The moment when theoretical models and empirical studies intersect

Mathematical Biology Lab. Professor
Hisashi Ohtsuki

Q. What is the one thing you want to know the most right now?

My ultimate goal is to understand the origin of life and how this world works by unraveling the various principles that exist in the world of living organisms. In physics, many fundamental laws of mechanics and electromagnetism are known, but a biological organism is a complex system with a large degree of freedom that is based on the interaction of various substances such as DNA and proteins, even for a single individual. You may think that no fundamental laws can ever be found in such a system. Nevertheless, many laws have been found so far. This is remarkable.

I am particularly interested in understanding the biological world based on evolution. The theory of natural selection, proposed by Darwin, states that individuals adapted to their environment leave more offspring, thus making adaptive traits more prevalent in the population. Every species on earth has undeniably experienced this principle of evolution. Therefore, I believe that many new things can be found by asking what kind of evolutionary process organisms went through to be here today.

Q. What is the mystery you are trying to solve right now?

One central question is to understand how cooperation among organisms is accomplished. Cooperation can range widely, from individuals of the same species helping each other, to individuals of two (or more) different species giving each other the benefit of their expertise (the latter is sometimes called “symbiosis”). Such cooperation, however, has the property of being very fragile. If there are selfish individuals who do not cooperate themselves but only receive cooperation from others, this “selfish” nature can spread through natural selection due to its reproductive advantage. There are no police or courts in the biological world, so we cannot expect someone to crack down on selfish individuals. So why is the biological world so full of cooperation?

The second is to unravel the characteristics of ourselves, i.e., humans, from an evolutionary perspective. While we share many characteristics with our close relatives, such as chimpanzees, we also have many things that we are particularly good at or those that are not often seen in non-human organisms. For example, humans are extremely socially developed and very cooperative, even with strangers. Humans could also be seen as an odd organism in that we have a menopause and end reproduction prematurely in the middle of our lives. Furthermore, it is an indisputable fact that humans are culturally fluent and receive not only genetic information from their parents, but also a lot of non-genetic information such as knowledge and ideas, and this information supports our prosperity. By considering how these physical and psychological characteristics of humans have evolved, I would like to understand human nature.

Q. Could you share your thoughts on the future prospects of this field?

Mathematical biology is a cross-disciplinary field formed by the combination of biology and mathematical sciences, and it is an active field where researchers from different fields are entering one after another. In the past, mathematical biology was limited to epidemiology, genetics, ecology, and so on, but in the 21st century, mathematical methods have been widely used in other disciplines such as molecular biology and developmental biology, covering a wider range of biological fields. However, when trying to understand humans, what biology can do is limited. I would like to see biology break out of its shell and become a field of study that collaborates with the humanities and social sciences. In fact, the importance of big data and theoretical models has been recognized in social sciences in recent years, and mathematics has become a universal method in all fields. In such a case, it may no longer be called mathematical "biology" but rather mathematical "human science" , but I would like to continue to call it "mathematical biology" because human is undoubtedly a biological species.

Q. What was the most enjoyable moment and the most challenging moment during your research?

I originally grew up as a math boy, so I always enjoy analyzing a model because I feel like I am given a jewel of a puzzle. What is better is that the puzzles are not artificial but come from nature.

But the most enjoyable part is when the predictions of my theoretical model are proven correct by experiments. When I was a graduate student, I built a theoretical model of ants and predicted that a certain behavior would stop when the colony size was large, and I was really happy when that prediction was proven to be correct in 2018. Of course, I remember being disappointed for a while when my prediction was shown to be incorrect in another work, but there is nothing like the moment when mathematical equations at my hand and simulations in my computer connect with the vivid natural life.

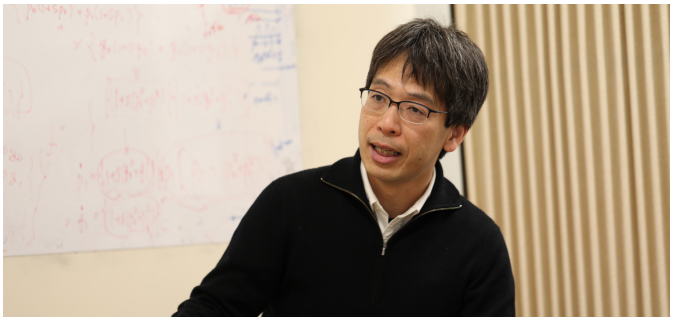
However, I believe that we should not hesitate to submit our theories for fear that our predictions might be wrong. Of course, it should be avoided to submit an incorrect theory without sufficient scrutiny, but science is based on many failures. In a sense, the theorist plays the role of an "idea person", and I believe that one of the significance of theorists is to keep throwing new hypotheses at the scientific community and keep asking to test those possibilities.

However, it is not easy to come up with an idea that no one has ever thought of before. Sometimes you can think about it for a long time and come up with nothing at all, and I find that time difficult. Surprisingly, when I stop thinking for a moment and let my mind be refreshed, I sometimes come up with a promising idea. The time when I have nothing to do is actually a good chance, and I even came up with a new model on the airplane. Mathematical biology is a research field that does not require a wet laboratory, so it is one of my advantages that I can conduct research on the plane.

Q. Do you have a message for undergraduate and graduate students who are interested in joining your lab?

There is full of freedom in Mathematical biology. You can study anything from viruses to elephants. The important thing is to be interested in biological phenomena on a regular basis and to find a "why" question in even if it is trivial. This "why" may have already been explained by previous researchers, or it may be something that no one has noticed yet. A seed of research can be hidden in such a "why" question. Therefore, I encourage you to cherish such everyday insights.

The backgrounds of people who want to study mathematical biology vary widely. In my experi-



ence, one-third of them come from biological backgrounds, one-third from mathematical backgrounds, and the remaining one-third from other fields (psychology, sociology, medicine, etc.). Mathematical biology is literally a combination of mathematics and biology, but it is difficult to find people who can do both. Also, many students have never heard of mathematical biology during their undergraduate days. It is not necessary to have all the skills at the time of admission, so I would like you to have one thing that you are good at. It does not matter if that strong point is mathematics, biology, or another subject. If you are good at one thing, you are ready to get started in mathematical biology.