C:Biophysics

Complexity Science and Engineering

Physical measurement for Cells

Hayashi Laboratory

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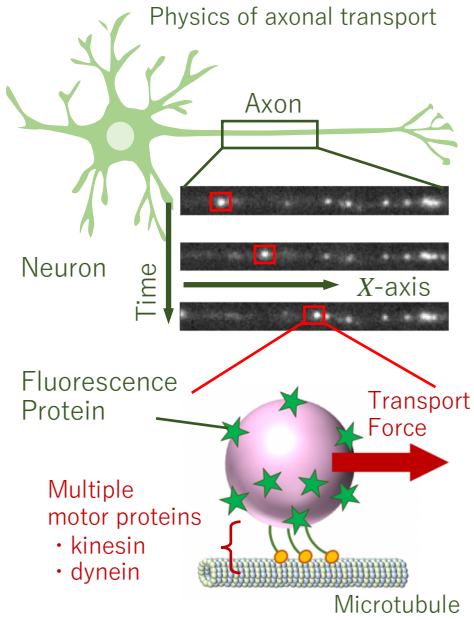
Precise physical measurements are important for cells to understand molecular mechanisms occurred in cells as well as for solid state materials. However, *in vivo* measurements are difficult because intracellular environments are complex non-equilibrium states, in which theories of statistical physics are often violated.
In our lab, we develop techniques to precisely measure physical quantities such as force, velocity and energy for proteins and organelle inside cells, based on fluorescence microscopy. We think development of analytical methods (software) using statistical physics, information science and mathematics as well as development of microscopes (hardware). We aim to understand cellular phenomena quantitatively by constructing theoretical models using the measured physical quantities. We hope such theories can contribute to the understanding of neurological disorders particularly.
Biophysics is a new field and it will grow in future. People who are interested in biology from the viewpoint of physics are welcome. Because we belong to Biophysical Society, people who speak English are also welcome.

Research topic 1 : Fluorescence observation of axonal transport in iPS cell derived neuron

Materials synthesized in the cell body of a neuron are transported by motor protein (kinesin and dynein) along the axon (axonal transport). Because this logistics is important for neurons, deficits of axonal transport is related to neurological disorders [1].
We apply non-equilibrium statistical physics to time course analysis of axonal transport, we measure physical quantities such as force, velocity, number, entropy production of motor proteins [2].

Research topic 2 : Force measurement of motor protein kinesin by using a nano-sized spring

Kinesin is a motor protein in charge of axonal transport. Its force has been measured by using optical tweezers (Nobel Prize in Physics 2018) [3].
As a substitute of optical tweezers, we aim to measure its force by uing nano-sized spring, made of DNA-origami, developed in the previous study [4].
We try to develop the force measurement using the spring in order to measure transport force of motor proteins inside cells.



Research topic 3 : Extreme value analysis applied to axonal transport by motor proteins

We obtain information on force of motor proteins engaging in axonal transport, by applying extreme values analysis to transport velocity data, noting that *in vivo* force measurements are difficult in general.
We performed *in vivo* fluorescence observation of axons inside living *C. elegans* worms, and found the difference of force generation mechanism between kinesin and dynein [5].

Research topic 4 : Theoretical modeling of synapse formation related to axonal transport

We aim to construct theoretical models to explain synapse formation. It has been known that KIF1A mutants cause abnormal synapse formation, where KIF1A is one kind of kinesin family transporting synaptic materials [6].
We try to relate "physical properties of KIF1A mutants (force, velocity, number)" and "those of synapses (size, interval, position), to contribute to understanding of KIF1A associated neurological disorder [1].

Reference
[1] KIF1A.org
[2] Hayashi, *et al.*, Mol Biol Cell 2018; Phys Chem Chem Phys 2018; Sci Rep 2019
[3] Svoboda, *et al.*, Nature 1993
[4] Iwaki, *et al.*, Nat Commun 2016
[5] Naoi, *et al.*, bioRxiv 2021
[6] Niwa, *et al.*, Cell Rep 2016

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