Asexual reproduction usually leads to a lack of genetic diversity. Not for these ants

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Clonal raider ants tend to their larvae. Credit: Kronauer Lab

Genetic diversity is essential to the survival of a species. It's easy enough to maintain if a species reproduces sexually; an egg and a sperm combine genetic material from two creatures into one, forming a genomically robust offspring with two distinct versions of the species' genome.

Without that combination of different genetic makeups, asexually reproducing species typically suffer from a lack of diversity that can doom them to a limited run on Earth. One such animal should be the clonal raider ant, which produces daughter after genetically identical daughter directly from an unfertilized ovum through parthenogenesis, a method of asexual reproduction in which the offspring inherits two sets of genetically identical chromosomes from its mother.

Over time, the random inheritance of these chromosomes on endless repeat should lead to catastrophic loss of genetic distinctiveness and eventual species collapse. And yet this blind, queenless insect—a native of Bangladesh that is now found in tropical settings around the world—seems to be surviving just fine. How is that possible?

As researchers at Rockefeller University recently discovered, the clonal raider ant doesn't gamble when it comes to passing along its genes. Instead, it ensures that offspring inherit two distinct versions of its entire genome, largely preserving the genetic diversity present in the ancient founder of each clonal line.

In theory, this shouldn't work: Chromosomes are thought to randomly shuffle during meiosis, the type of cell division used to produce sperm and egg cells during reproduction in all animals, plants, and fungi. Yet in this animal, the process seems to be anything but random, as they reported in *Nature Ecology & Evolution*.

"We think we've discovered how clonal raider ants are avoiding the loss of genetic diversity that otherwise routinely results from parthenogenesis," says first author Kip Lacy, a graduate fellow in the Laboratory of Social Evolution and Behavior, led by Daniel Kronauer. "Maybe this diversity enables the survival of the species."

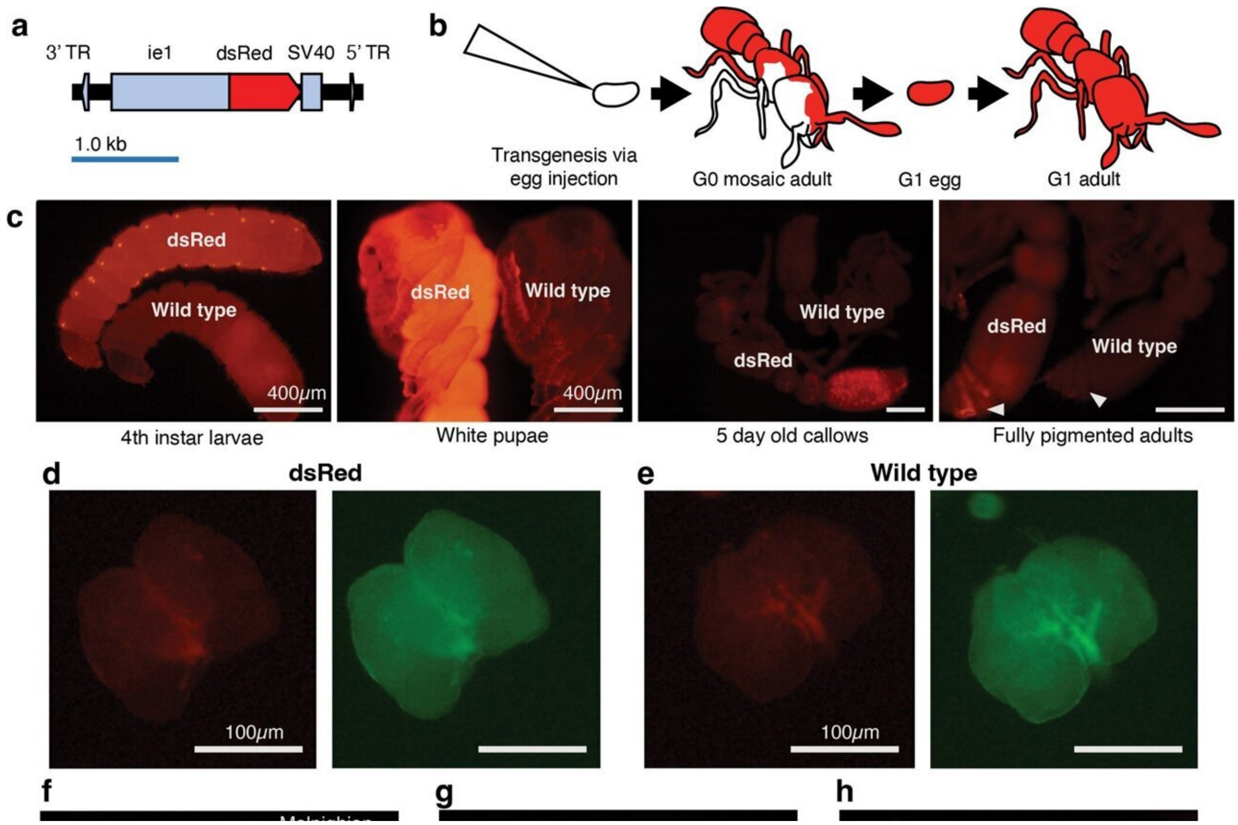
Asexual conundrums

Parthenogenetic species are rare but found among a variety of life, including reptiles, amphibians, nematodes, fish, and birds. Their chances of long-term existence are slim. "Purely asexual species tend to go extinct pretty fast," Lacy says.

"Reproducing clonally is kind of a one-way street to deterioration," adds Kronauer. "Every time there's a mildly deleterious mutation, you can't purge it from the genome, which is just going to accumulate more mutations over time."

The problem starts with two challenges that asexual species must overcome at the cellular level. The first is that they need to make diploid genomes, which contain two sets of chromosomes, to pass on to their offspring.

"But if you're a clonal raider ant," Lacy points out, "there is no sperm involved in reproduction, so where are you going to get an extra set of chromosomes?"



Generating the transgenic line. Credit: *Nature Ecology & Evolution* (2024). DOI: 10.1038/s41559-024-02455-z

The second is that the offspring must have a genetic makeup that is compatible with development and reproduction—which many asexual species, saddled with two sets of genetically identical chromosomes, lack.

Lacy became interested in parthenogenesis during his Master's degree studies at the University of Georgia while studying the tropical fire ant, some colonies of which asexually produce queens. As he discovered, these ants had almost completely lost their genetic diversity. When he joined Kronauer's lab in 2019, he sought to find out how the clonal raider ant may avoid such pitfalls.

Mothers and daughters

During meiosis, chromosomes break apart and recombine, resulting in new combinations of gene copies. After these so-called crossover events occur, chromosomes are randomly shuffled through cell divisions.

In parthenogenetic reproduction, a clonal line draws from two identical chromosomal sets, "so you expect to lose a lot of diversity during each cycle," says Kronauer. It's akin to watering down the genetic soup.

To understand how this may not be true for clonal raider ants, the researchers focused on mother-daughter and sister-sister pairs of ants. To make sure they had true family duos, they tracked transgenic ants that fluoresce red when viewed through a microscope—a breakthrough method of genetic manipulation developed in Kronauer's lab by researcher Taylor Hart. These pairs were the only animals in their colonies to glow.

Using linked-read genetic sequencing—which allows the reconstruction of whole chromosome sequences—they found that no genetic diversity was lost from mother to daughter. However, the daughter's genomes showed evidence of crossovers. In all, they documented 144 crossover events, and only one showed a loss of genetic diversity.

"That's because the chromosomes that have recombined with each other are always inherited together," Lacy says. "This co-inheritance could explain how this species continues to survive. In clonal raider ants, it's 800% more likely to occur than would be expected from a random roll of the genetic dice."

A new tactic

This strategy for retaining genetic diversity has never been documented before, according to Kronauer. Its existence suggests there may be more ways to get around random genetic inheritance than we knew. One well-known deviation from random inheritance, for example, is when "selfish" genes promote their own propagation over other genes, essentially rigging the game in their favor.

But this deviation can't account for clonal raider ant reproduction, which is "unselfish" because no gene has an advantage; all gene copies are co-inherited. Whether this strategy of unselfish inheritance occurs in other animals—including sexually reproducing species—is unknown.

This finding highlights the usefulness of studying species with unusual reproductive biology, Lacy says, "If we hadn't studied these asexual ants, we might never have learned about this mode of reproduction."

More information: Kip D. Lacy et al, Co-inheritance of recombined chromatids maintains heterozygosity in a parthenogenetic ant, *Nature Ecology & Evolution* (2024). DOI: 10.1038/s41559-024-02455-z

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