Interdisciplinary research into neuroethology and genetics

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

I am interested in understanding how the insect brain develops to equip the neural circuits that control the social behaviors (fighting, courtship, mating, etc.) exhibited by adult insects.

Until now, research on the neural circuits governing fighting, courtship, and mating behaviors in insects has primarily focused on *Drosophila melanogaster* as a model organism due to the availability of powerful genetic techniques. While insects other than *Drosophila* also exhibit fighting, courtship, and mating behaviors, the "brain mechanisms" (i.e., neural circuitry) controlling these behaviors have not been studied intensively in recent years.

In my laboratory, I use the two-spotted cricket (*Gryllus bimaculatus*) as an experimental model, which belong to a basal lineage of insects that undergo hemimetabolous development. Crickets exhibit fascinating social behaviors, such as communication through chirping and fierce fighting among adult males. Furthermore, because crickets do not have an inactive pupal stage, it is possible to analyze their brain development and behavioral acquisition continuously from nymphal to adult stages. We expect that neuroethological research using crickets will help us understand the brain mechanisms underlying the fascinating behaviors of a wide variety of insects.

Q. What is something you find mysterious right now?

Many of the social behaviors exhibited by adult insects, such as fighting, courtship, and mating, are deeply linked to leave better (more) offsprings. Consequently, these behaviors include many sex-specific elements. Neuroethological studies have suggested that sex-specific behaviors are controlled by the "sexually dimorphic circuits" exist in the brain.

Research on sexually dimorphic circuits in the insect brain has been active since around 2000, primarily in Japan, using *Drosophila melanogaster* as a research model. As a result, the molecular cascade controlling sex in the *Drosophila* brain has been elucidated, and significant advances have been made in understanding the neural circuits involved in sex differences in behavior. However, the question of whether the molecular cascade controlling sex in the *Drosophila* brain is a widely conserved sex-determination mechanism in insects remains unanswered.

As mentioned earlier, my laboratory conducts neuroethological research using crickets. In “chirping insects” such as crickets, males attract females through chirping. Additionally, the fierce fighting behavior of adult male crickets has influenced the Chinese gambling culture. Using these sex-specific behaviors as behavioral indicators, I have investigated whether the sex determination facotrs in the *Drosophila* brain contribute to sex differences in the cricket brain. My recent findings suggest that sex is determined by completely different molecular mechanisms in the *Drosophila* brain and the cricket brain.

Although the exact mechanism of the sex-determination cascade in the cricket brain has not yet been elucidated (this is currently one of the hottest research topics in my lab!), I am eager to clarify this mechanism. Following this, I aim to elucidate the evolution of the molecular mechanism controlling sex differences in the insect brain through molecular evolutionary studies considering the 500 million years of insect evolution and expansion.

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

“Neuroethology” is the study of behavior as a function of the nervous system. Classical neuroethological research was built on a combination of three research approaches: neuroanatomy to understand brain structure, neurophysiology to study the function of the brain and neural circuits, and behavioral physiology to understand the correspondence between behavior and neural activity. As neurogenetic methods become more widely used, especially in model organisms, these three research approaches can be seamlessly integrated. My lab aims to broaden the scope of neuroethological research by incorporating neurogenetic approach into studies on non-model organisms, such as crickets.

We now live in an era where genomic information is readily available for many organisms. This makes it easier than ever to compare and detect genome-level differences between species. Although behavioral differences between species can ultimately be attributed to genomic differences, understanding how genomic and gene-level differences produce behavioral differences is very challenging. To address this challenge, we must study the effects of differences in gene sequences on gene function (molecular evolution and biochemistry), the effects of these functions on cellular function (cell biology), and carefully elucidate how these effects influence brain function.

Using insects (crickets) as experimental models, my laboratory promotes research that integrates genetics, molecular evolution, biochemistry, and cell biology within the framework of classical neuroethological research. In the future, I believe that by advancing research using a similar approach in different animal species, we will be able to understand the evolution of behavior in detail from the perspective of brain and genome evolution.

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

Research is always fun. My research style involves working hard every day, which leads to small daily successes and advances. However, since our research involves living animals, it is very relaxing to observe the growth of the animals we are breeding. For example, we sometimes perform experiments where DNA is injected into fertilized eggs of crickets for gene transfer. I am happy when I confirm that the eggs injected with DNA have successfully hatched after about 10 days of embryonic development. It is fun to imagine what kind of experiments I will do when they grow up.

One of the difficulties is that I am doing research for which there is almost no previous research, so it is basically necessary to construct experimental methods by ourselves from scratch. When writing a paper, I am troubled that the chapters on materials and methods are inevitably heavy. Also, this is also related to the breeding of living animals, but I cannot let my guard down when it comes to breeding because if a disease appears, all my research will come to a halt (and if I am not careful, I will lose everything I have built up so far).

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

My laboratory is looking for motivated students who are willing to work together with us on “the soul of tiny insects.” We are always open to trial enrollments, so please contact us if you are interested.