Soft Matter and its Interface with Biology

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To understand how biological systems work, Jaques Prost, professor of biological physics and managing director at the Ecole Supérieure de Physique et de Chimie Industrielles in Paris, is developing theoretical tools and new experiments to extract physical laws governing the morphology and dynamics of biological cells. He described his work at the EPL symposium, "Physics In Our Times" held today (10 May) at the Fondation Del Duca de l'Institut de France, Paris.

In particular, he is interested in areas such as cell traffic and motility, cell duplication and oscillations and signal transduction. He wants to know what characterises living systems as opposed to dead ones. One example is how the so-called fluctuation dissipation theorem is violated in a living system.

Much of eukaryotic cell dynamics results from the dynamical interaction of three major cell components. These are phospholipidic membranes, cytoskeletal networks and molecular motors. During his presentation, Prof. Prost gave three examples that illustrate how a quantitative description of basic biological processes can be obtained. He first discussed how molecular motors can pull phospholipidic nanotubes and how to obtain a theoretical description (without adjustable parameters) of this process - known to play an important role in eukaryotic cell traffic.

Next, he discussed cell motion. On a substrate, cells extend a thin layer, called the lamellipodium, which drags the cell forward. Using only symmetry and conservation arguments, he described the concept of "active gels" and discussed the shape and dynamics of the lamellipodium. In particular, he showed how the observed "retrograde flow" of gel naturally emerges out of the theory description.

Using the same framework, Prof. Prost also discussed how oscillations are obtained when cells are suspended in a fluid and suggested that the early stage of mitosis (cell division) is the bipolar manifestation of this same instability.

Prost says his team's most exciting result to date has been to show that "hair cells" (the cells that detect sound in the inner ear) work with excellent precision at the verge of an oscillation instability - called a "Hopf bifurcation". This finding explained no less than six previously unanswered questions, some dating from the 18th century.

"It is extremely difficult to drive a system so close to instability in a laboratory experiment," explained Prost. "However, during evolution our ears have had plenty of time to drive 16 000 cells close to such instabilities! This shows how biology is interesting for physicists - evolution can drive systems under unlikely conditions that are almost inaccessible in the lab."

Prof. Prost and colleagues have also developed a description of biological gels in which molecular motors provide "life" to these structures. "We are now in a position to raise questions about cell dynamics including cell duplication in terms of condensed matter physics," he stated.

It is now clear that statistical physics and condensed matter physics are important for understanding biology. Prof. Prost believes that over the next 20 years we will finally be able to describe the connection between specific protein activity and global cell function in a quantitative way. "Such knowledge will have a profound impact on our understanding of pathologies such as cancer and neurodegenerative diseases, and hopefully help us find therapies," he said.

Source: Institute of Physics