Chapter 9
Autopoiesis:
Some Questions

Brian R. Gaines

9.1 Objectives

The concept of autopoiesis as a characterization of that which makes a system living, as proposed by Maturana and Varela (1973), has aroused a great deal of interest and derived work, but is has also aroused controversy.[1] This paper is concerned with some aspects of the grounds for criticism of presentations of autopoiesis to date. It is not an attempt to answer criticism, or to give definitive elucidations of unclear aspects of the theory. However, it does attempt to make the problems clear and delimit the forms of acceptable, and of unacceptable, answers. I hope it will serve to stimulate others into providing detailed expositions of the matters raised.

9.2 Some Questions

The controversy stems from several sources. To begin with, the theory so far advanced (in Maturana and Varela 1973; Varela, Maturana and Uribe 1974; Maturana 1975; Zeleny 1977) is informal and obscure, giving

[1] Many of the points discussed in this paper arose in the frequent interchanges within continuously changing groups that were such an important feature of the conference on Applied General Systems Research that George Klir organized at Binghamton in August 1977. The session on autopoiesis commenced with an exposition by Nicolas Varela and a demonstration of the computer simulations developed by Milan Zeleny, followed by presentations of several other papers in this volume. It roused considerable interest, but mixed feelings, in the large and varied audience present. In particular, several biologists expressed to me views that prompted some of the questioning in this paper.

rise to the following questions:

1. Has the theory any content? That is, does it explain anything, predict anything, or in some other way provide something that we would regard as a reasonable objective for proposing a theory?
2. Does the theory give a characterization of life in itself, or is it an explanation of how we come to characterize life? That is, is it an ontological theory or an epistemological one?
3. Can it be formalized? That is, can the verbal expositions be given a logicomathematical framework together with a system of interpretation?

I should state immediately that these are not intended to be positivist strictures and that there are a variety of answers possible to each question that might not be acceptable—for example, in terms of the received view (Suppe 1974)—but would satisfy many current scientists. The motivation of the presenters of autopoiesis is both foundational and biological; clearly there is basis for the argument that the science of biology is not amenable to the framework of the science of physics (or perhaps its caricature as conventionally accepted in much of the "philosophy of science" literature). However, at the very least the role of the above three questions in the science of autopoiesis ought to be established, and preferably the answers to them also.

A second source of the controversy is that the theory, in so far as it is well defined,[2] makes at least a two-part characterization of living systems in terms of their unitary organizations and its maintenance through recursive self-production. Both these concepts seem comprehensible, if not well defined; but they also seem at rather different systemic levels, and similar concepts of organizational attributes alone, or self-production attributes alone, have been used in the past to characterize certain aspects of living organisms. The new insight is supposedly concerned with the essential interplay of these two features, and again raises questions:

4. What is unity? That is, is there a decision procedure whereby one can determine that a particular system constitutes a unity whereas another does not?
5. What is organization? That is, is there a system of description by which we may say "this specifies the organization of this system?"

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[2] Such qualifications in this paper are not intended as the usual rhetorical trick of sowing doubt by insinuation. For many people, including myself (on Mondays, Wednesdays, and Fridays!), the theory is reasonably well defined. What I sometimes wonder is whether all our definitions agree, and whether we have a rich enough common framework of terminology, belief, and experience to seek out and determine the form and nature of disagreement.

A related question concerns the nature of structure, since again the presenters of autopoiesis make a careful distinction between the role of organization and that of structure but do not present an equally careful distinction between these two terms themselves. Perhaps this, as a criticism, is too pedantic since we "all know" what is meant by "organization" and "structure." However, as soon as such terms take on technical denotations in terms of a new theory, the previous connotations that we "all know" become potentially misleading.

6. What systems have the unity of organization characteristic of autopoiesis but are not so because of their lack of recursive self-production? And, vice versa, what systems exhibit self-production but lack unity of organization? In other words, let us have not only intensional definitions but let us also enrich the context with extensional, discriminatory ones.

This, informally and in part, has been done in some of the literature but it needs further examples. I also suspect, from discussions between different workers in the field, that there would be differences of opinion on some possible exemplars that would themselves be illuminating.

A third source of the controversy is that apparently similar considerations as to the organization and nature of life have been advanced by others in the past (e.g., Paul Weiss 1940, 1962, 1969), and one question that has been raised many times in discussion is the degree and type of novelty involved:

7. How does the concept of autopoiesis differ from other frameworks for the characterization of life proposed in the past (e.g., in essential terms or in greater precision, or in terms of new system-theoretic tools now available better to express previous concepts, etc.)?

Fourth, it is reasonable to ask whether any attempt to characterize living systems is not creating a distinction without a difference. Would a biologist or biochemist nowadays be prepared to advance a clear decision procedure that divides the living from the nonliving?:

8. What are the grounds for supposing that the living can be discriminated from the nonliving? Note that the implied metaquestion is "does the discrimination essentially involve autopoiesis?" (i.e., are we dealing with an explanatory theory of an already well-defined phenomenon, or a new definition of a previously ill-defined phenomenon?). Either could be useful, but the basis for evaluation is different in each case.

Fifth, the derivative literature on autopoiesis (e.g., Zeleny 1977, and papers in this volume) has a common pattern of commencing with biological problems at a cellular level and then switching to commentaries

on societal organizations. It is again reasonable to ask whether we are to evaluate the theory over such a broad spectrum (in which case, why the emphasis on "living"—the concept that a social group has "life" is not unreasonable but it is radical scientifically to equate this in a foundational theory with the life of a cell), or whether the social examples are to be taken as analogies only to clarify certain concepts but are not essential to the status of the theory:

9. Is autopoiesis essentially a biological theory at cellular level or does it apply to a wide spectrum of "autopoietic unities"? In other words, are the social examples applications of analogical reasoning from well-established biological domains to less-known social situations, a possibility for much biological theory, or are there "real" autopoietic systems at a noncellular level?

Sixth—and the answer to the previous question is clearly very relevant to the legitimacy of this one—there have been many previous characterizations of life at varying levels, in terms of reproduction, self-organization, adaptation, learning, intentionality, self-awareness, and so on, and it is reasonable to ask whether these definitions are implied by, imply, or are correlated with those based on autopoiesis. Again, this question is touched on in the literature but mainly in terms of the autopoietic characterization somehow preceding any other.

10. What is the relation of characterizations of living organizations based on autopoiesis with those based on other features of living systems? That is, are any derivable from the others? If not, what are examples of systems satisfying one definition but not another?

Finally, there is one question that, apparently, should have been asked first:

11. Is it worth it? Do we really want a characterization of living organizations? This is not just a flippant remark, since the full corollary to a "yes" answer must be "why is it worth it?" That is, what are we going to do with the characterization once we have it?

I suspect this is where much of the elucidation lies; definitions are the tools of science and it is the use to which they are put that ultimately determine their legitimacy.

9.3 Some Possible Forms of Answer

If the questions in the previous section had been rhetorical I could now go through them again giving the "correct" answers. However, this would destroy the dialectical intent of this paper. The (diverse) answers of others

more closely associated with the field will be more interesting and relevant than mine, and examining other chapters of this book for answers to the questions posed will itself be informative.

Before we can evaluate new system-theoretic or scientific concepts we must decide on the basis for such evaluation (and be prepared to change it since that may be part of the proposal). When life decides to reflect upon itself we have a situation analogous to that of a television camera looking at the picture at its own output: forms may flow and boundaries may shift. We cannot expect fundamental work such as Monod's (1972) on the role of chance and necessity in developmental biology, Dawkins' (1976) on the dynamics of evolution in social biology, or Maturana's (1975) on the characterization of life in foundational biology to fit tidily into current frameworks. Biology is itself going through an introspective phase of examining its own fundamentals and presuppositions (Ayala and Dobzhansky 1974; Hull 1974; Lewis 1974),[3] and to pose the right questions about the nature of life is a key problem. The formulation of a framework, a language, in which to pose these questions is a formidable task: If the terms used correspond too closely to existing vocabularies we may dismiss the discussion as clearly ill conceived, whereas if the terms themselves reflect their new content then we may dismiss the discussion as vague and metaphysical.

Maturana's 1975 paper represents an extended attempt to define clearly and communicate the terms used in formalizing the notion of autopoiesis. He states the aim:

> To explain the organization of living systems by describing the organization that constitutes a system as an autonomous unity that can, *in principle*, generate *all the phenomenology* proper to living systems if all the historical contingencies are given [Maturana 1975, p. 317].

The italics are Maturana's and suggest that the answer to my question 10 is that we should, by viewing the effect through autopoiesis of outside influences, be able to generate the other, correlated, manifestations of life.

Maturana also gives definitions of some of the terms I have queried, for example, unity:

> A unity is an entity (concrete or conceptual) separated from a background by a concrete or conceptual operation of distinction. A unity may be treated as an unanalysable whole endowed with constitutive properties, or as a composite entity with properties as a unity that are specified by its organization and not by the properties of its components [Maturana 1975, p. 315].

He emphasizes the observer-generated nature of actual "unities" as re-

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[3] Similar moods of massive introspection have occurred in physics (Korner 1957) and psychology (Royce 1970). They are probably an essential component of the maturation of any science.

sults of ostension that makes a distinction, and notes (Maturana 1975, pp. 325–326):

> Different operations of total distinction separate different kinds of unities because they define different kinds of boundaries and, therefore, imply different organizations.

This suggests in answer to my question 2 that the theory is basically epistemological and that "unities" are entities hypothesized by observers in the way that they view the world. Such a relativistic view of the basic phenomena of life corresponds to similar views of the nature of possibly related phenomena such as "adaptation" (Gaines 1972).

However, Maturana (1975, p. 326) later states, "The organization and structure of a unity specify all the operations of distinction through which it can be separated from the background." Now, either this is trivial in that any arbitrary distinction made by an observer must, by definition, be possible for the unity, or it is intended as a strong ontological statement restricting the freedom of the observer to ostend only such unities as are "actually there." This exemplifies a fundamental problem for those attempting to propound a formal theory of autopoiesis: they have to decide which terms are undefined and open to unrestricted application subject only to the defined constraints of the theory. It is thereafter confusing to argue for the "reality" of such terms; some uses of the definitions will clearly be more fruitful than others, but that relates to a stage of the theory that we have not yet reached with autopoiesis, its evaluation (e.g., in terms of internal coherence or external correspondence).

This dilemma is no new one, but a basic conflict between epistemology and ontology, between knowing and being. As a biological example from a previous generation of theories of life, take the dialogue between Koestler and Weiss on "hierarchical organization":

> As Paul Weiss said yesterday: "The phenomenon of hierarchic structure is a real one, presented to us by the biological object, and not the fiction of a speculative mind." It is at the same time a conceptual tool, a way of thinking, an alternative to the linear chaining of events torn from their multidimensionally stratified contexts [Koestler 1969].

Replace "hierarchic structure" with "autopoiesis" and you might have a direct quote from recent literature.

I am tempted to quote here from propounders of *the* ontological argument, such as Descartes: his power of rhetoric in stating St. Anselm's proof of the necessary existence of God (Plantinga 1968) is a salutory reminder of the difference between the arts of persuasion and the pursuit of science. On the other hand, we have also to accept that the ultimate, undefined terms of any theory are accepted as "acts of faith," not that they be true (for the word is meaningless in this context), but at least that they be potentially useful. If we go looking at the world in terms of unities, recursive self-production, and autopoietic organization, then we shall find

a certain kind of world: It is not yet clear why we should want to find it or what we will do with it when we have it.

To summarize the preceding discussion, I should conclude currently that the answer to my question 1 is still lacking; we do not have a clear statement of the objectives of a theory of autopoiesis. We have an aim certainly, to characterize the organization of living systems, but no clear definition of objectives whose satisfaction may be used to determine whether our aims have been successfully carried out. This basic lack is probably the prime cause of further difficulty in answering later questions. The theory is not yet formalized, although the papers to date, particuarly Maturana (1975), sketch some informal definitions that might be formalized given appropriate tools.[4] However, question 3 can only be answered in the light of clear answers to questions 1 and 2—then question 11 might also be evaluable.

Turning now to question 7, I am not concerned with priorities of discovery but instead with the apparent novelty of the concepts of autopoiesis. Maturana (1975) has only three references, none to other authors. Zeleny (1977) has a considerable bibliography of past, related studies, but no detailed statement of what the relationships are (e.g., which are previous attempts to characterize the organization of living systems, which failures, or successes, when concepts are the same or different). The comparison is all the more difficult because Zeleny has widened the scope of "autopoiesis" to social system organization.

The intended novelty of their work is stressed by Varela, Maturana, and Uribe (1974, p. 187):

> All living systems must share a common organization . . . . At present there is no formulation of this organization, mainly because the great developments of molecular, genetic and evolutionary notions in contemporary biology have led to the overemphasis of isolated components.

This insight and the reaction against the stress on the components brought about by the tremendous advances in molecular biology in the past 20 years is no new one (see Goodfield 1974 for an excellent survey). In particular, the Alpbach Symposium, *Beyond Reductionism* (Koestler and Smythies 1969), was primarily concerned with just this problem, and the names of the participants—Weiss, Waddington, Bertalanffy, Hayek, and so on—read like a roll call of honor for those who for many years have emphasized the role of "organization" in biology and its systemic for-

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[4] It would be a book in itself to discuss what are "appropriate tools." Varela (1977) has been developing an extended form of Brown's (1969) logic, which is particularly attractive as its basic semantics is one of "making a distinction"; the extension consists of allowing self-referential systems within the calculus, essentially of using Russell's paradox to generate new descriptions within the existing logical framework.

mulation. In this symposium will be found not only the overall insights that led to the formulation of the concept of autopoiesis, but many of the detailed criticisms of the relevance of "self-reproduction," and so forth. It is singularly unfortunate that this volume is omitted as a reference from all the key papers on autopoiesis, not because of (scientifically irrelevant) claims for priority of publication, but because it illuminates so much of the thinking that lies behind the concept of autopoiesis.

The foregoing does not imply that there is nothing new in the work on autopoiesis, only that much of the groundwork has already been done and many of the insights existed before. The novelty is best seen, however, in the divergence between the *emphasis* in, for example, Weiss's work on *hierarchical* organization and that in Maturana's work on *self-producing* organization. As bald paraphrases, Weiss sees the whole hierarchy as characterizing life, while Maturana sees a particular phenomenon at a given level of it characterizing our right to apply the term "living" at that level. I have personally tended to view the formulation of autopoiesis as a refinement of the analytical tools necessary to formalize the earlier insights, and Maturana's emphasis on the characteristic organization at a single level seems precisely the form of introduction of isolated, "automic" concepts, analyzable in their own right, that characterizes the "precisiation" stage of a science (Carnap 1962).

Questions 8–10 are related and all difficult to answer without some clear statement of objectives in reply to question 1. However, it is in relation to these three questions in particular that very different, yet totally legitimate, answers may be given. For example, in reply to question 8 we may adopt the extreme relativistic view that there is no absolute distinction—many systems can be characterized as either "living" or "nonliving," according to the viewpoint adopted (e.g., the distinctions one ostends). Also, one does not expect the middle to be excluded: under any definition there will always be systems whose inclusion in either category seems artificial. This is a problem of any program of precisiation and it is possible to deal with it in a variety of ways (Gaines 1976). It does not necessarily indicate that false distinctions have been drawn, although that too is possible (Popper 1976, p. 24).

The answer to question 9 can be indeterminate in general, although one must make a specific answer in any particular context. In formal terms, the theory of autopoiesis cannot be confined to biology: it is a theory of systems and it is unlikely, although not impossible, that the only extant systems satisfying the specified constraints are those at a particular biological level; on the other hand, an obviously crude fit to a social organization would not, for example, in any way undermine the theory as applied to cellular organization.

Finally, it is to question 10, in the light of the answers to all the preceding questions, to which we may turn in future for the most fruitful devel-

opments arising out of a theory of autopoiesis. In the first quotation of this section Maturana's aim is to generate *all the phenomena* proper to living systems. The prima facie plausibility that an adequate theory may allow this is the major attraction to the study of autopoiesis. Clearly, even if this is done, it does not rule out alternative starting points; it seems likely that we discover connections rather than equivalences between the many phenomena associated with life. However, the challenge now is to formulate clearly and consistently a characterization of living organizations that allows the derivation of as many of these connections as possible.

9.4 Conclusions

The 11 questions in Section 9.2 are intended to stand apart from the remaining material. Even if the rationale given for them is demonstrably false or based on misunderstanding, the questions themselves should still be answerable, and answered. I should not rule out meta-answers of the form, "at this stage in the development of the theory it is not possible to give a clear answer to that question"; at least the questioner would know what level of discourse to adopt. To some of the questions also no short answer may be given, and the "answer" has to take the form of a dialogue since the preconceptions of the questioner are as important as those of the answerer.

I hope that the questions here will serve as tools to the reader of this book, helping him to prize much that is of value from the main papers on autopoiesis itself.

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Gaines proposed 11 questions to be asked of students of autopoiesis (he refers to them as "propounders"), or of any field of inquiry for that matter. This editor has responded to some of the questions in a short personal comment while introducing this section of the book.

What is interesting about Gaines's approach is that he not only poses questions, but actually attempts to supply some answers. The reader will find his answers at least as good as, if not better than, his questions.

Gaines's critique of autopoiesis can be characterized as constructive, involved, and reasonably informed. A great service could be rendered to the field of autopoiesis if its "propounders" became more receptive to Gaines's comments. Compare the silence that permeated general systems and cybernetics after the famous "sound from Puget Sound" (David Berlinski) launched his attacks.

What is Gaines's view of autopoiesis? He seems to have an intuitive appreciation of its potential explanatory power, its appealing computer modeling possibilities, and the elegance of its underlying holism. On a more rational level, Gaines is obviously turned off by a certain flamboyance and the nontraditional style of the "propounders," the "bandwagon" effect of autopoiesis, unsubstantiated claims, not enough respect for what he considers the best tradition of scientific papers. His unhappiness about the latter simply overwhelms his natural propensity toward the former.

Gaines sensitively affirms that we cannot expect Maturana's fundamental work on the characterization of life to fit tidily into the current frameworks of biology. Nor should one expect it to fit the current versions of general systems and cybernetics. But ignoring it or claiming ignorance of it would be a case of self-inflicted blindness.

Gaines elevates autopoiesis to a theory of systems, yet the propounders

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