A couple of physics applications in the immune system: cytokine fields evolution and hematopoietic stem cells (HSCs) motility

I will describe our efforts in two (unrelated) directions in studying the immune system: 1) spatial dependence of interactions between immune cells through cytokines, and 2) the dynamics of HSCs in their natural environment.

The first topic relates to the coordination of immune response by the immune cells. The coordination occurs through the exchange by the cells of small signalling molecules - cytokines. Some time ago, we demonstrated that for T cells such interactions mediated by interleukin-2 (IL-2) cytokine can be quantitatively described in the framework of a simple diffusion/consumption physical model. The competition between the cytokine diffusion and cytokine consumption by T cells sets the characteristic spatial scale for the interactions. Furthermore, the signalling through IL-2 affects the expression of its receptor on the T cells, which changes the consumption kinetics and, respectively, should change the cytokine concentration fields, which, in turn, change the spatial distribution of IL-2 receptor expression and so on. I will address the question of how the two fields, the cytokine and its receptor, co-evolve.

The second direction is related to hematopoietic stem cells (HSCs) that are the progenitors of all of the immune cells in the body. They reside in the bone marrow but can be mobilized into blood for use in transplantation. In homeostasis, HSCs were thought to stay static within their bone marrow niches. We used two-photon laser scanning microscopy to visualize genetically labeled HSCs in the bone marrow of live mice for several hours. The majority of HSCs showed a dynamic non-spherical morphology and significant motility, undergoing slow processive motion interrupted by short stretches of confined motion. Interestingly, mobilization-inducing drug treatment rapidly abrogated HSC motility and shape dynamics in real time. Our results reveal an unexpectedly dynamic nature of HSC residence in the bone marrow.