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Systems and the Biological Significance of Molecular Interactions within and between the Cells

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For long, Biology has been the study of the organization of the living organisms and cells as well as that of various types of biomolecules, such as proteins and nucleic acids, present in these cells. It has soon appeared, however, that it is impossible to reduce the properties of a complex biological system to the individual properties of its elements, the molecules, which constitute such a system. The concept of system has, for a large part, benefited from numerous studies of physical chemists such as Prigogine. Today, a biological system is often conceived as a set of elements in mutual interaction according to some physical laws. Many enzyme reactions that take place in the cell cannot occur, when they are isolated, for they are endergonic i.e. they need free energy to take place. Hence many biochemical events that take place in the cell would not occur if they were in isolation. It is because they constitute some kind of a physical system that they can exist. There is little doubt that the structure and the molecular organization of the cell play a major part in the occurrence of dynamic events that take place in the same cell. Some of the chemical events that take a major part in the dynamic organization of the living cell are the following:

- the diffusion of mobile ions and their partition by charged matrices;
- the compartmentalization of enzyme reactions in the living cell;
- the coupling between reactant diffusion and bound enzyme reactions;
- the electrostatic partitioning of ions by charged membranes and cell walls, etc…

This new field, located at the border between cell biology, physics and physical chemistry, might well be considered somewhat disturbing but it is no doubt an important new domain of research. It is remarkable, in that respect, that, for instance, gycolysis *in vivo* displays a periodic dynamics that cannot exist *in vitro*. In fact, both the coupling between the chemical reactions of glycolysis and other chemical reactions, as well as the structure of the cell, explain the dynamics of the whole process. As a rule, there is no simple relationship between the dynamics of the same reactions occurring *in vitro* and *in vivo*.

Considering biological processes as some kind of physical systems, the main features of systems biology is to introduce physical concepts in this new field of systems biology. Biologists have already accepted the use of physical techniques, it is now time to accept the presence of physical concepts in biological problems. The consequence of this approach is to use *in fine* mathematical concepts as a tool for approaching biological problems. Studying biological systems is equivalent to study experimental results in an integrated physical perspective. Studying biological systems in a physical perspective imply we are studying, for instance, one of the following topics: how enzyme reactions may be viewed as elementary dynamic life processes; how coupling between scalar and vectorial processes can be considered as signalling devices; how metabolism is controlled; how cell compartmentalisation may explain energy storage and active transport; how information and small molecules are transferred within multienzyme complexes; how complexity of the cell envelope can modulate catalytic activity of cell wall bound enzymes; how the free energy stored in the cell may generate cell motility; how complexity of cell organelles can generate temporal organization of metabolic cycles such as oscillations and chaos; how diffusion of morphogens in the young embryo can induce spatio-temporal organization of biochemical processes and emergence of patterns.

It thus appears that the very concept of *System,* i.e. the way different molecular entities are organized in time and space plays a major role in the understanding of biological functions. Another main advantage of this type of approach is that it allows to build-up artificial models that may constitute physical models of biological events.

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