

An Intriguing Journey:
A Review of *Investigations* by Stuart
Kauffman
Oxford University Press, 2000

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This is a preprint of an article published in *Complexity*,
Volume 6, Number 4, pp. 22–23 (2001).

Readers of *Complexity* will already know Stuart Kauffman well as a pioneer in this interdisciplinary field. He has been associated with the Santa Fe Institute—the “home” of complexity studies—since its foundation. He has made seminal contributions, particularly in his analysis and sometimes trenchant advocacy of the role of “self organisation” in the emergence of complex systems. His previous two books, *Origins of Order* and *At Home in the Universe*, have been widely read and cited.

This new book does revisit some now familiar territory—such as collective

autocatalysis and self-organised criticality. Nonetheless, it is not intended as an evolutionary development from such precursors. Rather, Kauffman consciously sets out to attempt revolution: nothing more or less than answering the Kantian challenge to explain how mere “mechanism” can give rise to authentic *agency*!

Let me say that for this reviewer, this already places the book in a very select and important category. The willingness to boldly tackle the profound questions seems to me a hallmark of great science. Kauffman recalls for us the explosive impact of Erwin Schrödinger’s excursion into interdisciplinary territory, begun with his seemingly innocent little question “What is Life?”. Yet, as Kauffman says, and I fully agree, there is serious unfinished business here. Despite our recent breathless arrival in the so-called “post-genomic” era, we still do not have a satisfactory answer to Schrödinger’s simple question. If *Investigations* does nothing more than remind us that the distinctive nature of living organisation is still profoundly mysterious it will have more than justified itself.

But of course, Kauffman does not wish merely to reopen this question; he has at least some glimmerings of a possible answer. His proposal, in short, is that “. . . an autonomous agent is a self-reproducing system able to perform at least one thermodynamic work cycle” (p. 4). Unfolding the implications of this tentative proposal is then the declared purpose for much of the book. And indeed, this turns out to be an intriguing journey. In the full spirit of an integrated science of complexity, Kauffman ultimately uses it as a launching pad for explorations not just in biology, but economics and ultimately cosmology on the grandest scale.

So, does it all work?

Notwithstanding the vast sweep of the overall book, I will focus here on the core proposition—the characterization of autonomous agents. It seems to me that Kauffman’s proposal here certainly is a novel one, and deserves to be explored in much greater depth. Equally, and not surprisingly at this early stage, some caution is surely necessary.

A first caution is that I found the very explanation of this core proposal quite confusing. In particular, the text repeatedly seems to confuse *replication of molecular components* (via collective autocatalysis) with *reproduction of a composite agent*. Although replication of components is normally a necessary element in achieving systemic reproduction, these are clearly not the same thing. And of course, it is trivially the case that many living systems—which are the prototypical “autonomous agents”—are *not* capable of systemic reproduction (e.g., a sterile hybrid such as a mule, or any organism which lives beyond its reproductive age). It follows—I presume—that the proposal strictly requires of an autonomous agent *only* that it manifest catalytic closure of component level replication (i.e., molecular collective autocatalysis) rather than systemic reproduction.

But this then points at a second caution, which in turn suggests a deeper problem. Kauffman does not—explicitly at least—seem to address the problem of how an autonomous agent constitutes itself as an entity—an individual—distinct from its ambience. This is a subtle but key question: not least because without a “self” in the first place, one cannot even coherently speak of “self-reproduction”.

The idea of recursively self-generated “selfhood” is the core concept in

autopoiesis or literally “self-production” developed by the Chilean biologists Maturana and Varela almost 30 years ago (documented in Maturana and Varela, 1980). Autopoiesis is closely related to the notion of collective autocatalysis; indeed, one view of autopoiesis is precisely as collective autocatalysis reciprocally and necessarily coupled with individuation (McMullin, 2000). It is true that autopoiesis has had only limited impact or acceptance within biology to date. Nonetheless, given the strong overlap in both motivation and execution with Kauffman’s “autonomous agents” it would have been very interesting to see the two compared and contrasted in some detail.

My final caution relates to Kauffman’s second proposed criterion for an autonomous agent: its ability to carry out “thermodynamic work cycles”. The issue here is that a precise definition of “thermodynamic work cycle”—as applied to this particular context—seems to be lacking. Rather we have only exemplars. These, of course, are useful, but are not sufficient in themselves. In particular, Kauffman emphasises (p. 68) that the notion of a (chemical?) thermodynamic work cycle which he has in mind is somehow more strict than, or a refinement of, the conventional concept of “metabolism”—but what exactly is the nature of this refinement? His exemplar is an imaginary reaction network where an endergonic reaction is sustained through a “chemical engine” driven by incident photon energy. Clearly only relatively few living organisms utilise photon energy directly, so this cannot be a *requirement* per se; but in that case it remains unclear what *is* the specific “refinement” (over conventional metabolism) which is being pointed at by the example.

Of course I have only scratched the surface here of the many disparate topics which Kauffman explores. However, in closing let me re-iterate the

great value of this kind of exploratory book: it is precisely because it attempts such a bold synthesis that it is both stimulating and provoking. With this in mind, I leave the last words to Kauffman himself: "... having completed *Investigations*, I remain profoundly puzzled by what I have said, despite the fact that I think I am correct." (p. xii)

References

Maturana, H. R. and Varela, F. J. (1980), *Autopoiesis and Cognition: The Realization of the Living*, D. Reidel Publishing Company, Dordrecht, Holland.

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