IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

G. PATRICELLI

D. A. MURAWSKI/STILL PICTURES

The mating game: having used a robotic bowerbird (left) to examine courtship behaviour, researchers plan to use the same technique on sage grouse (above).

When robots go wild

A steady stream of mechanical animals is marching out of the lab into the field. Jonathan Knight tunes in to see how these motorized models can expose what makes real creatures behave the way they do.

As the sage grouse gather on the Wyoming prairie to find mates this spring, a few of the strutting, posturing males are in for a surprise. One of the hens they'll be trying to court will be a mechanized impostor rolling around on tracks from a model railroad.

A dozen metres away, crouching in the brush, behavioural biologist Gail Patricelli will be guiding its every move by remote control — ready to rescue her decoy should things get out of hand. "The worst-case scenarios are the bird derails and gets torn up by the males, or an eagle swoops in and grabs it," says Patricelli. Either would put an abrupt end to an experiment she has spent months setting up.

Patricelli, an assistant professor at the University of California, Davis, is one of several technically savvy biologists who have latched on to the use of robotics in behavioural studies. Radio transmitters, computer chips, digital cameras and audio recorders have become smaller and cheaper, placing home-made robots within the reach of even junior researchers on a tight budget.

As a result, a menagerie of robots — from squirrels to lobsters — has been deployed to test ideas about animal behaviour that had previously been too tricky to tackle. Robots are making new avenues of research possible, says behaviouralist Christopher Evans at Macquarie University in Sydney, Australia. "We tend to seize on technologies like this and say: 'I've been waiting to do that experiment for 20 years, and now I can'," he says.

Among the first to explore the potential of mechanized animals was Axel Michelsen at the University of Southern Denmark in Odense. In the early 1990s, he built a mechanically controlled honeybee of wax-coated brass to help him decode the insects' dances, which tell others in the hive where to find food. The brass bee was slightly larger than normal and had just one wing, fashioned from a broken razor blade. It didn't look much like a real bee. Fortunately, beehives are completely dark.

Because they can't see the dancer, honeybees perceive its movements mainly through the pulsing currents of air it creates. By making his bee perform sections of the dance to an audience of real bees, Michelsen discovered how the dance revealed both the direction to and the distance from food[1].

Wired for romance

Patricelli was so fascinated by this approach that she built a robot bird for her postdoctoral research on the courtship of satin bowerbirds (*Ptilonorhynchus violaceus*). It was fairly simple: a stuffed female that could crouch, turn its head and fluff its feathers at the tweak of a joystick. To real males it was utterly convincing. Patricelli found that males modified the intensity of their display in response to cues from the female: hamming it up if she seemed receptive and toning it down if she was aloof[2].

The bowerbird has been retired to a cardboard box while Patricelli works on the more sophisticated grouse-bot. This radio-controlled model not only turns and makes provocative crouching movements, it is also equipped with video and audio recorders to catch the males' responses.

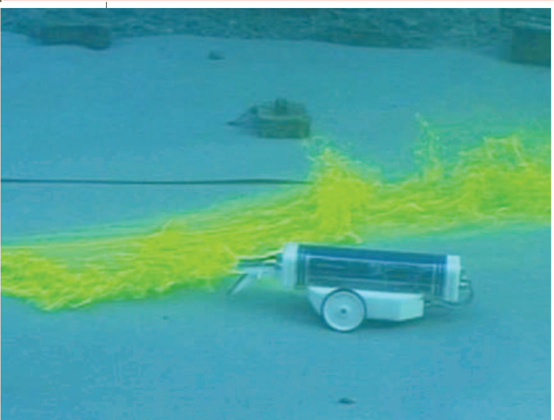
The point of the experiment is to monitor the grouse's mating signals. "It's very hard to tease apart the conversation when you are just watching from the outside. But when you control one side of it, you get a better idea of what is going on," Patricelli says. Sage grouse (*Centrocercus urophasianus*) mate in leks, open fields where males strut around, displaying their feathers and emitting a loud drumming noise from vocal sacs on their chests. Like real females, the robot will wander through the lek, 'observing' different males and showing interest by moving its hindquarters. Patricelli hopes to learn which of the hen's moves are most exciting to a male and how he responds.

Giving a robot natural movement is fairly easy for birds, as their motion is somewhat jerky and robotic to begin with. In fact, the wheeling motion of Patricelli's grouse may be a bit smooth, but that won't necessarily matter, as animals seem to respond to very specific cues when identifying members of their own species. For instance, Evans and his Macquarie colleague Ann Göth last year built a series of robot chicks to find out what cues newly hatched brush turkeys (*Alectura lathami*) look for in spotting their nest mates. All

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

J. MCDONALD/CORBIS (SNAKE); A. RUNDUS

Fur will fly: with a tail that heats up and swings from side to side, this robotic rodent (above) is helping to test theories about how ground squirrels try to frighten away real rattlesnakes (above left).



N. SHASHAR/INTER-UNIV. INST.

Not to be sniffed at: a robotic lobster attempts to follow a model odour plume to its prey.

the robots looked the same, but it was the one that made the jerky pecking motion typical of game birds that got all the attention[3].

Robots are also proving their worth in studying communication between different species. Just across campus from Patricelli is a room housing several dozen rattlesnakes (*Crotalus viridis*) that, courtesy of graduate student Aaron Rundus, face regular encounters with a robot squirrel.

California ground squirrels (*Spermophilus beecheyi*) are a favourite prey of rattlesnakes, but they are not always easy targets. Adults are resistant to snake venom and so can be quite bold, often driving off a snake with an aggressive display that involves swinging their tail like a windscreen wiper.

What is unique about this display is that it seems to use both visual and infrared cues. Rattlesnakes are exquisitely sensitive to heat, and a squirrel will heat up its tail by as much as 2 °C during tail-flagging. As Rundus told the annual meeting of the Animal Behavior Society in Oaxaca, Mexico, last June, the same squirrel seems to keep its tail cool when flagging a heat-insensitive gopher snake (*Pituophis melanoleucus*).

To test how much the rattlers' response is influenced by the heat signal, Rundus teamed up with Davis mechanical engineer Sanjay Joshi to rig a stuffed squirrel with a motorized, heat-controlled tail. Rundus is coy about discussing his unpublished findings, but hints that things are going well. What's important, Rundus says, is that robotics has made possible a controlled experiment that couldn't have been done in the wild — there is no way to convince a squirrel to keep its tail cool when facing a rattler. "This is long overdue in behavioural biology," he says.

Mock lobster

Researchers can learn a lot by building robots that mimic animal behaviour, even if the machines don't interact with live creatures. For instance, Frank Grasso, director of the Biomimetic and Cognitive Robotics Lab at the City University of New York in Brooklyn, has studied how lobsters sniff out their prey by using a robo-lobster that follows a scented plume in the water. "The robots allowed us to improve on ideas that had been around for a long time," he says.

It had been assumed that lobsters locate their prey by swimming towards higher concentrations of odour. But in lab trials, a robo-lobster working on this principle alone did poorly, particularly if it was a long way from its target. Guessing that this might be the result of turbulence muddying the odour gradient in the water, Grasso's team gave the robot a sense of flow, allowing it to assume that odours come from upstream. The robot then behaved much more like the real thing[4].

But even so it didn't quite act naturally. Grasso has continued to refine the model, for instance by adding a memory algorithm to help it if it loses the odour plume. "This is allowing us to build step by step a model of what is going on in the lobster's brain," he says.

The approach has its limits. Even if the real and fake lobsters behave the same, there is no direct test to show that the robot algorithm and a lobster's brain are making decisions in the same way. But such experiments can at least establish a minimum, says psychologist Jeffrey Schank, who is working with Joshi to build robotic rats that also follow simple behavioural rules. "If we can get robots to mimic the rats, that's the first step to understanding them," Joshi explains.

The robo-rats are entirely autonomous, and make decisions about where to go based on which sensors are activated in combination with a probability algorithm programmed into their computer brains[5]. For Schank the important question is: how little does the brain have to do? "We are trying to quantify the lowest level of cognitive ability necessary for certain types of behaviour," he says. This can then feed into theories of how animals behave in the wild.

Certainly, the robotic toolbox has only just been prised open. In addition to one-on-one interactions, some researchers are looking at group behaviour. A European team led by Jean-Louis Deneubourg at the Free University of Brussels has built robo-roaches that can interact with groups of live cockroaches. The researchers are using them to understand collective decision-making, such as choosing a safe hiding place.

The herd instinct may also encourage more behavioural researchers to use robots. "Every time I go to a conference, I hear about more people using robots," says Patricelli. "It's catching on." ■

Jonathan Knight writes for *Nature* from San Francisco.

1. Michelsen, A., Andersen, B. B., Storm, J., Kirchner, W. H. & Lindauer, M. *Behav. Ecol. Sociobiol.* **30,** 143–150 (1992).
2. Patricelli, G. L., Uy, J. A. C., Walsh, G. & Borgia, G. *Nature* **415,** 279–280 (2002).
3. Göth, A. & Evans, C. S. *J. Exp. Biol.* **207,** 2199–2208 (2004).
4. Grasso, F. W. *Biol. Bull.* **200,** 160–168 (2001).
5. Schank, J. C., May, C. J., Tran, J. T. & Joshi, S. S. *Adap. Behav.* **12,** 161–173 (2004).