Press release

14 November 2011

A biological model system ending up in an “absorbing state”:

Perfect micro rings woven from muscular fibers

A freight train would drive the rails as far as they go, if the locomotive is supplied with sufficient energy. But nature knows systems whose dynamics suddenly turn into a kind of endless loop. Like in a hamster wheel the train caught in such a system would still be running, but not move forward. Scientists from the Cluster of Excellence Nanosystems Initiative Munich have now succeeded in building a simple model system consiting of only three components to study the laws of such so called absorbing states.

Scientists speak of active systems if these systems continuously consume energy. Active systems are everywhere around us, from simple machines to highly developed creatures. However, our knowledge and understanding of these systems are still very limited. Often we find complex phenomena, where we would have actually expected simple patterns.

That is what happened to a team of physicists around the NIM-scientist Andreas Bausch Biophysics professor at the Technische Universitaet Muenchen (TUM) and Erwin Frey, Biophysicist at the Ludwig-Maximilians-University Munich (LMU). They investigated how fibers – consisting of the muscle protein actin – behave when they are transported while being linked together. The physicists discovered that at a certain point the system suddenly entered a so-called absorbing state, although it didn’t stop to consume energy.

An absorbing state means that the system cannot escape from this particular state. The model system of the researchers consists of only three components: the muscle protein actin, motor proteins that are responsible for transport and movement in cells and fascin molecules which cross-link the actin fibers. With this simple but well controllable model the scientists now are able to investigate the fundamental principles of absorbing states.

In the experiment millions of biological motor proteins anchored on a glass surface are responsible for the transport of the actin fibers They are the active component in the model system. After adding adenosine triphosphate (ATP), the „fuel“ for the motor proteins, the fibers begin to move randomly. Now the researchers added crosslinking molecules in order to connect the fibers. This leads to larger and larger structures moving around on the substrate. In the end of the experiment, all fibers are incorporated into larger structures. However, these structures can no longer move freely across the surface. They are now fixed and run in circles – the system is trapped in an absorbing state.

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Surprisingly the resulting structures are quite complex. The structures that develop are rings of perfect shape, consisting of several millions of individual fibers, which rotate constantly under the influence of motor proteins. "The amazing thing is not only the complexity of the structures, but the fact that even this simple system consisting of only three components – fibers, motor proteins and crosslinking molecules – runs into an absorbing state," said Volker Schaller from the Institute of Biophysics (TUM), first author of the work.

"Such a minimal system should allow us to understand the experimental results with the help of theoretical models," adds Christopher Weber from the Department of Statistical and Biological Physics of LMU Munich. He works with Professor Frey on theoretical concepts to describe active systems. Within the cooperation they succeeded to uncover the underlying principles of the ring formation. Specifically, they were able to track back the rings' properties such as size and shape to random movements at the molecular level.

The special charm of the model system relies on the apparent contradiction. “Our active system is able to enter an absorbing state, although it continues to consume energy,” says Bausch. "For the system the absorbing state is like a dead-end street: if only one part of the system decided to ‚walk' towards the dead-end, there is no escape." Such absorbing states can be found in numerous, far more complex active systems, such as the growth of competing cell populations.

A central question is, whether the dynamics of all these systems rely on the same fundamental laws. According to Frey the answer to this question can be one of the key points in physics of complex systems. "To answer such questions model systems that consist of only a few ingredients are ideally suited," says the Munich physicist.

The research is supported funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013)/ERC CompNet (279476), from the Deutsche Forschungsgemeinschaft (DFG) in the framework of the Sonderforschungsbereich (SFB) 863 and the Cluster of Excellence Nano-Initiative Munich (NIM), the Institute for Advanced Study and the International Graduate School of Science and Engineering (IGSSE) of the Technische Universitaet Muenchen and from the Elite Network of Bavaria by the graduate programmes CompInt and NanoBioTechnology.

Original publication:

Volker Schaller, Christoph A. Weber, Bejamin Hammerich, Erwin Frey und Andreas R. Bausch: Frozen steady states in active systems. PNAS, Early Edition, online Nov. 14, 2011.
DOI: 10.1073/pnas.1107540108 – www.pnas.org/cgi/doi/10.1073/pnas.1107540108

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Pictures and Videos:

(Coming soon after the publication is online)
Ring formation: http://bio.ph.tum.de/home/e27-prof-dr-bausch/bausch-home.html
Theory: http://www.theorie.physik.uni-muenchen.de/lsfrey/research/biological_physics

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