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Sensible Animals: [Dr. Donald R. Griffin]

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And finally one finds oneself asking what the animals do with their living machinery, for after both the structure and the functioning of all the parts have been described there remains to be understood the behavior of the intact, living animal.

—DONALD GRIFFIN,
Listening in the Dark, 1958

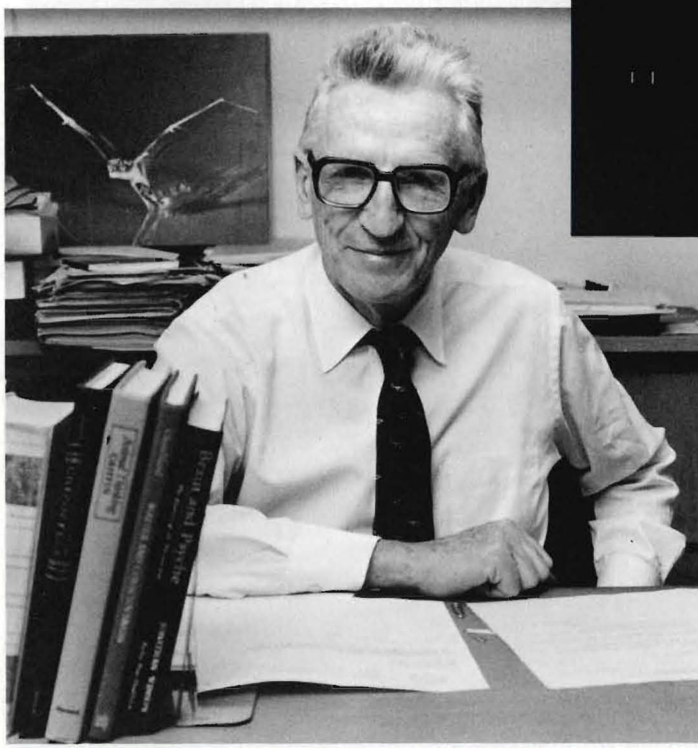
Sensible Animals

For forty years Donald Griffin conducted seminal investigations into the behavior of animals. Adopting a bird's eye (and bat's ear) view, he strove to see into what he calls "the sensory windows through which animals experience the world." He learned to fly a plane so that he could follow homing gulls and gannets. He listened in to hear what fish hear underwater. Hauling oscilloscopes and recorders into pitch-black caves, he discovered the secret world of ultrasonic echoes by which bats navigate in the dark.

The elegance and meticulousness of his research earned him early and universal respect both in his own field of ethology, the study of animal behavior, and among biologists in disciplines where such research is sometimes viewed as "soft." In 1965, while chairman of the biology department of Harvard University, he was invited to Rockefeller University to establish what has become one of the most distinguished centers for ethological investigation in the world.

Then, ten years ago, this "rigorous sceptic," as he has been called, wrote a book entitled *The Question of Animal Awareness.* In it he challenged half a century of scientific assumption that the behavior of animals is automatic and unconscious, resulting solely from genetic instructions programmed by natural selection or acquired by conditioned responses to stimuli in the manner of Pavlov's dogs. "The flexibility and appropriateness of animal behavior," he stated, "suggest both that complex

A fish-catching bat reflected in the its water, hind legs reaching for prey.



Donald R. Griffin at his desk, left, and below, bat banding in Vermont in the 1930s.

processes occur in their brains, and that these events may have much in common with our own conscious mental experiences."

For Dr. Griffin it was a basic philosophical question too long neglected. "It was a hot potato," says colleague Peter Marler. "Other people had thought about animal consciousness, but it was considered just too difficult to approach experimentally." Dr. Griffin proposed that the time was ripe for researchers to attempt to design experiments to make animal minds "accessible to scientific scrutiny and analysis." Since animals often exchange meaningful signals with their companions, he suggests that these "may tell us a great deal about any conscious thoughts or feelings they experience. Thus communicative signals of animals provide scientists with objective data about possible thoughts and feelings. In other words, animal communication is a scientifically useful 'window' on animal minds."

He spent the next five years preparing a revised edition of *The Question of Animal Awareness,* to address its critics, and in 1984 published another book, *Animal Thinking.*

The ideas that impelled him had been simmering in his mind for a long time, he says, inspired initially by the work of Karl von Frisch, the first investigator to discover, many years ago, a simple but truly symbolic communication system in another species. In honeybees. Von Frisch demonstrated that the distinctive "waggle dance" that foraging honeybees perform on returning to the hive tells their sisters about food sources they have found. The dance conveys information about the odor of the food, but also indicates the distance and direction of food supplies. Learning of von Frisch's discoveries, Dr. Griffin remembers being "shook out of my reductionist complacency. I began to wonder whether animals might not be doing a lot of things we never imagined they could do."

Recording the sonar signals of fishing bats from a dugout canoe on the Chagras River, Panama, 1953.

James Gould, a graduate student of Dr. Griffin's in the 1970s, who is now on the faculty of Princeton University, has followed up and expanded upon some of von Frisch's findings. In one experiment, which Dr. Griffin describes in *Animal Thinking,* Dr. Gould offered honeybees a dish of sugar water at the entrance to their hive. He then moved the dish a short distance away from the hive, where the bees found it. He continued to move it at regularly spaced distances. Finally, some of the bees began waiting for the dish beyond the spot where it had last been left, at what would be the logical next stopping place. "They seem to have realized," Dr. Griffin wrote, "that this splendid new food source moves and that to find it again they should fly farther out from home. Real flowers do not ordinarily leap 20 or 30 meters in a few minutes, so it is diffiult to imagine how natural selection would have prepared honeybees to extrapolate the position of a moving food source."

Do honeybees "realize"? Is a sea otter "conscious" when it uses a beer bottle it has found as an anvil against which it hammers open shellfish? Is a bird "aware" that it wants to lure a predator away from its nest when it behaves as if it has a broken wing? "That someone of Don's reputation dared to reopen such questions," says Dr. Marler, "sparked a minor revolution among zoologists about whether or not the animal mind is a proper subject for research."

BATS WITH SONAR

The achievement for which Dr. Griffin is best known is the discovery of the phenomenon of echolocation, a term he coined to describe both natural sonar certain animals use in navigation and hunting and such human artifacts as radar. He first encountered echolocation in bats. Flying in the dark, bats emit chirps

that bounce back to them from objects in their path. From the returning echoes the bats seem to form a mental picture of their surroundings. Biologists had suspected that hearing played a role in bat navigation, but ordinarily we can hear no sounds as bats thread their way through dark caves. Dr. Griffin's work showed that most of the sounds they use for orientation are above the range of human hearing.

He began this research while an undergraduate at Harvard, where he arrived after a rather unpromising beginning for a scholar. In a delightfully irreverant memoir he wrote recently, he revealed that his most vivid memories from his early school years are of learning from his classmates to shoot craps, and how one school principal told the class that the horticulturist Luther Burbank "had been struck dead by the Lord because of his blasphemous advocacy of evolution."

He first pursued his naturalist's bent in the fields around Scarsdale, New York, still relatively rural when he was a boy, and later in Barnstable, Massachusetts. He spent his study hours poring over "such learned periodicals as *Fur, Fish and Game.*" Midway through high school his parents sent him off, happily and successfully as it turned out, to Phillips Academy, in Andover, which happened to have its own bird banding station. By the time he entered Harvard he was an experienced bird bander, and he had also got the notion to band bats, a considerably more difficult enterprise from which the Bureau of Biological Survey tried but failed to dissuade him. With the help of college friends, he conducted one of the first large-scale efforts to study bat migration, homing behavior, and lifespan. More than twenty years later, bats he had banded were still turning up, providing the first evidence of their unsuspected longevity.

It was a natural outgrowth of his interest in homing behavior, he says, that he began to wonder how bats get around in the dark, displaying the most remarkable dexterity in manoeuvering through the tortuous passages of caves and on long nocturnal migrations. As he started reading up on the subject, he found reports of experiments showing that bats flew perfectly well with their eyes blindfolded and that the only thing that disoriented them was having their ears plugged. There were suggestions that they might use high frequency sounds in some way, but no experimental evidence.

"It was a great stroke of luck for me that I happened to be at Harvard. There was a physics professor on campus named George Washington Pierce who had virtually the only equipment in existence at that time suitable for studying ultrasonic sounds, and he was using it to listen to insect noises. I was hesitant about approaching him. He was very distinguished, and I had barely managed a C-plus in one physics course I'd taken. When I finally did screw up the courage, he was delighted to find someone who knew one end of a bat from the other."

Pierce had designed a sonic detector that consisted of a crystal microphone placed inside a long parabolic horn, vacuum tube amplifiers, and a circuit similar to a radio receiver. This apparatus could translate high frequency sounds into the range of human hearing. "The minute I brought some bats into his room, we heard the most astonishing pops and rattles," Dr. Griffin recalls. To make sure it was the bats that were ultrasonic, and that they weren't picking up incidental noises, Pierce turned off the loudspeaker and connected a recording device to the detector that, when activated, drew lines on a moving strip of paper. It recorded very clear signals from animals held in front of the equipment, but very few from flying bats. "It took us a while before we realized that because Pierce's microphone was directional and so were the bats—their chirps go out pretty much ahead of them—we were picking up sounds only when they flew straight toward the microphone's beam."

For the next few years, Dr. Griffin pursued the project with a fellow student, Robert Galambos. "I knew about bats and he knew about hearing," Dr. Griffin says. "The initial findings on echolocation we made together, fifty-fifty. I'm not sure I'd have been able to do it without him." Dr. Galambos went on to become a distinguished auditory physiologist. His colleague, ignoring the voice of conscience, which told him that he, too, should aspire to "serious physiology," seized the opportunity to continue studying animal behavior afforded by the arrival at Harvard of Karl S. Lashley, an eminent psychologist who had studied the homing of birds.

Catching bats in a mine tunnel near Simla, The New York Zoological Society's field station in Trinidad, 1964.

FLYING WITH THE BIRDS

The migrations of animals, often across many thousands of miles, are among nature's most beautiful, awesome, and tan-

talizing mysteries. Bird navigation falls into two categories, long distance migrations and shorter homing flights. As a graduate student with Lashley, Dr. Griffin studied homing behavior in a number of bird species. He began with petrels, small ocean birds that come ashore only to nest. He would take some birds from their nesting grounds and transport them hundreds of miles into unfamiliar terrain. "Sometimes they came back, and sometimes they didn't," he says, "but they didn't come back fast enough, nor did enough of them return to tell me anything about homing orientation. For all I knew they could have scattered around until some of them accidentally found a recognizable landmark."

Turning to herring gulls, which were believed to have good homing ability, he obtained better but still ambiguous results. It occurred to him that the only way he would get a definitive answer would be if he followed them in an airplane, something no one had attempted. First he enlisted a flier friend to take him up. Then he scraped up a few hundred dollars, augmented by a small research budget from the Harvard Society of Fellows, bought himself an "elderly two-seater," and got a pilot's license.

"It was exhilarating and difficult," he recalls. "Herring gulls are diabolically ingenious at finding stretches of white sand or glare spots. Once I lost a bird from view, it was almost impossible to find that small white speck again. And I didn't want to fly too close for fear of influencing their behavior." The results again showed that the bird did not always head straight for home.

Bird following halted during World War II, which Dr. Griffin spent at Harvard working on research projects for the military related mostly to improving equipment for hearing and seeing under battle conditions. For a while he was assigned to a group testing cold weather gear. He remembers that one of the more "hilarious" tasks they were given was to assess the speed of buttoning and unbuttoning trouser flies equipped with different kinds of buttons while wearing different types of gloves.

After the war, he received an appointment to teach comparative physiology at Cornell University, where he conducted many more homing experiments. During this period he also spent some time working at the Woods Hole Oceanographic Institution and helped settle an old zoological controversy as to whether or not fish hear underwater. (They do.) He returned to Harvard in 1953, first as professor of zoology and later as chairman of the biology department.

It was not until the 1960s, when he moved to Rockefeller University, that he began a novel type of bird observation in the field. By that time there were studies that seemed to show that birds use the sun and stars as navigational aids, an idea considered "ridiculous" when he first proposed it years earlier. But birds also fly on cloudy nights. At Rockefeller, Dr. Griffin and a group of his graduate students, working at the University's field station and on trips at sea, followed the course of birds flying blind inside of or between layers of opaque clouds. They tracked them with the aid of a radar unit, a Korean War relic they dubbed "The Witch." Crucial to their efforts were Lawrence Eisenberg and Michelangelo Rossetto of the University's electronics laboratory. "It took all of Larry's ingenuity to get The Witch to do what we wanted her to do," says Dr. Griffin. "With a lot of work and waiting on the weather we found out that, yes, a few migrants are foolish enough to fly in clouds and some remain reasonably well oriented."

The sensory basis for bird navigation has still not been fully explained. Recently, many biologists have come to believe that birds are able to utilize the earth's magnetic field, wind currents, and olfactory clues as orientational aids. Dr. Griffin is not convinced by the current evidence. "The nut remains to be cracked," he says.

A flight cage with fishing bats, Simla, 1964.

With student Ronald Larkin and "The Witch," Millbrook field station, 1974.

Dr. Ristau and "Rocky" raccoon.

BACK TO BATS

At Cornell, and later at Harvard, Dr. Griffin resumed his bat studies. By the summer of 1950 he was ready to begin experiments to obtain more quantitative measurements of bat sonar, to see how precisely bats can distinguish between various obstacles. With a graduate student, he built a plywood flight chamber to run his tests in, "but the bats defied us at every turn," he says. "They flew any which way with no apparent relation to anything around them. It made no sense. In sheer frustration I took my equipment outdoors to observe wild bats. It was a messy thing to do because the apparatus we had then was heavy and cumbersome. I needed a gasoline generator, oscilloscopes, and I was still using Pierce's big collecting reflector.

"What happened was totally unexpected and spectacular. Even with our crude equipment it became clear that the bats were using their sonar to catch insects. The notion that a tiny thing like a flying insect could reflect enough sound for bats to detect was something that, had one suggested it, would have seemed even more unlikely than the idea that they use sounds to get around in the dark. Some people did think it was far-fetched. The rate of chirping varies according to the bats' need for information. One critic suggested that they were yipping like dogs chasing a rabbit."

To get conclusive evidence as to whether the bats really were hunting by echolocation, Dr. Griffin again set up controlled experiments. Again he encountered problems. "No matter how hard I tried I couldn't get the bats to catch insects in the laboratory. I tried. Other people tried. But the bats wouldn't pay attention. An entomologist who heard of my plight wrote to me from Florida where he was studying mosquito control. He had a roomful of mosquitoes, and he bet me that my bats would catch them. I flew down with some bats and put them in his room. He was right. I flew back to my laboratory and tried mosquitoes there. The bats started hunting. Eventually we figured out that the problem before had been simply one of density—I hadn't had enough insects in my original experiments to excite the bats. We quickly switched to fruit flies. Not only were they a lot pleasanter to work with, their flight is virtually silent. We were able to mask the slight sounds they made and prove that the bats were using echolocation to catch them and not simply hearing them."

Dr. Griffin traveled over broad areas of North America, and to Latin America, Europe, New Guinea, and Australia to compare insect-hunting bats, fish-catching bats, fruit-eating bats, and vampire bats. He discovered a wide diversity in the way and the extent to which bats use echolocation. His work inspired other researchers to study echolocation in a variety of animal species, particularly marine mammals. The growth and vitality of the field Donald Griffin introduced was reflected in a massive symposium report, *Animal Sonar Systems,* published in 1980 and dedicated to him.

One of his bat-surveying trips took Dr. Griffin to the New York Zoological Society's field station in Trinidad where he met the Society's president, Fairfield Osborn. Not long after, Osborn suggested to Detlev Bronk, then president of Rockefeller University, that they ask Donald Griffin to set up a program in ethology utilizing the Zoo's field and animal resources and the University's laboratory and technical facilities.

"It was a terrific wrench to leave Harvard, which had been my intellectual home for so many years," Dr. Griffin says, "but I was excited by the prospect of having total freedom to concentrate on research, which is one of the great attractions of Rockefeller." Among those he enlisted into the new program were Peter Marler and Fernando Nottebohm, two of the world's leading scholars in the field of animal communication and songbird learning, Roger Payne, a specialist in whale studies, and George Schaller, who has studied and written extensively on the large mammals of Africa and Asia.

In 1971 the University was given a tract of land in Millbrook, New York, for its own ethological field station, the gift of the Mary Flagler Cary Charitable Trust, but ties with scientists from the Zoological Society are still maintained. One particularly gratifying consequence of moving to Rockefeller, Dr. Griffin has found, is the degree of interest in ethological studies expressed by colleagues in very different fields of research. "After twenty years," he says, "the intellectual oomph of this place still impresses me."

LYING PLOVERS AND TALKING BEES

In the spring, piping plovers make their nests in sand dunes. For the past few years, Carolyn Ristau, a member of Dr. Griffin's laboratory, has been visiting plover nesting grounds on Long

Island and in Virginia. Plovers are birds that feign injury—the so-called "broken-wing display"—when intruders approach their nests. The standard explanation has been that the display is an unconscious, hormonal reaction to a stimulus. "The old texts refer to it as 'hysterical'," Dr. Ristau remarks.

Dr. Ristau and her co-workers are interested in finding out whether this behavior is solely reflex or whether there are conscious elements involved. "If the bird is at all conscious," she explains, "there should be some flexibility in its reactions. For example, it should want to lure the intruder from the nest. It should pay attention to the intruder, monitor it. It should vary its behavior depending upon what the intruder does. It should be able to discriminate between different intruders who do or don't come close enough to threaten the eggs or young. We've been systematically testing these assumptions and the data we've collected so far seem to be mostly postitive."

When Dr. Ristau was setting out on these experiments, Dr. Griffin, an ardent lover of all things mechanical, devised an ingenious "intruder," a souped-up remote-controlled toy dune buggy with a stuffed raccoon at the wheel. "Unfortunately," says Dr. Ristau, "it sometimes got stuck in ruts and in beach grass, and the birds seemed to learn quickly to run for the beach grass when they saw it coming." She and her co-workers solved the problem by becoming the intruders themselves. "To be certain that a bird has learned to tell 'safe' from 'dangerous' intruders, we try to appear very distinctive in the two roles. Sometimes we look pretty ludicrous walking around in wigs and silly outfits acting 'dangerous'."

Dr. Ristau first worked at Rockefeller in the early 1970s, studying primate communication systems with Peter Marler. She returned several years ago to complete a project with Dr. Marler, who suggested to her that she and Donald Griffin "would have a lot to say to one another." Neither Dr. Ristau nor Dr. Griffin presume, at this point, to give any but tentative answers to the question of what animal consciousness is. They are conducting experiments they hope will give them clues.

Last summer Dr. Griffin began to follow his own advice that students of animal behavior should try to study animal minds by looking through the window provided by their communication. With one of his "academic grandsons," William Towne, a student of James Gould's at Princeton, he is studying the near-field acoustics of honeybee waggle dances, the activity that first aroused his curiosity about the minds of animals. "We're investigating the possibility that air motion may be important in the messages," Dr. Griffin says. "But my long-range dream is to make a model bee and exchange messages with real bees. I'd like to talk to the bees. So far we've only been eavesdropping." □

Studying the acoustics of the honeybee waggle dance in the Princeton laboratory of James Gould, Summer 1984.

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