

places that males can reach, and particular body places that males can genitally pierce, among others. These adaptations apparently serve to filter males via female cooperation. In water striders, on the contrary, it seems that mating became too costly for females and that is why they have evolved structures to avoid matings. What is true, nevertheless, is that females, far from being passive players, can be ascribed as architects of sperm competition, as Patricia Gowaty, a behavioral ecologist, has called them.

The field of sperm competition is still growing up, and important gaps still remain to be clarified. Some questions to be uncovered are: What benefits (direct and/or indirect) do females gain from male sperm competition traits? How extended are those cases of species whose males have controlled female reproductive decisions? Given the rapid evolutionary nature of male–female interactions in sperm competition traits, what is the effect in relation to speciation? And there are other questions. Surely, equally exciting answers, as those we have already found, will be discovered shortly.

Further Resources

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Robotics

Animal Robots

Imagine your dog “talking” to an animal robot! Scientists in Paris and Budapest are doing just that. Luc Steels and Frederick Kaplan at Sony Computer Science Laboratory in Paris pursue research in artificial intelligent using a four-legged robot called “AIBO” (Artificially Intelligent roBOt). This robot can sense the environment, walk toward and away from things it sees, crouch, bark, wiggle its ears, and wag its tail. Hungarians Eiko Kubinyi and Adam Miklosi have field-tested AIBO with real dogs. The dogs apparently view the robot as lifelike. Puppies approach and try to play with AIBO. Adult dogs curl their lips, growl, and even attack AIBO if it approaches them while they are feasting on meat.

The scientific field of animal robotics is just emerging. The design and anatomy of animals has previously been used as inspiration for building robots that move in efficient ways (called “biomimetic robots,” which mimic biology). Now animallike robots are being created to interact with live animals with the express goal of better understanding the behavior of the live animals themselves. Since the study of animal behavior is called *ethology*, we could call this new field *ethorobotics*. This innovative method has the potential to answer

questions about behavior that have been difficult to answer with previous methods for studying animal behavior.

Suppose that you want to understand the meaning of a particular animal display. For example, male lizards can expand the colorful skin on their throats, called dewlaps, to produce vivid visual displays. What would you do if you wanted to find out what the dewlap display means?

The most direct way to understand behavior is simply to observe it carefully. Much of ethology has been based upon observation. You might go outside on a warm day, settle yourself quietly by a large banyan tree, for example, and watch until you see a small brown anole lizard darting up one of the thick roots that arc away from the base of the tree. The lizard may stop suddenly and stand motionless. Then, very slowly, he starts to extend his dewlap. You see it first as a thin slice of orange by his neck, and then the movement accelerates and the shape of the lizard is suddenly transformed, with the large round curve of the dewlap fully extended before you. You can describe the movement; you can document when and where it occurs. But how do you figure out what the display *means*?

A behavior “means” something if it causes other animals to react in a predictable way. With the observational method, we can watch for other, neighboring, lizards, and document their responses to the display. By observing whether the other lizards approach or run away, for example, we have an idea of whether the display was friendly or aggressive. But how do we know for certain what caused the neighboring animals’ behavior? What if it was a hawk swooping down below the branches of the tree that caused the other lizard to run, rather than the dramatic display of the first lizard?

Ethologists have found ways to ask the animals what displays mean. One method is to use playbacks. We can play an audio recording of a bird song back to live birds in the field, for example, and see what they do. We can show videos of lizards extending their dewlaps and flexing their legs in “pushup” displays, and then see how live lizards respond. Playback is a nice method because it removes the variability of the real life observational situation by allowing us to control the environment. We can conduct repeated playback trials, varying only the display that we are interested in and keeping everything else constant. If an animal responds to one trial and not to another, we will know exactly what caused its change in behavior. But can animals see video screens? We have convincing evidence that they can. Video playbacks have now been successful with monkeys, birds, lizards, and fish, for example, and more animals are being tested. But is a flat, 2-dimensional video or LCD screen as salient (meaningful) as a real, 3-D figure? And what if the animal responds; how can we manipulate the video image to respond back, to create a “conversation”?

Imagine if we could create realistic 3-D robotic animals models that could interact in real time with live animals. We would create an endless variety of displays, limited only by the hardware and software design of the robot. The robot could produce displays in new combinations as it interacts with the animal subject. We could then use the record of the behaviors produced by the robot and the responses made by the live subject to determine the impact of each behavior on the recipient. In other words, we could find out the *meaning* of each behavior. This ideal scenario is still the stuff of dreams, since the first animal robots that have been made are not yet sophisticated enough to have a highly variable repertoire of behavior or to be able to react in real time to live subjects. But the dream is quickly becoming reality.

At least three other research teams, in addition to the AIBO group, have now built animal robots that have communicated successfully with live animals. These robots are programmed to do a few simple behaviors activated by direct motors or remote control.

Although they only perform a few behaviors, the behaviors were carefully chosen to be key to successful communication with the animal. One of the first “animal-bots” was a bee, built by Danish and German researchers in the early 1990s. Axel Michelson and colleagues built a bee that wiggles, dances, and hums like a real bee. The model didn’t look exactly like a bee, but that didn’t matter because bees communicate in the dark of their hive, so they couldn’t see the robot anyway. Bees perceive each other with senses of taste, touch, sound, and vibration. The scientists were able to use the model bee to communicate to real bees about the location of food items in their environment. The robot bee “told” the live bees where the food was, and the live bees found it!

Recently, a research group built a robotic bird in Australia. Gail Patricelli and her colleagues built a beautiful model of a female bower bird which can crouch, fluff its wings, and turn its head like a real bird. In this species, the male builds an elaborate “bower” for the female. This is a nest, constructed of sticks and twigs, that resembles a throne with an arch overhead. The females travel around and try out the bowers until they find one they like. Gale and her collaborators built such a convincing female robotic bird that they fooled the males, who courted the robot vigorously, hoping to win her as a mate!



A rendering from video frame illustrating aggressive behavior of a male dart-poison frog toward the electromechanical model frog (left) placed in his territory.

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We can also use robots to test questions about how combinations of signals affect meaning. This is important because natural behavior includes many components. When humans laugh, for example, we produce a sound (an acoustic component), our mouth moves and the skin around our eyes may wrinkle, and your whole body may even shake (multiple visual components). In some cases, we may also touch a friend on the arm to emphasize how helpless our laughter has left us (a tactile component). Why do we include so many components? Are the components redundant with one another or do they provide extra information? We don’t know.

Animal displays are also made of multiple components. The iguana, for example, a relative of the smaller anole lizard, hisses while it does its visual display. We can investigate the impact of both

visual and auditory channels on behavior by building tiny speakers into the robot, so that the robot can produce sounds as well as visual displays. The sense of smell is also of paramount importance to many animals. Perhaps the field of chemical ethology will advance to the point that we can manufacture specific pheromones (animal scents) for each emotion to add to the milieu of signals being produced by the robot. By observing the responses of live subjects to each component of the display separately, as well as to the entire suite of signals together, we could better understand what the signals mean and why animal displays are so complex.

Peter Narins and his colleagues in Vienna have built a small robotic frog to test questions about which sensory channels are necessary for effective communication in the dart-poison frog. The robot, dubbed the “robo rana,” has one main moving part: its throat pouch, which inflates into a round bubble. Inflation of the throat pouch is used to create croaking sounds in real frogs. Robo rana is mounted on a circular pedestal that can rotate to point the model in different directions. It also has an imbedded speaker used to produce

prerecorded croaks. When the robot expanded its throat and croaked, live frog in the area approached and even attacked this apparent intruder. Both the motion of the throat pouch and the vocal signal were necessary to elicit the response from the live frogs.

The success of these new animal robots at communicating with real live animals is exciting, and makes me wonder. . . how long until my beloved yellow lab, Tundra, has her very own Robo-Fido to play and commiserate with while I am away at the office?

See also Robotics—Artificial Pets

Further Resources

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Sarah Partan

Robotics

Artificial Pets

Artificial pets are robotic toys with petlike behavior. Unlike traditional robots, which are made to be intelligent tools that serve their owner, artificial pets are autonomous creatures that elicit *attachment* from their owner.

Artificial pets provide a fascinating arena for examining the relationship between behavior and attachment. Physically, many are unremarkable: One of the most successful artificial pets to date, the Tamagotchi, was a small plastic key-chain egg with simple animations on a low-resolution screen. Yet people became extremely attached to them, giving high priority to caring for them and mourning them when they “died.” It is the behavior of the artificial pet that fosters this attachment.

Although artificial pets have been developed in a variety of forms, from the simple key-chain pets to complex robots such as AIBO, an artificial dog, they share several key behaviors: They appear to act autonomously, they are dependent on their owner for nurturance, they require frequent interaction, and they develop in response to their owner's actions.

Autonomy: An artificial pet acts—or, more precisely, appears to act—autonomously. This means that its actions seem to be internally motivated, it appears to have its own goals, feelings, and desires. It does not necessarily accept the commands of a human and instead makes its own demands on the person. When machines work exactly as we expect them to and do what we request of them, we think of them as simply machines. It is when they do not work as expected that they appear to have a will of their own, and we ascribe intelligence to them.