a human cDNA sequence in their database similar to bacterial *MutL*. In December, they called J. Craig Venter, TIGR's director, and asked him if he had identified any such candidates. "Within a few minutes of checking," says Kinzler, "they told us that they had three such genes." The cDNA fragment tagged by the computer as the closest match to *MutL*, as it happened, mapped to chromosome 3, position 21. Further analysis revealed the complete gene: *hMLH1*.

The paths of the two groups again converged for the final task: proving that families afflicted with HNPCC consistently had mutations in *hMLH1*. To do so, both teams turned to genetic samples from families previously identified as likely to harbor an HNPCC gene at chomosome 3. And both teams found mutations in *hMLH1*.

The precise functions of these genes on the human repair pathway haven't been worked out, but they do show similarities to their bacterial analogs (see diagram p. 1559). The human gene discovered in December, *hMSH2*, works much like its bacterial equivalent *MutS*—by initially spotting mismatched nucleotides, says Kolodner. If that's the case, it seems logical that *hMLH1* would act like *MutL*, which grabs on to *MutS* and orchestrates the other repair proteins. But no work with the human system yet supports this inference. Nor have scientists charted the entire pathway, for 10% of HNPCC cases are not accounted for by the two known genes—suggesting that at least a third gene and its product are at work. (Indeed, both teams have identified at least one gene as a likely candidate.)

Clearer than the specific mechanism at this point is the speed with which cDNA sequencing produced results. "[The Hopkins-TIGR-HGS study] provides a wake-up call to the future value of the databases that will hold cDNA sequences," says Jefferey Trent, chief of the Laboratory for Cancer Genetics at the National Center for Human Genome Research. "The reason is very simple," adds Vogelstein. "If TIGR or HGS has the gene already, it takes essentially 5 minutes to get this gene, whereas it could take months with the traditional approach." Though Kolodner notes that traditional gene hunters are keeping pace for now, he confesses he's considered the cDNA approach for finding additional human mismatch repair enzymes. "The potential of those databases wasn't lost on us," he says.

Still, many researchers are concerned about work done with the cDNA database because of its effect on research collaborations. The databases belong to private organizations, worries Francis Collins, the director of the National Center for Human Genome Research at the National Institutes of Health, which could keep much of the information out of the public domain. "I'd be a little more relieved if all this work was going to be made available to the scientific community," says Collins (*Science*, 11 October 1991, p. 184). Venter insists that TIGR's work on a large number of sequences will be made public by October. HGS, however, only allows academic researchers access to their libraries if they sign an agreement to give HGS first crack at commercializing any meaningful results; Vogelstein has just signed such an agreement.

One other issue raised by the elucidation of this housekeeping pathway is whether scientists now know enough about it to develop a screening test for HNPCC. Accurate tests require the ability to spot all the different mutations to these genes that cause the disease. At this point, "we have to know a lot more about the spectrum of mutations in these genes," says Collins. But with the repair pathway nearly characterized, the next race—to identify that mutation spectrum—is already well under way.

–Robert F. Service

CONSERVATION BIOLOGY

Fire Ants Parlay Their Queens Into a Threat to Biodiversity


SANFORD D. PORTER

In 1942, an entomologically minded teenager named Edward Wilson spotted some strange ants in a vacant lot near his home in the port city of Mobile, Alabama. They were tiny red things (like the one above) swarming about a conical mound almost a foot high; when threatened, they attacked en masse, stinging repeatedly and painfully. Wilson, now a distinguished entomologist at Harvard, still thinks back to that day with regret. "I am always wishing," he says, "that I had rushed to City Hall in my Boy Scout uniform and told them to wipe out the ants on that lot."

Wilson had made the first recorded observation of the red imported Argentine fire ant, *Solenopsis invicta*—an accidentally introduced species that has become famous as a catastrophic example of what can happen when organisms from one ecosystem are released in another. Within two decades, the ants on that lot spread through the South, hitching rides on sod and nursery shipments. Because this furiously active predator can make outdoor life difficult—even killing small pets—the federal government launched a massive eradication program in 1957. It failed. Today *S. invicta* has invaded territory from southern Virginia to central Texas, and many entomologists believe its appearance in California is only a matter of time.

Southerners long since concluded they have to live with a permanent nuisance, but that may change. Fire ants are spreading in a new, more virulent form that lives in such remarkably high densities it could inflict untold harm on entire ecosystems. Meanwhile, the long-dormant federal fire ant program has begun to gear up for a new round of combat, replacing old chemical weapons with modern armaments of biological control—natural pathogens, parasites, and predators. "Nobody has ever tried biological control on a social insect before," says Walter R. Tschinkel, an entomologist at Florida State University. "If it works, it would be really exciting. More than that, it better work, because the [new form of fire] ants may really be something to worry about."

One of about 20 fire ant species in the New World, *S. invicta* spreads like a weed. Mature queens are 70% ovary and can lay 5000 eggs a day. Their offspring, the workers, forage through a network of tunnels that may extend 50 feet from the central mound. Most ant species have a few hundred workers in a colony; *S. invicta* can have up to half a million—which is why they seem to be everywhere in affected areas.

The ants Wilson saw were territorial and "monogyne"—that is, each colony had a single egg-laying queen. In the 1980s, however, fire ants increasingly appeared in a nonterritorial, "polygyne" form, which creates interconnected "super-colonies" that may have scores of egg-laying queens. "There are places now around Austin [a polygyne center] where you can almost hop from one mound to another like a frog on a lily pond," says Sanford D. Porter, an entomologist at the Insects Affecting Man and Animals Research Laboratory, an Agriculture Department facility in Gainesville, Florida. "You'd better hop lightly, of course."

Genetically, the two forms seem indistinguishable, and nobody knows why the transition occurred. Small polygyne colonies appeared in Mississippi in the late 1970s, later others popped up in Louisiana, Florida, Georgia, and Alabama. Today they dominate Texas and may be ready to spread throughout the South. As a result, entomologists believe, the fire ant is transforming itself from an annoyance into a serious ecological problem. The reason is that polygyne super-colonies increase fire ant densities, already extremely high, by up to a fac-

tor of 10. The polygyne form exists as "a kind of sheet of fire ants through the earth," says David F. Williams of the Medical and Veterinary Entomology Research Lab at the USDA Agricultural Research Service in Gainesville, Florida. "When you've got 500 to 600 fire ant mounds to the acre," he says, "there's not too much area for anything else. They take over completely."

SANFORD D. PORTER

Holding court. Multiple queens in a polygyne fire ant nest.

With Dolores A. Savignano, now at the U.S. Fish and Wildlife Service office in Hadley, Massachusetts, Porter measured the effects of a polygyne invasion at the Brackenridge Field Laboratory, a 70-acre tract owned by the University of Texas. The ants moved in an unsteady line across the country, advancing a few hundred feet a year. When they came into an area, the number of other ant species there fell by 70%; the number of arthropod species—insects, spiders, ticks, and so on—dropped by 40%. "The fire ants just seem to have outcompeted everything else," Porter says. "The monogyne form is a nuisance to people, but the polygyne form may pose a significant threat to biodiversity."

Even before this new form appeared, however, fire ants prospered in spite of what is arguably the largest insect-control program ever mounted in the United States. At its peak in the 1960s, the fire ant program employed a fleet of converted Second World War bombers to douse entire counties with a potent cocktail of soybean oil (an ant bait), ground corncobs (as the bait carrier), and mirex (an ant poison). "It was the Vietnam of entomology," Wilson says. "And it was about as successful."

S. BRADLEIGH VINSON

Zounds! Mounds! A Texas pasture infested by polygyne fire ants, which can build as many as 500 to 600 mounds per acre.

In fact, many entomologists believe the campaign may have helped spread fire ants, rather than controlling them. *S. invicta* is native to the flood plain of the Paraguay River on the southwestern border of Brazil. Over the millennia, it has been victimized by frequent, devastating floods. As a result, the species has evolved to recover quickly from disaster. Surviving colonies produce thousands of sexual ants, which fly and mate on nuptial flights. The females land and begin new colonies, thousands alighting on every acre to battle for space. (Polygyne ants do not create new colonies this way; rather, their colonies "bud" by trundling queens to a new site nearby.)

Rather than exploiting the fire ant's weakness, Tschinkel argues, the mirex program inadvertently played to the ant's strengths. Spraying powerful ant-killer destroyed all native ants, which were the chief barriers to the spread of the fire ant. When the poison washed away, the land—from a fire ant's point of view—was open for recolonization, as if it had just been flooded. All competition removed, *S. invicta* quickly took over. "It's quite likely," Tschinkel says, "that fire ant control programs made the world safe for fire ants."

Although the impact of the fire ant campaign remains subject to dispute, few disagree that mirex damaged the environment. Studies showed that it had toxic effects on crabs, catfish, crayfish, mice, rats, chickens, starlings, and other organisms. The Environmental Protection Agency banned mirex in 1971, though it reinstated the compound for some stiffly regulated uses a year later. In general, Uncle Sam conceded defeat—the fire ant seemed here to stay, and the control program languished in the bureaucratic limbo reserved for the ecologically incorrect.

Now, Tschinkel says, the fire ant program may be "rejuvenated." Although no new initiative has been formally proposed, Williams says the outlines of a new program are clear. It will not resemble the mirex orgies of the past. Instead, the program will be a "three-legged stool": occasional use of mirex, educational efforts, and biological control, attacking pests with their natural enemies. On its native turf, *S. invicta* is not usually a problem, because the ant is preyed on by up to 50 other organisms. These enemies, says Porter, are "like a 10% to 20% tax on their growth and survivability. If we can introduce those enemies here, we may be able to tip the balance enough to give native ants a chance to fight back."

According to Williams, research into the biological armamentarium is concentrating on three organisms, of which the most promising may be *Thelohania solenopsae*, a protozoan parasite. Found in Argentina, it has been known to kill as many as two-thirds of the *S. invicta* in a colony. "Our efforts are really gearing toward the *Thelohania*," he says. "Of course the trick will be to learn what else it does. If it also kills native ants, we'll be no better off." Initial tests are being conducted at a laboratory in Argentina.

Less microscopic are phorid flies, a set of species in the genus *Pseudateon* that prey exclusively on fire ants. The flies hover over foraging workers, seeking to lay eggs behind their heads. "Workers actually peel off the trails and try to hide," Williams says. "The idea behind this is that it disrupts their ability to forage—the workers won't go out when the phorid flies are around." Porter has worked with the flies for several years, but has found them difficult to rear in captivity. If the problem is solved, he says, they may be test-released "in a couple of years."

The third and most distant prospect is *Solenopsis daugerri*, a parasitic ant. Once introduced into the fire ant nest, *S. daugerri* directly attacks the queen, clamping onto her antenna, legs, or thorax. "You'd think the [fire ant] workers would rip them to pieces," says Williams. "But they don't, because the parasite mimics the queen's pheromones"—the chemical recognition signals insects use to communicate. The hornswoggled workers then devote their efforts to feeding the parasites, half a dozen of which might yoke the queen. Eventually the queen starves to death in full view of the workers who serve her.

Although a great deal of basic biology remains to be done—"we don't even know yet how *daugerri* gets into the nest," Williams says—the prospect of worker fire ants happily starving their queen to death is sure to bring a smile to the millions of people who have experienced the nasty sting of *S. invicta*. More than that, says Wilson, controlling fire ants may be necessary to avert a small-scale catastrophe for insect biodiversity in the South. "We don't know the consequences of letting this predator wipe out arthropod diversity, at least locally, in an entire region," he says. "But it is hard to imagine that they could be good."

–Charles C. Mann

Charles C. Mann is a writer who lives in western Massachusetts.