From Artificial Life II, Santa Fe Institute Studies in the Sciences of Complexity Proceedings, Vol. X, Eds. C. Langton, C. Taylor, D. Farmer & S. Rasmussen, Addison-Wesley, 1991, pp 767-773

Aspects of Information, Life, Reality, and Physics

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PROLOGUE

In this paper, I shall comment on some fundamental questions, which inevitably emerge in our attempts to understand life. It is surprising to me that these attempts confront us with both foundation problems in physics and with philosophical questions about the definition of reality. At some level, a part of the following conception seems similar to Wheeler's ideas[15] of the "Meaning Circuit" and to Sakharov's[13] and Wheeler's ideas[9] of pre-geometry. These similarities exist despite the fact that both the central problem and the current context are very different, and the following may, therefore, give a new angle for discussing some of the foundation problems in physics. The emerging ontological questions are, of course, reformulations of classical questions. They involve aspects of: the solopsism problem, the mind-body problem, and the problem of other minds. However, these ontological questions are rooted in a new setting which allows us not only to ask these questions in a new way, but also to draw some new conclusions. This new angle to the foundation problems in physics as well as to the philosophical problems, are prompted by the development and the use of computers. It is the emergence of this new tool that has allowed us to view these problems in a new perspective. I believe that our attempts to understand life force us to develop a new conception of the relations between information, life, reality, and physics.

The intended format is as short as possible so that the ideas do not vanish in moderations and discussion. This means that much of the relevant discussion, a lot of important questions, and many references are excluded. I shall pose postulates, comment on these postulates, raise questions, and draw conclusions. I lay out arguments to see what follows from the postulates and, thereby, provide reasons for a closer investigation of the truth of these postulates. Note that I am not claiming that all the following postulates are true; I am merely exploring the logical consequences of assuming them true.

1. INFORMATION AND LIFE

POSTULATE 1. *A universal computer at the Turing machine level can simulate any physical process (Physical Church-Turing thesis).*

Since we can construct universal computers, we know that our physics supports universal computation. Since we, up until now, have been able to simulate the information transformation rules of any physical mechanism for which these rules are known (to know and formulate the rules is the difficult part of this), it is tempting to claim that physical processes themselves can be viewed as computations. This idea is clearly discussed by Fredkin[3] and may in fact be a good working hypothesis. However, we do not know whether Nature is able to support a more powerful and general form of information processing than that supported by a universal computer of the Turing class.

POSTULATE 2. *Life is a physical process.*

This idea was originally due to John von Neumann,[11] and has recently been clearly reformulated by Chris Langton.[4] Life is associated with the functional organization of the different parts of an organism and does not depend on the properties of the hardware in which it is implemented. Details of such a functional organization will, of course, be determined by the-actual hardware, but these details are not central for life *per se*. Note that not any kind of hardware can support or implement living processes.

COROLLARY 1. Hence from Postulates 1 and 2 it should be possible to simulate living processes on a universal computer. Still, a simulation of a living process is not the same as the real thing.

POSTULATE 3. *There exist criteria by which we are able to distinguish living from non-living objects.*

It is very difficult to set up objective criteria by which we can define life, and I do not think that we can do it in a satisfactory manner at present. We have not yet been able to synthesize life, and, therefore, we do not really know what life is. No matter how precisely we try to define life, there always seems to be a "grey" zone between the non-living and the living, in which we will have difficulties in deciding whether a given object is alive or not. There is a vast literature about what properties life should have. See, for instance, Schrödinger,[14] Monod,[10] Mayr,[7] or Farmer and Belin.[2] Although there is no formal agreement on this question, we all have an intuitive notion of what is alive and what is not. A vague definition of a living system should include a notion of *a metabolism, adaptive organism environment responses, reproduction, and evolvability.* For sake of argument we claim that postulate 3 is possible in principle.

COROLLARY 2. From postulate 3 it should, for instance, be possible to determine if some potential, future computer process is alive or not.

2. LIFE AND REALITY

POSTULATE 4. *An artificial organism must perceive a reality R_2, which, for it, is just as real as our "real" reality, R_1, is for us (R_1 and R_2 may be the same).*

One of the criteria for a process to be alive involves adaptive organism-environment responses. This implies that even the simplest living object, for example, a hypothetical process implemented on a computer, must have a primitive notion of itself and its surrounding environment. Such responses imply the existence of an internal model of the world. The living object perceives a reality. We assume that a sufficient condition for the existence of a reality is the existence of life. There is a vast philosophical literature on what reality is which I will not go into. Here, I shall refer to John Wheeler's[15,16] "Meaning-Circuit." The basic idea behind this concept is that the world is a self-synthesized system of existence. On one hand, physics provides the means for communication (light, sound, etc). Reality can, thereby, acquire its meaning through a conscious conception of the world, via an organization of the information we get from our senses. On the other hand, physics also gives rise to chemistry and biology, and through them, an observer participation, namely the emergence of life and later the evolution of man.

POSTULATE 5. *R_1 and R_2 have the same ontological status.*

Assuming R_2 exists in a computer, its properties may be very different from the properties of R_1. From a logical point of view it is possible to create interactions in R_2 which do not in any direct way obey the physics in R_1. We can, thereby, create a more general physics in our universal machines than the physics we know. Such an independence exists although R_2 in a material way is embedded in R_1. Due to the physical embedding, we can affect R_2 from R_1 by "pulling the plug" or through a re-programming of the code that supports R_2. However, R_2 should, in principle, also be able to effect R_1, since self-programming abilities[12] are likely to exist in R_2, and, thereby, a re-programming of interface systems is also possible from "the inside."

In postulate 4 we argued that a reality obtains its meaning through the existence of an observer. Since R_2 is being perceived, just as R_1 is being perceived, R_2 becomes a reality with equal ontological status as R_1, whenever R_2 has a living observer. Why should one have priority over the other?

Note that all R_2 processes have a *physical* instantiation in R_1. The physical instantiation of a modern computer process is electron relocations in semiconductors in R_1.

COROLLARY 3. We can now use postulate 5 to rephrase corollary 1 and say that the ontological status of a living process is *independent* of the hardware that carries it. This perspective removes the problem with the term "simulate," indicating that processes are occurring in "some" hardware. Since the two processes have the same ontological status the one cannot be more real than the other. Real life in a digital computer should, thereby, be possible.

3. REALITY AND PHYSICS

POSTULATE 6. *It is possible to learn something about the fundamental properties of realities in general, and of R_1 in particular, by studying the details of different R_2's. An example of such a property is the physics of a reality.*

We may be able to make some interesting conclusions, if we, as a guiding example for our thoughts, use current low-level computational attempts, such as those presented in this volume, to set up environments to develop living processes (e.g., the systems programmed at the level of the "local physics" of the system). For the following arguments it is important to note that the structure of the relation between a living process, implemented on a computer; and its computational environment and the relation between a living process outside the computer, implemented in carbon chemistry, and its environment, is the same. This follows from postulates 4 and 5.

The common sense view of our physical world is that there is an absolute physical reality independent of us, where the geometry of this reality is a "three dimensional box" in which all the events occur. This is also referred to as the Newtonian view. We know, however, from modern physics (geometrodynamics) that matter and geometry are coupled, and that it is impossible to define one without the other.[1] The computational approach we are undertaking indicates that one can go a step deeper: Matter, as well as *geometry, can* be derived from information processing. It is not possible to separate the topological (geometrical) and the functional (the matter related: particles, forces, reactions) properties from each other.[1] No single piece of code defines the topology nor the functional entities.

Both the geometry and the forces in these universes are created through the *logical interactions* carried by the software and the hardware on the virtual and physical universal machine. We, thereby, end up with a conception, very close to John Wheeler's and Andre Sakharov's idea of pre-geometry: *The calculus of propositions as the basis for everything.*[9,16] According to Wheeler, pregeometry precedes physics, just as logical rules for functional interaction precedes whatever properties our computational systems have. How far this analogy between our physics and our computational systems will hold is at present unknown.

EPILOGUE

Once again, let me stress that I am not claiming the truth of each of the above postulates, but exploring some of the consequences of assuming them to be true. I am making explicit the assumptions that lead to conclusions, which are held by many people in the field, in particular for the conclusions in section 1 (*Information and Life*). It is my hope that an uncovering of the underlying assumptions will make it clearer what kinds of questions to ask and where a discussion on these controversial issues should occur.

Along the current effort to formulate physics in terms of information theory (see Zurek[17]), Lloyd's[5] and Miller's[8] work on an information metric is a step towards the definition of a geometry of interactions. It would be an interesting and worthwhile project to continue along these lines and try to define *geometry in* terms of functional interactions in computational systems.

With respect to life and reality, I am not sure what I believe myself. Something instinctively tells me that whatever can emerge "in there" is of another nature and cannot really be alive. Anyway, these problems will probably clear up in the near future, when "things in there" become more obvious; some day we may even be able to ask them....

[1] Viewing geometry, and hence space, in the way I do here, has some similarities with Mach's[6] view on space, e.g. as the totality of instantaneously distances between all material points.

ACKNOWLEDGMENTS

Thanks to almost everybody I met during the fall of 1989 and the spring of 1990 both at Los Alamos and at the Santa Fe Institute. I am in particular grateful to William Wootters who initially gave direct pointers to relevant literature on pre-geometry and took the time to discuss these issues with me. I am also grateful to Mark Bedau, Jeffery Davitz, Doyne Farmer, Rasmus Feldberg, Stuart Hameroff, Carsten Knudsen, Chris Langton, and Warner Miller who have critically reviewed earlier versions of the paper.

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From: Artificial Life II, SFI Studies in the Sciences of Complexity, vol. X, edited by C. C. Langton, C. Taylor, ,J. D. Farmer, & S. Rasmussen, Addison-Wesley, 1991, Aspects of Information, Life, Reality, and Physics, Steen Rasmussen, pp.767 – 773

POSTULATE, Santa Fe Institute, pre-geometry, organism, computational systems, Andre Sakharov, functional interactions, S. Rasmussen, mindbody problem, foundation problems, physics, Los Alamos, New Mexico, functional interaction, philosophical questions, John Wheeler, ontological status, Artificial Life, R2, modern physics, R1, Wheeler, logical rules, interactions, Center for Nonlinear Studies, universal machine, Doyne Farmer, information theory, Chris Langton, Theoretical Division, Addison-Wesley, Santa Fe, Ihrer Entwicklung Historiche Kritich Dragestellt, IBM Journal of Research and Development, Quantum Fluctuations, English translation, Information Geometry, J. Wheeler, Harvard University Press, Open Court Publications, University of Illinois Press, W. H. Zurek, Steen Rasmussen, Physics Steen Rasmussen Complex Systems Group, Santa Fe Institute Studies, ontological questions, C. Taylor, Los Alamos National Laboratory, objective criteria, functional organization, universal computer, computer process, information processing, C. Langton