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## **SYMPOIETIC AND AUTOPOIETIC SYSTEMS: A NEW DISTINCTION FOR SELF-ORGANIZING SYSTEMS**

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### **ABSTRACT**

Heuristics provide essential tools for understanding living systems, their characteristics and their behaviours. My intent in this paper is to describe a considerably different heuristic than the conventional tools. My motivation is a concern that heuristics based on the organism metaphor are often inappropriate and misleading for understanding complex systems. I propose a new concept based on an interpretation of ecosystems: sympoietic systems. These are complex, self-organizing but collectively producing, boundaryless systems. A subsequent distinction between sympoietic and autopoietic systems is discussed. This distinction arises from defining a difference between three key system characteristics: 1) autopoietic systems have self-defined boundaries, sympoietic systems do not; 2) autopoietic systems are self-produced, sympoietic systems are collectively-produced; and, 3) autopoietic systems are organizationally closed, sympoietic systems are organizationally ajar. A range of other characteristics arise from these differences. Autopoietic systems are homeostatic, development oriented, centrally controlled, predictable and efficient. Sympoietic systems are homeorhetic, evolutionary, distributively controlled, unpredictable and adaptive. Recognized as caricatures at ends of a conceptual continuum, these descriptions present a useful heuristic. By introducing an alternative to the organism metaphor, the conceptualization of sympoietic systems draws attention to many, often neglected, complex system characteristics. In addition, the heuristic provides a means for recognizing trade-offs between the two sets of characteristics that are associated with the two system types. These, and other distinctions, lead to a range of new questions that have significant implications relevant to understanding complex living systems. Since it is based on generic system descriptions, the heuristic can be applied to a wide range of situations, including social, political, economic and cultural systems.

Keywords: autopoiesis, sympoiesis, self-organizing systems, boundaries

### **INTRODUCTION**

The underlying motivation for my research is a concern for sustainability, broadly interpreted as including social, cultural and ecological interactions. If we are to promote appropriate human behaviour we must gain some understanding of the complexities that arise from these various interactions. Research must focus on biological and ecological systems, but also social, economic, political and cultural systems, and

the interconnections among them. The complexity implied by this diversity of factors requires that we use sense-making devices – heuristics that will aid us in organizing our perceptions of reality into something sensible and comprehensible. My concern is that many of the heuristics we apply are inadequate for gaining appropriate understanding of the complex systems and interactions involved. The difficulty, then, lies in finding appropriate devices.

Two common heuristics – mechanical systems and organisms – seem inappropriate for the complex situations noted. In my earlier research I found this especially true for ecosystems, most notably with respect to our apparent insistence on delineating boundaries. My intent in this paper is to describe an heuristic that includes a different set of characteristics more relevant for conceptualizing ecosystems. The heuristic arises from questioning how to cope with systems that do not have clearly defined boundaries. My response has been to conceptualize systems as complex, self-organizing and boundaryless. In particular, I propose the notion of *sympoietic systems* (Dempster 1995, 1998a) – as a contrast to the conception of autopoietic systems (Maturana and Varela 1980).

I begin by defining the concepts of autopoiesis and sympoiesis as well as other concepts that are critical for understanding the description of the two poietic systems. The essential differences between the two types of poietic systems relate to the presence and lack of self-defined boundaries and their different degrees of organizational closure. These differences, and a suite of other characteristics, that arise from these differences, are also described. The resulting heuristic creates a distinction that can be applied to consider differences between organisms and ecosystems, and other comparable systems.

This paper is primarily a report based on research carried out for my Master's thesis, which provides a basis for ongoing research. Further descriptions and details can be found in earlier work (Dempster 1998a, 1998b).

## AUTOPOIESIS AND SYMPOIESIS

To establish what they believed to be the essential quality that differentiates living systems from non-living systems, Maturana and Varela (1980, Varela *et al.* 1974) pointed to the self-producing capacity of living systems, conceptualizing what they called *autopoietic systems*:

A dynamic system that is defined as a composite unity as a network of productions of components that, a) through their interactions recursively regenerate the network of productions that produced them, and b) realize this network as a unity in the space in which they exist by constituting and specifying its boundaries as surfaces of cleavage from the background through their preferential interactions within the network, is an autopoietic system.

This organization that defines an autopoietic system as a composite unity is the autopoietic organization, and we claim that an autopoietic system in the physical space, that is, an autopoietic system realized as a composite unity by components that define the physical space by satisfying the thermodynamic requirements of physical phenomena, is a living system (Maturana 1980: 29).

As evidenced by the lack of discussion in the literature, the notion of autopoiesis as *the* defining quality of living systems has not been taken up by the biological community as sufficient criterion for establishing the difference between living and non-living. However, the concept has been applied to a wide variety of systems in disciplines that range from psychology (e.g. Kenny 1990), communication (e.g. Kincaid 1987, Krippendorf 1996), and management organizations (e.g. Kickert 1993, Morgan 1997) to social systems more generally (e.g. Zeleny 1980, Luhmann 1986, 1995). Such application, however, has not been without contention (Fleishaker 1992, Mingers 1995).

The autopoietic system heuristic has two characteristic attributes. First is the ability of these systems to continuously and recurrently produce relations among their components through a dynamic process that allows them to continually reproduce the same pattern of relations. For example, a living system at its most basic is a bundle of complex molecules arranged by a complicated set of relations. These systems use energy to organize physical matter into particular dynamic arrangements. These arrangements, in turn, are capable of producing the necessary components and arranging them in the necessary pattern to allow for their own continuation.

The second characteristic attribute of autopoietic systems is their ability to produce their own boundaries through “preferential neighbourhood interactions” (Maturana and Varela 1980). The phrase is used to emphasize that interactions *internal* to the system form the boundary, not external forces.

Due to their self-defined boundaries and self-referential nature, autopoietic systems are autonomous units, distinctly separated from their environment. As will be explained further below, this does *not* mean that the systems are totally independent of their environment. They are only autonomous in the sense of being self-governing, not being independent.

Many complex living systems do not match these characteristics – especially regarding boundary production. Typical ecosystem definitions, for example, note the fuzzy nature of ecosystem boundaries in both spatial and temporal dimensions (e.g. Golley 1993, Noss 1995, Agee 1996). Although boundaries may be delineated by an observer if particular criteria and scale are chosen, such boundaries are then observer-produced, not self-produced.

I propose the conceptualization of boundaryless systems and have constructed the term sympoiesis, from the Greek words for *collective* and *production*, to describe such systems (Dempster 1995, 1998a). In contrast to autopoietic systems, they are characterized by cooperative, amorphous qualities. Sympoietic systems recurrently produce a self-similar pattern of relations through continued complex interactions among their many different components. Rather than delineating boundaries, interactions among components and the self-organizing capabilities of a system are recognized as the defining qualities. ‘Systemhood’ does not depend on production of boundaries, but on the continuing complex and dynamic relations among components and other influences. The concept emphasizes linkages, feedback, cooperation, and synergistic behaviour rather than boundaries.

The contrasting characterizations, of autopoietic and sympoietic systems, provide a pair of heuristics that are useful for attempting to understand complex living systems. I emphasize two points. 1) These characterizations are heuristics and consequently must be recognized as caricatures. No ‘real’ system will fit

either description, but will rather sit at some position on a continuum in between the two ideal descriptions. 2) While I focus discussion on comparison between organisms and ecosystem in this paper, I believe the notions have applicability to other scales and other types of systems. Further descriptions can be found in earlier work (Dempster 1998a).

To gain an understanding of the two poietic system heuristics and the significance of their differences, some specific definitions applied by Maturana and Varela (1980, Varela *et al.* 1974, Maturana 1980) are important for the discussion.

The *pattern of organization* of a system is the relations among components that define a system as a specific type of system. The pattern of organization of a tree, for example, is the relationship between the leaves, trunk, roots, and other components. Different types of system, have different patterns of organization, such as an herb (with no trunk) or an elephant (with no leaves). Maturana and Varela use only the term *organization*, however, this can be confusing, when extending the discussion into social systems where organization carries a different meaning. I therefore follow Capra (1996) and use the phrase *pattern of organization*.

The *structure* of a system is the actual relations and components that constitute a particular system in a particular domain. A tree, for example, exists in the physical domain, so its structure will be the actual physical arrangement of the components that make it a particular tree. A spruce has a different structure than a maple. Note that this specific definition of the term *structure* does not match the definition applied in some disciplines. For example, in some cases *structure* more closely represents what is here being termed *pattern of organization*. As used here, *structure* more closely represents vernacular usage, which typically refers to a physical entity – something present and ‘real.’ To some extent, pattern of organization correlates to a blueprint, and structure to manifestation of that blueprint in some domain. Any pattern of organization can be manifest in many different structures.

Distinguishing between these two aspects of a system allows definition of the following concepts:

*Organizational closure* refers to the degree of self-containment a system has with respect to its pattern of organization. A system can be organizationally *closed*, *open* or *ajar*. A system that organizes the relations among its components in such a manner as to ensure the continuation of its own pattern of organization is organizationally closed. Consider a tree, which has a specific pattern of organization that governs the receipt of energy and nutrients to perpetuate its structure and subsequently its pattern of organization as a tree. Although the system receives external inputs, it maintains a pattern appropriate for its own development and continuation.

A system which relies completely on external sources for determining its pattern of organization, such as a human made artifact, is organizationally open. A system that relies on external sources, yet limits these inputs in a self-determined manner, is organizationally ajar. For example, an ecosystem, which allows, but limits, the introduction of new species fits the latter description. Maturana and Varela discuss the notions of organizationally open and closed systems. I add organizationally *ajar* systems in order to describe the characteristics of ecosystems and, subsequently, of sympoietic systems.

*Structural coupling* refers to the recognition that a system’s *structural* relationship with its environment

will determine its responses to disturbances or triggers. Continued system survival depends on having a structure, which can respond suitably to the system's environment. For example, a house plant moved to a different location will not survive if it no longer receives the structural inputs (energy and material) that it requires even though its pattern of organization has not changed. Allergic reactions also illustrate the concept. All people have the same pattern of organization, yet each individual has a specific structure. An individual's response to peanuts, for example, will vary according to their specific structure.

There is a certain degree of subjectivity here, which arises from categorization. The pattern of organization of any system defines it as a member of a particular class of systems. The role of the observer is to define the class, a subjective process. For example, instead of considering all people as having the same pattern of organization one could separate people into two organizational classes: those who are and who are not allergic to peanuts. This does not negate the importance of structural coupling. In the end it is the system's structural interaction with the environment that determines continued autopoiesis. Nor does it negate recognition that the system, not the observer, defines its own boundaries, as argued more clearly below.

*Poiesis* refers to the ability of a system to continually and recursively produce its own set of relations. A particular pattern of organization will produce a particular structure. To be sustaining, this structure must in turn produce a pattern of organization that will ensure continued production of a continually suitable structure. This recurring cyclic production does not mean that the structure and organization cannot change, but simply that each must produce the other and the structure must couple with its environment. Maturana and Varela use the term self-producing for this process, but since the 'self' of sympleiotic systems is less apparent, I have taken to using the term *poiesis*. There is also some difficulty in using the term self-producing, for autopoietic systems. Although the systems produce the components essential for their own continuation, they do not produce the components of those components. This is a slippery slope argument, however, as ever smaller constituent parts appear to exist. Since the term autopoiesis is rather entrenched, I continue using it, although "self-constructing" (see Kay 1984) may be more accurate. *Poiesis*, then, will be used in reference to the continual production of a self-similar set of relations.

## COMPARISON OF AUTOPOIETIC AND SYMPOIETIC SYSTEMS<sup>1</sup>

The distinguishing differences between autopoietic and sympleiotic systems are the presence and lack of boundaries and the difference regarding their degree of organizational closure. Autopoietic systems are organizationally closed, sympleiotic, organizationally ajar. Two significantly different sets of characteristics, behaviours and advantages arise from these defining differences. These sets are listed in Table 1. The advantages/disadvantages must be recognized as contextual traits. For example, whereas efficiency may be an advantage in some situations, it may not be in others. This is also the case for other characteristics, such as central versus distributed control. The value of the distinction, then, is to provide a theoretical basis for grouping these two sets of characteristics. As heuristics, each set of characteristics must be

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<sup>1</sup> The characterization of autopoiesis described here primarily results from making the distinction between autopoietic and sympleiotic systems. In consequence – although based on the literature – my descriptions of autopoietic systems may diverge from those offered by others. Key sources contributing to my understanding of autopoiesis include: Maturana and Varela (1980), Maturana (1980), Varela (1981), Bednarz (1988), Fleischaker (1992), Mingers (1995), and Capra (1996). Any misinterpretations and misrepresentations are obviously my own.

recognized as the description of an ideal, a caricature. No ‘real’ or observed system is expected to match these descriptions but rather to carry greater and lesser degrees of fit with each set.

The heuristics are presented as two different lenses for looking at the world, which lead to different descriptions and interpretations of that-which-exists. To illustrate, I compare some of the differences that arise from the distinction.

## **BOUNDARIES**

As noted above, I do not argue against the delineation of boundaries as a means for identifying systems by choosing particular criteria at a particular scale. However, I believe, that the potential for delineating boundaries in a non-arbitrary manner is fundamentally different for autopoietic and sympoietic systems. In autopoietic systems, the criteria for delineation are effectively pre-determined because the system, by producing its own boundaries, indicates the relevant criteria and scale of observation. This does not mean that autopoietic boundaries are clear and distinct when approached. As with categorizations in general, the closer one gets to a boundary, the less distinct containment becomes. For example, at an atomic level, organism boundaries are less substantial. The question of when food ingested by an organism becomes part of the organism also involves a fuzzy boundary. For most intents and purposes, the biological boundary of an organism can be distinguished with some degree of clarity. Since it autonomously organizes itself, anything less than the whole is obviously a part, and anything greater, is obviously ‘environment.’

The description of clear boundaries should not be taken to suggest that autopoietic systems can be objectively described, however. The subjective aspect of distinction shifts from delineation of system boundaries to definition of the system’s pattern of organization as noted above in the discussion on structural coupling. In either case, the observer must list a set of criteria for system identification. In one case, the focus is on boundaries, with everything inside as part of the system, in the other case, the focus must be on describing the pattern of organization.

The same degree of clarity is not possible when delineating boundaries for ecosystems, which usually fade gradually from one type of system into another. Consider forests, for example: even at ‘treeline’ there exist small tree islands that may or may not be considered part of the forest. Even if considered as boundaries, these lines are either determined by the environment (hence are not self-defined) or, the environmental factors determining the edge must be considered part of the system, in which case the boundary would not be at the treeline (Dempster 1998b). Such forest systems, then, can be more appropriately characterized as boundaryless sympoietic systems.

## **INFORMATION**

Maturana and Varela (1980: 90-92, 98-102) claim that information must be irrelevant to *self*-producing systems since it is an *extrinsically* defined quality. Beer (1980: 69), prefacing their work, agreed: “Nature is not about codes: we observers invent the codes in order to codify what nature is about.” While recognizing the importance of their arguments, I believe that including information strengthens the heuristic value of the concept. This is especially the case regarding organizational closure, the role of boundaries, and the potential to consider systems history and evolution.

I define information as that part of a message (process or structure) that has the potential to carry meaning for a recipient (Dempster 2000). Consequently, information is context and recipient dependent, but also – as indicated by Beer’s comment – observer dependent. The latter point is key. Information *is* irrelevant to the autopoietic systems themselves: in maintaining autopoiesis, they either have the appropriate structure or they do not. Information is an heuristic applied by observers to point to particular attributes of living systems. For example, I find the concept of information is especially useful for understanding a system’s degree of organizational closure. The latter can be interpreted as the degree to which a system is open to information that has the potential to alter its pattern of organization: Can a system receive information that carries organizationally relevant meaning? Due to their self-produced boundaries, autopoietic systems can control system inputs and outputs. The systems, therefore, can maintain organizational closure by restricting undesirable organizational information while keeping the information essential for their continued production. Considering information, then, makes it possible to follow system history and recognize the increased complexity of system structure and pattern of organization.

Autopoietic systems benefit from boundaries and organizational closure by gaining the ability to contain their pattern of organization through recurring successful interactions between structure and environment. The resulting organizational information tends to be carried centrally and transferred as a ‘package.’ Genes provide the most obvious example. However, autopoietic systems have a limited capacity for coping with uncertain and changing environmental circumstances. Since their organizational information is circumscribed by self-containment, they have a restricted potential for adapting their pattern of organization and, consequently, for adapting their structure and for successfully remaining structurally coupled. The example of a house plant noted above illustrates this point. Recognition that trees have provenance – geographically specific genetic histories – is another indication.

Lacking self-defined boundaries, sympoietic systems consequently lack the same degree of control and are open to a continual flux of organizationally relevant information. I refer to the systems as organizationally ajar (Dempster 1998a 1998b), since they are not *totally* open. Sympoietic systems regulate the input of organizational information through internal structural coupling: information must be contained in a suitable structure in order to be integrated into the system even though such input is not regulated by a boundary. As an example, consider the incorporation of information into an ecosystem through the introduction of exotic species. Only those species with structures suited to the ecosystem will survive. For example, a species suited to a dry environment, such as a cactus, will not survive in a wet environment since it lacks the essential structural adaptations. Information carried by a cactus will not be incorporated, but an exotic that does have the appropriate structure will be incorporated and may subsequently alter the ecosystem’s pattern of organization. The difficulties presented by many invasive species that have ‘taken over’ new environments attest to this potential for change. This dynamic, though restricted, flux of information allows sympoietic systems to evolve continuously by adapting to changing conditions and by generating new ones. Historical and successional change in ecosystems are also examples.

These factors indicate one of the critical differences between autopoietic and sympoietic systems regarding how their pattern of organization is codified. As noted above, autopoietic systems tend to carry ‘packaged’ organizational information. In contrast, sympoietic systems carry different bits of information distributed among their components and subsequently have no centralized control. Their pattern of organization arises from the interaction among components and influences, rather than from a pre-defined ‘pro-

gram.’ This factor realizes their distinctive character as amorphous, cooperative, self-organizing entities. An example illustrating the importance of information storage in an ecosystem is the influence of seeds stored in the substrate as a determining factor in the shifting mosaic of a mixed-wood forest (e.g. Mladenoff *et al.* 1993) and in the vegetation composition of fresh water marshes (Keddy and Reznicek 1985, Parks Canada 1991).

This means sympoietic systems depend on the organizational information contained in their components, which are typically autopoietic systems. Yet there is also organizational information contained in the network of interactions among the autopoietic systems – the pattern of relations and processes that manifest the sympoietic system structure. This information is not held by any particular entity, but is distributed among the interconnected components and processes, hence leading also to distributed control. Sympoietic systems build their complexity by incorporating a variety of complex components. Although they may be restricted by their organizational information content, sympoietic systems have the advantage of also being open to new organizational information.

## **REPRODUCTION**

The differences regarding boundaries and information content indicate another significant difference between the two systems types – reproduction. In this case, the process is different enough that the same term should not be applied to both. I suggest that for sympoietic systems the term is effectively irrelevant since they are characterized by continuing poiesis: recursive production of structure and pattern of organization. Rather than *reproducing* – they are just *continually*-producing. This is not necessarily equivalent to growth of the system, but refers to continual replacement, and possible alteration, of components and relations.

Poiesis occurs in autopoietic systems, yet these systems produce in a different sense as well: they produce offspring, something other than themselves. This emphasizes a point made by Krippendorf (1987), that reproduction is actually an *allopaietic* (other-producing) process. Although contrary to Maturana and Varela’s comment that reproduction is a “moment in autopoiesis” (1980: 101), this notion may provide a loop-hole for understanding the attainment of highly complex organizational information despite the reiterative and restricted *self*-production as described by Maturana and Varela. For autopoietic systems, change occurs *between* generations, which in some systems includes the potential for new combinations through sexual reproduction.

## **HISTORIES AND TRAJECTORIES**

Understanding the role of system history is crucial for understanding a system’s potential behaviour and direction. This is particularly true in systems carrying complex organizational information since the latter is a result of both developmental and evolutionary system history. Autopoietic systems, for example, develop predictable responses to particular environmental conditions, passing on the accumulated information to subsequent generations. Due to structural coupling, the resulting pattern of organization provides the potential for producing a system structure that is relevant to, yet also restricted to, particular environments. As noted below, these potentials and restrictions are important for considering system predictability.



Although sympoietic systems rely on a flux of information and are continually evolving, this does not cancel the importance of system history. The acceptance of new organizational information depends on a system's structure, which will be a result of past interactions among component autopoietic systems, consequently incorporating *their* history as well. In addition, historical consideration of the self-organizing factors involved in system generation may be critical.

The differences in the preceding characteristics mean the two system types have different types of temporal paths or trajectories. Autopoietic systems have a growth/developmental focus; sympoietic systems, an evolutionary focus. By this I mean that autopoietic systems follow some sort of path from a less to a more developed stage, whereas sympoietic systems are continually, although not necessarily consistently, changing. There is no particular sense that the latter systems will reach a 'higher' or 'more mature' level of development or organization.

I use the term trajectory to indicate that a system's path has a certain degree of inevitability, even though it may not be a predictable one, especially for sympoietic systems. Autopoietic systems, for example, are limited to a single trajectory: caterpillars turn into butterflies, not trees or elephants or even similar butterflies. Birth, youth, maturity, and death are relatively clearly defined concepts. If there is an opportunity to observe ancestral autopoietic systems, there can even be a reasonable degree of certainty as to when such changes will occur.

In sympoietic systems, there is uncertainty regarding both when and into what a system will change. Yet, given the restrictions noted above, they do not have unlimited possibilities. The shifting mosaics of mixed-wood forests can manifest quite different species distributions in the same area over the long-term. Yet, even if a selection of tropical rainforest species were introduced, the mixed-wood forest would not become a rainforest. There are external influences also at play. The system trajectories do, however, have the potential for making dramatic and surprising changes. The dynamics of spruce-budworm infestations (Holling 1973, Baskerville 1995), "weed species" takeover preventing reinstatement of the "forest" after a clearcut, and a flip between benthic and pelagic species dominance (Regier and Kay 1996) are examples of unpredictable trajectories in sympoietic systems. Again, I use the term trajectory to suggest the inevitability of such changes. Given a particular combination of components and influences, a particular system will manifest. For example, at the onset of a budworm outbreak, the natural path of the system has a particular direction.

These examples emphasize recognition that surprise is an observer defined quality. As Casti (1994: 3) puts it: "*surprise* is just shorthand for the way we feel upon discovering that our pictures of reality depart from reality itself." In many cases these 'surprises' are integral aspects of sympoietic systems. For example, fire in a boreal forest may be a surprise to a summer visitor, yet to the forest, such disturbance is a critical ecosystem process.

The second aspect of system trajectories to consider is the temporal dimension. In this respect, autopoietic systems have finite trajectories. Among those discussing autopoiesis, Zeleny (1977) and Bednarz (1988) are rare, by pointing out that death is also an issue. In essence, the systems have clearly defined temporal, as well as spatial, boundaries. Especially when applying the concept in the social realm where death of a system is not generally assumed, many authors seem to disregard this key point. Noting the finitude of biophysical autopoietic systems, however, makes me question whether this is a fundamental characteristic

of autopoietic systems. Is a finite temporal trajectory inescapable regardless of what domain a system is defined in?

The significantly different characteristics of sympoietic systems give them potentially infinite trajectories. This makes definition of developmental stages, ‘beginnings,’ and ‘ends’ – their temporal boundaries – also difficult to delineate in a non-arbitrary manner. The organism metaphor – an autopoietic metaphor – has, however, enabled and reinforced an interpretation of ecosystems as progressing through various stages of development as indicated by the notion of succession. Admittedly, such an interpretation is more useful in some ecosystems, or at some scales, than others. For example, the metaphor is somewhat applicable regarding succession in ecosystems dominated by a disturbance regime such as pests in forests or fire in grasslands. In both of these cases conceptualizing some sort of life/death cycle or reproduction seems relevant for understanding the systems as a whole.

The same metaphor is less useful, however, for conceptualizing mixed-wood forests, temperate rainforests, or pelagic communities. These systems seem to correlate more strongly with sympoietic characteristics. This range of examples illustrates the need to emphasize these descriptions as caricatures – the ‘ends’ of a continuum with ‘real’ systems existing at various middling positions. It also illustrates the need to emphasize these descriptions as heuristics – lenses to peer through when looking at the world. There is the potential, then, to apply both lenses to any situation and subsequently generate different questions and different understanding.

## **SYSTEM SUSTAINABILITY AND PREDICTABILITY**

Continued autopoiesis requires successful structural coupling to particular environments. Due to their limited adaptability, this means they require continued and predictable structural inputs. In consequence, autopoietic systems are geared toward self maintenance; toward maintaining a structure that is suited to a particular environment. Trees, for example, need to maintain a particular leaf area in order to satisfy a balance between loss of water and receipt of solar radiation. The systems are homeostatic and are primarily controlled by negative feedback – a mechanism which keeps them centered on maintaining or returning to a particular identity or internal condition. Warm-blooded animals provide an obvious example. Such systems have a specific range of viable internal body temperatures. Since environmental conditions change they have developed mechanisms for maintaining internal temperature: sweat or pant if it is too hot, shiver or put on a sweater if it is too cold. A key point, however, is that these responses have developed to cope within a *relatively predictable* range of environmental changes such as seasonal or diurnal changes. System responses may be inadequate if change beyond the ‘normal’ range is experienced. Even ectotherms must maintain body temperature within a particular range and will stay in, or move to, habitats that allow them to satisfy these requirements.

Sympoietic systems carry a variant of ‘stability,’ but it must be distinguished from that of autopoietic systems. Lacking centralized control, their balance is maintained by dynamic tension: the mechanism for holding the position is self-organization. Interactions among system components, coupled with various ‘external’ influences, generate an evolutionary dynamic balance, which provides a degree of stability and predictability in these systems (see Dempster 1998a, 1998b).

Due to their limited adaptability, autopoietic systems are threatened by uncertainty in their environment.

Since environments are continually changing and uncertain, autopoietic systems may eventually reach a point at which adaptation is no longer possible. This is true in both a developmental and an evolutionary sense. Rather than acting as an impediment for sympoietic systems, however, uncertainty provides a critical advantage: it is the very source of opportunities for adapting to change. The characteristics described suggest that autopoietic systems are weighted toward maintaining the status quo, sympoietic systems toward adapting to change.

Since autopoietic systems are restricted in the manners described, they are relatively predictable through observation of ancestral autopoietic systems. Their characteristics emphasize the degree to which future trajectories are entrenched, especially by organizational closure.

Prediction is also often assumed to be possible for sympoietic systems, yet there is need for caution in making such an assumption. Part of our current difficulty regarding the achievement of sustainable systems has been a result of inaccurate interpretation: mis-taking sympoietic systems as the more predictable autopoietic systems. Since sympoietic systems are organizationally ajar, the interactions generating them can change as a result of new organizational information. It is still important, however, to consider the degree to which the trajectory of these systems is entrenched. There will be some restrictions on possible future systems states, due to restrictions on information input and due to restrictions on their component autopoietic systems. Although the systems are inherently unpredictable, they are not necessarily *completely* unpredictable. Since sympoietic systems do demonstrate some degree of stability or continuity, there is a strong desire to believe in the possibility of forecasting the changes that will occur, or at least knowing which ones will be predictable. However, because these systems are organizationally ajar and evolutionary, it is not possible to know and understand all the potential influences, interactions and possibilities. In addition, the systems may be subject to catastrophic change, which – even in much simpler systems – can only be understood in retrospect (Casti 1994).

## **SELF-ORGANIZATION**

To consider the role of self-organization in autopoietic and sympoietic systems, I distinguish between two *different* types of self-organization, which I refer to as *creative* and *transmitted* self-organization (Dempster 1998a, 1998b). To some extent, these reflect differences between the discussion of self-organization in different types of systems, notably physical/chemical systems versus biological systems. Creative self-organization refers to the process primarily described regarding the former systems. This includes Prigogine's description of dissipative structures which emerge in non-equilibrium thermodynamic conditions (e.g. Nicolis and Prigogine 1977, 1989) and Haken's use of synergetics to describe lasers and other systems (e.g. Haken 1981, 1988). Through such creative self-organization, structures or behaviours emerge at critical points of tension among interacting global and local influences (see Dempster 1998a, 1998b, 2000). These structures or behaviours are not necessarily sustainable, since they rely on the system poising at this position of dynamic tension, held by counteracting influences. If the tension is lost, so is the emergent structure or behaviour.

In contrast, transmitted self-organization refers to the ability many complex biological and social systems have to organize themselves without external direction or control. Pattee (1987) refers to these as information dependent self-organizing systems. The work of Kauffman (1993) and Kampis and Csanyi (1991, Kampis 1991) provide examples of this type of perspective. Transmitted self-organization, then, refers to

that potential in systems, which may initially have begun through creative self-organization, but which has been codified and passed on through subsequent generations. Many of these systems have reached a level of complexity that precludes spontaneous generation (i.e. creative self-organization) of another, similar, entity. The systems are consequently reliant on self-production and reproduction. Although these systems can organize themselves by arranging their components in the requisite manner, they do this through some type of pre-programming. The original creative self-organization process will not necessarily be apparent in continued self-organization. This somewhat static form of self-organization allows increased complexity but restricts flexibility and is a characteristic of autopoietic systems.

Sympoietic systems carry a combination of the two types of self-organization. They emerge through a creative self-organizing process among autopoietic systems which carry transmitted self-organizing potential. This more dynamic yet complex process matches the description of sympoietic systems. Recognizing this combination points to a fundamental paradox. Sympoietic systems arise and evolve by virtue of the complexity of their component autopoietic systems. Due to their characteristics, autopoietic systems require specific predictable inputs from the sympoietic systems they are embedded within, yet the latter depend on uncertainty and continual change for their continued existence. This uncertainty and continual change, of course, results from the complex interactions among the increasingly complex autopoietic systems. The paradox of interdependence: neither system is 'better,' or more 'independent,' than the other is.

The differences between the systems types suggest that the characteristics required for system sustainability are quite different among the different types. Perhaps one of the more important differences between autopoietic and sympoietic systems relates to the balance between their ability to maintain their identity despite changes in the environment or to adapt their identity to fit with changes. Autopoietic systems rely on organizational closure, emphasizing the need to maintain the status quo, whereas sympoietic systems use a continual flux of information, increasing their adaptability. The standard perception of stability – as homeostasis – reasonably reflects autopoietic system requirements, yet is inappropriate for sympoietic systems. While environmental uncertainty is anathema to autopoietic systems, it is an adaptive advantage for sympoietic systems.

## CONCLUSION

The concepts of autopoiesis and sympoiesis provide a pair of contrasting heuristics that are valuable for conceptualizing a range of complex phenomena. Table 2 lists a few examples. In particular, the notion of sympoietic systems – complex, self-organizing, boundaryless systems – offers a set of characteristics that may be useful for describing ecosystems and other complex systems in a manner that differs from standard approaches. There are a number of concepts in the literature that reflect characteristics similar to those I describe for sympoietic systems. In particular, I note SOHO (self-organizing holarchic open) systems (Koestler 1978, Regier and Kay 1996), CANL (complex adaptive non-linear) systems (Bella 1997), emergent complex systems (Funtowicz and Ravetz 1994) and complex adaptive systems (e.g. Holland 1992, Kauffman 1993). In comparison, I consider sympoietic systems to be a special case of these more general complex systems conceptions. The key differences are the inclusion of 'self'-production, the conception of boundaryless systems, and the distinction that systems can be organizationally ajar, which emphasizes an informational aspect relevant to the organization of systems.

While I believe these distinctions are important, I also believe plurality provides an advantage, and, hence, suggest these concepts as an *alternative*, rather than as a *replacement* for other concepts. The complexities we face cannot be fully understood from a single perspective. Although the basic ideas set forward in this paper parallel other system descriptions, I believe the distinctions and subtleties offered by the concept of sympoiesis provide new and different opportunities for understanding. Perhaps most useful is the contrast between autopoietic and sympoietic systems and the theoretical basis for grouping the two different sets of systems characteristics described. Applied as heuristics, these descriptions lead to different types of questions about a range of phenomena, which may subsequently lead to different understanding of the complexities involved.

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