ECOLOGY

Meet the New Boss, Same as the Old Boss

A chemical defense helps an invasive ant species to outcompete an earlier invader that originates from the same native region.

Michael Kaspari and Michael D. Weiser

In Nature's marketplace, there are many ways to compete. Most species carve out a niche where they are particularly effective at turning resources into offspring. Others play a more dangerous game: They win not by outcompeting their adversaries but by killing them. Sometimes this is as simple as applying a little poison. On page 1014 of this issue, LeBrun *et al*. (*1*) reveal how the tawny crazy ant (*Nylanderia fulva*), newly arrived to the United States from South America, may be ending the more than 60-year reign of the red imported fire ant (*Solenopsis invicta*), a competitor armed with a powerful alkaloid venom. The crazy ant's secret? It knows the antidote.

The tawny crazy ant was transported in the early 1980s to the southeastern United States from the savannas of South America (*2*). It is not choosy where it nests; colonies can be found "under or within almost any object or void, including stumps, soil, concrete, rocks [and] potted plants" (*3*). Erratic carpets of tawny crazy ants can be found in the lawns of Houston, Texas. It is replacing native invertebrates, including native ants (*2*), in grasslands and river bottoms. Along the way, tawny crazy ants are doing something rather remarkable. They are battling and, in many cases, wiping out an invasive ant notorious among three generations of U.S. southerners: the red imported fire ant. Crazy ants even take over fire ant nests. One key to the crazy ant's success lies in its ability to detoxify the fire ant's potent and painful alkaloid venom.

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Toxins are often used by predators (e.g., spiders and vipers) and by potential prey aiming to deter predators (e.g., monarch butterflies and lionfish). However, the use of poisons to reduce the fitness of competitors—known as antibiosis by microbial ecologists and as allelopathy by botanists—is rarely observed in animals. This is partly a result of the ways in which poisons work. First, poisons work best when they stay where you put them (*4*): You don't spray mace into a headwind, and soil bacteria are more likely to try antibiosis than their aquatic counterparts (*5*). Ants have evolved a diversity of structures that dab, squirt, and otherwise target venom. Second, poisons must be kept away from the rapidly developing embryos that yield future generations (*6*). Ants can overcome this second constraint because their colonies, like those of the red imported fire ant, are superorganisms. The colony's functioning eggs, sperm, and larvae remain back at the nest with the queen(s), leaving sterile workers free to wreak chemical havoc on the edges of their territories. The red imported fire ant's powerful chemical mace has been a key reason for its successful spread through the southeastern United States (*7*).

The fire ant's toxin tends to deter most North American ants—but not, apparently, the crazy ant. When fire ants find a morsel like a dead cricket, some workers begin to carve it up and bring the pieces back to the nest. Others surround the cricket and "gaster flag": They raise their abdomens, extrude a drop of alkaloid venom from the stinger, and splatter or dab it on anything within reach. This venom cocktail, which burns and raises pustules when injected into humans, is a potent contact poison for insects (*7*). Most other ants stay away from gaster flagging fire ants. The risk of death by venom detracts from the benefit of the food. Yet, crazy ants charge into the defensive ring, spraying a mist of pungent formic acid. What keeps this battle from devolving to a simple war of attrition?

First, and a bad omen for the fire ants, both species coexist in the same South American habitats, where crazy ants regularly outcom-

When old foes meet again. (**A**) An imported fire ant dispenses venom from its stinger in the direction of a tawny crazy ant. (**B**) A tawny crazy ant, standing on a cricket's leg, detoxifies after conflict with an imported fire ant.

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pete fire ants (*8*). A fire ant, when drenched with formic acid, has no apparent defense and falls over dead (*9*). In contrast, the crazy ant, when dabbed with fire ant venom, will use its own weapon as its ultimate defense: It rinses itself clean with its own formic acid. LeBrun *et al*. show that 98% of crazy ants survive fire ant venom; when they are experimentally denied access to their formic acid, survival drops to 48%. Moreover, when crazy ants competed against eight Texas ant species, each of which uses some form of chemical defense, the red imported fire ant triggered seven times more application of formic acid.

The authors hypothesize that formic acid rinses are an adaptive trait in crazy ants, evolved in its native range and employed when the two old foes are reunited. But formic acid rinses don't seal the crazy ant's advantage. Forty years ago, Bhatkar *et al*. (*9*) found that the lowly lawn ant *Lasius neoniger* (which also produces formic acid) can groom away a dose of fire ant poison; it just loses a chemical war of attrition to the more populous colonies of the fire ant. Crazy ants can achieve worker densities that are 100 times as high as those of species in the invaded habitat (*2*). Its antidote gives it the edge.

Biological control efforts often build on the premise that successful invasive species have escaped the parasites and predators of their native ecosystem (*10*). LeBrun *et al.* make a strong case that the red imported fire ant owes its long ride in the American South to its escape from a competitor. The crazy ant may be the fourth in a sequence of ant species that have hit the American Gulf Coast in the past century, each replacing the preceding as common and pernicious (*2*).

Given their ubiquity and impact (*10*), invasive ant species are model ecological systems for studying the many factors that regulate populations. As successive invasions reconstruct the population interactions of a South American ant community in South Texas, a logical next step is to search for the crazy ant's Achilles heel. One fruitful avenue may lie in evolutionary games of rock-paper-scissors (*4*), where round robins of toxins and antidotes make the competitor of your competitor your friend. A more basic puzzle in our homogenizing world is why some—or perhaps all—disruptive invasions eventually crash (*7*, *11*).

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MATERIALS SCIENCE

The Surface Mobility of Glasses

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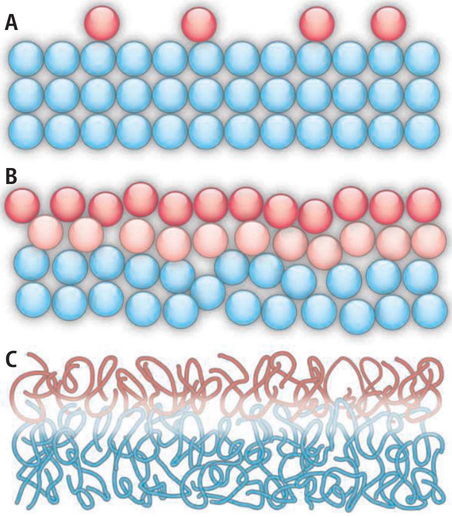
Surface diffusion on frozen polymer glasses is influenced by the surface dynamics of the glass itself.

The diffusion of atoms and molecules on a crystal surface plays an important role in myriad applications including thin-film deposition, sintering, and heterogeneous catalysis (*1*, *2*). Surface diffusion is frequently observed at temperatures appreciably below the crystal's melting point, implying a role for enhanced surface mobility in the process. However, understanding the dynamics of surface diffusion in glasses is a research area still in its infancy. On page 994 of this issue, Chai *et al*. (*3*) present an experimental technique that enables detailed quantification of the near-surface mobility of glasses.

Although enhanced surface mobility was found by Chai *et al*. as well as by others in small-molecule and polymer glasses (*4*–*7*), there is a noteworthy distinction between these and the analogous observations in crystals. In crystals, the substrate surface is frequently much less mobile than the surface atoms or molecules (see the figure, panel A). In glasses, however, the first or several surface monolayers are molten even below the glass transition temperature T_g (where the glass freezes), and the change in dynamics from the surface is gradual (see the figure, panels B and C). The reason for such a difference may be that the temperatures commonly used in studies of glass surfaces are close to T_g. This proximity in temperature is attributable to a broad interest in connecting enhanced surface mobility, if present, with the anomalous T_g reduction observed in polymer films (*8*) and, more recently, fast organic crystal growth and the formation of ultrastable glasses (*7*).



Moving along. Mobile adatoms on a crystal surface (**A**) and their counterparts in the surface mobile layer of an organic glass (**B**) and a polymer glass (**C**). The mobile species are shown in red; the less mobile bulk-like species are in blue.

Computer simulations have consistently revealed the presence of a surface mobile layer in glasses (*9*). Experimental verification has been made only recently. In one method, the relaxation time for the flattening of nano-dimples created on a polymer surface was measured (*4*). In another, polymer films were doped with fluorescent molecules whose dynamics are tied to those of the polymer (*6*); the relaxation time and relative population of the component exhibiting faster dynamics were measured. However, it is generally not straightforward to relate these relaxation times to familiar transport measures such as mobility or diffusivity. Typically, the mobility is determined by monitor-

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