

ENTOMOLOGY

Getting the Behavior of Social Insects to Compute

By envisioning ant colonies as computer networks, entomologists have begun to unravel complex behavioral patterns

CAMBRIDGE, U.K.—In a recent AT&T commercial, blue ants scurry through a maze and across a chasm in pursuit of an unknown goal. Only when the cartoon “camera” zooms out does the bigger picture come into view: The streams of ant traffic are forming the familiar lines of AT&T’s logo. These fictitious bugs are a tongue-in-cheek illustration of how global order can emerge from what appears to be local chaos—a concept that computer programmers have been cribbing from insect behavior for years to make networks run more efficiently. For example, in a routing program called Ant Colony Optimization, virtual ants lay pheromone trails to direct the flow of data packets without cumbersome central planning.

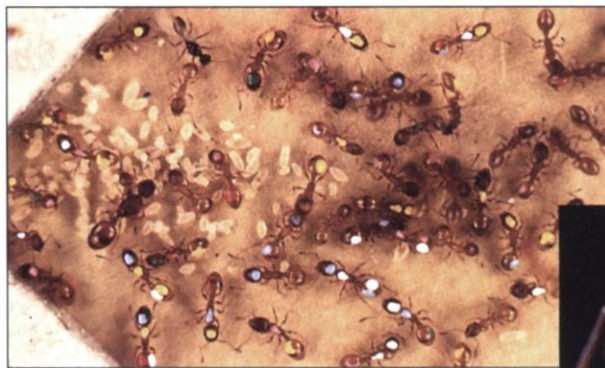
Now, reversing roles, a handful of entomologists are cribbing from the computer scientists. They deconstruct many behavioral patterns of social insects and show how these operate much like computer algorithms. “It’s not a superficial resemblance,” says Tom Seeley, who studies bee communication at Cornell University in Ithaca, New York.

For decades, entomologists have known that insect colonies are capable of complex collective action, even though individuals adhere to straightforward routines. When foraging, for example, workers appear to march to a drumbeat that dictates when to turn and when to lay down pheromone to guide other workers. As simple as these rules are, they create an effective dragnet to haul in food as efficiently as possible. In this manner, “ants have been solving problems very skillfully every day of their lives for the last 100 million years,” says Nigel Franks of the University of Bristol, U.K. But it’s harder to fathom the roots of more complex problem solving, such as group decisions made without central planning or the management of complicated traffic patterns. To tackle such problems, researchers are redefining their work as a search for evolution’s source code.

Franks was among the first entomologists who turned to computer science for fresh ideas. Beginning in 1990, his work with Chris Tofts, now at Hewlett-Packard Labs in Bristol, helped sweep away old notions that have long clouded entomologists’ vision. For example, intellectuals since Aristotle have assumed that an insect’s age always determines its task. Early research suggested that older workers toil

farthest from the nest, as foragers or soldiers. But Franks and Tofts reverse-engineered a colony and showed that this correlation arises from a simpler rule: Workers do the nearest available job and move outward when they are replaced, usually by a younger ant.

By thinking like computer programmers and scrutinizing the actions of individual



The original microchips. From the brutish *Eciton burchelli* (right) to the diminutive *Leptothorax albipennis* (above), ant problem solving resembles the inner workings of computer circuitry.

ants, scientists have revealed behavioral rules that govern group problem solving, just as assemblies of simple circuits can perform complex calculations. For example, Stephen Pratt of Princeton University and his colleagues at the University of Bath, U.K., have discovered how colonies of the tiny English ant *Leptothorax albipennis* reach a consensus on moving to a new nest. Their findings, in press at *Behavioral Ecology and Sociobiology*, show how the colony integrates information, overcoming slow communication and lack of central information processing.

After a nest is damaged or the colony grows too large, “recruiter” ants explore potential nest sites. When a recruiter finds a promising site, she (all workers are sterile females) returns to the nest and attracts another recruiter with pheromone, initiating a tandem run to the site. If the second worker likes the site better than others she has seen, she recruits another worker. Most recruiters visit only a few sites, using two rules to integrate data. Rule one: If a site is not so attractive, the recruiter delays initiating a tandem run, so that mediocre sites amass recruiters more

slowly than premium sites. Rule two: Once an undetermined threshold number of workers are recruiting for the same site, the recruiters become movers, carrying the entire colony to its new digs. As a result, the colony always agrees on the best site, even if it is discovered later than other sites.

Also employing meticulous observations of individuals, Iain Couzin of the University of Leeds, U.K., has uncovered the laws of army ant traffic. Just as computer networks must maintain speed during high data flow, *Eciton burchelli* must avoid getting knocked off the trail or turned around during foraging expeditions known as “swarm raids.” Up to 200,000 foragers moving in opposite directions must follow the same pheromone trail, so the risk of gridlock is high. At the “Mathematics of Social Insects” meeting in Cambridge, U.K., last December, Couzin and

Franks reported that the colony maximizes the flow of ants with two simple turning rules. Outbound workers turn aside sharply from encounters with ants moving in the opposite di-



rection, while inbound workers, laden with food, turn aside more slowly. In computer simulations, these rules keep both streams in line and maintain a steady return of food to the colony. The same ordered traffic patterns appear both in simulations and in real swarm raids: a central lane of returning ants flanked by columns of outbound ants.

Seeley admires the precision of such observations and how they make sense colony-wide. “They’ve got the whole colony, the whole process under a video camera, and they can quantify the activity of individuals,” he says. But although the approach is great for entomology, the payback for computer science could be a ways off. “The process that takes you from the work of biologists to real-world applications is not linear,” notes Marco Dorigo, a computer scientist at the Free University in Brussels who invented Ant Colony Optimization. The “algorithms” these entomologists have found are remarkable, he says, but in the programming world they remain solutions in search of a problem.

—BEN SHOUSE

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