World's first genetically modified ants shed light on how complex insect societies evolved

By Elizabeth Pennisi

http://www.sciencemag.org/news/2017/03/world-s-first-genetically-modified-ants-shed-light-how-complex-insect-societies-evolved

Mar. 8, 2017 , 10:15 AM

Every ant colony is a marvel of cooperation, where each ant goes about her appointed tasks in such close concert with her sisters that a colony is sometimes called a "superorganism." Now, a new study on the world's first genetically modified ants finds that ants' sociality depends on their sense of smell. The finding provides key clues to how social behavior evolved in these insects.

"This is a real breakthrough in experimental sociobiology," says Bert Hölldobler, a behavioral biologist at Arizona State University in Tempe who was not involved with the work. Before this, no one had succeeded in genetically modifying ants for study.

Biologists as far back as Charles Darwin have been fascinated by the evolution of social behavior, in which organisms as different as ants and people form cohesive groups that work together and, sometimes, let one or few individuals do all the reproducing. Studies of honey bees have provided tantalizing hints of what genes might be involved in that insect's sociality, but pinning down the functions of those genes in bees and other insects like ants has been difficult. That's because researchers had no good way to disrupt genes of interest—the way they can easily do in mice—or even to ferret out the exact genes involved.

Social insects are especially hard to genetically modify. Even if scientists can modify the genome of an individual, "the eggs of ants are very sensitive and difficult to raise without workers," so it's hard to get a genetically modified egg to survive, explains Laurent Keller, an evolutionary biologist at the University of Lausanne in Switzerland. Also, the life cycle of social insects is complicated and drawn out, making it difficult to obtain large quantities of genetically modified offspring in a reasonable time frame.

So Daniel Kronauer, an evolutionary biologist at The Rockefeller University in New York City turned to a species called clonal raider ants (*Ooceraea biroi*). Unlike other insects, these stocky invasive ants—about as long as a U.S. nickel is thick—lack queens in their colonies; instead each one lays unfertilized eggs that develop as clones. That means that once researchers modify an individual ant's genome, they can quickly breed a genetically modified strain. "For the vast majority of ant species, doing real genetics is basically impossible," because of the complications of dealing with eggs and larvae and that it can take years to get a genetically modified strain going, says Kronauer, but because these ants are clones, "this species allows us to take shortcuts."

To modify the raider ants' genes, Kronauer's graduate student Waring Trible and Leonora Olivos-Cisneros, a research assistant, turned to CRISPR, a gene-editing technique that makes altering genes much easier than before. Still, the odds were against them.

Over 2 years, the researchers learned that existing eggs give off a chemical that inhibits other adults from egg-laying. Once the scientists discovered that, they were able to isolate ants, synchronize egg production, and get the numbers they needed. But it took 10,000 tries to develop the right touch to not damage the eggs while taping them to slides, injecting them with genetic material, and raising them to hatching. Then it took months to learn how to put the newly hatched young back into an ant colony and get the ants there to take care of them. The secret: Put the larvae in groups of 10.

For most animals, including mice, producing one individual with a modified genome is just the first step, as it can take many generations to ensure all offspring carry the modification. In social insects, those steps can take months, if not years. But because these raider ants are clonal, Trible was able to easily test the first offspring for any effects.

Trible disrupted a gene called *orco*, which produces a protein essential to the function of specialized odor-sensing nerve cells in an ant's antennae. Those cells, called odorant receptors, are one of several kinds of sensors that detect chemicals called pheromones that ants and other animals use to communicate. Ants have many more odorant receptors than most other insects—at least 350 compared with the fruit fly's 46, whereas the number of other kinds of sensors is about the same as other insects. So Kronauer wondered whether this expansion had made the ants' complex social system possible.

The behavior and brain anatomy of the transgenic ants suggest that, indeed, the expansion in the number of odorant receptors played a role. Young adult ants—which are light colored—tend to spend their first month motionless with their nest-mates. But the young transgenic ants had "ants in their pants" so to speak, and immediately started wandering around, the team reported last week in bioRxiv. "To see these baby ants running around is just utterly bizarre," Trible says. The transgenic ants also failed to follow trails laid down by other ants. Both sticking together and following trails are behaviors that keep a colony cohesive and working together.

These ants were at a long-term disadvantage as well. Clonal raider ants typically lay six eggs every 2 weeks, whereas the transgenics laid only about one egg in that time period. And the transgenics tended to die within 2 to 3 months, instead of the usual 6 to 8 months.

Even more surprising was the effect the genetic modification had on the brain. There the nerve endings of each type of odorant receptor meet up in clusters called glomeruli. When other researchers knocked out the *orca* gene in fruit flies, their glomeruli were unaffected. But in the ants, the glomeruli never formed. That's just what happens to the equivalent part of the brain in mice when similar genes are knocked out.

This was "the real eye-opening result," says Gene Robinson, a behavioral genomics researcher at the University of Illinois in Champaign who was not involved with the work. "It provides the opportunity to be comparing and contrasting brain development" in different species. Such comparisons could be important for assessing how brains evolve to manage the complex behaviors seen in social animals, another key aspect of the evolution of sociality in ants and other species.

DOI: 10.1126/science.aal0880