A Fresh Hypothesis for The Development of Honeybee Brains

The evolution of higher brain functions and behaviors in the insect **Hymenoptera** order, researchers have put up a new concept. The scientists studied the **Kenyon cells**, a subset of **neuronal cells**, in the mushroom bodies of sophisticated honey bees and "primitive" sawflies, a region of the insect brain that is important in learning, memory, and sensory integration.

They discovered that in honey bee brains, three different, specialized Kenyon cell subtypes seem to have descended from a single, multifunctional Kenyon cell-subtype ancestor. This research may one day enable us to comprehend the development of some of our own higher brain processes and behaviors.

Are you a "**social butterfly**," "**busy as a bee**," or a "**fly on the wall**"? There are many instances where we draw parallels between our behavior and that of insects, and it turns out that these comparisons may be more than merely metaphors. We might be able to learn more about the behavior of highly evolved species, such as ourselves, as a result of studying insects.

It is challenging to pinpoint which behaviors, as well as neurological and genetic modifications, have co-evolved over time in mammals due to their large and complex brains. In contrast, insect brains are far more compact and straightforward, making them suitable study models.

Professor Takeo Kubo from the **Graduate School of Science** at the **University of Tokyo** and co-author of the current study published in Science Advances said, "In 2017, we reported that the complexity of **Kenyon cell (KC)** subtypes in mushroom bodies in insect brains increases with the behavioral diversification in Hymenoptera (a large and varied order of insects)."

In other words, an insect's brain and potential behaviors are more complicated the more KC subtypes it possesses. But we had no idea how these many subtypes had developed. That served as the impetus for this latest investigation.

The solitary turnip sawfly (which has one KC subtype) and the sophisticated, social honey bee (which has three KC subtypes) were the two Hymenoptera species selected by the team from the **University of Tokyo** and Japan's **National Agriculture & Food Research Organization (NARO)** as examples of various behaviors.

I was surprised that each of the three KC subtypes in the honey bee showed comparable similarity to the single KC type in the sawfly," said Assistant Professor Hiroki Kohno, a co-author from the Graduate School of Science. "We had previously assumed that additional KC subtypes had been added one by one based on our initial comparative examination of many genes. But it seems that functional segregation and specialization allowed them to diverge from a multifunctional ancestral kind.

The researchers were looking for a specific behavioral illustration of how sawfly and honey bee ancestral KC functions coexist. As a result, they trained sawflies to perform a typical honey bee behavior test in which they are educated to link an odor stimulus with a reward. Even though it was difficult initially, the team eventually succeeded in getting the sawflies to participate in the memory challenge.

The scientists then performed genetic manipulations on sawfly larvae of the **CaMKII gene**, which in honey bees is linked to the development of long-term memory, a KC function. The fact that the long-term memory of the larvae was compromised when they grew into adults suggests that the gene affects both sawflies and honey bees in a manner that is similar. In honey bees, CaMKII was preferentially expressed in just one KC subtype, despite the fact that it was expressed (i.e., active) across the entire single KC subtype in sawflies. This shows that the specific KC subtype in the honey bee received the function of CaMKII in long-term memory.

Insect and mammalian brains differ in size and complexity, but they have similarities in terms of function and the fundamental design of the nervous system. The idea put forward in this work for the diversification and evolution of KC subtypes may therefore contribute to a better understanding of the development of our own behavior. The team is also interested in researching KC kinds that develop concurrently with social behaviors like the "**waggle dance**" of honeybees.

Takayoshi Kuwabara, a PhD student and the lead author from the **Graduate School of Science**, said, "**We would like to clarify whether the model presented here is applicable to the evolution of other behaviors.**" "There are numerous unanswered questions regarding the neurological underpinnings of social behavior, whether in humans, animals, or insects. Its evolution is still largely a mystery. I think this study is a ground-breaking contribution to the field.

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