

The Immune System as a Cognitive System: New Perspectives for Information Technology Society

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Survival and maintenance in living organisms, from invertebrates to mammals, are assured by a variety of evolutionary conserved mechanisms. From this point of view, a critical role is played by cognitive systems, capable of acquiring and elaborating information from the environment (external world), as well as from the internal milieu (internal world).

Three biological systems, the immune system (IS), the nervous system (NS), and the endocrine system (ES), evolved to play such a fundamental role for complex living organisms. These systems are deeply interconnected among them, and share some basic architectural and organisational characteristics, despite having specific peculiarities.

The lecture will highlight the major characteristics of the IS as a whole stressing the fact that the IS is constituted by a very large number of heterogeneous interacting cells, which can be considered as the main components of a real world complex network, in the context of the danger/damage signals perspective. Indeed, when an organismal damage is going to occur, because of infections or stressing events pushing the body out of the physiological working range, danger/damage signals are delivered inside the system triggering the appropriate immune response.

The response as a whole is in fact a temporal and spatial coordination between mechanisms belonging to the two major IS subsystems, the innate and the clonotypic ones. In the case of foreign antigens (pathogens) danger signals are delivered as molecules detected by Toll-like receptors while damage signals as “alarming” cytokines due to local inflammatory processes. Thus, it is the association of foreign molecular patterns owned by pathogens with the danger and/or damage molecular signals that is able to trigger the immune response, allowing to put forward the concept that the innate IS is sensitive to and perceives the context.

Key molecular elements for building the immunological context are cytokines. Cytokines, regulatory molecules of immune phenomena, are locally produced and handled by the interacting immune cells (macrophages, T and B lymphocytes, among others) during immune responses (cytokine field hypothesis), in order to indirectly induce functional status changes in the immune cells themselves. Their role can be considered as fundamental during the establishment and maintenance of the following immunological processes:

1. The cascade of different pattern recognition processes involving the innate as well as the clonotypic immunity, during which molecular patterns shared by different antigens, stimulating the innate IS, work as a prerequisite for the subsequent effective recognition of individual and specific patterns of the same antigens by cells of the clonotypic IS compartment. A key role in all the quoted mechanisms, being the antigen recognition process at the basis of the structural capabilities of the IS at any time of its ontogenetic evolution, is played by the proteasome and its changes with age. The proteasome is the cellular “machinery” (organelle) devoted to chop self and foreign proteins for showing the resulting antigenic fragmented peptides to the appropriate immune cells.
2. The temporal and spatial dynamics of various network systems, corresponding to different levels of system description where elements, cell pools, cells and/or molecules have as main characteristics promiscuity and/or redundancy. Among others we can mention:
 - i. the two-layer connected network, in which one layer has the peculiarities of elements and mechanisms of the innate IS and the other of the clonotypic IS;
 - ii. a multi-layer connected network, inspired to the interaction among the IS, the ES and the NS;
3. The self antigen stimulation (internal activity of the IS), the exogenous antigen stimulation (acute antigenic stress), and the immunological noise (fluctuating chronic exogenous antigenic stress), which can act separately or jointly to eventually give rise to the IS long time scale evolution (immunosenescence) by influencing:
 - i. the type of connectivity of the IS, envisaged as a dynamical network evolving over short and long time scales. Such a connectivity is tightly bound to the phenomenon of the expansion of specific cell clones, which has different weights over short and long time scales, taking into account the limitation of the Immunological Space;
 - ii. the realization and maintenance of immunological memory in presence and absence of antigens.

All these major characteristics of the IS can inspire new and innovative models, useful for other branches and disciplines of computer science, information technology and artificial intelligence. From this point of view the graph theory approach applied to real world complex systems deserves particular attention.