5 Reconsidering the Notion of the Organic

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CONTENTS

Abstract

The advent of the Enlightenment entailed a radical shift in worldviews from one wherein life dominates all events to the perspective that all phenomena ultimately are elicited by encounters between lifeless, unchanging particles. A necessary casualty of this shift has been the notion of organic behavior. The possibility exists, however, that both the pre- and post-Enlightenment attitudes are extremes, and that a general, more complete description of nature might lie between these poles. One useful tool for such interpolation appears to be Karl Popper's definition of propensity as an agency that is intermediate to deterministic force at one end and pure chance at the other. Another is Robert Rosen's description of organic behavior as self-entailing. One way of interpreting self-entailment is to identify it with the influence of the aggregate configuration of processes upon the structure and composition of the organic system. To paraphrase Alfred North Whitehead, the creature is derivative of the creative process. One particular embodiment of the top-down influence of processes upon components might be akin to the action of autocatalysis among propensities, the effects of which can be measured using network and information theories. Once one expands the scope of consideration to include boundary conditions as well as dynamics, it then can be argued that the organic narrative is actually more compact than the conventional neo-Darwinian construct. Furthermore, the revised organic narrative provides a more appropriate metaphor for other self-organizing systems than did classical organicism, and it has the advantage of serving as a more congenial setting within which to portray the origin of life.

5.1 INTRODUCTION

Fascination with organic behavior held sway over much of Western thought for centuries preceding the dawn of the Enlightenment. One encounters the metaphor of human institutions in the guise of organisms as early as Aristotle and Paul of Tarsus. By way of contrast, Democritus and Lucretius, with their view on nature as comprising encounters between unchanging, lifeless atoms, were notable for being exceptions to the prevailing view that the universe was suffused throughout with life [1]. So dominant was the vision of the ubiquity of life that the overriding challenge to philosophical thought before the 17th century had been to explain somehow the existence of death in the world.

The situation changed radically with the advent of Newton and the publication of his *Principia*, which (by accident) [2] obviated the necessity to invoke living agencies to explain the movements of the spheres. Thereafter the fashion in natural philosophy quickly came to emphasize the material outlook of Hobbes in conjunction with the mechanical notions of Descartes. Lucretius would have found himself quite at home with the precipitating consensus that the world is dead in all its dimensions. Living beings became annoying exceptions in the world of the dead, and how to explain the origin of the "epiphenomenon" called life has become a vexing conundrum for contemporary thinkers.

One necessary casualty of the Enlightenment was the notion of organic behavior. True, remnants of the organic metaphor remained in the writings of Liebnitz, Comte, Spencer, and Von Betalanffy, but by and large organicism has been eschewed by modern thinkers (and not entirely without justification, it should be added. Any number of totalitarian leaders over the past two centuries have invoked the organic metaphor to justify their own oppressive agendas.)

The extremism of dictators, however, provides a clue to resolving the confusion left in the wake of the Enlightenment revolution. It is easy to recognize that the predilection of the ancients and medieval scholastics to see life everywhere was an extreme view, but one can also hold that it likewise remains a radical stance to view the world as dead, through and through. Organicism, because it focused primarily upon those rigid, almost mechanical aspects of organismal behaviors, also could be classified as extreme. Is there indeed no refuge from such radical caricatures of the world in which we live — some narrative of behavior that portrays a more balanced dialogue between the quick and the dead? [3] Here, the reader's attention is drawn to the domain of ecosystems. In a world where phenotypic characteristics appear to be the ineluctable consequences of genomic traits, the study of ecosystems affords a refreshing breath of freedom. As the renowned developmental biologist, Gunther Stent so neatly puts it,

"Consider the establishment of ecological communities upon colonization of islands or the growth of secondary forests. Both of these examples are regular phenomena in the sense that a more or less predictable ecological structure arises via a stereotypic pattern of intermediate steps, in which the relative abundances of various types of flora and fauna follow a well-defined sequence. The regularity of these phenomena is obviously not the consequence of an ecological program encoded in the genomes of the participating taxa [4]."

When viewed in a Newtonian context, the relative independence of ecosystems from the mechanics of genomes leads some to regard the concept of "ecosystem" as irrelevant — they see the biotic community as nothing more than stochastic disarray [5]. Obviously, such conclusion was not what Stent had in mind. Rather, it appears he may have been making the rather bold suggestion that ecosystems come closer to the crux of organic behavior than do organisms themselves. That is, ecosystem behavior is ordered to a degree, but that degree falls pointedly short of mechanical determinism. Just perhaps, then, ecosystems offer the desired refuge from extremism.

Another inference we might draw from Stent's comments is that mechanisms are not the only causal entailments at work in ecosystems. Such a conclusion, however, conflicts with the metaphysics underlying all of scientific thought since *Principia*, which allows for only two types of causalities — material and mechanical. Robert Rosen, among others, has also questioned the assumed completeness of mechanical causal entailment in living systems [6]. He illustrates such incompleteness by referring to the rational numbers, which seem at first glance to be arbitrarily dense — between any two rational numbers it is possible to find an infinity of other rational numbers. Yet we know from number theory that the rational numbers are incomplete as regards our conception of what constitutes a number. Between any two rational numbers one can also find infinity of irrational numbers. Kurt Gödel was able to show with his Incompleteness Theorem that any attempt to formalize completely a notion of mathematics will comprise a syntactic truth that is always narrower than the whole set of truths about the mathematical concept itself. (Some unformalized semantic residue always remains.) Whence, Rosen goes on to argue that the formalisms of physics describing the causal entailments in mechanical systems will perforce remain incomplete descriptions of organic behavior. It seems that in our zeal to apply Occam's Razor and avoid an "alpha type error" (the assumption of false agencies), we have gone to an extreme, thereby committing a "beta type error" by proscribing any forms of causal entailment other than those material and mechanical.

5.2 CHANCE AND PROPENSITIES

Yet another aspect of the radical minimalism inherent in the Newtonian worldview has been provided by Karl R. Popper [7]. Popper noted as how mechanical causality exists only at one pole (extreme) of the causal spectrum: Either a cause has a precise effect or it has none. There is positively no room for chance in the Newtonian rendition of the world. Should any particle anywhere swerve from its lawful course, it would eventually throw the entire universe into shambles. Yet chance and contingency seem to be very much evident in natural phenomena in general and in biological systems *a fortiori*. Conventional wisdom has reconciled mechanism and chance via what is commonly referred to as the "Grand Synthesis." Upon closer inspection, this "synthesis" resembles nothing more than a desperate and schizoid attempt to adjoin two mutually exclusive extremes. That is, narrative is constantly switching back and forth between the realms of strict determinism and pure stochasticity, as if no middle ground existed. Once more, the picture is incomplete, and a more effective reconciliation, Popper suggested, lies with agencies that are intermediate to stochasticity and determinism. Toward this end, he proposed a generalization of the Newtonian notion of "force" that extends into the realm between strict mechanism and pure chance. Forces, he posited, are simple idealizations that exist as such only at the extreme of perfect isolation. The objective of experimentation is to approximate to the fullest extent possible the isolation of the workings of an agency from interfering factors. In the real world, however, where components are loosely, but definitely coupled, and all manner of extraneous phenomena interfere, he urged us to consider the more general notion of "propensities."

A propensity is the tendency for a certain event to occur in a particular context. It is Bayesian in that it is related to, but not identical to, conditional probabilities. Consider, for example, the hypothetical "table of events" depicted in Table 5.1, which arrays five possible outcomes, b_1, b_2, b_3, b_4, and b_5, according to four possible eliciting causes, a_1, a_2, a_3, and a_4. For example, the outcomes might be several types of cancer, such as those affecting the lung, stomach, pancreas or kidney, while the potential causes might represent various forms of behavior, such as running,

TABLE 5.1
Frequency Table of the Hypothetical Number of Joint Occurrences that Four "Causes" ($a_1 \dots a_4$) Were Followed by Five "Effects" ($b_1 \dots b_5$)

	b_1	b_2	b_3	b_4	b_5	Sum
a_1	40	193	16	11	9	269
a_2	18	7	0	27	175	227
a_3	104	0	38	118	3	263
a_4	4	6	161	20	50	241
Sum	166	206	215	176	237	1000

TABLE 5.2
Frequency Table as in Table 5.1, Except that Care Was Taken to Isolate Causes from Each Other

	b_1	b_2	b_3	b_4	b_5	Sum
a_1	0	269	0	0	0	269
a_2	0	0	0	0	227	227
a_3	263	0	0	0	0	263
a_4	0	0	241	0	0	241
Sum	263	269	241	0	227	1000

smoking, eating fats, etc. In an ecological context, the b's might represent predation by predator *j*, while the a's could represent donations of material or energy by host *i*.

We notice from the table that whenever condition a_1 prevails, there is a propensity for b_2 to occur. Whenever a_2 prevails, b_5 is the most likely outcome. The situation is a bit more ambiguous when a_3 prevails, but b_1 and b_4 are more likely to occur in that situation, etc. Events that occur with smaller frequencies, e.g., $[a_1,b_3]$ or $[a_1,b_4]$ result from what Popper calls "interferences."

We now ask how might the table of events appear, were it possible to isolate phenomena completely — to banish the miasma of interferences? Probably, it would look something like Table 5.2, where every time a_1 occurs, it is followed by b_2; every time a_2 appears, it is followed by b_5, etc. That is, under isolation, propensities degenerate into mechanical-like forces. It is interesting to note that b_4 never appears under any of the isolated circumstances. Presumably, it arose purely as a result of interferences among propensities. Thus, the propensity for b_4 to occur whenever a_3 happens is an illustration of Popper's assertion that propensities, unlike forces, never occur in isolation, nor are they inherent in any object. They always arise out of a context that invariably includes other propensities. That is, propensities are always imbedded in a configuration of processes.

The interconnectedness of propensities highlights an unsung aspect of the role of contingency in systems development — namely, that contingencies are not always simple by nature. Chance events can possess distinctive characteristics and can be rare, or possibly even unique in occurrence. Inculcated as we are in the atomic assumption that undergirds Newtonianism, we almost always consider chance events as generic in nature, point-like in extent, and instantaneous in duration. Thus, when Prigogine writes about macroscopic order being elicited by microscopic fluctuations, it is implicit that the latter are generic and structure-less [8]. Chance perturbations, however, happen to come in an infinite variety of forms, and any given system may be very vulnerable to some categories of disturbance and relatively immune to others.

Even should disturbances come in different flavors, we have been conditioned by the Francis Bacon to expect all phenomena to repeat themselves in due time. Repeatability is, after all, a cornerstone of normal science. Once we open the door to complex contingencies, however, we must be prepared to face the possibility that some contingencies might be *unique* for once and all time. In fact, we should even gird ourselves to encounter a world that is absolutely rife with one-time events. The key to this possibility is that contingencies be more generally regarded as configurations or constellations of both things *and processes*. That many, if not most, such configurations are probably unique for all time follows from elementary combinatorics. For, if it is possible to identify *n* different things or events in a system, then the number of possible combinations of events varies roughly as *n* factorial.

It does not take a very large *n* for *n*! to become *immense*. Elsasser called an immense number any magnitude that was comparable to or exceeded the number of events that could have occurred since the inception of the universe [9]. To estimate this magnitude, he multiplied the estimated number of protons in the known universe (ca. 10^{85}) by the number of nanoseconds in its duration (ca. 10^{25}) to yield a maximum of about 10^{110} conceivable events. It is often remarked how the second law of thermodynamics is true only in a statistical sense; how, if one waited long enough, a collection of molecules would spontaneously segregate themselves to one side of a partition. Well, if the number of particles exceeds 80 or so, the *physical* reality is that they would *never* do so (because $80! >> 10^{110}$).

Because propensities always exist in a context, and because that context usually is not simple, it becomes necessary to consider the reality and nature of complex contingencies. To capture the effects of chance and history, it will no longer suffice simply to modulate the parameters of a mechanical model with generic noise [10]. In a complex world, unique events are continually occurring. They are by no means rare; they are legion! Perhaps fortunately, the overwhelming majority of one-time events simply happen and pass from the scene without leaving any trace in the more enduring observable universe. On occasion, however, a singular contingency can interact with a durable system in such a way that the system readjusts in an *irreversible* way to the disturbance. The system then carries the memory of that contingency as part of its *history*. Again, no amount of waiting is likely to lead to an uncontrived repetition of what has transpired.

The efficacy of Popper's generalization is that the notion of propensity incorporates under a single rubric law-like behavior, generic chance and unique contingencies. We note for reference below that, irrespective of the natures of any eliciting interferences, the transition depicted from Table 5.1 to Table 5.2 involves proceeding from less-constrained to more constrained circumstances. It is the progressive appearance of constraints that we have in mind when we speak of the "development" of an organic system. We now ask the questions, "What natural agency might contribute to the transition from Table 5.1 to Table 5.2?"; or, in a larger sense, "What lies behind the phenomena we call organic growth and development?," and "How can one quantify the effects of this agency?"

5.3 THE ORIGINS OF ORGANIC AGENCY

If Rosen deconstructed the notion that an organic system can exist exclusively as a collection of mechanisms, he was at least responsible enough to hint at a direction in which one might seek to construct a new theory of organic behavior. Rosen claimed that, in contradistinction to mechanical systems, organic systems are self-entailing. That is, all of the processes necessary for the continued existence of the organic structure are present *within* the system. Various forms of anabolism, catabolism, reproduction, and maintenance all exist within an organic system and causally entail one another. Although material and energy are required from the external world, such resources resemble more objects than processes. In keeping with Popper's emphasis on context and arrangement of propensities, we choose to identify the configuration of constituent processes as the very kernel of the organic system, from which most behaviors derive. In Popper's own words: "Heraclitus was right: We are not things, but flames. Or a little more prosaically, we are, like all cells, *processes* of metabolism; *nets* of chemical pathways [11]." [Emphases mine.]

The priority given to the configuration of processes over the structure of stable components in organic systems is likely to sound either exotic or transcendental to many readers, but it is neither. Its roots lie in the "process philosophy" of Alfred North Whitehead and Charles Saunders Peirce. Whitehead, for example, was inclined to identify any "creature [as being] derivative from the creative process [12]." As for a nontranscendental exemplar, I offer the dynamics of autocatalysis, or indirect mutualism.

To make clear exactly what I mean by "autocatalysis," I take it to be a particular manifestation of a positive feedback loop wherein each process has a positive effect upon its downstream neighbor [13]. Without loss of generality, we will confine our discussion to a serial, circular conjunction of three processes A, B, and C. Whenever these processes involve very simple, virtually immutable chemical forms or reactions, then the entire system functions in wholly mechanical fashion. Any increase in A will invoke a corresponding increase in B, which in turn elicits an increase in C, and whence back to A.

Matters become quite different, however, as soon as the configuration of processes grows combinatorically complex. Such entities, by virtue of their rich continuum of variations, are capable of small, contingent changes in structure, each variation of which will continue to function as an autocatalytic loop as before, albeit with somewhat more or less effectiveness. In keeping with Popper's ideas, it would also be more appropriate to say that the action of process A under such circumstances has a *propensity* to augment a second process B. That is, the response of B to A is not prescribed deterministically. Rather, when process A increases in magnitude, most (but not all) of the time, B also will increase. B tends to accelerate C in similar fashion, and C has the same effect upon A.

Autocatalysis among propensities gives rise to several system attributes, which, as a whole, distinguish the behavior of the system from one that can be decomposed into simple mechanisms [14]. Most germane is that such autocatalysis now becomes capable of exerting *selection* pressure upon its ever-changing, malleable constituents. To see this, we consider a small spontaneous change in process B. If that change either makes B more sensitive to A or a more effective catalyst of C, then the transition will receive enhanced stimulus from A. Conversely, if the change in B either makes it less sensitive to the effects of A or a weaker catalyst of C, then that perturbation will likely receive diminished support from A. We note three things about such selection: (1) that it acts on the constituent processes or mechanisms as well as on the elements (objects) that comprise the system, (2) that it arises *within* the system, not external to the system, and (3) that it can act in a positive way to select *for* a particular system end (greater autocatalysis), rather than always *against* the persistence of an individual material form. The first attribute defeats all attempts at reductionism, while the latter two distinguish autocatalytic selection from the "natural selection" of evolutionary theory.

It should be noted in particular that any change in B is likely to involve a change in the amounts of material and energy that are required to sustain process B. Whence, corollary to the selection pressure is the tendency to reward and support those changes that serve to bring ever more resources into B. As this circumstance pertains to any and all members of the feedback loop, any autocatalytic cycle of propensities becomes the epicenter of a *centripetal* configuration, toward which as many resources as available will converge. Even in the absence of any spatial integument (as required by the related scenario called autopoeisis), [15] the autocatalytic loop itself defines the focus of flows.

Centripetality implies that whenever two or more autocatalytic loops exist in the same system and draw from the same pool of finite resources, *competition* among the foci will ensue. In particular, whenever two loops share pathway segments in common, the result of this competition is likely to be the exclusion or radical diminution of one of the nonoverlapping sections. For example, should a new element D happen to appear and to connect with A and C in parallel to their connections with B, then if D is more sensitive to A and/or a better catalyst of C, the ensuing dynamics should favor D over B to the extent that B will either fade into the background or disappear altogether. That is, the selection pressure and centripetality generated by the autocatalytic configuration can guide the replacement of elements.

Of course, if B can be replaced by D, there remains no reason why C cannot be replaced by E and A by F, so that the cycle A, B, C could eventually transform into D, E, F. This possibility implies that the characteristic lifetime of the autocatalytic form generally exceeds those of most of its constituents. The incipience of the autocatalytic form before, and especially its persistence beyond, the lifetimes of most of its constituent objects imparts causal priority to the agency of the configuration of processes. True, the inception of the feedback loop can be interpreted as the consequence of conventional mechanistic causes. Once in existence and generating its own selection pressures, however, those instigating mechanisms become accidental to the selection agency that arises. Any argument seeking to explain the behavior of the whole system entirely as the result of shorter-lived constituent objects erroneously ignores the ascendant agency of the configuration of processes, which winnows from among those ephemeral and transitory mechanisms.

We recall that with Democritus, the aim of rational explanation was to portray all processes as the consequence of universal laws that act on eternal and unchanging fundamental atoms. At atomic scales, this reductionist agenda has worked reasonably well, but, as soon as one encounters complex configurations of processes, temporality becomes reversed. At the mesoscales, it is the configurations of processes that are most enduring in comparison with which their constituents appear merely as transients. Therefore, the most natural direction for causality to act at intermediate scales is from the persistent configurations of processes toward their transient constituents, whose creation the former mediate.

5.4 THE INTEGRITY OF ORGANIC SYSTEMS

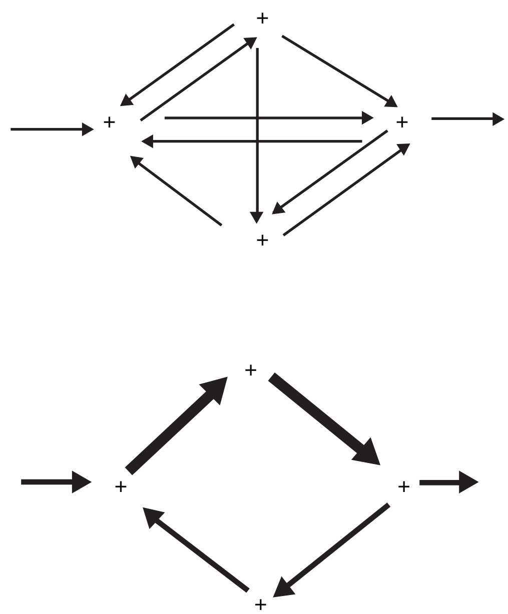
Although autocatalytic systems appear to be potent and durable, their continued existence is not without its own contingencies. As Popper noted, any configuration of processes can be considered as a network, and the overall topology of networks leads one to some striking conclusions about some inherent limitations possessed by organic systems. Earlier, Rashevsky had also described the constituent processes of in an organism in terms of a network wherein the various forms visible in the system (nose, brain, kidney, etc.) [16] are connected to each other by processes. Whence, the nose transmits olfactory signals to the brain via the electrical process of neural transmission. In ecosystems one might link a lower species, such as an anchovy, to a higher trophic taxon, such as a striped bass, via the process of predation. (Striped bass consume anchovies.)

Rashevsky's student, none other than Robert Rosen, was able to prove a theorem about the vulnerabilities of organisms (particular instances of our more general "organic system") using nothing more than the general topology of their networks [17]. He identified two classes of processes in organisms — those that can generally be called metabolism and those that are restituent or effect repairs. Rosen proved that it is impossible for every restituent process in an organism to be reestablishable. That is, there is at least one restituent process in each organism, which, if rendered inoperative, cannot be reconstituted. He went on to prove a second theorem that if the nonreestablishable process happens to connect with external sources, then the destruction of that process will cause the failure of the whole system. Organisms are mortal, it seems.

To prove his theorems, Rosen had to consider what he called a "closed circuit of restituents." He was able to show how, if one process in a closed circuit of restituents fails, all the others will fail as well. Rosen's reasoning applies as well to autocatalytic loops, so that one might view as a corollary of his theorem the fact that autocatalytic systems are in general nondecomposable. For, if one process of an autocatalytic cycle is obviated, there is no guarantee that its antecedent and subsequent processes will link with one another in catalytic fashion, whence autocatalysis breaks down, and all its constructive and integrative powers vanish with it. We see how Rosen's conclusion for one subclass of organic systems (organisms) bears implications for the more general category: Organic systems are nondecomposable. They differ radically from purely mechanical systems, which can be broken apart into disjoint objects and reassembled again without any discernible loss of function.

5.5 FORMALIZING ORGANIC DYNAMICS

As Rosen and Gödel demonstrated, formalizing any set of entailments always carries with it the risk of incompleteness. Such danger did not deter Rosen himself from engaging in his own formalizations – to good end. Furthermore, the scientific enterprise demands at least some degree of quantification before a proposition can be legitimately entertained. Accordingly, we reconsider



$$\begin{pmatrix} O & X & X & O \\ X & O & X & X \\ X & O & O & X \\ X & O & X & O \end{pmatrix}$$

$$\begin{pmatrix} O & X & O & O \\ O & O & X & O \\ O & O & O & X \\ X & O & O & O \end{pmatrix}$$

FIGURE 5.1 Schematic representation of the major effects that autocatalysis exerts upon a system. (a) original system configuration with numerous equiponderant interactions. (b) same system after autocatalysis has pruned some interactions, strengthened others, and increased the overall level of system activity (indicated by the thickening of the arrows.) corresponding matrices of topological connections indicated to the right.

the effects that autocatalysis works upon a system in the hopes of discerning some pattern among them. There appears to be two major facets to its actions: Autocatalysis serves to increase the activities of all participating constituents; and it prunes the network of interactions so that those links that most effectively contribute to autocatalysis come to dominate the system. These facets of behavior are extensive (size-dependent) and intensive (size-independent), respectively. Schematically this transition is depicted in Figure 5.1. The upper figure represents a hypothetical, inchoate four-component network before autocatalysis has developed, and the lower one, the same system after autocatalysis has matured. The magnitudes of the flows are represented by the thickness of the arrows. To the right appear the matrices that correspond to the pattern of flows. One recognizes that the differences between the matrices in Figure 5.1 resemble those between Tables 5.1 and 5.2 above, and we recall how that transition was associated with the appearance of progressive constraints.

There is not sufficient space to detail how these two facets of autocatalysis came to be quantified [18]. Suffice it here merely to convey the results. We begin by designating T_{ij} as the amount of some conservative medium transferred from compartment i to some other compartment j within the organic system. The sum of all such magnitudes for all the processes in the system becomes what is known in economic theory as the "total system throughput" — a measure of a system's total extent, or activity. In symbols,

$$T = \sum_{i,j} T_{ij}$$

where T is the total system throughput. Growth thereby becomes an increase in the total system throughput, much as economic growth is reckoned by any increase in Gross Domestic Product.

As for the "pruning," or development effected by autocatalysis, it will be related to changes in the probabilities of flow to different compartments. We note, therefore, that the joint probability that a quantum of medium both leaves i and enters j can be estimated by the quotient T_{ij}/T, and that the conditional probability that, having left i, it then enters j can be approximated by the quotient

$$T_{ij} \Big/ \sum_k T_{ik}.$$

One can then use these probability estimates to calculate how much information is provided by the increased constraints. The appropriate measure in information theory is called the "average mutual information" or AMI,

$$AMI = \sum_{i,j} \left(\frac{T_{ij}}{T}\right) \log \left(\frac{T_{ij}T}{\sum_p T_{pj} \sum_q T_{iq}} \right).$$

The AMI has recently been shown to be the logarithm of the number of distinct roles in the system that is sculpted by its various constraints [19]. To demonstrate how an increase in AMI actually tracks the "pruning" process, I refer the reader to the three hypothetical configurations in Figure 5.2. In configuration (a) where medium from any one compartment will next flow is maximally indeterminate. AMI is identically zero. The possibilities in network (b) are somewhat more constrained. Flow exiting any compartment can proceed to only two other compartments, and the AMI rises accordingly. Finally, flow in schema (c) is maximally constrained, and the AMI assumes its maximal value for a network of dimension 4.

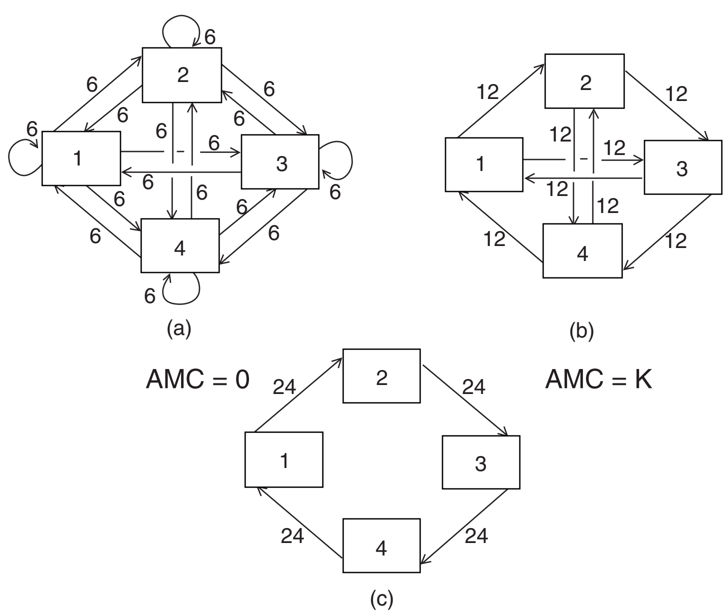


FIGURE 5.2 (a) The most equivocal distribution of 96 units of transfer among four system components. (b) A more constrained distribution of the same total flow. (c) The maximally constrained pattern of 96 units of transfer involving all four components.

Because autocatalysis is a unitary process, we can incorporate both factors of growth and development into a single index by multiplying them together to define a measure called the system ascendency, $A = T \times \text{AMI}$. In his seminal paper, "The strategy of ecosystem development," Eugene Odum identified 24 attributes that characterize more mature ecosystems [20]. These can be grouped into categories labeled species richness, dietary specificity, recycling, and containment. All other things being equal, a rise in any of these four attributes also serves to augment the ascendency. It follows as a phenomenological principle of organic behavior that "in the absence of major perturbations, organic systems have a propensity to increase in ascendency." Increasing ascendency is a quantitative way of expressing the tendency for those system elements that are in catalytic communication to reinforce and mutually entail each other to the exclusion of nonparticipating members.

I should hasten to emphasize in the strongest terms possible that increasing ascendency is only half of the dynamical story. Ascendency accounts for how efficiently and coherently the system processes medium. Using the same mathematics, one can compute as well an index called the system overhead, Φ, that is complementary to the ascendency [21].

$$\Phi = \sum_{i,j} T_{ij} \log\left(\frac{T_{ij}^2}{\sum_k T_{kj} \sum_q T_{iq}}\right).$$

Overhead quantifies the inefficiencies and incoherencies present in the system. Although these latter properties may encumber overall system performance at processing medium, they become absolutely essential to system survival whenever the system incurs a novel perturbation. At such time, the overhead comes to represent the degrees of freedom available to the system and the repertoire of potential tactics from which the system can draw to adapt to the new circumstances. Without sufficient overhead, a system is unable to create an effective response to the exigencies of its environment. The configurations we observe in nature, therefore, appear to be the results of a dynamical tension between two antagonistic tendencies (ascendency vs. overhead.)

5.6 UNDER OCCAM'S RAZOR

As mentioned above, some readers will regard the description of the development of organic systems to be unnecessarily complicated in comparison to the very simplistic scheme that emerged from the Grand Synthesis and usually is referred to as the neo-Darwinian scenario of evolution. Neo-Darwinians will immediately grasp for Occam's Razor to excise the offending notion of organic behavior. But I wish to rejoinder with the question, "Which description is really simpler? [22]" Howard Pattee (personal communication) emphasizes how any description of change in nature must consist of two elements — the dynamic by which those elements interact and the boundary conditions or context within which the dynamic transpires.

Charles Darwin consciously followed the prevailing Newtonian approach toward describing nature by explicitly externalizing all the agencies that elicit change under his rubric, "natural selection [23]." The remaining dynamics are rather easy to codify and describe. Natural selection, however, remains an enormously complicated "boundary condition" that at times is described in almost transcendental tones. We implicitly are urged to keep our eyes focused intently on the simple dynamical description and to pay no attention whatsoever to the overwhelming complexity within which that dynamic occurs. Subsequent emendations to Darwin's scheme have not altered his basic Newtonian separation and focus.

According to Pattee, however, any natural description should be judged in its entirety. By this standard, neo-Darwinism, due to the encumbrance of the complexity hidden in natural selection, does not fare well under Occam's razor. By contrast, self-organization theory (of which this organic narrative is an example) *includes* far more agency into its dynamics. A slightly more complicated description of the operative dynamics ensues, but the cost of such complication is more than repaid by the degree to which it simplifies the boundary value problem. That is, a significant amount of biological order, which under the Darwinian scheme had to be explained by arbitrary and innumerable manifestations of "natural selection," is now consolidated as the consequences of dynamics that are *internal* to system description. Kauffman called this class of phenomena "order for free," in the sense that the given pattern did not have to be encoded into the genome of the organism [24].

As regards overall problem description, the jury is still out as to whether neo-Darwinism or self-organization theory better satisfies Occam's criterion, but proponents of the latter description have every reason to be optimistic that the scales are beginning to tip in their favor.

Apropos simplicity of description, one may well ask, which metaphor more simply and appropriately pertains to *biological* phenomena — the mechanical or the organic? The answer should be tautologically obvious, but the minimalist/mechanists would have us think otherwise. Daniel Dennett, for example, bids us imagine the progressive complexity of biological entities as analogous to "cranes built upon cranes," whereby new features are hoisted on to the top of a tower of cranes to become the top crane that lifts the next stage into place [25]. He specifically warns against invoking what he calls "skyhooks," by which he means agencies that create order but have no connection to the firmament.

Once one is convinced that the organic metaphor does have a legitimate place in scientific narrative intermediate to the mechanical and the stochastic, then organic analogs for biological phenomena become the simplest and most natural possible. This point was brought home to me via one of the few "Eureka!" experiences I have ever encountered. I was working distractedly in my garden, pondering why I thought Dennett's analogy was inappropriate, when my eye was drawn to a muscadine grapevine that has grown on the corner of my garden fence for the last 25 or so years. In the initial years after I had planted it, the lead vine had become a central trunk that fed an arboreal complex of grape-bearing vines. Eventually, the lateral vines had let *down* adventitious roots that met the ground some distance from the trunk. Then in the last few years, the main trunk had died and rotted away completely, so that the arboreal pattern of vines was now being sustained by the new roots, which themselves had grown to considerable thickness.

No need for skyhooks here! The entity always remains in contact with the firmament, and bottom-up causalities continue to be a necessary part of the narrative. Yet it is the processes within the later structures that *create* connections, which eventually replace and displace their earlier counterparts. Top-down causality, the crux of organic behavior, but totally alien to mechanistic-reductionistic discourse, fits the developmental situation perfectly. Evolution is like a muscadine grapevine. As strange as that analogy might seem at first, it fits the description far better than Dennett's mechanical construct. In striving for causal simplicity by concocting mechanical metaphors for what is more inherently and legitimately organic phenomena, mechanists wind up complicating the picture unnecessarily and lead us astray from a more natural perspective on the living world.

5.7 THE ORGANIC PERSPECTIVE

To summarize, the realm of ecology appears to require a metaphysics that differs in essence from the conventions of the Enlightenment [26]. This ecological metaphysics can more readily accommodate a looser statement of the organic metaphor. To wit:

1. The causal entailments in organic systems are more replete than those of simple mechanical systems. In the organic context, Newtonian causal closure does not impart the virtue of simplicity, but rather is seen as a procrustean minimalism. Newtonian closure cannot be as easily reconciled with stochastic events without resorting to a schizoid view of nature. Causal agency is more naturally apprehended as a continuum of propensities, rather than an admixture of the extremes of mechanical determinism and pure chance.

2. An organic system is the culmination of a *history* of chance events that have been embedded into their functioning. While some of the entrained events may have been of a generic nature, others most assuredly were complex, unique, and nonrepeatable.
3. Organic systems, although they decay after they have ceased to function organically, are strongly *nondecomposable* while they are functioning (living.)
4. The key feature of organic systems appears to be the top-down influence that combinations of processes exert upon their constituent elements (objects) and mechanisms (constituent processes.) The strength of such top-down influence can vary among the types of organic systems, approximating the deterministic in ontogenesis, but allowing for considerable plasticity in ecosystems.

As regards organicism, heretofore the major problem has been that organic behavior was miscast as almost deterministic or mechanical. Even early ecologists, like Frederic Clements could conceive of organic agency only in this fashion. They can hardly be faulted for such assumption, however, when the most obvious manifestations of organic behavior, organisms themselves, lie against one extreme of the range of organic behavior and *do* develop in close approximation to rigid determinism. But the crux of organic behavior is neither mechanism nor determinism. These are only peripheral limits toward which organic behavior, if left unimpeded, could drift. The kernel of organic systems lies rather in the coherence and direction that system-level configurations of processes impart to their components. This "ecological" form of organicism seems far less threatening a notion than its earlier counterpart. To convince oneself of this, one need to only consider the absurdity of a dictator trying to describe his/her totalitarian state in terms of an ecosystem with its loose connections and manifold feedbacks.

As regards any similarity of ecological organicism with vitalism, we note as how the former concept does not involve any independent "elan-vital" that enters the system from without. The contributing processes are all internal to the system itself. Furthermore, like the muscadine grape, autocatalytic configurations of processes are all inexorably connected with their material resources.

Finally, to return to the radical shift in attitudes toward life and death that opened this essay, it should now be apparent that the notion of creativity in organic systems can afford an appealing resolution. We need to simply place more emphasis upon the creative role of configurations of processes, and the conundrum evaporates. Physicists, for example, relate how the conjunction of processes that gave rise to the elementary forms of matter bear marked formal similarity to those that have just been described. No longer must dead matter and living forms be juxtaposed in our minds across an unbridgeable chasm, but rather now both should be viewed as outgrowths of a common form of creative agency.

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