Intracellular Transport

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Many processes in cells rely in active transport along the cytoskeleton; cargoes such as vesicles, organelles, protein complexes, or mRNAs are pulled by molecular motors (kinesins, dyneins and myosins) that move along the filaments of the cytoskeleton. Over the last two decades these motors have been well characterized at the single-molecule level with respect to their speeds, forces, chemical states etc. More recently the focus of research has been moving towards understanding cooperative phenomena, which are key to understanding the patterns of motion seen in cells.

In the talk, I will introduce the most important molecular players and review the their known properties at the level of individual molecules. The main focus is on cooperative transport by several molecular motors, a situation that is typical for the transport in cells. Moreover, the recent development of synthetic multi-motor constructs has made this type of transport accessible to systematic quantitative experiments. Specifically, I will discuss two issues that are both related to the generation of force between motors working together: (i) how force can coordinate bidirectional motion driven by motors moving in opposite direction, and (ii) how the stochastic built-up of force between motor pulling in the same direction can interfere with their stepping or reduce their binding to the filament along which they move.

The first question, how bidirectional transport is coordinated, has been subject to debate for a long time. Motors pulling in opposite direction were simultaneously found on many cargoes in cells, but it was not clear whether the two motor teams were active at the same time, thus fighting a tug-of-war or whether only one type was active at a time. Theoretical analysis of the tug-of-war between molecular motor indicates that a tug-of-war can explain the patterns of motion seen in cells and that the force between the two motor teams can provide an efficient mechanical coordination mechanism. Recent experiments provide support for such coordination, but there is also evidence that, in transport in cells, mechanical coordination may be supplemented by biochemical coordination mechanisms.

The second question, the effect of forces between motors pulling in the same direction is directly motivated by recent experiments on synthetic motor complexes, where such effects can be observed. Such forces are generated by the stochastic stepping of the motors, which is typically not synchronized among the motors in a team. Surprisingly, a theoretical analysis indicates that the main effect of such force is different for different types of motors and dependent on the force characteristics of single motor molecules, a view that is supported by recent experimental studies.

In addition, I will discuss cytoskeletal transport from a „traffic perspective“ and address question related to the transportation network and the control of traffic. This perspective will allow comparisons with macroscopic transport systems and stimulate discussion about how organizing principles of cyctoskeletal traffic can be used in macroscopic traffic as well as how ideas from macroscopic traffic may be used to understand cytoskeletal transport.