lowers Earth's temperature wouldn't address the problem of the steadily acidifying ocean.

Modeler Raymond Pierrehumbert of the University of Chicago in Illinois warned that geoengineering could become a global addiction. "I don't actually work on geoengineering," he told the group. "But now that the genie's out of the bottle, I feel I have to." In one unpublished experiment, Pierrehumbert simulated a future scenario, presumably in the next century, in which the amount of atmospheric CO_2 had quadrupled but Earth was kept cool by a yearly dose of geoengineering. His model showed that a halt in the geoengineering effort—"by, say, a war or revolution"—would result in an 7°C temperature jump in the tropics in 30 years. That rise, he says, would trigger unimaginable ecological effects.

Sallie Chisholm, an MIT biological oceanographer, urged caution. She told *Science* that her colleagues are downplaying the difficulty of determining how "inherently unpredictable" biospheric feedbacks will react to "turning the temperature knob. … We cannot predict the biosphere's response to an intentional reduction in global temperature through geoengineering."

Other scientists were more willing to entertain the idea of studying climate manipulation but warned about a likely public backlash. Political scientist Thomas Homer-Dixon of the University of Toronto in Canada talked about street protests. "Some people may consider geoengineering to be an act of ultimate hubris," he says. "It's going to provoke fear, anger, guilt, and despair."

Others, however, viewed public alarm about geoengineering as a potentially positive effect. "If they see us talking about this as a last-ditch effort, it might increase their alarm" and drive them to cut emissions, explained Harvard climate dynamicist Peter Huybers during one of the sessions. By the end of the 2-day event, participants were stunned that they had come so far. "In this room, we've reached a remarkable consensus that there should be research on this," announced climate modeler Chris Bretherton of the University of Washington, Seattle. Nobody dissented.

Mixed in with his new sense of "responsibility," Battisti says, is dismay that the climate problem has grown so serious as to drive scientists to contemplate steps that, in theory, might lead to more serious problems than continued warming. After speaking on the phone with his wife from his hotel room, Battisti confessed, "I told her this meeting is terrifying me."

(For a discussion of the topic with some of the meeting participants, go to www.sciencemag.org/hottopics/geoengineering.)

–ELI KINTISCH

BEHAVIOR

Robot Cockroach Tests Insect Decision-Making Behavior

Science-fiction writers have long envisioned societies in which the boundaries between humans and lifelike droids blur and man and machine freely intermingle. José Halloy has taken the first steps toward creating that world, at least for insects. His tiny, autonomous robots lack legs, wings, and antennae, but they nonetheless pass muster with cockroaches. Indeed, these wheeled machines are so well accepted by the household pests that the robots become part of the insects' collective decision-making process, Halloy, a theoretical biologist at the Free University of Brussels, Belgium, and his colleagues report on page 1155. The robots persuaded many of their insect "peers" to hide in an unconventional place.

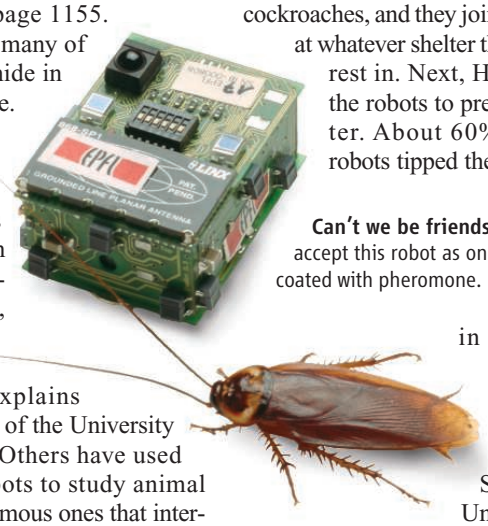
Halloy's innovative approach puts theories of collective behavior among insects into practice. "We can manipulate these behaviors very easily in a model, but doing so in experiments is often challenging," explains ethologist Jerome Buhl of the University of Sydney, Australia. Others have used remote-controlled robots to study animal behavior but not autonomous ones that interact with animals on their own. "In many ways, [the work] is a big step in the study of collective behavior in animals," says animal behaviorist Stephen Pratt of Arizona State University in Tempe.

Halloy and his Brussels colleague Grégory Sempo picked cockroaches for these robot experiments in part because they had earlier found that cockroaches typically self-organize; within a few hours, for example, they settle together in one place, preferring darker spots when available. For those experiments, and the later ones with the robots, Halloy, Sempo, and their colleagues built a 1-meter-diameter arena with two "shelters," the roofs of which were made of plastic discs covered by red filters. By adding layers of filters, Halloy and Sempo can make one shelter darker than the other.

Based on observations of insects in this arena, Halloy and his colleagues developed a mathematical model that predicts which shelter a cockroach should pick depending on the level of darkness of the shelter and the number and activity of its fellow roaches. Halloy's group then used this model to program robots designed by him and Francesco Mondada and other engineers at the École Polytechnique Fédérale de Lausanne, Switzerland.

The roaches usually ran away from the robots but not if the machines smelled like the insects. For the experiments, Halloy and Sempo covered the robots with a filter paper containing the pheromone equivalent of one cockroach.

Halloy initially programmed the robots to have the same darkness preference as the cockroaches, and they joined the cockroaches at whatever shelter the majority chose to rest in. Next, Halloy programmed the robots to prefer the lighter shelter. About 60% of the time, the robots tipped the group's preference in favor of the light shelter. "This is a true example of automated leadership," says David Sumpter of Uppsala University in Sweden. "Instead of the robots rounding up the cockroaches like sheepdogs, they lead through social attraction."



Can't we be friends? Cockroaches seem to accept this robot as one of their own once it's coated with pheromone.

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But Coby Schal, an urban entomologist at North Carolina State University in Raleigh, has reservations about the effectiveness of the pheromone guise in convincing the roaches that the robot is just like them. He wonders if the physical presence of the robots made the lighter shelter more attractive simply by increasing the structural complexity of this hiding place. "In my view, the jury is still out" on whether the robots became part of the decision-making, says Schal.

Nonetheless, roboticist Daniela Rus of the Massachusetts Institute of Technology in Cambridge calls the idea that robots can influence biological group behavior "very powerful." She speculates that the work could have many applications, such as robots that aid pest control by luring insects into traps or that help herd livestock.

–ELIZABETH PENNISI

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