Active matter physics unravels the mysteries of life phenomena and expands the scope of medicine

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In nature, there are many creatures that move in groups. For example, birds flying in the sky and fish swimming in the sea. Other examples that move in groups include bacteria and eukaryotic cells, which are often used in research. What are the common properties of the collective motion of these self-moving objects? The group of them is called “active matter”, and the field of study to investigate it is called “active matter physics”, which has been actively studied in recent years.

Here, I will explain research by Kawaguchi et al. from many studies related to active matter physics [1]. This study investigated the collective motion of neural progenitor cells (NPCs). NPCs are cells that will become neurons after some time. Since NPCs move on their own, a group of NPCs can be considered active matter. At low density, they tend to move randomly like amoeba. However, at high density, cells align with each other according to their elongated shape, which lead to a macroscopic pattern. When elongated objects align with each other to form a pattern, special points called “topological defects” may appear. Topological defects are the points where local orientation of the elongated objects cannot be defined. A vortex of water is an example of topological defects. In the case of vortex, “local orientation of the elongated objects” corresponds to the direction of water flow. There are many types of topological defects according to the orientation around the points. In the population of NPCs, two types of topological defects appear frequently: +1/2 defects and -1/2 defects. This study revealed that in the collective motion of NPCs at high density, cells clustered around +1/2 defects

and moved away from -1/2 defects. The relationship between such cell motions and topological defects was also explained in this study based on active matter theory and simulations. Such accumulation and escape of active matter components associated with topological defects were not known prior to this study, including theoretical and numerical simulations. The discovery of new phenomenon like this is very important to advance our understanding of active matter physics.

This study indicates that the future distribution of cells can be predicted according to where the topological defects are now. This suggests the possibility that we can also predict the motion of other things that can be considered active matter by taking advantages of their properties. Also, if we could place topological defects to where we want, we could even control the motion and the distribution of active matter.

There are many other studies on control or prediction of the motion of active matter. One example concerns bacterial turbulence. Bacterial turbulence is a turbulent flow created by the swimming of bacteria in high density condition. It is reported that by placing columns at equal intervals in bacterial turbulence, vortices that rotate in opposite directions next to each other are created [2]. The other example is about bacteria swimming in liquid crystal solution. Liquid crystals are elongated molecules. We can easily change the orientation of liquid crystals by applying electric fields. It is known that when the orientation of liquid crystals is changed, the motion of bacteria swimming in the liquid crystal solution is affected [3]. It means that we can control the motion of bacteria by changing the orientation of liquid crystals.

There are many other things that can be regarded as active matter. Especially about living things, not only flocks of birds or fish, but also cells that move by itself or molecular motors, which are proteins that generate force or transport substances within

cells, can be considered active matter. Various life phenomena are the subject of active matter physics because there are many things associated with living organisms that can be considered active matter. Such life phenomena include formation of organs and flow of materials within cells. A better understanding of active matter in general will lead to a better understanding of these various life phenomena. Also, if the motion of active matter can be controlled, it may be possible to transport certain substances to desired locations in the living body. This shows the potential for active matter physics to be applied to medicine and pharmacy, such as drug delivery in the body.

Because of the complexity of active matter dynamics, not much research had been done until recently. It is expected that the study of active matter will advance our understanding of some life phenomena, which are also very complicated and often unknown. This is very important in development of biology and physics. Not only that, but active matter physics also has a potential to apply to medicine. In addition to the direct medical applications like drug delivery mentioned earlier, it is expected that active matter physics will expand the scope of medicine by revealing mechanisms of some life phenomena. The study of active matter will thus provide development of science and applications in medicine, leading to a better society in the future.

Reference

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