Unitary Steps of Supermolecular Motility Machineries in Gliding Bacteria and Swimming Archaea

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Identification of the step is one of the most important tasks to establish the mechanisms of motor proteins. In conventional linear motors in eukaryotic cells, such as myosin and kinesin, sizes of unitary steps indicate either periodicities of substrate filaments or projections of tilting of lever parts, e.g., 8 nm for double-headed kinesin, 36 nm for Myosin V and ~5 nm for myosin II. Additionally, rotary motor F_1-ATPase exhibits 120° steps, which coincides with the pseudo symmetry of the catalytic cylinder as it has three engine cores. As exemplified above fruitful results, researchers can directly address mechanisms how motors work with sizes of their unitary steps.

Our group has developed techniques of optical microscopes that enable to visualize the molecular function of single motor proteins[1-4]. We applied them to two microorganism, (1) gliding bacterium *Mycoplasma mobile* and (2) halophilic archaeon *Halobacterium salinarum*.

The membrane-permeabilized ghost model of *M. mobile* took 70-nm steps in the gliding direction[5], which was presumably induced by the movement of the protein that connects the leg to ATPase. Because a protein similar to the catalytic subunit of F_1-ATPase is located at the cytoskeleton-like structure, we hypothesize a model in which the crank-like protein converts a rotational motion of ATPase to a directed linear motion, much like a connecting rod between the wheels of a steam train.

Motile archaea swim using a rotary filament, the archaellum, which is evolutionarily and structurally related to type IV pilus in bacteria. We analyzed the rotation of the archaeal motor in great detail with high-speed imaging in a tethered-cell assay[6]. Notably, intermittent pauses were detected, with steps of multiple numbers of $\sim 2\pi/6$ and $\sim 2\pi/10$ as main peaks of the histogram. Although the origin of the steps was not conclusively settled, the rotation symmetry of ATPase, or of components in the stator or rotor, possibly correlates to and directly reflect the number of 6 and 10.

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