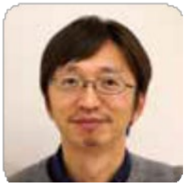
Laboratory of Biomolecular Machine Design

Advanced ICT Research Institute



Guest Associate Professor Ken'ya FURUTA

furutak @nict.go.jp

URL:http://www.nict.go.jp/frontier/seitai/

Biomolecular motors are molecular machines that produce various "movements" of living organisms. The most important function of these machines is to reliably "move in one direction" in the nanoscale world that is governed by thermal fluctuation. However, the basic mechanism of this function is still unclear. Focusing on biomolecular motors, kinesin and dynein, we are interested in the mechanism of energy conversion—the mechanism by which these machines produce unidirectional motion, and the mechanism of determining the force and direction of motion. We are also interested in the properties of their collective dynamics and the properties in the intracellular environment. For application-oriented research, we are working on the design and creation of new molecular machines that are redesigned with reference to naturally occurring molecular machines. We are now developing autonomous micro-robots that implement computational functions and memory by combining these machines.

Design principles of biomolecular motors

In an environment governed by thermal fluctuations, it seems difficult for a protein to move unidirectionally. In addition to analyzing existing biomolecular motors, we are trying to establish a constructive approach by combining simple domains into a new biomolecular motor prototype and by observing how it behaves (Fig. 1).

Design and control of collective dynamics

Individual molecular motors cannot explain many biological phenomena. It is known that there is a complex chain of events that occurs between the layers, for example, molecules, teams of molecules, organelles, cells, and individuals. This chain organizes the disparate movements into orchestrated ones which are then fed back to each layer of the hierarchy. However, the question of how these layers are linked remains unclear. We believe this is the key to understanding how organisms are designed. We are creating experimentally accessible model systems using DNA nanostructures and other biological materials to explore such collective dynamics (Fig. 2).

Design of autonomous micro-robots

The three key elements of a robot are sensors, processors, and actuators. Cells are equipped with these elements and can be viewed as micro-robots that move autonomously. We would like to understand the mechanisms by which cells remember information, make decisions based on the information, through a synthetic biology approach—the creation of such micro-robots by assembling structures using biological materials and self-assembling techniques (Figure 3). To accomplish this, we use DNA nanostructures with excellent controllability. We have also built our own instruments such as microscopes and optical tweezers, control and analysis software, and basic experimental apparatuses, using machine tools and 3D printers. We also built a high-throughput research environment with the aid of pipetting robots and automated microscopes.

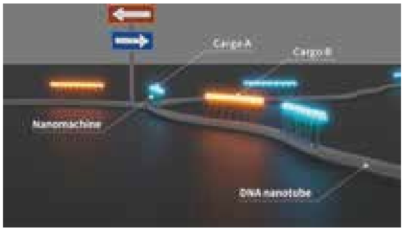


Figure 2: Schematic diagram of two types of nanomachines sorting two different cargos on a Y-shaped DNA nanotube (Ibusuki et al, *Science* 2022).

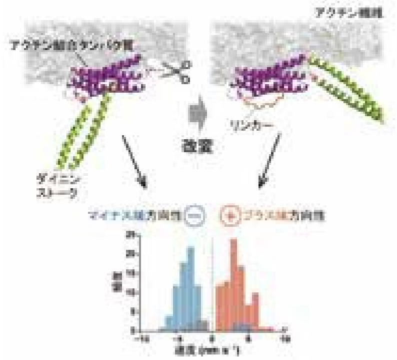


Figure 1. Protein engineering to create reversible molecular motors (Furuta et al., *Nat Nanotech* 2017).

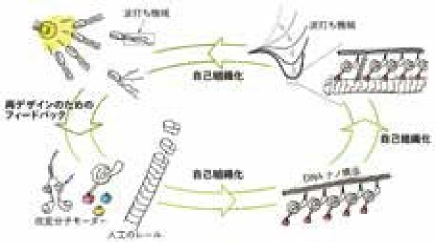


Figure 3. Example of an autonomous micro-robot with a hierarchical structure, which is our goal (Furuta et al., *Curr Opin Biotechnol* 2017).

The aims of our research will not be realized by methods in one particular field alone but requires the combination of methods of diverse fields. When we combine different materials or ideas into one, nature sometimes presents us with hints for solving mysteries that could not be solved within the conventional framework. The moment when we realize these hints is the most exciting part of such a research.

Advanced ICT Research Institute, National Institute of Information and Communications Technology, 588-2, Iwaoka, Nishi-ku, Kobe, Hyogo, 651-2492, Japan

TEL: +81-78-969-2214

FAX : +81-78-969-2239

Scan here for the lab's website >>