Ecosocieties:
Societal Aspects of Biological Self-Production

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Zusammenfassung: Es wurde mit Erfolg behauptet, daß alle biologischen (lebenden) Systeme autopoietische Systeme sind. Mit geringerem Erfolg wurde die umgekehrte These vertreten, daß alle autopoietischen Systeme biologische (lebende) Systeme seien. Kürzliche Fortschritte auf den Gebieten des „Artificial Life", der synthetischen Biologie und der osmotischen Wachstumsprozesse haben aber gezeigt, daß zumindest einige autopoietische Systeme nichtbiologisch sind: d.h. autonom und selbstproduzierend in einem physikalischen, anorganischen Milieu. Das Phänomen Leben ist einer spezifischen Organisation der Materie zuzurechnen, nicht einer besonderen (e.g. organischen) Materie.

Weiterhin existiert eine ausführliche Diskussion darüber, ob soziale Systeme (diejenigen, die spontan geordnet und nicht vom Menschen entworfen sind) autopoietische Systeme sind.

Dieser Essay behauptet, daß die Frage der Autopoiesis spontaner sozialer Systeme irrelevant ist: Nicht nur, daß spontane soziale Systeme autopoietisch sein müssen, sondern die Umkehrung dieser Relation gilt noch bestimmter: Alle autopoietischen und also alle biologischen (lebenden) Systeme müssen soziale Systeme sein.

Diese These impliziert nicht, daß alle sozialen Systeme autopoietisch sind; es gibt viele vom Menschen entworfene und gemachte heteropoietische „Wunder" des sozialen „engineering", die weder autonom noch selbstproduzierend oder selbsterhaltend sind. Aber alle autopoietischen Systeme, die organischen und die anorganischen, müssen notwendigerweise soziale sein (Gesellschaften, Populationen, Kommunitäten).

Es ist nicht wichtig anzumerken, daß einige (d.h. spontane) Sozialsysteme autopoietisch sind; entscheidend ist, daß alle lebenden Systeme (und alle ihre lebenden Subsysteme) Gesellschaften sind und als solche untersucht werden müssen.

Introduction

> „One could say that the expulsion of the biological and natural ecological determinants of human existence has been one of striking features of sociological studies since the 1930s."
>
> Edward Shils, 1985

E. Shils, in his *The Calling of Sociology* (1985), as well as in several later works, insists that the capacity to discern connections between activities or institutional arrangements which appear to be unconnected derives from the postulate of the systemic character of society. Society, according to this postulate, is a whole of interdependent parts, each of which forms the „environment" for all the others.

Shils's is a properly (in the sense of Smuts) holistic view, recognizing a whole as a unity of parts that affects the interactions of those parts. The temporal and territorial parochiality of the traditional sociological research, although rich in concrete and descriptive detail, is often short on fulfilling the programmatically announced intentions of universal validity. Yet, Shils [1985] insists:

> Although sociologists have made little progress in the delineation of whole societies, either in theory or in particular investigations, the idea of a „society" as a whole or as a system whose parts are interconnected in many ways, is a *fundamental postulate of sociology* [Italics M. Z.].

Modern sociology is increasingly being challenged by the urgent issues related to the sustainability or self-sustainability of social networks (ecosystems, ecosocieties and metapopulations). These challenges can be met only if the „fundamental postulate of sociology" becomes firmly embedded within sociological research methodology. Developing a sufficiently general notion of a „social system," with sufficiently generalizable organizational and structural properties, is a necessary step towards producing sound knowledge which can be of practical utility. The discovery of the fundamental laws of social life remains an unfulfilled promise of sociology.

According to Shils: „There is at present no systematically articulated general theory in sociology which would find general acceptance among sociologists." Consequently, the rich results of sociological investigations are not clearly and precisely cumulative.

The purpose of this essay is twofold: (1) To propose that many important social systems are self-producing (autopoietic), rather than purposefully „engineered" or constructed (heteropoietic), and, more radically, (2) To propose that all self-producing (autopoietic) systems, including biological „living" systems, must also be social systems.

The first proposition attempts to unveil the nature of self-organization and thus self-sustainability of spontaneous social orders and thus provide a foundation for non-ideological, non-political and sustainable social action.

The second proposition suggests and points to potentially significant intersections of biology, economics and sociology. The resulting interdisciplinary „crosspollination" of these disciplines would go a long way towards effectively addressing the issues of environmental self-sustainability.

Since the times of Parsons and Luhmann, „actions" and „communications" have been considered the components of social (sociological) systems. Autopoietic theory attempts to reinstate the individuals to their proper place as the proper components, with all their inaction and miscommunication abundant.

Individuals and Networks

„Cells move, die, divide, release inductive signals or morphogens, link to form new sheets, and repeat variants of the process. Genes control the whole business indirectly by governing which morphoregulatory or homeotic product will be expressed."
Gerald E. Edelman, *Bright Air, Brilliant Fire*, 1992

Since Huxley's *The Individual in the Animal Kingdom*, the idea of individuality has continued to present fundamental difficulties in biology. Is a colony of „white ants" an individual? Huxley proposed that: „Wherever a recurring cycle exists (and that is in every form of life) there must be a kind of individuality consisting of diverse but mutually helpful parts succeeding each other in time, as opposed to the kind of individuality whose parts are all co-existent." Huxley, in 1912, distinguished between individuality in time (species-individuality) and our ordinary, simultaneous or spatial individuality.

It is the first kind of individuality, the individuality of a cyclically recurring network of „ordinary" individuals, that is crucial for an enhanced understanding of self-sustaining social systems or networks.

Every organism, even if spatially and temporarily isolated, can emerge, survive, and reproduce *only* as part of a larger societal network or metapopulation of organisms. Similarly, each cell, organelle, or neuron can exist only as part of a group or society of cells, organelles, or neurons. Each component of an autopoietic (Varela/Maturana/Uribe 1974; Zeleny 1981) system can emerge, persist, and reproduce only within the complex of relationships that constitute the network of interconnected components and component-producing processes.[1]

Before any organism can reproduce, it must first be produced (or self-produced), and it must survive. Autopoiesis (self-production) therefore precedes, and in fact creates, the conditions for any and all subsequent reproductions.

Survival (economic and ecological) activities of separate organisms directly form and reform their metasocieties of interactive populations which are further concatenated into regional networks and full ecosystems. Reproductive organismic activities can take place only within such preformed networks and thus assure their own (i.e. ‚networks') reinforcement and self-production. In fact, autopoietic systems can, and many do, adapt and evolve without their own reproduction; only their components may reproduce.[2]

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1 In this sense, talking about, for example, „social insects" is inadequate as all insects – and also all other organisms – *must be social* by the virtue of their existence.

2 So called „giant organisms" are good examples of genetically uniform societies. The Northern-Michigan creeping mega-fungus (30 acres, 100 tons) is just the „tip of an iceberg" of the unknown and to be uncovered world of biological societies. The Utah Wasatch Mountains stand of some 47,000 quaking aspen trees (106 acres, 6,000 tons) is

Eldredge (1996) concludes that a gene-centered view of such systems is unnecessary, and that social networks are demonstrably biotic systems. The entire human society can be viewed as such an autopoietic superorganism (Stock/Campbell 1996), embedded in an autopoietic Gaia – as is often propounded by L. Margulis (Mann 1991).

Margulis has also targeted Neodarwinism[3] and its inability to answer important questions or explain fundamental phenomena – for example, there is not a single case of a new species created by building up of chance mutations. She has embraced the so called „autopoietic Gaia".

The so-called „Gaia hypothesis" is not new in the history of science; A. A. Bogdanov formulated it quite clearly (Zeleny 1988a):

> The entire realm of life on earth can be considered as a single system of divergence, based on the rotation of carbon dioxide. This rotation forms a basis for complementary correlations between life as a whole – the „biosphere" – and the gaseous cover of the Earth – the „atmosphere." The stability of atmospheric content is sustained in the biosphere, which draws from the atmosphere the material for assimilation.

Bogdanov, the father of tectology (the precursor of modern autopoiesis), has thus conceptually coupled biosphere, atmosphere, hydrosphere, and lithosphere into a single holistic[4] system of mutually co-evolving influences.

Organisms cannot be separated (except through artificial cleavage) from their economic, ecological, or social environments which they themselves co-produce and mutually provide to each other. Only a temporarily disembodied human mind can imagine removing itself, temporarily, from its social surroundings – from its life base.

Self-Sustainability

The significance of natural ecological and biological qualities has been denied by sociology in favor of a conception of the environment as preponderantly, if not exclusively „social". Yet, any successful addressing of the challenging issues of sustainability of social systems must address much longer and remoter (past and future) historical periods than has been customary.

Even though we often talk about sustainable systems, it is the self-sustainability of systems which is of greater interest. The question is not:

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another example of a communicating society, „marching" harmoniously over the mountainscape. Humans can hardly see the „whole thing," identify its boundaries or „prove" its intactness.

3 In fact a very old (since 1896) and mostly exhausted paradigm (or paradigmatic aberration), fatally unable to explain even the prevalence of stasis in the fossil record or how one species could evolve from another.

4 Holistic here does not coincide with the popular „wholistic" as the opposite or the complement to reductionism or atomism. J. Ch. Smuts's holism (1926) is based on the essential circularity of autopoietic systems: a whole is a unity of parts that affects the interactions of those parts. There can be no parts apart from the whole, and the whole cannot be contemplated apart from its parts: the whole is the parts.

How can we sustain a given system?, but: How can a system sustain itself in a given milieu?

Another dimension of sustainability must be its organizational mode. It is important to realize that sustainability (and self-sustainability) is directly related to system organization and its self-production (autopoiesis). How are systems organized is much more important than how its individual agents think or what values they uphold.

Self-sustainable systems are autopoietic and must therefore be organized for autopoiesis. Sustainable systems are heteropoietic, i.e., their sustainability does not come from within (from its own organization) but from without, from planned, system-sustaining activities of external agents. Non-sustainable systems are allopoietic, i.e., they are organized to produce things other than themselves. Allopoietic systems necessarily deplete their environment.

Heteropoietic systems can be sustainable as long as external agents sustain their system-sustaining efforts. Only autopoietic systems replenish their own environment and thus can become self-sustaining.

Self-sustainable systems must maintain their ability to coordinate their own actions. Purposeful coordination of action – or knowledge – has to be continually produced and maintained: self-sustaining systems must be knowledge-producing, not just labor or capital consuming entities. An autopoietic view of knowledge is also presented through the corporate epistemology of Georg von Krogh et al. (1994).

In summary, the presented view of sustainability can be characterized as follows: both sustainability and self-sustainability are time and context dependent system properties emerging from system organization. System organization must be continually produced or renewed via operating a common, shared resource system, optimally managed through competition and collaboration of agents. Continued functioning of the organization thus requires continued coordination of action, i.e., continued production of knowledge.

Most systems can be sustained over long periods of time through an external supporting agent disbursing ideas, effort, money or resources. Once this external agent withdraws its support, system's sustainability can be directly challenged. Externally sustainable systems do not have to be internally self-sustainable.

Any relationship External agent $\rightarrow$ Sustainable system can be transformed into a self-sustainable metasystem (External agent $\leftrightarrow$ System). While an external agent can in principle make any system sustainable, only a meta agent-system can become self-sustainable: through making the external agent an internal part of the system.[5]

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5 An infant is sustainable through his mother's care, but it is not self-sustainable as a separate, autonomous system. A mother-infant metasystem is not only sustainable by others, but also self-sustainable in its social or even physical milieu..

Autopoiesis

> If Nature possesses a universal psyche, it is one far above the common and most impelling feelings of the human psyche. She certainly has never wept in sympathy, nor stretched a hand protectively over even the most beautiful or innocent of her creatures.
>
> Eugène Marais, *The Soul of the White Ant*, 1970

Among the physical, biological, and social systems, the most complex and the most interesting are those which are autopoietic, i.e., autonomous and self-producing. The definition of these systems has been introduced by Varela, Maturana, and Uribe (1974). Also Haken (1986), defining synergetics, refers to systems composed of many individual parts which, by their cooperation, form organizations and structures – i.e., he refers to social systems.

An autopoietic system has been defined as a system that is generated through a closed organization of production processes such that the same organization of processes is regenerated through the interactions of its own products (components), and a boundary emerges as a result of the same constitutive processes.

Varela et al. (1974) have conceived autopoietic organization as an autonomous unity of a network or meta-network of productions of components, which participate recursively in the same network of productions of components, which produced these components, and which realize such a network of productions as a unity in the space in which the components exist.

Such *organization* of components and component-producing processes remains relatively invariant through the interaction and turnover of components. The invariance follows from the definition: if the organization (the relations between system processes) changes substantially, there would be a change in the system's categorization in its identity class. What does change is the system's *structure* (its particular manifestation in the given environment) and its parts. The nature of the components and their spatiotemporal relations are secondary to their organization and thus refer only to the structure of the system.

System's boundary is a structural manifestation of the system's underlying organization. The boundary is a structural realization of the system in a particular environment of components. In physical environments this could take the form of a topological boundary. Both organization and structure are mutually interdependent.

The concepts of the autopoietic nature of a system were developed by Varela et al. (1974) based on a living (biological) system as a model of self-production. Yet self-production has the potential of being interpreted through many different ways by a variety of observers. „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 all living systems. A cell, a system that renews its macromolecular components thousands of times during its lifetime, maintains its identity, cohesiveness, relative autonomy, and distinctiveness despite such intense turnover of matter. This persisting unity and its holism is called „autopoiesis."

Zeleny (1981) presents an overview of autopoiesis as a theory for the living organization. Varela et al. (1974) have developed a six-point key that provides the criteria for determining whether or not a system is autopoietically organized.

These criteria, as they are applied to biological (living) systems, can also be applied to other systems that are currently not considered „living." This is a simple exercise with very important implications. We have found (Zeleny/Hufford 1991, 1992) that not only are spontaneous social systems autopoietic, but also that the relationship is much stronger. Although all living systems are autopoietic, not all autopoietic systems are living. For example, inorganic osmotic growths (Zeleny/Klir/Hufford 1989) are often temporarily autopoietic.

All autopoietic systems must be social systems. In other words, all autopoietic, and therefore all biological (living) systems, are social systems. Also, 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 take a physical form in other types of systems, e. g., in social systems.

In social systems, dynamic networks of productions are being continually renewed without changing their organization, while their components are being replaced; perishing or exiting individuals are substituted by the birth or entry of new members. Individual experiences are also renewed; ideas, concepts and their labels evolve, and these, in turn, serve as the most important organizing factor in human societies. The organizing core for the implementation of ideas must be the emergent society as an autopoietic entity.

Autopoietic systems can persist in their autopoiesis for many decades (humans, trees), for many days (cells) or for mere flashes of hours, minutes, seconds, or even milliseconds (osmotic growths). The „lifespan" of autopoiesis in no way enters (or should enter) into its definition. Also, autopoiesis is bound to exhibit gradation; it does not jump into being in a magic instant – it becomes. It gradually degrades itself; the processes of autopoiesis weaken and dim, more or less rapidly (Zeleny 1978).

There is a great modeling, methodological and explanatory potential, certainly on the rise in modern sciences, in treating autopoietic systems as social systems.

Social Systems

> „Have you ever seen, in some wood, on a sunny quiet day, a cloud of flying midges – thousands of them – hovering, apparently motionless, in a sunbeam? ... Yes? ... Well, did you ever see the whole flight – each mite apparently preserving its distance from all others – suddenly move, say three feet, to one side or the other? Well, what made them do that? A breeze? I said a quiet day. But try to recall – did you ever see them move directly back in the same unison? Well, what made them do that? Great human mass movements are slower of inception but much more effective."
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> Bernard M. Baruch, Foreword to Mackay's *Extraordinary Popular Delusions*, 1849

It is time to define social systems and to elucidate the meaning of „social" for the purposes of this paper. Such definition should be as general as possible, encompassing a rich variety of contexts, yet being fully amendable, adjustable and applicable to all such contexts.

Social systems are renewable, self-producing networks or meta-networks characterized by internal (rather than external) coordination of individual action achieved through communication among temporary agents. The key words are coordination, communication, and limited lifespan of the individual agents or their groupings.

It should be self-evident that the general notions of coordination, communication and individual lifespan will acquire different meanings in different contextual embeddings.

Coordinated behavior includes *both* cooperation and competition (and all forms of conflict), in all their shades and degrees. Actions of predation, altruism, and self-interest are simple examples of different and interdependent modes of coordination. Communication could be physically, chemically, visually, linguistically, or symbolically induced deformation (or in-formation) of the environment and consequently of individual action taking place in that same environment.

So I, as an individual, can coordinate my own actions in the environment only if I coordinate it with the actions of other participants in the network. In order to achieve this, I have to in-form (change) the environment so that the actions of others are suitably modified; I have to communicate. As all other individuals are attempting to do the same, a social network of coordination emerges, and, if successful, it is being „selected" and persists. Such a network improves my ability to coordinate my own actions within the environment effectively. Cooperation, competition, altruism, and self-interest are thus inseparable.

Social systems cannot and should not be limited to human systems, especially when addressing the issues of ecological self-sustainability. Human systems simply in-form a special meaning on the universal acts of coordination, communication, and birth-death processes in *general social systems.*

A group of fish thrown together by a tide wave is a passive aggregation, not a social system. A swarm of moths lured to a porch light is an active aggregation, but not a social system. A flag-pattern of athletes „constructed" through bullhorn-shouted commands from a coordination center is a purposeful heteropoietic aggregation, not a social system.

All of these can transform into social systems as soon as internal communication patterns become established; they should then temporarily persist (become autonomous), even after removing the external impetus.

Merely externally induced interaction of components does not suffice: billiard balls interact and so do wind-blown grains of sand – nobody would call them social systems.

Human waiting queues are often engineered and externally induced (enforced, not voluntary) interactions. To a large degree however, they do exhibit, at least temporarily, the voluntary self-organization characterized by its own specific behaviors, rules of conduct, choice of distance and modes of communication.

Similarly, schools of fish, swarms of bees, flocks of birds, packs of animals, and even the spontaneous wave-patterns of Olympic-games spectators are, however, no matter how ephemerally shortlived, undoubtedly social systems.

Any social system, in order to adapt and persist in its environment, must be capable of reshaping itself, controlling its growth, and checking the proliferation of individuals. In other words, the long-term persistence of a social system is critically dependent on harmoniously balanced birth and death processes. There can be no collective life without individual death.

A proliferation of individuals without balancing death processes and without death-inducing communication is „cancer"- a shortlived, environmentally destructive outburst of life-like processes, but not the life itself. A dominant death process, without a sufficient birth-process complement, takes any social system towards its extinction.

Life of a social system, and thus life itself, is based on a dynamic and autopoietic harmony between birth and death processes. Life is necessarily a social phenomenon: the life of an individual cannot take place outside a social network, and the individual life itself must be socially embodied at the level of its components.

This view is quite different from the deterministic and essentially non-biological dogma that (somehow) the growth of an organ is genetically (symbolically) programmed into the cells which are then guided (read-only memory) by this „geneprogram" through an exquisitely precise and predetermined series of events.

No communication and no death implies no life.

Detecting Autopoiesis in Systems

To illustrate the diversity of autopoiesis in its application to systems analysis, Zeleny and Hufford (1991; 1992) have analyzed three systems: a biological (living) system, a chemical system, and a spontaneous social system. Here we summarize their main conclusions.

1. The Eukaryotic Cell
The generalized non-plant eukaryotic cell 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.

After applying the Varela-Maturana-Uribe six-point key to the generalized eukaryotic cell, it can be concluded that the cell is an autopoietic unity in the space in which its components exist.

L. Margulis (Mann 1991) is one of the few biologists who viewed eukaryotic cells as autopoietic populations of components. „We are walking communities," she insisted.

2. Osmotic Growth
Stephane Leduc (1911) described an „osmotic growth," a membrane of precipitated inorganic salt, as having many processes, functions, and characteristic forms that appear to be analogous to those found in living systems. The osmotic experiments performed by Leduc have been also reproduced by Klir, Hufford, and Zeleny (1988).

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. An actual photographic sequence has been provided by Zeleny, Klir, and Hufford (1989).

After applying the six-point test, based on the evaluation of 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.

At the macroscopic level, the osmotic precipitation membrane exhibits fluidity, elasticity, and resealability identical to the properties of the plasma membrane. As the internal osmotic pressure increases, an expansion occurs (not a rupture) allowing components from the internal and external spaces to flow through the membrane and „couple" within the membrane. The osmotic growth phenomenon occurs because the operational integrity of the precipitation membrane is maintained.

Osmotic growths are, temporarily and often ephemerally, autopoietic. This implies that if we hold the current autopoietic theory to be correct and intact, then we must reassess our definition (redefine our criteria) of what it means to be „living." If we do not give up our current definitions of „living," then we must conclude that there is a fundamental problem within the existing theory of autopoiesis which needs to be addressed.

3. Kinship System – A Spontaneous Social System

As our third system, the kinship system is an example of a spontaneous social order that has a substantial impact and great significance in the life of social, economic, and political networks. A kinship system 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 kinship system organizes its social domain and coordinates its social action in a spontaneous, self-perpetuating fashion. It must continually adapt to the external challenges and interferences of the society,[6] social engineers and reformers.

Social networks, embodying kinship systems, are not static and unchanging structures, but highly dynamic ones. Cochran et. al., in their study of kinship systems (1990), established that the distribution of different types and roles of network participants (kin, friends, neighbors, formal ties) remains relatively stable, even though the names and faces of network members keep changing. In the language of autopoiesis: It is their organization that remains stable, while their structures and components continually change.

Social networks can therefore change in their structure or in the nature of their component relationships (organization). One can therefore study shifts in the network's structure, turnover among its members, and changes in the character of continuing network ties. For example (Cochran et al., 1990), in spite of frequent moving and changes of neighborhoods, American white children maintain the largest stable social networks (8 adults, 8 peers) while relatively immobile Swedish children maintained the smallest (4 adults, 4 peers).

Viewing families and kinship networks properly as autopoietic systems could lead to new and important understanding of the effects of residential mobility, divorce rates, death and disease disruptions, loss of employment, or state intervention on the structure, organization and durability of social bonds in important social and support networks – primary, functional, peripheral and formal.

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6 We do not discuss the human-engineered and purposefully constructed social systems and institutions, although they are undoubtedly of great importance. Autopoietic behavior of groups can take place within them, at least temporarily, but it is *not constitutive* of them. There are spontaneous social orders and systems within a concentration camp, but the concentration camp does not emerge from them.

Through social autopoiesis, one also can learn more about which social environments produce desirable social supports in transaction with parents. What is the role of friends and relatives? What is the role of parental self-confidence, and how can it be enhanced? What is the role of a parent's level of formal education? How do intervention programs interact with the spontaneous self-organizational nature of social autopoiesis? The research agenda of self-producing social systems is remarkable in its challenge and significance.

It was F. A. Hayek who integrated the concepts of self-production directly into the domain of social systems (1988). Hayek 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.

Consequently, the individuals in a society spontaneously assume the sort of conduct and evolve the rules which assure their continued existence within the whole. Of course, this conduct and rules 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. The individual actions are motivated by their own goals and purposes.

Amoeba: Biotic Social Systems

> What do human beings, ants, and slime have in common? Despite their differences in structure, physiology and ecology, all three consist of individuals whose behavior is sufficiently coordinated for the group to be called a society.
>
> Howard Topoff, 1981

Is this „coordination" and the resulting society due to executing a preconceived plan of a social engineer, central planner, or a great designer (like in heteropoietic systems), or is it due to the distributed and unintended self-coordination of goal-seeking and autonomously behaving individuals (like in autopoietic systems)?

Cellular Slime Mold (Garfinkel 1987) is another good example of an autopoietic social system. The slime molds (Gymnomycota) are an example of a fungus-like protist. They are decidedly fungus-like at some stages and animal-like at others. Their life cycle includes an ameoboid stage and a sedentary stage in which a fruiting-body develops and produces spores.

In Dictyostelium discoideum (Garfinkel, 1987) the vegetative cell is ameoboid. Ameobas are individual cells moving around in search for bacteria to feed on. They will grow and divide indefinitely. Often they digest so much and produce new amoebas so rapidly that their food supply has no chance to replenish itself. When the food supply has been exhausted, they move rapidly to a central point, collecting themselves into a well-differentiated spontaneous aggregation (center cells, boundary cells, etc.) – a pseudoplasmodium. The aggregation is triggered by the production of cyclic adenosine monophosphate (AMP) which attracts other amoebas in a chemotactic fashion.

The group then assumes the shape of a „slug" with a head, tail, and an apparent „purpose": searching collectively for a new, potential source of food. Around the outside is secreted a mucoid sheath (aggregate boundary). It migrates as a unit across the substratum as a result of the collective action of the amoebas. The changing of the roles of individual amoebas is prevalent: the original leaders who formed the center of attraction are dispersed throughout the „slug", and new leaders emerge, forming the „goal-seeking" head.

The head of the home-hunting „slug" are simply the fastest-moving amoebas. The „slug" is just a spontaneous temporary metaorganism, preserving each amoeba as a separate individual. The slug is positively phototactic (migrates toward light), and it usually migrates for a period of hours. Its behavioral responses are essential „to ensure" that the spores will be borne in the air and so can be effectively dispersed.

Fruiting body formation begins when the slug ceases to migrate and becomes vertically oriented. The „leading" amoebas change quickly from the first to the last. The head of the slug forms the base of a stalk which follower-amoebas continue to build (they secrete cellulose to provide rigidity) up into a mushroom-like metaorganism. At its top, hundreds of thousands of amoebas differentiate into spores that are embedded in slime and, after the mushroom „head" matures, it bursts. It disperses the spores to new and potentially nourishing environments. When they fall to earth, they change once again into the individual amoebas which reproduce by cell division. This ecological cycle is then repeated.

Amoeba: Human Social Systems

> To the naive mind that can conceive of order only as the product of deliberate action, it may seem absurd that in complex conditions order, and adaptation to the unknown, can be achieved more effectively by decentralising decisions, and that division of authority will actually extend the possibility of overall order.
>
> F. A. Hayek, *The Fatal Conceit*, 1975

After the undisputed failures and fatal conceit of large-scale social engineering and experimentation of the past (Hayek 1975, 1988), the phenomena of spontaneity and emergence in social systems are becoming important again. The survival and robustness of social institutions, such as market, family, culture, money, language, economy, city, and myriads of other voluntary orders, are being noticed.

The biological amoeba metaphor has recently found its organizational embodiment in the most successful „amoeba system" at Kyocera Corporation (Hamada/Monden 1989).[7]

The Kyocera „amoebas" are independent, profit sharing and self-responsible units of three to fifty employees. Each amoeba carries out its own statistical control, profit calculus, cost accounting and personnel management. They compete, subcontract, and cooperate among themselves on the basis of intracompany market of transfer prices.

Depending on the demand and amount of work, the amoebas can divide into smaller units, move from one section of the factory to another, or integrate with other amoebas or departments. All amoebas are continually on the lookout for a better buyer for their intermediate products. Many amoebas even produce the same or similar products. They are authorized to trade their intermediate products with the outside companies; if the internal vendor is unreasonable, the buyer amoeba will search for a satisfactory supplier outside the company.

A most remarkable feature towards system autonomy is the member trading. Heads of amoebas lend and borrow members and so eliminate losses caused by surplus labor. So, Kyocera's amoebas multiply, disband, and form new units in the spirit of autopoiesis (self-production) of the enterprise. Amoeba division and breakup are frequent occurrences and are based on the criteria of output and a worker's added value per hour.

This concept of ultimate flexibility is best summed up by Kyocera's President Inamori: „Development is the continued repetition of construction and destruction" (Hamada/Monden 1989), as if coming directly from the systems theories of autopoietic self-organization.

Another example would be Australian TCG (Technical Computer Graphics), a self-producing network in a business-firm environment. There are no coordinating divisions, „leading firms", or management superstructures guiding TCG's 24 companies; the coherence, growth and maintenance of the network is produced, according to J. Mathews (1992), by a set of network-producing rules.

Boundaries of Social Systems

In kinship systems, their boundaries are usually well defined. The distinction between family and non-family members is rarely ambiguous or subject to fuzzy interpretation. A definite family boundary can be estab-

7 This system is also reminiscent of the famous Bata-system of management in the 1920s and 1930s in Moravia (Bata 1992; Zeleny 1988c).

lished, although it is not necessarily topological. In the context of the family, the concept of boundary might be defined as the members included in a set. Family members are usually distinguished from their environment (from the „society") more sharply than any engineered or designed physical „membrane" can assure.

All social systems, and thus all living systems, create, maintain, and degrade their own boundaries. These boundaries do not separate[8] but *intimately connect* the system with its environment. They do not have to be just physical or topological, but are primarily functional, behavioral, and communicational. They are not „perimeters" but functional constitutive components of a given system.[9]

Boundaries do not exist for a human observer to see or identify the system, but for the system and its components to interact and communicate with its environment. Boundaries range from phospholipid bilayers, globular proteins, osmotic precipitates, and electric potentials, through cell layers, tissues, skins, metabolic barriers, and peripheral neural synapses, to laterally or upwardly dispersed boundaries of territorial markers, lines of scrimmage, social castes, secret initiation rites, and possessions of information, power, or money.

A company can have a number of geographically separate offices or be a virtual company, entirely „in the air" of electronic communication. The U.S.A. includes Alaska and Hawaii. A doctor does not leave the social system of a hospital while „on call" or connected by a beeper. Many additional examples and details of non-topological social boundaries are discussed by Miller and Miller (1992).

Although social systems are necessarily physical because their components realize their dynamic network of productions in the physical domain (their components are cells, termites, lions, adult humans, etc.), many computer simulations (Zeleny 1978) of autopoietic systems show that topological boundaries arise only if very minute rates of production processes are very finely adjusted and harmonized. In other words, the underlying organization of processes has to be „tuned up." If not, a human observer might not be able to „see" or recognize any „topological" boundary. Yet the organization remains functional and invariant; autopoiesis continues; we do not see any boundary, but the system remains autopoietic.

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8 This topological notion of „separation" still persists in some theories of systems, see, e.g., Miller/Miller 1992: A living system's boundary is a region at its perimeter that separates the system from its environment.

9 The food moving through mouth and the digestive tube is not necessarily „inside" the body, but remains „outside," in the „captured" or „enveloped" environment of the body torus. The same holds true for all other „boundary" organs; there is no inside or outside, and boundary does not separate anything, except in the human observer's mind.

All Autopoietic Systems are Social Systems

Recent advances in the areas of Artificial Life (Langton 1989), synthetic biology, and osmotic growths (Klir/Hufford/Zeleny 1988; Leduc 1911; Zeleny/Klir/Hufford 1989) have established that at least some autopoietic systems could be nonbiological, i.e., self-producing in inorganic milieus.

Autopoiesis can take place only where there are separate and autonomously individual components interacting and communicating in a specific environment according to specific behavioral (including birth and death) rules of interaction.

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

F.A. Hayek (1988) pointed out that 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 Hayek calls „constructivist rationalism" and which E. L. Khalil (1990) traced to Karl Marx's concept of social labor.

Although the family (and other spontaneous social orders (Zeleny 1985; Zeleny 1991)) can easily produce and generate systems other than itself, its primary capability is that of producing (and reproducing) itself.

The removal of external pressures, support and props is one of the safest tests of viability (i.e., autopoiesis) in 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 and self-sustaining.

It is only in the sense of such centrally-imposed „command" systems that we present our conjecture: *All autopoietic (biological) systems are social systems.*

Social organization can be defined as a network of interactions, reactions, and processes involving at least:

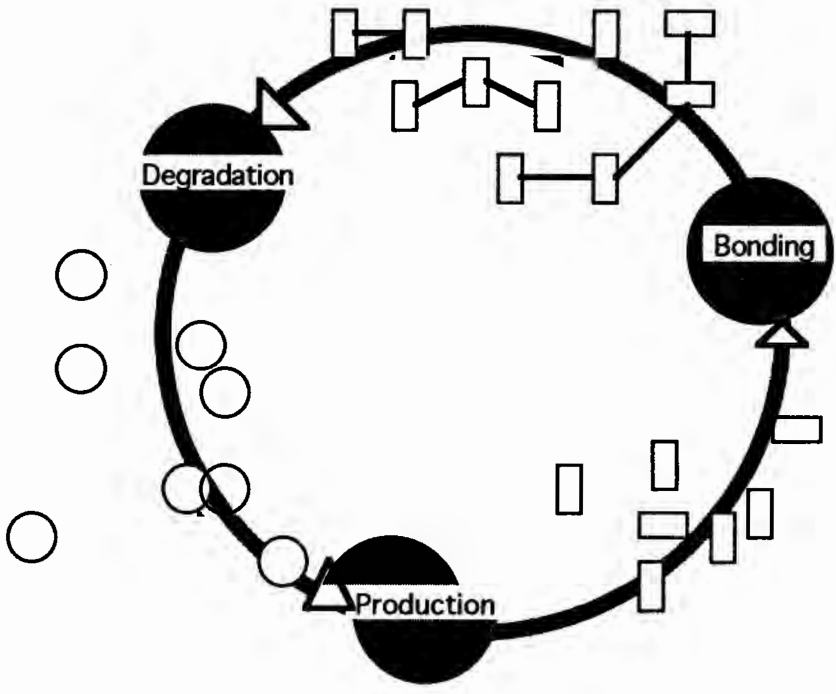
1) Production (poiesis): the rules and regulations guiding the entry of new living components (such as emergence, birth, membership, acceptance).
2) Bonding (linkage): the rules guiding associations, functions, and positions of individuals during their tenure within the organization.

3) Degradation (disintegration): the rules and processes associated with the termination of membership (death, separation, expulsion).

In Figure 1 we graphically represent the above three poietic processes and connect them into a cycle of self-production. Observe that all such 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 interconnected, the above three-process model represents the minimum conditions necessary for autopoiesis to emerge.

From the vantage point of Figure 1, 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.

Figure 1: Circular organization of interdependent processes and their „productions"



Marvin Minsky has titled his recent book *The Society of Mind* (1986), attempting to exploit the social metaphor in studying the mind as a society. According to Minsky, mind is neither a unified, homogeneous „black box" or entity, nor a collection of entities, but a heterogeneous system of networks of processes. Unfortunately, Minsky's view of „society" is the hierarchy of agents (or experts), based on extreme division of labor (Zeleny 1988b), each of them doing „some simple thing that needs no mind or thought at all."

Minsky writes like a social engineer of command systems, with little or no awareness of spontaneous social orders (Zeleny 1985): „ ... when *we* [italics M. Z.] join these agents in societies – in a certain and special way – this leads to true intelligence".

G.M. Edelman (1988) improves upon Minsky by stating:

> Any satisfactory developmental theory of higher brain function must remove the need for homunculi and electricians at any level and at the same time must account for object definition and generalization from a world whose events and „objects" are not prelabeled by any a priori scheme or top-down order.

Biological Organisms As Social Systems

> The body of a mammal with its many vital organs can be looked upon as a community with specialized individuals grouped into organs, the whole community forming the composite animal.
>
> Eugène Marais, *The Soul of the White Ant,* 1970

Although here we cannot analyze biotic systems in specialist's detail, let us explore the cellular organism, including the human organism, as a social system. Living organisms have often been studied as „black boxes," or as components-free machines, by mechanistic cybernetics.[10]

Biological organisms are not components-free black boxes but communicating, birth-death process balancing social systems. Jim Michaelson of Harvard is one of the few biologists who is prepared to treat biological systems as social systems, positing the „competition" of cells, the selection and survival of the most „fit" during their embryonic development, as being dependent on the cell's ability to secrete enzymes, rates of proliferation, etc.

1. Communication

Whenever a living cell is unable to communicate with other cells, it does not die, but rather grows uncontrollably, multiplying into other non-communicating cells, forming a malignant tumor which is unable to survive in its life-sustaining environment because it destroys it.

10 Yet, the true roots of cybernetics are essentially non-mechanistic and rooted in proto-autopoiesis and spontaneous self-organization (Zeleny 1990).

All organismic cells are interconnected through tiny channels in cell membranes or gap junctions. Through these channels, all molecular, chemical, metabolic, and electric communication among cells takes place. These communicative junctions are made of proteins (connexins) that align all cells into one continuous channel-network: a social system.

Malfunction in intercellular communication channels affects the intercellular social system and thus could „kill" the organism itself. If regulatory and inhibitory signals do not get through, the uncontrolled, deathless growth, and the voracious feeding on its own environment, would result.

To study cancer processes without studying cellular gap junctions amounts to a case of professional neglect. Clogged channels block social-regulatory signals and allow cells to go awry; clear channels allow the propagation of deadly signals. Gap junctions themselves are selective and self-regulatory; they tend to close and protect against chaotic signals and to open for and receive regulatory signals.

Even a fetus could not develop if particular groups of cells would not stop reproducing and growing „just-in-time," or more precisely, would not start dying.

In order to treat cancers, one has to either re-establish communication channels and thus self-regulation or block the growth of communication and support channels (like blood capillaries) in order to stop rampant proliferation. This is not a trivial mechanistic task; it can be mastered if we view biological systems as social systems.

2. Social Neighborhoods

As discussed in an AAAS symposium volume (Zeleny 1980), cellular neighborhoods, rather than some inheritable genetic „programs," are the main determinants of cells' functions. Sociologically, autopoietic systems are better illustrated by the American plan of development, where one's status and fate are determined by one's neighborhood, rather than by the British plan, where one's status and fate are determined by one's ancestors.[11]

The neural network especially, i.e., autonomous autopoietic system embedded in a larger complex of organismic networks, requires quick-response flexibility and adaptability which cannot wait for a mutations buildup or rely on requisite but cumbersome „genetic alterations." Neural networks develop as autopoietic societies; individual cells wander around, get exposed to differential signalings of different cellular neighborhoods, and ultimately settle down (or get captured) within these neighborhoods, becoming functioning neurons of the visual, hearing, or smell regions of the cerebral cortex.

H. Maturana insists in (Zeleny 1980) that „genes" and viral DNA are only structural components of autopoiesis. Their distribution and mutation therefore affect structures and structural characteristics (inheritable shapes and adhesion properties of proteins), but they do not partake in

11 This analogy was first suggested by the British geneticist Sydney Brenner.

organization: they do not organize matter, but are themselves organized and ordered by autopoiesis.

The greatest error biologists could make at this paradigmatic bifurcation point is searching for the seat of the master plan behind the body's gray matter. There is no master plan and there are no black-box feedback loops within feedback loops. There is only a society in autopoiesis, organizing matter of different structural attributes and properties (including viral DNA), thus arriving at different, sometimes important, structural manifestations. Dr. C.L. Cepko of Harvard Medical School put it quite bluntly: „The mother cells do not impart specific information to their daughters about what to become".

3. Death Process

In addition to communication, social systems are also characterized by limited lifespans of individual agents-components, i.e., by death. If molecules would not break down, or cells, organisms, individuals and entire species would not die, there would be no social systems and thus no self-sustaining life on Earth.

Death dominates development. The vestigial webbing between human fetus fingers must be dissolved before birth. About eighty percent of the nerve cells of the baby's brain must perish within hours of their creation. Caterpillar's crawling muscles must be sloughed off in order to have a butterfly; female genitalia must be whittled away in order to have a male.

Still, an uncontrolled and massive death is non-redeeming: Alzheimer's, Parkinson's, and Lou Gehrig's degenerative disorders result. Uncontrolled and massive birth is equally unredeeming: cancerous cellmasses, killing their own environment (i.e., host organism) result. Individuals must die in order to maintain their social system.[12]

Death is not a chaotic, haphazard, or disorganized part of social system autopoiesis; it is a harmonized, choreographed, and often suicidal dance of the most exquisite complexity. The creation of autopoiesis is inconceivable without the trimming of apoptosis.

The study of apoptosis is crucial in biology: in fact, no true biology can exist without it.[13] Death is not the absence of life, but the crucial building block of life. Life is never „individual" life, but life of a social network of balanced and communicating birth-death processes.

A good example is the immune system. Millions of T and B cells are continually generated, each capable of assaulting foreign proteins, but unfortunately also the body's own proteins. Up to 98 percent of them

12 Why do biologists study protein production and cell proliferation, while neglecting protein degradation and cell death, amounts to one of the great mysteries of life. Is it the result of extreme specialization (Zeleny 1988b), where some study only the „ins" and others only the „outs" of the intellectual intercourse? Can such be a way towards understanding a „conception"?

13 A promising start could be made by learning to properly pronounce the term apoptosis, meaning „falling from the trees," coined by Andrew Wyllie of Edinburgh.

have to undergo immediate apoptosis in order to maintain the body's autopoiesis in a hostile environment.

Death is a productive process of the social system; it creates space, it generates production substrate, it brings in the innovation, and it allows trial-and-error adaptation to the environment. Individual cells are created in order to die, and thus their social system, i.e. living organism, can persist.

4. Evolution

> The idea that reason, itself created in the course of evolution, should now be in a position to determine its own future evolution is inherently contradictory, and can readily be refuted.
>
> F.A. Hayek, *The Fatal Conceit*, 1988

Social systems persist. They can persist as societies of agents only if their individual agents are born, communicate, and die in harmony with themselves and their environment. Because of the turnover of components, the social networks not only persist and are renewed, but they also evolve.

The unit of evolution (at any level) must therefore be a network capable of variety of self-organizing configurations. It is the entire social network, including neuronal groups (Eldredge, 1996), that is being „selected," not its individual components. Such evolving networks are interwoven and co-evolving with their environment; they do not only adapt to the environment, but also adapt the environment to themselves – through mutually intimate structural coupling.

A bird must undoubtedly adapt to a mountain. However, a society (network) of birds can make the mountain adapt to them. By overconsuming particular berries, the new brush growth is controlled, the mountain's erosion enhanced, and the production of both berries and birds thus limited until a temporary balance or harmony is restored. Colors of flowers have coevolved with the trichromatic vision of bees; shapes of flowers with the structural traits of insects and animals; modern breeders with the changing tastes and preferences of man. We quote from R. Lewontin (1982):

> The environment is not a structure imposed on living beings from the outside but is in fact a creation of those beings. The environment is not an autonomous process, but a reflection of the biology of the species. Just as there is no organism without an environment, so there is no environment without an organism.

Varela et al. (1991), in their book *The Embodied Mind*,[14] conform to the view that living beings and their environments stand in relation to each other through mutual specification or codetermination:

> The world is not a landing pad into which organisms parachute; nature and nurture stand in relation to each other as product and process.

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14 The index of this remarkable text does not contain any references to Autopoiesis, Maturana, or Artificial Life (AL). Yet it refers quite profusely to Abhidharma, Madhyamika, Mahayana, and Sunyata. This constitutes a profound enigma: the book clearly builds upon or motivates the former, while being profoundly irrelevant to the latter.

This new view of evolution of social networks implies that there can be no intelligent distinction between inherited and acquired characteristics. What evolves is neither genetically encoded nor environmentally acquired, but is ecologically embedded in a social network. The sociological implications of such realization are profound.

There is also no one fixed or pregiven world (a universe), nor is its dynamics simply observed or viewed differentially from a variety of vantage points (a multiverse), but this world itself is continually re-shaped, and re-created by coevolving social networks of organisms.

The evolution of paradigms is itself an autopoietic process, and it is thus inevitable to observe how the aged „revolutionaries" are clinging to the old and suddenly ineffective ideas, how they themselves have become conservatives, and how they individually resist the new interpretations of their younger colleagues, often without realizing that their collective time has passed ...

Closure

> When I began my work I felt that I was nearly alone in working on the evolutionary formation of such highly complex self-maintaining orders. Meanwhile, researches on this kind of problem – under various names, such as autopoiesis, cybernetics, homeostasis, spontaneous order, self-organization, synergetics, systems theory, and so on – have become so numerous...
>
> F.A. Hayek, *The Fatal Conceit*, 1988

Living systems, i.e., cells, organisms, groups, and species are social systems. Their interaction forms the entire terrestrial biosphere or Gaia, a social system akin to the unified organism of a living cell, which itself is a social system of its constitutive organelles.

Connecting different species into a coherent, interactive, and self-organizing system cannot happen without the death and dying – the fuel of environmental adaptation. The natural death of species does not signal maladaptability of the species, but harmony, adaptability, and systemic perseverance of the social network of species. Death is a cosmological event – the most exquisite assurance of life yet to be. At one point, individuals of all species receive, by waves on the shore, sound of the wind, or with radio telescopes, the exquisite, life sustaining message: „Now, now it would be indecent not to die."

Harmony and fitness does not imply dominance or competitive advantage but intimate coupling with the environment through all-embracing communication. The nature, as a social system, is replete with communication channels of great variety and subtlety. All life on Earth (and most likely interstellar too) is interconnected through internal and external harmonies, often unnoticed or ignored by linear sciences.

The connexins of cells, dances of bees, odors of fire ants, allochemicals of Douglas firs, and the language of humans are only the hints, only the shy peepholes into the veiled mysteries of life – and the promises of science yet to come.

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