Ants, Mushroom and Mold: An Evolutionary Arms Race

By NICHOLAS WADE

One of the most remarkable examples of symbiosis, the interdependence of different species, involves a tropical ant called the attine, or leaf-cutter. The ants grow a mushroomlike fungus in vast underground gardens, and they protect the fungus against a devastating mold with antibiotics produced by a bacterium that lives in a patch on their skin.

This ménage à quatre — the ant, the mushroom, the bacterium and the mold — form a stable association that has evolutionary biologists scratching their heads. The interplay of the four species seems to be the most complex symbiosis known.

Now the puzzle has grown more challenging with a report in the journal Science that suggests that the mold has been part of the system for a long time and, perhaps, accompanied the mushroom fungus that the ants first domesticated some 50 million years ago. Like original sin, the pathogen was in the first garden.

Also like original sin, the puzzle has to do with sex, though in this case the lack of it. Biologists have long been perplexed to understand why organisms go to the bother of sex, when by far the best way to get all one's genes into the next generation is by virgin birth or asexual reproduction (as any stick insect can testify). Sex passes on only half an individual's genes, so what could possibly be worth paying such a price?

The biologist Dr. William D. Hamilton, who died in 2000, suggested that the answer was parasites. They are usually small creatures like bacteria or molds that can evolve faster than their large-bodied hosts can devise defense mechanisms. The hosts keep one step ahead by resorting to sex — the purpose of which may be to reshuffle the genes between generations and produce new combinations faster than the parasite can mutate.

The ants, however, do not allow their crop plant to form fruiting bodies, which is how fungi have sex. Each queen ant takes a sample to start a new nest, so the fungus is spread vegetatively. Recently, biologists analyzed the DNA of mushroom fungi from attine ant gardens in many countries and found that all belonged to a single clone, presumably dating from 50 million years ago, the first and only time when the attine ants domesticated the fungus.

At the time of that research, in 1994, the ants and their mushroom fungus were the only two members of the symbiosis known. Cameron R. Currie, then a graduate student at the University of Toronto, felt sure that a clonal monoculture, especially one so widespread as that of the ants’ fungus gardens, had to be highly vulnerable to parasites, even though none had been found by generations of ant biologists.

His intuition was right. He discovered the Escovopsis mold, which can wipe out a whole garden in a couple of days, and the antibiotic-producing bacterium that the ants use to keep it in check.
In his article in the current Science, Dr. Currie, now at the University of Kansas, and colleagues report they have analyzed the DNA of Escovopsis molds from ant fungus gardens in many different countries.

They find that all the molds that attack attine ant gardens are sprigs of the same family tree, indicating a single origin in the distant past. Escovopsis is found just in the ants' fungus gardens, but it is related to the dreaded “green mold” that is well known to commercial mushroom farmers.

Is Escovopsis also a clone? Does the symbiosis between mold and mushroom work because this is a true battle of the clones, each mutating too slowly to overwhelm the other? Dr. Currie said he had not yet found Escovopsis in a sexual stage and did not know whether it was a clone. His guess is that it is not.

But if Escovopsis is sexual and can evolve quickly, then how does the fungus stay one step ahead of its deadly pursuer? Dr. Douglas Futuyma of the University of Michigan suggested that the antibiotic-producing bacterium might hold the key to the puzzle. The mushroom has been forced to quit the sexual race, but it could have handed over its evolutionary defense to the bacterium, as deployed by the ants.

"The bacterium is a major player," Dr. Futuyma said. "Bacteria do have a certain amount of sex and can evolve very rapidly."

Dr. Currie and his colleagues said they believed that an evolutionary arms race had occurred between the mold on one side and the fungus, the ant and the bacterium on the other. The ants could play an important role because they are known to remove assiduously all foreign microbes from their gardens and will abandon a garden with any uncontrollable strain of Escovopsis. When an Escovopsis strain begins to escape the ants’ control, the bacteria may be able to evolve a new brew of antibiotics to even the balance.

Dr. Currie said he hoped to complete in six months the genetic family tree of bacteria from different species of attine ants and would start to analyze their antibiotics. That may take him to a real battlefront, the chemicals produced by the bacteria and the mold’s countermeasures.

In nature’s impassive eyes, this may be just a protracted chess game among four species. But except for those who side with molds and microbes, it is hard not to admire the ant’s achievements. They developed two remarkable inventions — agriculture and antibiotics — some 50 million years before people did.

Beyond that, they have learned how to handle technologies more skillfully than the bumbling civilization above their heads. They can grow a monoculture — a genetically homogeneous crop, something that in human hands generally leads to disasters like the Irish potato famine — and they have also learned how to deploy an antibiotic without the target pest’s becoming resistant to it.

Dr. Currie and his colleagues have uncovered the intricacy of the mechanism but know that they are still a long way from understanding it.

"Every step along the way," he said, "there are more questions and new directions."