Looking at the Beginnings

Walter Riofrio

Looking at the Beginnings

Walter Riofrio*

Abstract

It seems important to find the conceptual and simulated ways that will help us advance to a more integral understanding of the properties that enable concerted interaction among all the components in biological systems.
What are the reasons in the physical reality that make possible both the emergence and self-maintenance of cellular organization, the nature of which is functional?
An interesting problem is ascertaining the causes that produced the emergence of dynamic organization in living organisms.
Hence, to ask about the emergence of the dynamic organization of living systems prompts us, by necessity, to ask about its origin.
Perhaps, the crucial controversy between "RNA-first" and "metabolism-first" scenario would be better comprehended focusing our quest in the deepen implications of biological functions and information emergence.

Keywords: evolvability; far from thermodynamic equilibrium; open-ended evolution; prebiotic world dynamics; self-organized systems.

* *Walter Riofrio is Associate Professor of Theoretical and Evolutionary Biology at the Neuroscience and Behavior Division, Universidad Peruana Cayetano Heredia, Lima-Peru.* This version is the first draft of November 2006.

Dynamic systems are dynamic entities that include different types of activities among their components. Depending on the type of complex system, the different forms of interrelation that exist among its components will produce certain activities that will be subject to observation and measurement (Capra 1997, Mainzer 1997, Bak 1996).
A characteristic shared by all complex systems is that, at the moment a determined activity is produced, a uniform distribution over time does not follow. In other words, the "timing" in which the determined action or activity is produced is important. Or put a different way, "when" things happen is important (Rensing et al. 2001, Carr 2004, Bell-Pedersen et al. 2005, Vanrullen et al. 2005).
For example, it is not totally true to assume that (a) email users send their messages at uniform intervals in time, (b) an infection by a determined contagious disease can be adequately represented through the Poison distribution, or (c) molecule X, moving on a metabolic pathway, running into molecule A is equivalent, in terms of probability, to it running into molecule B.
These reflections force us to face a very important issue in the study of complex systems; of particular interest is discovering the causes that produce their dynamic organization in spontaneous conditions.
These issues are especially important when our research is directed to living systems.
We know that biological systems are self-organized and self-reproductive, and, in this context, we also understood that the self-organizational dynamic of these systems is composed of many levels and types of processes that are interconnected and interdependent (Fontana et al. 1994, Furusawa, Kaneko 2002).
One of the most characteristic global behaviors of biological systems is the one that enables an autonomous and agent behavior with respect to their environment (Kauffman 1993). Another important global behavior leads us to ask whether something exists in the biological system that enables it to feature a great deal of resilience and robustness in the face of adverse conditions or of breakdowns in certain components in its processes: its incredible homeostatic capacity (Barkai, Leibler 1997, Levin 1998, Carlson, Doyle 2002, Kitano 2004, Stelling et al. 2004).
Even when the knowledge and isolation of the different molecular components in biological systems continues to accumulate on an increasing basis in the respective data banks, we are still lacking a descriptive scheme that enables us to understand – fundamentally – what the essential properties are for determining and

characterizing the organizational dynamic of living systems (Quastler 1964, Maturana, Varela 1973, Barabási, Oltvai 2004).

Origin of Prebiotic World

It would seem that a suitable place to consider certain explanations on this topic is at the beginning of the move from an exclusively chemical and physical-chemical dynamic towards a type of dynamic that has more in common with the evolutionary dynamics of living beings.
In other words, the search for the core of cellular organization may send our research back to the very origins of biological systems, proposing an alternative approach to what currently is being considered as the only possible explanations (Cairns-Smith 1985, Wächtershäuser1988, Maynard Smith, Szathmáry 1999, Hazen 2001).
It is possible to hypothesize that the reproductive and catalytic properties observed in all living systems would be most comprehended from other more primitive or more basic capacities.
For all of that, we claim that it is still important to continue with more research that is proposing to find alternative explanations about how, in the physical reality, the emergence of biological organization is produced in ways that are self-sustained, robust, autonomous, agent, and homeostatic with the addition of possessing the potential for increasing, throughout time, its levels of structural and organizational complexity.
In this new stage in the development of scientific knowledge, we find ourselves in unsurpassed conditions for broaching, with huge possibilities of success, the problems that remained unresolved in the earlier schemes of scientific research, problems such as the origin of life, which includes that crucial dilemma of the controversy between the "RNA first" or "metabolism first" scenario. We can visualize this dilemma from Eigen's proposal (Eigen1971), which identifies the relationship between biological information and biological function, like a "chicken-egg dilemma". We now understand that this question moves beyond being just a historical problem. Before inquiring which came first, it is more important that we ask ourselves which one of them could have given rise to the prebiotic evolutionary processes.
At present, we recognize that the solution for the old dilemma must necessarily pass through the stage of understanding the notion of biological information (Wills 1994) and of designing a definition of functions in naturalist terms (Collier 2000), that is, without falling

into epiphenomenic versions or appealing to some form of adscription.
We propose an initial working hypothesis with the purpose of contributing to the discussion and improving the understanding or clarification of what more than likely happened in the distant past, in the transition that meant the step from being inanimate to being animate.

Dynamic Organization and Internal Properties

To understand the conditions that make the appearance of living forms possible is to understand that *their most basic properties* were present at the origin of the pre-biotic world.
We also want to explain that when referring to the origin of the pre-biotic universe, it is illogical to speak in terms of a Darwinian evolution since neither DNA nor RNA had appeared and neither had anything like "genetic material". These emerged long in the history of the pre-biotic world. Therefore, we cannot speak of fitness and other concepts connected with biological evolution. There is just open-ended evolution – a type of evolution whose components are related to the idea of evolution by natural selection.
Nevertheless, it is possible for us to refer to the capacities that permit the gradual building of the structure and dynamic organization of those systems in terms of their internal properties (Bagley, Farmer 1992, Bak 1996, Jeong et al. 2000).
Likewise, the solution for the problem sketched above (the old dilemma) has to move through a period of establishing the criteria that can differentiate the self-organizing dynamics of the systems that make up the prebiotic world from other types of self-organized systems, and perhaps, through a time of a better understanding of the new science of networks (Bray 2003, Watts 2004), which enables us to understand the transition from the inanimate world to the animate world and to understand the step from random to scale-free networks. Another aspect is the design of a new version of *evolvability* that could be applied to the distinct changes that were produced in the prebiotic world (Kirschner, Gerhart 1998).
We are proposing a theoretical construct that visualizes the most basic properties of living systems, originating in the systems that provided the possibilities for its emergence in the universe: in the prebiotic systems.
More accurate put, we consider these original properties to be *autonomy, information, and function* (Riofrio 2005). The aforementioned theoretical construct is a type of dynamic system that we defend

as the one that decisively established a division in the different types of self-organized systems.
On one hand, we would have the self-organized systems that would be generating self-organized dynamics with certain degrees of ordering but whose matter and energy sources – which enable them to be in the far from thermodynamic equilibrium state – would strongly depend on their exterior environment.
Instead, we affirm that there might have existed a type of self-organized system that could have incorporated as part of its dynamic organization the necessary factors that provided it the ability to be and to maintain itself, *by its own dynamic*, in the far from thermodynamic equilibrium state. We have named this type of self-organized system the "Informational Dynamic System" and, moreover, we propose that it is this variation of a self-organized system that for the first time opened the doors of the prebiotic world. This is the one that caused the necessary and sufficient conditions to set off the succession of certain phenomena of the universe towards the possibility of the emergence of biological systems. It is also the system that might have been the driving force to the beginning of the move from the inanimate world to the animate one (Riofrio 2007).
Actually, this type of dynamic system would be composed of a group of molecular compounds that are interconnected by networks of processes, where determined types of actions take place and that, on a global scale, will enable this system to maintain and sustain itself in a robust manner over time and in conditions that are far from thermodynamic equilibrium.
To visualize the organization we are hypothesizing for the Informational Dynamic Systems, we need to include the interaction and interdependence among three different groups of molecular processes. The first corresponds to a process that enables the system to behave as a self-organized system for reasons that are systemically internal to it. It has managed to keep itself far from thermodynamic equilibrium since part of its organization is constituted by the group that links the endergonic processes with the exergonic ones and the facilitation that produces the coupling of molecules with "high energy" bonds. The second is a set of processes that constitutes the protoplasmic membrane. In this portion of the system's organization, the tasks of isolating the system from its exterior are done; in addition, it is the part of the system organization that is a complete agent in where solutions to chemical problems, such as the "osmotic crisis", the management of electrochemical gradients, will be

generated as well as the work associated with the problems of "recognition" and transportation of matter and energy compounds from the outside to its inside. The third group involves the processes which are linked to the tasks of reproduction, repair, and control of the internal dynamics. These processes interact among each other as well as with the ones inside the two groups mentioned above.

One of the basic characteristics of the first ancestors of living systems, those that opened the door of pre-biotic world, was the capacity to generate "meaningful information" about their environment and about their dynamical internal milieu. The important thing for our idea is that the information, properly said – The Information – *has a meaning* (very basic semantic) that is created on the inside of the system.

Any type of signal or sign can be a carrier of what might be information (or what we call "potential information"). We consider a signal or sign to be any matter-energy variation (sound wave, electromagnetism, concentration of a chemical compound, change in pH, etc.). The "potential information" carrier must be in the surroundings, on the inside, or have transmitted the information to some system component.

So, we need that one sign or signal which is the carrier of potential information must have been incorporated into some process inside the informational dynamic system. Secondly, the possible information becomes information ("information with meaning" for the system) since it has the capacity to produce something (an effect). Third, the effect has a repercussion in the system, influencing its own dynamic organization.

The effect of the information that has meaning for the system can be found in the maintenance or the increase of the system cohesion. Such cohesion is constituted by the group of relationships and interdependencies that exist among the processes; it is a relational and dynamic definition that encompasses the nature of the system organization (Collier 1986, 2004). As well, the effect could produce some level of interference in the system cohesion, possibly interrupting one or more processes. It is clear that meaningful information can be caused by some signal (that carries potential information) coming from the environment like a signal that is generated in the internal dynamic of the system. In all cases, whether an effect in favor of or in contrast to cohesion, the system will develop some type of response that will be correlated to that meaningful information and the process or processes related to the effect.

In the other hand, we consider the function to be located in the action that generates a determined process and what we can understand as 'what contributes' (cooperates, favors, supplies) to the interrelation and interdependence among the processes with a view to maintaining the far from equilibrium state.
On the inside of the process, each component will have the mechanism that is proper to its chemical constitution, but that chemical action (or group of actions) will have its *raison d'être* because of the process. Then, each process that carries out a determined and particular action (made up by the causal nexuses among the component mechanisms that constitute them) will be assimilated into the dynamic organization *only* if this particular action is maintaining, improving, or achieving the far from equilibrium. And this action is precisely *its function* in this organizational logic of the Informational Dynamic Systems.
Thus, a function is something that contributes or facilitates to maintaining or increasing the far from equilibrium state. A dysfunction, on the other hand, is something that does not contribute or facilitate to maintaining the far from equilibrium state.
Succinctly stated, we can say that our theoretical proposal visualizes the emergence of information and biological function in a sort of coordinated origin – at the same time – in the *local processes* of these types of systems.
This visualization of the physical emergence of Information and Function gives us to talk about the notion of ***"Information-Function"***; each time we observe functions happening in these systems' processes, we can be sure that some type of information has been transmitted through them. Likewise, when we observe the transmission of some type of information among the process, we can be sure that some function has been produced among them.

References

- Bagley RJ, Farmer JD. 1992. Spontaneous emergence of a metabolism. Pages 93-140 in Langdon C, Taylor C, Farmer J, Rasmussen S, eds. Artificial Life II, Addison-Wesley, New York.

- Bak P. 1996. How Nature Works: The Science of Self-Organized Criticality. New York: Springer-Verlag.
- Barabási AL, Oltvai ZN. 2004. Network biology: Understanding the cell's functional organization. Nature Reviews Genetics 5: 101–113.

- Barkai N, Leibler S. 1997. Robustness in simple biochemical networks. Nature 387: 913–917.

- Bell-Pedersen D, Cassone VM, Earnest DJ, Golden SS, Hardin PE, Thomas TL, ZoranMJ. 2005. Circadian rhythms from multiple oscillators: Lessons from diverse organisms. Nature Reviews Genetics 6: 544–556.

- Bray D. 2003. Molecular networks: The top-down view. Science 301:1864-1865.

- Cairns-Smith AG. 1985. Seven Clues to the Origin of Life. Cambridge: Cambridge University Press.

- Capra F. 1997. The Web of Life: A New Scientific Understanding of Living Systems. Doubleday.

- Carlson J, Doyle J. 2002. Complexity and robustness. Proceedings of the National Academy of Sciences USA 99: 2538–2545.

- Carr CE. 2004. Timing is everything: Organization of timing circuits in auditory and electrical sensory systems. Journal of Comparative Neurology 472:131–133.

- Collier J. 1986. Entropy in evolution. Biology and Philosophy 1: 5-24.

- Collier J. 2000. Autonomy and process closure as the basis for functionality. Pages 901: 280-290 in Chandler JLR, van de Vijver G, eds. Closure: Emergent Organizations and their Dynamics. Annals of the New York Academy of Science.

- Collier J. 2004. Self-organization, individuation and identity. Revue Internationale de Philosophie 59: 151-172.

- Eigen M. 1971. Self organization of matter and the evolution of biological macro molecules. Naturwissenschaften 58: 465-523.

- Fontana W, Buss LW. 1994. The arrival of the fittest: Toward a theory of biological organization. Bulletin of Mathematical Biology 56: 1–64.
- Furusawa C, Kaneko K. 2002. Origin of multicellular organisms as an inevitable consequence of dynamical systems. Anatomical Record 268: 327–342.

- Hazen RM. 2001. Life's rocky start. Scientific American. April, pp. 63-71.

- Jeong H, Tombor B, Albert R, Oltvai Z, Barabási, AL. 2000. The large-scale organization of metabolic networks. Nature 407: 651–654.

- Kauffman SA. 1993. The Origins of Order: Self Organization and Selection in Evolution. Oxford University Press.

- Kirschner M, Gerhart J. 1998. Evolvability. Proceedings of the National Academy of Sciences USA 95: 8420–8427.

- Kitano H. 2004. Biological robustness. Nature Reviews Genetics 5: 826–837.

- Levin S. 1998. Resilience in natural and socioeconomic systems. Environment and Developmental Economics 3:225-236.

- Mainzer K. 1997. Thinking in Complexity: The Complex Dynamics of Matter, Mind & Mankind. Springer-Verlag.

- Maturana H, Varela F. 1973. Autopoiesis: the Organization of the Living. Reidel.

- Maynard Smith J, Szathmáry E. 1999. The Origins of Life: From the Birth of Life to the Origin of Language. Oxford: Oxford University Press.

- Quastler H. 1964. The Emergence of Biological Organization. Yale University Press.

- Rensing L, Meyer-Grahle U, Ruoff P. 2001. Biological timing and the clock metaphor: Oscillatory and hourglass mechanisms. Chronobiology International 18: 329–369.

- Riofrio W. 2005. What is life? Again, is this question interesting? Paper presented at the Complexity, Science and Society Conference; 11-14 September 2005, University of Liverpool, England.

- Riofrio W. 2007. Informational dynamic systems: Autonomy, information, function. In: Gershenson C, Aerts D, Edmonds B, eds. Philosophy and Complexity: Essays on Epistemology, Evolution and Emergence. World Scientific. Forthcoming.

- Stelling J, Sauer U, Szallasi Z, Doyle F, Doyle J. 2004. Robustness of cellular functions. Cell 118 (6): 675-685.

- Vanrullen R, Guyonneau R, Thorpe SJ. 2005. Spike times make sense. Trends in Neuroscience 28: 1–4.

- Wächtershäuser G. 1988. Before enzymes and templates: Theory of surface metabolism. Microbiological Reviews 52: 452-484.

- Watts DJ. 2004. The "new" science of networks. Annual Review of Sociology 30: 243-270.

- Wills PR. 1994. Does Information Acquire Meaning Naturally? Berichte der Bunsen-Gesellschaft-Physical Chemistry Chemical Physics 98: 1129-1134.