systems autopoietic, but the relationship is much stronger: **All autopoietic, and therefore all biological (living) systems, are social systems.** To this end we will also consider that the topological boundary that has been necessary to describe an autopoietic system, within a favorable environment of physical components (such as those within and around a cell), may not necessarily exist in a physical form in other types of systems, e.g., in social systems.

AUTOPOIESIS—THE SIX-POINT KEY

To determine whether a system is or is not autopoietic in its organization, Varela *et al.*[8] have developed six key points or criteria that must be applied to a system. Their criteria are stated as follows (pp. 192–193):

Key Point #1: Determine, through interactions, if the unity has identifiable boundaries. If the boundaries can be determined, proceed to 2. If not, the entity is indescribable and we can say nothing.

Key Point #2: Determine if there are constitutive elements of the unity, that is, components of the unity. If these components can be described, proceed to 3. If not, the unity is an unanalyzable whole and therefore not an autopoietic system.

Key Point #3: Determine if the unity is a mechanistic system, that is, the component properties are capable of satisfying certain relations that determine in the unity the interactions and transformations of these components. If this is the case proceed to 4. If not, the unity is not an autopoietic system.

Key Point #4: Determine if the components that constitute the boundaries of the unity constitute these boundaries through preferential neighborhood relations and interactions between themselves, as determined by their properties in the space of their interactions. If this is not the case, you do not have an autopoietic unity because you are determining its boundaries, not the unity itself. If 4 is the case, however, proceed to 5.

Key Point #5: Determine if the components of the boundaries of the unity are produced by the interactions of the components of the unity, either by transformation of previously produced components, or by transformations and/or coupling of non-component elements that enter the unity through its boundaries. If not, you do not have an autopoietic unity; if yes, proceed to 6.

Key Point #6: If all the other components of the unity are also produced by the interactions of its components as in 5, and if those which are not produced by the interactions of other components participate as necessary permanent constitutive components in the production of other components, *you have an autopoietic unity in the space in which its components exist*. If this is not the case and there are components in the unity not produced by components of the unity as in 5, or if there are components of the unity which do not participate in the production of other components, you do not have an autopoietic unity.

Thus the successful application of the six-point key to a system will determine that the system is autopoietically organized.

SYSTEMS ANALYSIS USING THE SIX-POINT KEY

To illustrate the diversity of autopoiesis in its application to systems analysis, three systems (a biological (living) system, a chemical system, and a spontaneous social system) will be defined, analyzed using the six-point key, and then conclusions will be drawn as to the autopoietic nature of each system.

System One: The Eukaryotic Cell

The generalized non-plant eukaryotic cell that is shown in Figure 1, perhaps a single-celled organism or a single cell from a multi-cellular animal, may be described as having a plasma membrane which surrounds the cytoplasm and cytoplasmic components of the cell. The cytoplasm contains the nucleus, mitochondria, golgi apparatus, endoplasmic reticulum, various vesicles, lysosomes, vacuoles, cytoplasmic filaments and microtubules, centrioles, and other components of the cell.

Evaluation of key point #1 The eukaryotic cell has a definite boundary (plasma membrane), a separation from the environment that is formed by the cell from various phospholipids and proteins. Thus the eukaryotic cell, the unity, is describable.

Evaluation of key-point #2 The eukaryotic cell has distinguishable constitutive elements: components. Components such as the nucleus, mitochondria, etc. consist of materials that are found within the cytoplasm of the cell. Therefore the cell is not an unanalyzable whole: it has components that can be analyzed.

Evaluation of key-point #3 The properties of the eukaryotic cell components (as shown in Figure 1) are such that because they follow certain physical laws and re-

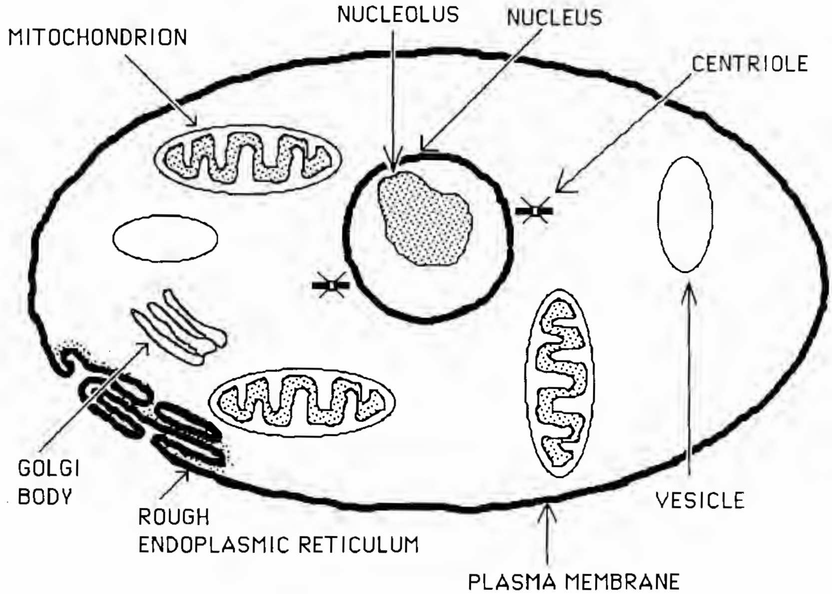

Figure 1 A generalized non-plant eukaryotic cell

lations (hydrophobic/hydrophilic interactions, laws of chemical reaction, diffusion, osmosis, etc.), the components have developed specialized functions. Due to these functions they generate the interactions and transformations of the components which create the cell membrane and the components contained within the cell. The cell is a mechanistic system.

Evaluation of key-point #4 The boundary, the plasma membrane, of the eukaryotic cell is formed by the association of phospholipids and various integral and peripheral proteins. This view of the membrane, the "fluid mosaic model," is shown in Figure 2. The membrane is formed as a result of the preferential neighborhood interactions of the phospholipid and protein molecules with each other and the surrounding media. Portions of the phospholipids seek either a polar (aqueous) or a non-polar (hydrocarbon) environment (see Figure 3). The same occurs with the surface elements of the proteins. These preferential neighborhood interactions occur such that the unstable interactions of a non-polar (organic) region and a polar (aqueous) region are minimized.

Evaluation of key-point #5 The function of the plasma membrane in the eukaryotic cell is to provide a boundary within which the cellular components will have an isolated and controlled environment in which to operate. Part of the cellular machinery is used to produce the membrane components from the transformation and/or coupling of non-component elements (amino acids, fatty acids, ions, etc.) into membrane components (phospholipids and proteins). Thus they are produced by the interactions of the components of the unity, the eukaryotic cell.

Evaluation of key-point #6 All of the other components (mitochondria, nucleus, etc.) of the unity are also produced by the interactions of its components. Some

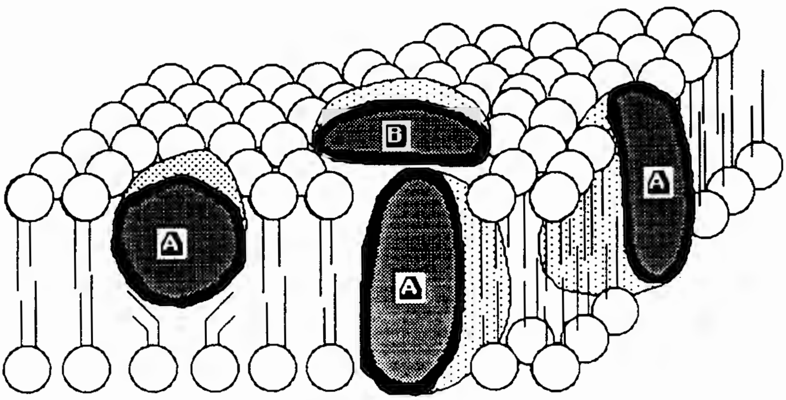

Figure 2 Fluid mosaic membrane model; A = integral proteins, B = peripheral protein

components (such as alkali and alkaline-earth metal ions) that are necessary for cellular activity may not be produced by the components of the cell. They are obtained from the environment through the membrane and participate as necessary permanent constitutive elements in the production of other components.

Conclusion Since the six-point key has been successfully applied to the generalized eukaryotic cell, it can be concluded that *the cell is an autopoietic unity in the space in which its components exist.*

System Two: Osmotic Growths of Stephane Leduc

In *The Mechanism of Life* (1911), Stephane Leduc[10] describes an "osmotic growth," a membrane of precipitated inorganic salt, as having many processes, functions, and characteristic forms that seem to be analogous to those found in living systems. The osmotic experiments performed by Leduc have been reproduced by Klir, Hufford, and Zelený.[11]

Unlike typical experiments in simple precipitation, where two solutions are mixed and a cloudy solution of an insoluble salt results, osmotic growths precipitate and grow over a period of minutes to days and go from a thin transparent membraneous state to an opaque state. A typical precipitation membrane system can be constructed as follows:

Components

$CaCl_2$—fused and broken into fragments
Na_3PO_4—saturated
A 250 ml beaker

Procedure

Pour 200 ml of the saturated Na_3PO_4 solution into the 250 ml beaker. Drop three or four fragments of fused $CaCl_2$ into the solution and let them sink to the bottom.

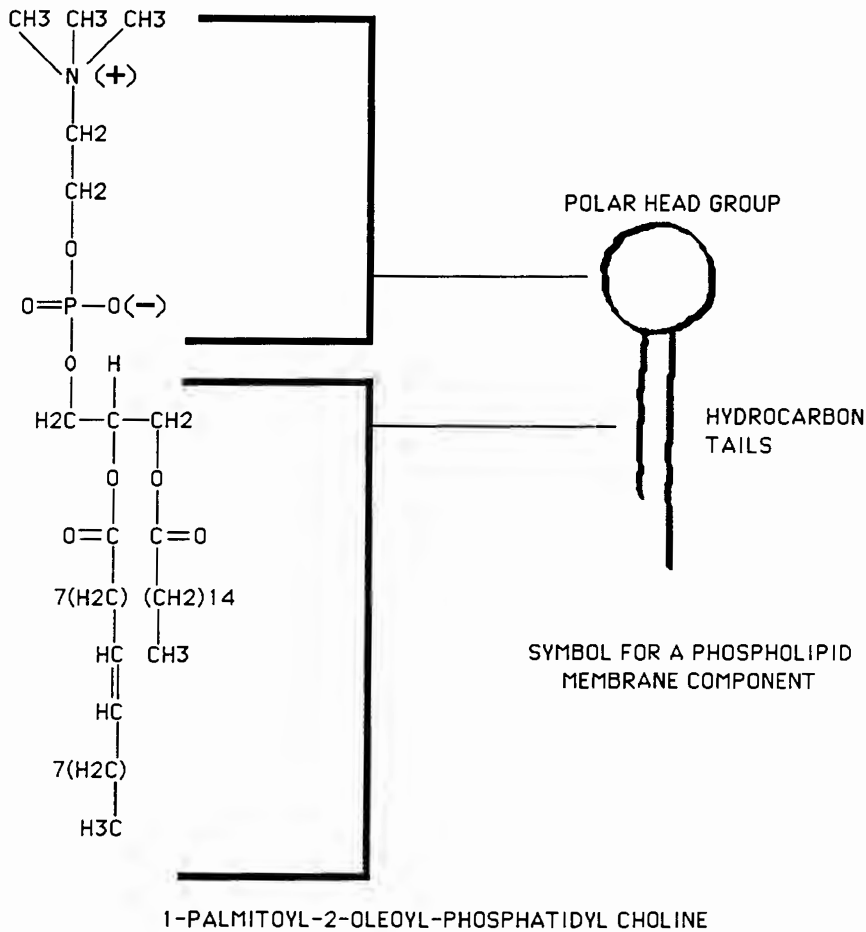

Figure 3 An example of a phospholipid

The precipitation, the osmotic growth, develops immediately. The process is represented diagrammatically in Figure 4. An actual photographic sequence has been provided by Zelený, Klir, and Hufford.[12]

At first glance Leduc's osmotic systems are such that by their existence they produce themselves and by the basic definition of an autopoietic system (self-producing) they appear to be autopoietic. To determine whether or not Leduc's osmotic growths are indeed autopoietic systems, Varela's six-point key can be applied.

Evaluation of key-point #1 The osmotic growths of Leduc have a definite boundary (an osmotic membrane), a separation from the environment that is created by the precipitated inorganic salt. Thus the unity is describable.

Evaluation of key-point #2 The osmotic growth itself has distinguishable constitutive elements: components. The components consist of the substances that form

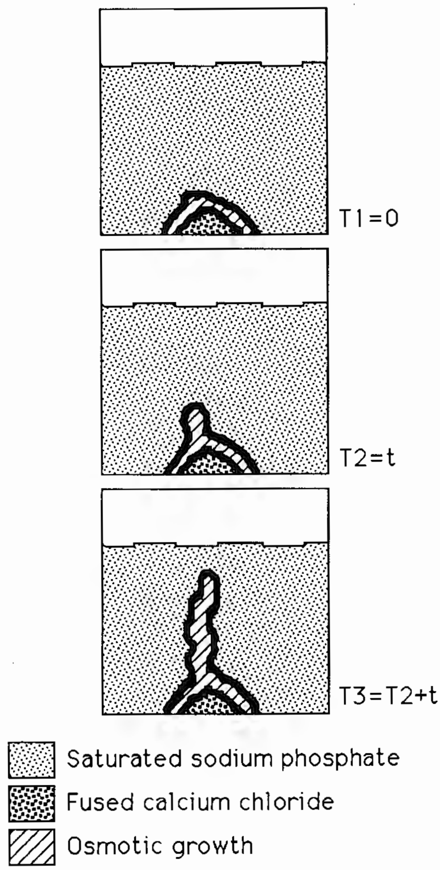

Figure 4 Osmotic growth sequence; T1 = precipitate on the surface of the fused fragment. T2 = water traverses the membrane and distension occurs. T3 = osmotic growth continues.

the osmotic membrane (boundary) and the internal substances confined within this membrane. Example: in the osmotic growth that arises from the otherwise independent materials—calcium chloride (solid) and tribasic sodium phosphate (saturated solution)—the osmotic membrane formed is a colloidal aggregation of calcium phosphate. The membrane-forming substances are aqueous calcium and phosphate ions (see Figure 4). Thus the osmotic growth is not an unanalyzable whole. It has components that can be analyzed.

Evaluation of key-point #3 The osmotic growth is a mechanistic system. The properties of the components (the membrane aggregates and associated ions) are such that because they follow certain physical laws and relations (precipitation, aggregation, osmosis, etc.) they generate growth and osmotic membrane formation.

Evaluation of key-point #4 The boundaries of the osmotic growth are formed by precipitated inorganic salt molecules that aggregate because of their preferential neighborhood relations and interactions that occur because of their components'

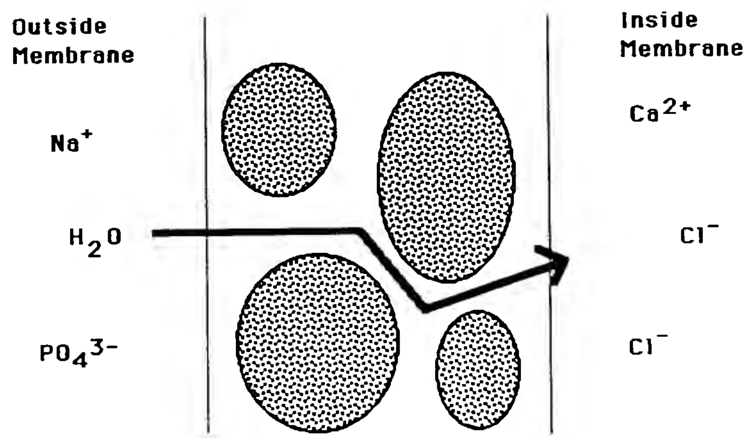

Figure 5 Net water flow into the osmotic growth

properties in the space in which they are interacting. The boundary of this unity occurs because of the chemical and physical properties and interactions of the osmotic membrane elements.

Evaluation of key-point #5 In an osmotic growth the components of the boundary are produced by the interactions of previously produced aggregates (membrane components). The aggregates allow the passage of water molecules through the boundary (driven by osmosis) to generate an increase in internal osmotic pressure (Figure 5). The osmotic membrane distends when it can no longer resist the increase in osmotic pressure. This allows the internal element (calcium ion) to contact and couple with a non-component element (phosphate ion) (Figure 6) and be transformed into a new component of the boundary (calcium phosphate) (Figure 7). Thus growth has occurred.

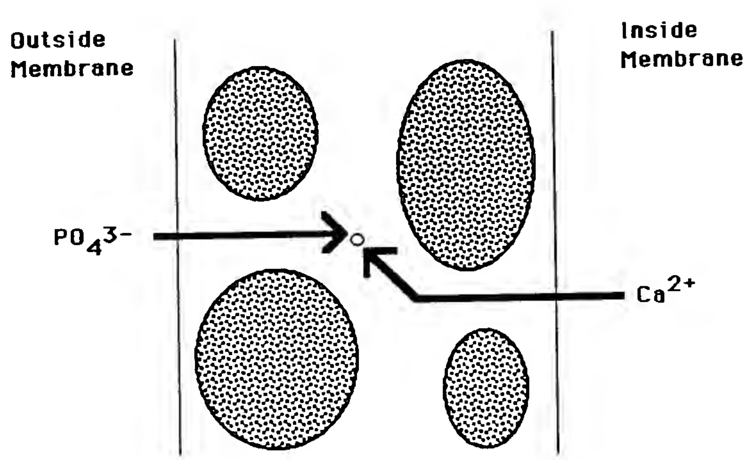

Figure 6 Expansion due to increased pressure

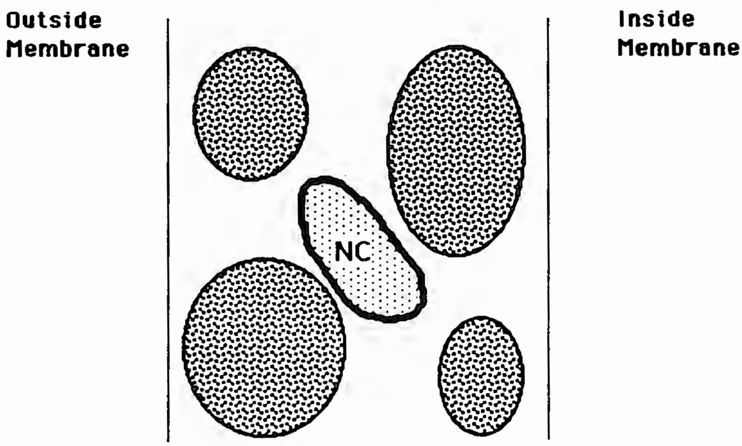

Figure 7 Formation of a new membrane component; NC = new component

Evaluation of key-point #6 The calcium ion that is used in the formation of the osmotic membrane (boundary) is not produced by the interactions of other components. But it does participate as a necessary permanent constitutive component in the production of other components.

Conclusion Based on the above evaluation of Stephane Leduc's osmotic growths (specifically the calcium chloride/tribasic sodium phosphate system), it can be concluded that *an osmotic growth is an autopoietic unity in the space in which its components exist.*

System Three: Human Family—A Spontaneous Social System

F. A. Hayek integrated the concepts of self-production directly into the domain of social systems.[17] He stated that "Although the overall order of actions arises in appropriate circumstances as the joint product of the actions of many individuals who are governed by certain rules, the production of the overall order is of course not the conscious aim of individual action since the individual will not have any knowledge of the overall order, so that it will not be an awareness of what is needed to preserve or restore the overall order in a particular moment but an abstract rule which will guide the actions of the individual." Therefore the individuals in a society, a social order, spontaneously assume the sort of conduct which assures their existence within the whole. Of course this conduct must also be compatible with the preservation of the whole. Neither the society nor the individuals could exist if they did not behave in this manner. The overall order, preservation of the society, is not the "purpose" or the "plan" of the individuals (we are not discussing human-engineered social systems). The individual actions are motivated by their own goals and purposes.

After the undisputed failures and fatal conceit of large-scale social engineering and experimentation of the past,[15,16] the phenomena of spontaneity and emergence in social systems are being re-emphasized. Of significance are the surviving and robust social institutions such as market, family, culture, money, language, economy, city, and myriads of voluntary groupings. These have spontaneously emerged as a result of the natural (non-human engineered) formation and organization of society.

As the third system, the human family is an example of a spontaneous social order that has a substantial impact and great significance in the life of social, economic, and political systems. A family constitutes, prototypically, an autopoietic system that is produced and maintained through organizational rules (which are potentially codified) of a given society. No matter what the particular mix of its components (men, women, and children) the family organizes its social domain and coordinates its social action in a spontaneous self-perpetuating fashion. It must also continually adapt, spontaneously, to the external challenges and interferences of society, social engineers, and reformers.

Evaluation of key-point #1 The family boundary is usually well defined. The distinction between family and non-family members is rarely ambiguous or subject to fuzzy interpretation. Limiting autopoiesis to purely physical or visually observable membranes (like human-engineered "Berlin Walls") is extremely restrictive and does not serve a useful purpose. A definite family boundary can be defined, although it is not physical. In the context of the family the concept of boundary might be defined as the members included in a set. In terms of crisp set theory the membership of the set (the symbolic set boundary, if Venn diagrams are used) is the family. Using "fuzzy" set theory others outside of the nuclear family have the potential (can be given a membership grade) to be included in the family organization. Family members are usually distinguished from their environment (from the "society") more sharply than any engineered/designed physical "membrane" can ever provide. Thus the family, the unity, is describable.

Evaluation of key-point #2 The family system is defined through its clearly identifiable and role-separable components. There are fathers, mothers, children, wage-earners, homemakers, extended family members, aunts, uncles, cousins, "black-sheep," and so on. The family is not an unanalyzable whole. It has components that can be analyzed.

Evaluation of key-point #3 Family members display system-derived properties that characterize them as family members. Specialization, role-playing, aspirations, preferences, goals, needs, etc. generate interactions which are different from the interactions of the market-place, church community, or concentration camp. In fact, the component properties are adapted to and derived from the very family mechanism they produce. Due to these system-derived properties the family members generate the interactions between the components (the family members) which generate the family boundary and the family components.

Evaluation of key-point #4 The boundary of the family is defined and maintained by the family members themselves (although this may be codified and also protected by laws), not by external observers or social engineers. The boundary is maintained through preferential neighborhood relations and interactions between the components (the family members). Social engineers can of course restrict the interaction between family components which distorts the spontaneous family boundary by force (often irreversibly) as can occur in other natural systems. Family components maintain the system cohesiveness (define the family boundary) in an often fierce and uncompromising fashion.

Evaluation of key-point #5 The components within the family (the family boundary) are produced through family interactions, not through "external appointments." Sons are transformed into fathers, fathers into grandfathers, mothers and fathers produce sons and daughters (brothers and sisters). To become the "head of the family" is an internal social production, not necessarily a biological one. This applies to both men and women in both nuclear and single-parent families. Even external components, through the adoption of various schemes, can be transformed into family members if desired. Man and woman biologically produce children, well-defined family members. Thus the children are produced by the interactions of the components of the unity, the family.

Evaluation of key-point #6 All components of the family, boundary or otherwise, are produced through both biological and social production, as in Key-Point #5. Any externally imposed components or component-roles (e.g., family "spies") are unnecessary and only transitory from the family vantage point. Others, like midwives or family doctors, constitute relatively permanent structures that are necessary for family reproduction. The family is well defined and exists in the domain of the family-produced family members.

Conclusion Based on the above evaluation, the six-point key being successfully applied, *the family is an autopoietic unity defined in the space of its own components.*

ARE ALL AUTOPOIETIC SYSTEMS SOCIAL SYSTEMS?

We have shown a number of systems to be autopoietic by applying the six-point key of Varela *et al.* It has been successfully argued that biological (living) systems are autopoietic (self-producing). Recent advances in the areas of Artificial Life (AL),[14] synthetic biology, and osmotic growths,[11,12] have established that at least some autopoietic systems are non-biological, i.e., self-producing in inorganic milieus. In short, the phenomena of biological autopoiesis is an organization of matter, not a particular matter ("organic") so organized.

It has been extensively (and sometimes heatedly) discussed whether social systems (i.e., their spontaneous-order component, not engineered or designed by man) are autopoietic. We now argue that posing the very question of autopoiesis in (or of) social systems is too restrictive; spontaneous social orders and systems are undoubtedly autopoietic, but the relationship is much stronger. **All autopoietic systems, and therefore also all biological (living) systems, are social systems.**

The above conjecture does not imply that all social systems are autopoietic; there are many man-made and man-designed "wonders" of social engineering that are neither self-producing nor self-sustaining (e.g., military heirarchies, concentration camps of national socialism, and assorted "Berlin Walls"). But autopoietic systems, both "organic" and possibly "inorganic," are necessarily social (societal, populational). Judgmental social agents do not need physical "walls" (or barbed-wire fences) in order to establish strong social boundaries.

Autopoiesis cannot take place where there are no separate and autonomously individual components interacting and communicating in a specific environment according to specific behavioral rules of interaction. This is why autopoiesis (autopoietic organization) can be studied by postulating each component as a separate entity and tracing its behavior through cellular automata types of computer simulation.

Approaches which sacrifice this essential individuality of components, like the statistical systems of differential equation used in the traditional sciences, cannot model autopoiesis. This is because they are definitionally incapable of treating autopoietic systems as social systems. Components and participants in autopoiesis must follow rules, interact, and communicate—they form a community of components, a society, a social system.

That the sciences of physics, chemistry, and biology are capable of treating their object systems as statistical masses, and not as social systems of communicating components, is bad enough. But the social systems proper (i.e., human systems) are also treated by differential mathematical equations, thus destroying their "social" quality. Even though all autopoietic systems are social systems, social systems themselves are not treated as autopoietic systems.

As F. von Hayek[13] pointed out, social engineers assume that since people have been able to generate some systems of rules coordinating their efforts, they must also be able to design an even better and "improved" system. The traditional norms or reason guiding the imposition and subsequent restructuring of socialism embody a naive and uncritical theory of rationality, an obsolete and unscientific methodology which von Hayek calls "constructivist rationalism."

Although the family (and other spontaneous social orders) can easily produce and generate systems other than itself, its primary capability is that of producing (and reproducing) itself. Concentration camps and other "engineered" societies are capable of heteropoiesis (producing "else") but not capable of autopoiesis (producing "self"), except by sustained force and coercion.

The removal of external coercive pressures and props is one of the safest tests of viability (i.e., autopoiesis) of social systems: if the coercive boundaries (physical or otherwise) dissolve and the social system ceases to exist, it was not autopoietic; if it reasserts its social boundary and voluntarily increases the level of cohesiveness, then it is autopoietic, self-sustaining, and worthy of human participation and pursuit.

The collapse of the non-autopoietic communist systems of Eastern Europe is a prime example of spontaneous social orders in action. As soon as the threats of force (or even the promises of support for the control-regimes) and the Red Army intervention were removed, people spontaneously (without prior plans, leaders, or "models") organized themselves into a highly disciplined, purposeful, and effective social (and simultaneously political) force.

It is both improper and unscientific to consider engineered social designs as *social* systems. Concentration camps, jails, command hierarchies, totalitarian orders, and so on, are not social orders but dictatorial, rule-based systems: everybody is put in place, told what to do and how to respond, where to go and when. Whatever social-system characteristics do emerge, do so only in spite and in defiance of the imposed order. There is nothing spontaneously social about them. As soon as the boundaries (the imposed rules, order, fear) are dissolved they do not re-assemble themselves spontaneously: rather, everybody goes home.

Such engineered command systems do have a role to play in some societies—for example, military hierarchies in war, concentration camps of national socialism, and assorted "Berlin Walls," assuring continued involuntary membership in modern times.

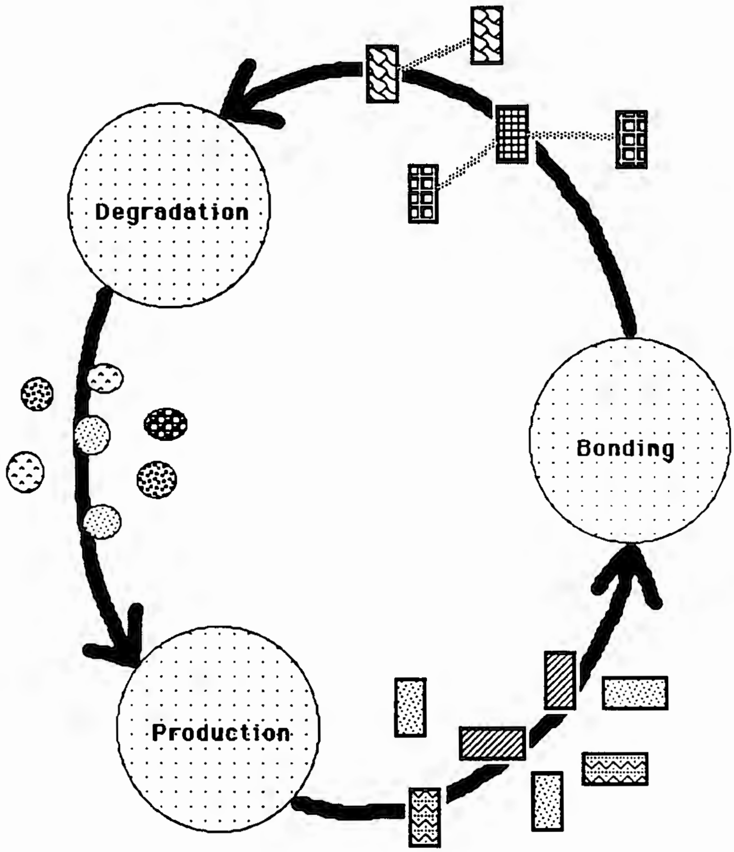

Figure 8 Circular organization of interdependent processes and their "production"

But it is only in the sense of "command" systems that we present our conjecture: **All autopoietic (biological) systems are social systems; they are not hierarchical command systems.**

Social organization is a network of interactions, reactions, and processes involving:

1) *Production* (poiesis): the rules and regulations guiding the entry of new living components (such as birth, membership, acceptance).
2) *Bonding* (linkage): the rules guiding associations, functions, and positions of individuals during their tenure within the organization.
3) *Degradation* (disintegration): the rules and processes associated with the termination of membership (death, separation, expulsion).

In Figure 8 we graphically represent the above three poietic processes and connect them in a cycle of self-production. Observe that *all* circularly concatenated processes represent productions of components necessary for other processes, not only the one designated as "production." To emphasize this crucial point we speak of poiesis instead of production and autopoiesis instead of self-production. Although in reality hundreds of processes could be so connected and/or interconnected, the above three-process model represents the minimum conditions necessary for autopoiesis to emerge.

From the vantage point of Figure 8, all biological (autopoietic) systems are social systems. They consist of production, linkage, and disintegration of related components and component-producing processes. An organism or a cell is therefore a social system. Without the understanding of the poiesis of their components, we cannot even hope to understand them as wholes.

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