

In *The Marvels of Animal Behavior*
(Washington, D.C.: National
Geographic Society, 1972), pp.88-111.

SAYING IT WITH SIGHTS AND SOUNDS

Richard D. Alexander

Consider a summer evening in the country. What comes to mind? The flashing of fireflies, clatter of katydids, pulsing chirps of crickets? Perhaps the repetitious droning of a bullfrog, the booming dives of a nighthawk, the calls of a whip-poor-will, or the quaver of a screech owl? Maybe even a coyote's bark or the snort of a white-tailed deer. And faint odors and a freshness on the breeze. Sight, sound, and smell, but for humans mostly sound—sounds so characteristic that adding them as background to a dimly lit movie or television scene gives the illusion of night.

Anyone who stays awake the entire night in a rural or wild locale will notice a hush as the night animals cease their activities just before dawn. Then birdsong bursts out of the grayness. When sunlight strikes across the meadow and into the forest undergrowth, a whole new bustle of activity begins. And again there are signals.

Anywhere in the world that men live—jungles, deserts, prairies, marshes, mountains, forests, or seashores—countless signals are broadcast. They are exchanged among the myriad creatures that have always lived with us, creatures helpful, harmful, or neutral to human existence. Primitive man's surroundings, moreover, must have resounded with many signals we will never experience. And because his life and happiness often depended upon them, he was probably more sensitive to animal signals and their meaning.

How many people today are aware of the messages in the behavior of animals they see at the zoo? A cheetah pauses beside a dead branch a few feet in the air, turns and shoots a jet of urine upward against it—a marking of territory under natural conditions. A lone howler monkey swings rapidly back and forth and emits long, ear-splitting cries; such howls in the jungle probably help monkeys keep acceptable distances between troops. A female rhinoceros assumes a stance that causes sexual arousal of the male. Zoo crowds often miss the special insight into the life of the animal which such signals afford.

Some signals are less easily overlooked. People usually stand in awestruck silence before the challenging stare of a big male gorilla. Once at a zoo in Miami I joined a group watching a new ape that crouched, terrified, in one corner of his exposed cage with his face buried in his hands. After a long silence a tiny, sympathetic voice from the crowd asked softly through the bars, "*¿Qué pasa?*—What's the matter?" A friend of mine was similarly impressed by the behavior of two chimpanzees in the London zoo separated by a wooden wall, solid except for one tiny hole. The chimps were sitting on either side, each gingerly poking a finger into the hole until fingertips touched; then both screamed with ecstasy or excitement or loneliness—or who knows what emotion.

Pulses of light and sound, subtle scents and touches link the lives of earth's social creatures.
PAINTING BY RICHARD SCHLECHT



My studies of crickets, katydids, and cicadas over the past two decades have taken me along many of the back roads of North America, Europe, Australia, and various Atlantic and Pacific islands. In rural areas, particularly those not yet invaded by roaring, whining motors, animal signals are more prominent than in cities, and people seem more aware of them. In a remote part of Mexico I once stopped to tape-record and collect a tiny cicada singing along a forest border. From a nearby hut two small boys approached timidly. I felt like a trespasser, and my headphones, 24-inch parabolic reflector, and other elaborate gear had to be a complete mystery to them. So I explained in halting Spanish that I was searching for a small *chicharra* singing in the grass. The boys nodded slightly but gave no other sign. I supposed they didn't really understand. But a few minutes later I heard in the distance, very faintly, a large forest cicada. When I lifted my head to listen, one boy murmured, "*Chicharra grande*—Big cicada."

What are animal signals all about? Why do they exist? How did they become complex and consistent and recognizable? Beyond mere curiosity, such questions interest us because communication is a central theme in the broader field of animal behavior. It refers



ANTHONY A. BOCCACCIO. BELOW: LOIS COX

Sunrise shimmers a quiet pond, gold-powders the white faces of Queen Anne's lace, and cues a company of daytime signalers. An old field gone back to nature, Edwin S. George Reserve serves University of Michigan students as a living biology laboratory. In the vicinity of Crane Pond 55 species of crickets, katydids, grasshoppers, and cicadas sing at various times of day and night.

A nocturnal pair, snowy tree crickets, meet on a twig. The male at left has called in the female by scraping the edge of his left wing on the toothed underside of the right. When she touches his antennae, he turns and offers fluid from a gland on his back. Mating follows. Songs differ with the species and the phase of courtship. Only male crickets sing, stepping up the tempo on warm evenings. The snowy has been called the "thermometer cricket." The number of chirps delivered in 15 seconds plus 40 gives the approximate temperature in degrees Fahrenheit. Neighboring males synchronize chirps into a steady, rhythmic beat. Nathaniel Hawthorne thus reviewed their nocturne: "If moonlight could be heard it would sound like that."





STEPHEN COLLINS, PHOTO RESEARCHERS. ABOVE: LARRY WEST, FULL MOON STUDIO

Twin voices of the night, signals of the tiny cricket frog and the true katydid, a cricket relative, may confuse the human ear but not others of their kind.

Passing air over vocal cords between lungs and a resonating throat sac, males of the inch-long amphibian call in concert from a breeding pond. In answer come females—and more males to amplify the chorus. Excited male frogs or toads may clasp any moving object of mate size; to cover errors they have evolved a signal for “release me.”

The katydid, conspicuous on dogwood, makes sound as does the cricket but is left-winged. (The toothed file is under its left wing, scraper on the right.) As with crickets, two tympana, or membranes, on each foreleg just below the “knee” provide highly directional hearing. Named for its raucous call, the flightless treetop chorister rarely is seen on the ground.



to systems of interaction by which animals transfer information—by which they effect changes in behavior. Communication opens the way to all the competitive and cooperative acts that almost define the word “animal.”

The formal study of animal communication is one of the youngest disciplines in biology. Understandably so, for many signals are tuned to receptors so different from man's that he has missed their subtleties. The ultrasonic echoes used by bats, the intricate dances of bees, and the chemical messages of ants come readily to mind. But even the songs of some well-known birds are delivered too fast for human ears to appreciate fully the intricacy of their patterns and the nuances of their sounds.

Once I taped the song of an indigo bunting and played it for a group of biologists. Most of them recognized the song at its normal speed. Then I replayed the tape at one-quarter speed to show what they had missed. They were astonished. I had previously noticed that this particular bird ends his song with a little flourish that at the slower speed sounded just like the opening bars of reveille. As a joke I had whistled the remaining bars of the tune and spliced it onto the tape. At normal speed, no one had noticed the addition.

Even when human senses are adequate to pick up an animal's signal, its meaning may not be obvious. The response may be too subtle. Or the effect may not take place immediately. People, as we know, can absorb a message, store it, and act on it hours, weeks, even years later. But the slow-acting effects of some animal signals seem more remarkable. Sounds made by brooding parakeets or ring doves will set lone neighbors, out of sight, into the complex cycle of changes that accompanies breeding: nest-building, gonadal enlargement, and loss of feathers from the brood patch. The male and female of these tropical species depend on stimuli from one another to synchronize breeding behavior. Social insects such as termites and ants communicate by means of body chemicals called pheromones (from the Greek *pherein*, to carry, and *horman*, to excite). Pheromones produced by reproductive members of a termite colony can cause others genetically like them to develop into sterile workers or soldiers rather than reproductives.

Charles Darwin discussed the probable origins and biological function of familiar kinds of signals: cricket chirps, bird songs, canine postures, even human facial expressions. He noted that some seem to derive from “direct action of the nervous system,” as with blushing in embarrassment or bristling with anger. Some derive from “serviceable associated habits”—lifting the eyebrows when surprised, he thought, might be a by-product of seeking a clearer view. Thirdly, a signal may convey a clearer message by being opposite to another of known meaning. A dog's submissive crouch, for example, is opposite to its aggressive rearing forward. Biologists still use Darwin's three generalizations in discussing some expressions and gestures of animals and man.

Darwin could only speculate about the functions of most signals; he was unable to analyze structurally any but the most obvious visual signals. Only in the past generation has technology given us the tools we need to make objective, repeatable studies of signal structure and function. High-speed portable motion picture cameras and ultrasensitive film capture rapid-fire visual signaling. Sound-recording equipment is sensitive well beyond the human hearing range. Gas chromatography and a variety of other techniques enable us to analyze and manufacture chemical signals.

Superior tools gave me an advantage over earlier biologists when I began to study North American field crickets. Earlier generations of entomologists had studied these crickets mostly in museums. They had examined, measured, and compared dead specimens. But because field crickets looked so much alike, even under the microscope, they were all believed to be of one species. It was known that cricket songs, produced by the adult males, differed widely. With portable high-fidelity sound equipment I was able to go into the field and bring back the songs along with the specimens. A laboratory device converted the taped sounds into audiospectrographs, or sound pictures. When these graphs were analyzed and the insects grouped according to their sounds, minute variations in body structure and size were found to follow the groupings. Further work showed that populations so identified do not interbreed in the wild. More than 20 species of North American field crickets have now been identified.

*O cricket, who cheats me of my regrets, the soother of slumber,
Muse of ploughed fields and self-formed imitation of the lyre,
Chirrup me something pleasant. . . .*

The Greek poet Meleager in the first century B.C. thus praised the cricket's melodious calling. An ancient to us, the poet is modern compared to his subject. Fossil evidence indicates that these insects have been noisy since the heyday of the dinosaurs; body parts were adapted for making and hearing sound at least that long ago.

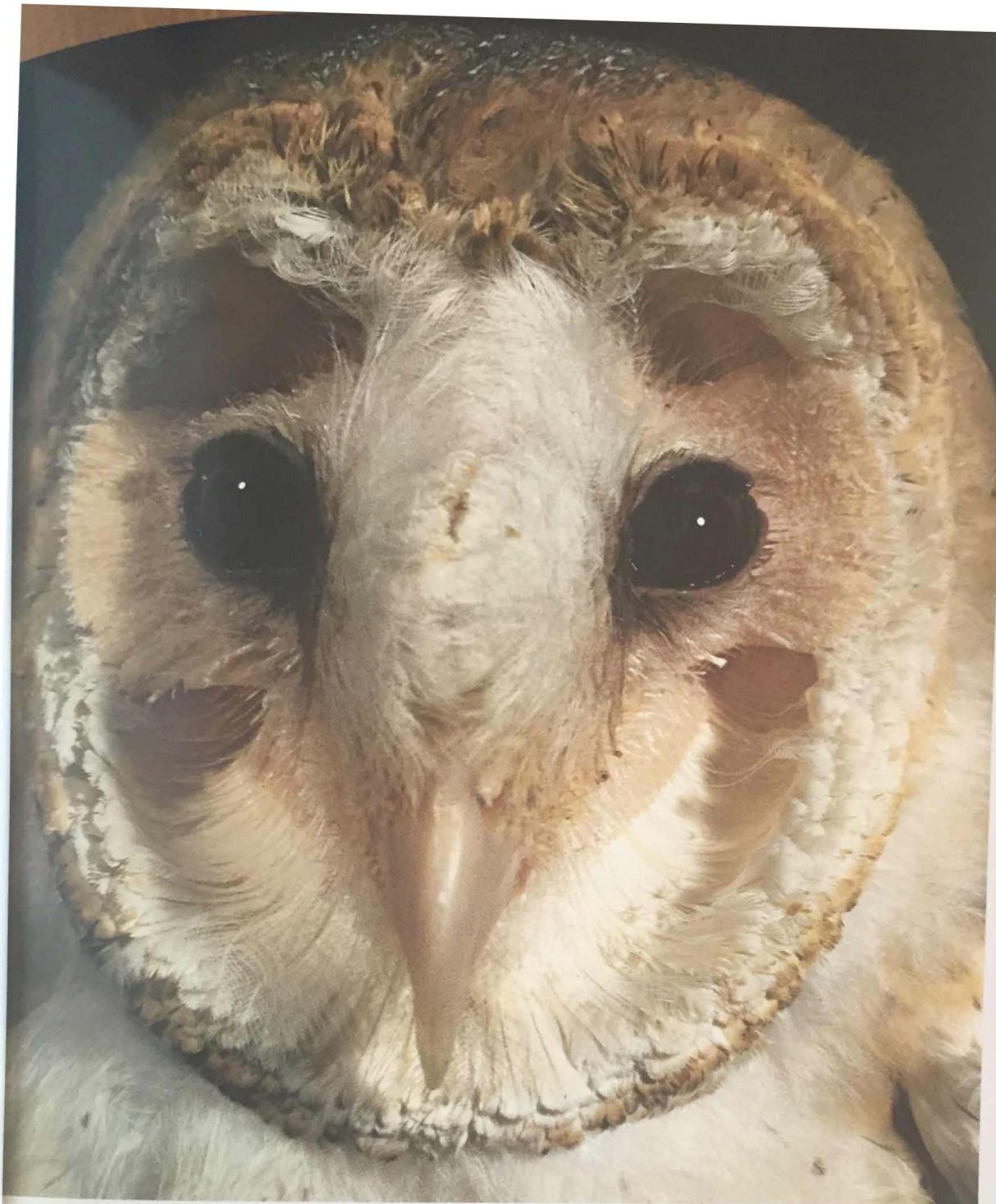
Evidence from comparative insect studies suggests that at an even earlier period crickets were simpler, cockroach-like creatures that did not signal acoustically but did shake their wings during courtship. An animal's means of signaling always derives from senses and body parts that originally served some other function. Female mosquitoes, for example, attract males by vibrating their wings. Birds signal with the colors and motion of their feathers, basically a body covering. Deathwatch beetles make a ticking sound by knocking their hard shells on wood. Various creatures use chemicals in body secretions as trail markers or beacons to find one another. Vocal animals, from frogs to man, make use of their breathing apparatus to produce sound.

As a particular way of communicating takes hold in an animal population, the body parts evolve along with the new function. Those animals that developed a complex social life developed many signals, often using more than one sensory channel.

Man himself is the super-communicator. He signals acoustically, visually, chemically, and by touch. To these "natural" kinds of signals his technology has added radio and X-ray waves and numerous others ways of passing and preserving information. He communicates on more different subjects than any other species. His complex social life leads to talk about sex, children and grandchildren, politics, social tolerance, war and peace. Not limited to the concrete or the close at hand, he discusses such abstractions as self-awareness and death-awareness and the nature of the universe—even communication itself. Unlike any other organism, man also communicates about events far removed in time and space, and he does so on a massive scale.

Man's communication is so complex that investigators searching for unique aspects of human behavior have increasingly focused on language.

(Continued on page 101)



JAMES E. RUSSELL

SENSES AT WORK

Dark-tipped feathers rim the heart-shaped sound collector that is a barn owl's face—all the better to hear with. Sensitive eyes enable the bird to see as well in starlight as man can under a full moon. But the night marauder also uses sound to take prey. And it hunts with consummate skill; in 25 minutes one night an owl was seen carrying 16 mice, 3 gophers, a rat, and a squirrel to its young. Densely packed, curving feathers form the collecting wall. Filmy overlying plumes—here partially clipped to reveal the channeling understructure—let sounds through. Ears beneath the downy veil have a hearing range less broad than man's, but can pick up many sound frequencies at fainter levels because of the efficiently shaped face.



Precision in pitch darkness

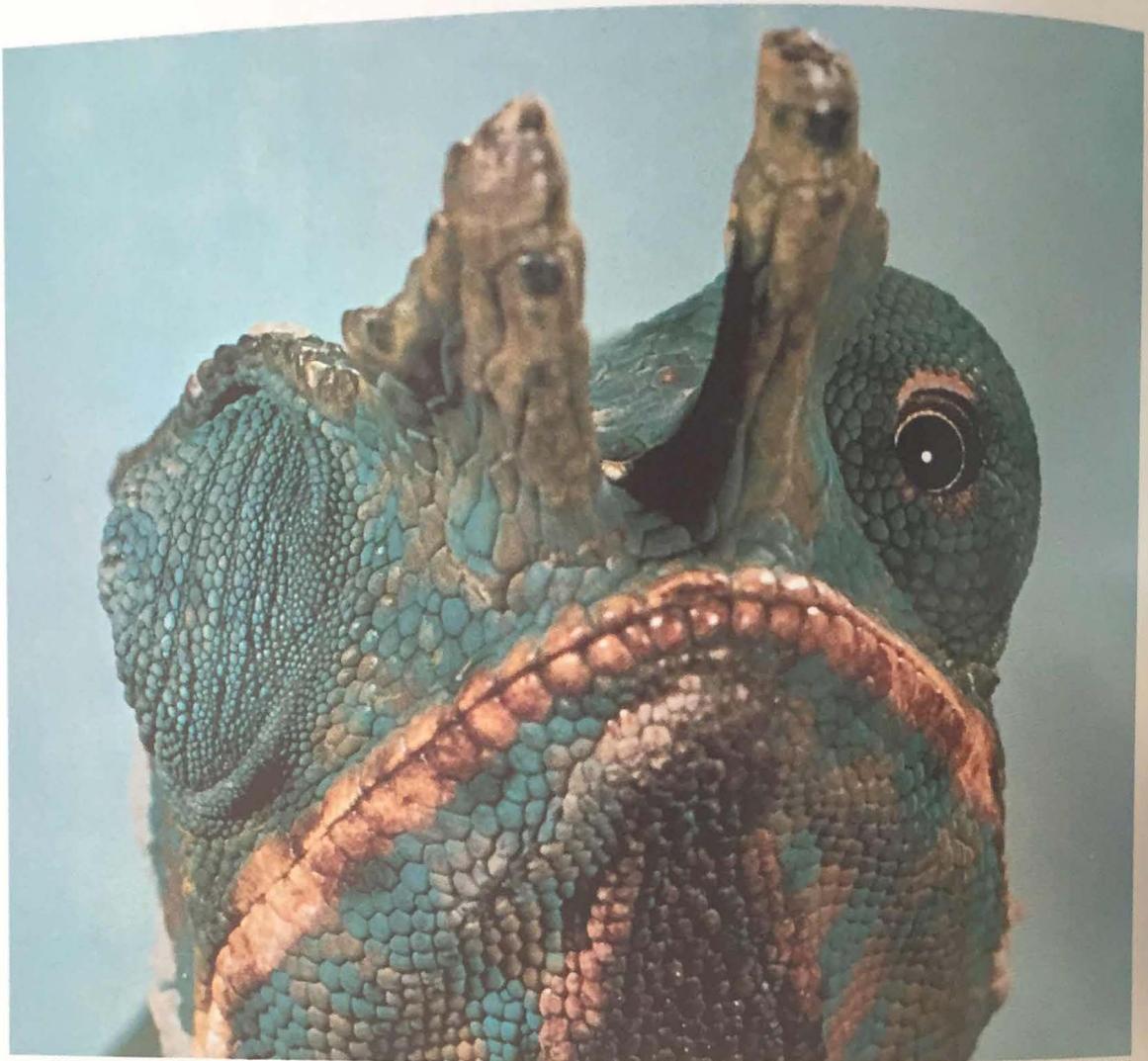
A telltale rustle in the blacked-out laboratory, and a barn owl arrows from its perch toward the unseen source; spread talons imprison the prey. What enables the owl to hunt so successfully when it cannot see? Its ears are proportionately larger and have a more specialized inner structure than most other birds'. Also, in many owl species ear openings are not placed symmetrically—presumably enabling the bird to sense direction in both horizontal and vertical planes at the same time. So discriminating is the barn owl's hearing that, after an alerting sound, it needs but one more to locate the source.

Leaving a perch, the owl pushes off head-forward on a flight path set by its ears. When there is light, the bird glides swiftly, feet tucked back. In total darkness it flaps its wings to slow its flight; feet swing pendulum fashion. At the last moment the bird turns end for end, talons replacing ears on the target line.

In another lab experiment a speaker emitting mouse noises was hidden under a sheet of paper. A switch on the perch stopped the sound the moment the owl took off, yet the bird regularly struck the covering. Talon holes always were carefully spaced to cage a mouse lengthwise (left); in the wild the owl maneuvers so the claw pattern aligns with the mouse's path. The silent-pinioned hunter makes mid-course flight corrections if it gets a mid-course clue.







CONSTANCE P. WARNER. OPPOSITE, LOWER RIGHT: GRACE THOMPSON

An eye for every need

One eye for the quarry, one for the foe? It's a matter of choice for Parson's chameleon (above). Its turreted eyes swivel separately. When an insect meal nears, the lizard's eyes coordinate while its long, sticky tongue whips the morsel in; then they diverge again.

Such oddball eyes make survival sense, having evolved to fit each owner's life-style. The stargazer, a bony fish that lies on the ocean floor, eyes upturned, luring food fish into its mouth, probably has no need of the detailed visual data essential to swift-moving predators like the cat or eagle. Scores of gemlike eyespots stud the mantle inside a scallop's fluted shell, but they sense light and motion only dimly; chemical sensors help the mollusk elude its nemesis, the starfish. The mosaic image perceived by the robber fly is also crude—despite the bulging bulk of its multifaceted eyes. Facets do not focus, yet compound eyes efficiently sense the movement of prey.

The keenest of eyes belong to birds of prey and sight-guided mammals. Flexible lenses focus sharp images from light rays entering an opening expandable for dim light. The cat's mirror-backed orb makes dual use of each stray glimmer. Feathery frame and bony hood shield an eagle's eye, among the most acute.



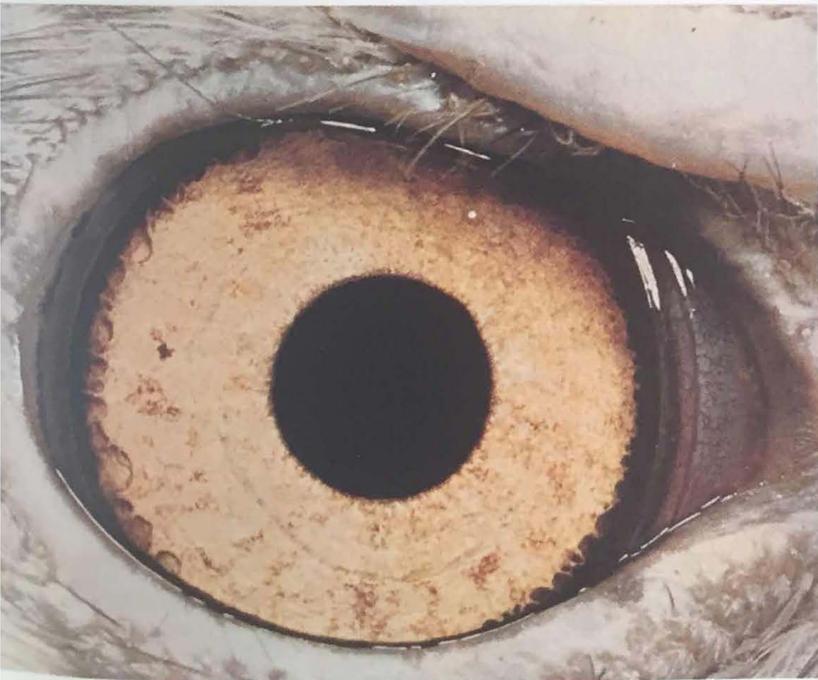
SOUTHERN STARGAZER



DOMESTIC CAT

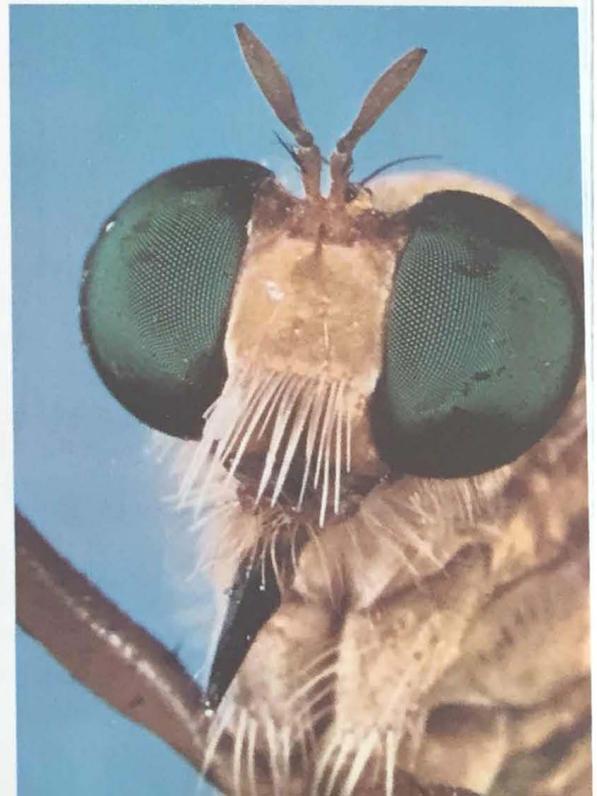


BAY SCALLOP



BALD EAGLE

ROBBER FLY





CONSTANCE P. WARNER

A sense of direction

A cold-blooded denizen of the jungle favors warm-blooded prey. Special senses help find it, even in the dark. Looped on a limb, the South American emerald tree boa can detect a nearby bird or small mammal by means of heat receptors in shallow grooves along the lips. The paired right and left pits probably help the six-foot constrictor zero in on prey and strike with precision. Snakes lack external ears but are sensitive to vibrations. The forked tongue, too, is a sensor, flicking about, carrying airborne particles to a chemical analyzer, called Jacobson's organ, in the roof of the mouth.

Many creatures of murky waters, where visual signals work poorly, rely on smell and hearing to find food, mates, or spawning places. Fishes possess a special sense, the lateral line system: rows of pores in the skin leading to fluid-filled canals. These organs, sensitive to minute currents and vibrations, help fish swim in large schools, thus reducing the individual risk of being eaten.

Man, they say, is the only species with "true language." Despite its complexity the structure of human language can be reduced to fundamental building blocks comparable to those of animal signals. Language is composed of two major kinds of units. The most basic are *phonemes*, the smallest divisible units of sound. Phonemes often correspond to letters of the alphabet. The smallest units that convey meaning are groups of phonemes called *morphemes*, and they correspond roughly to words, phrases, and sentences. The smallest complete message can be observed to bring a particular response from others using that communicative system.

I can remember a feeling of considerable pride and confidence accompanying my initiation into a new signaling system. It was my first day of school in a one-room country schoolhouse in Illinois. Sometime in midmorning I urgently needed to visit the outhouse in the far corner of the schoolyard. But talking was prohibited, and so was leaving one's seat except to sharpen a pencil or get a book. I was at a loss and sat in misery. Then I saw a boy near me hold up two fingers and, following a nod from the teacher, depart the room. Instantly my two fingers also shot into the air. But the teacher shook her head, frowned, and said, "Not until Leonard returns." When Leonard did return I had already realized, by the length of his absence, the significance of two fingers. Confidently I held up one finger and took my brief leave, a full communicating member, as I saw it, of the new society.

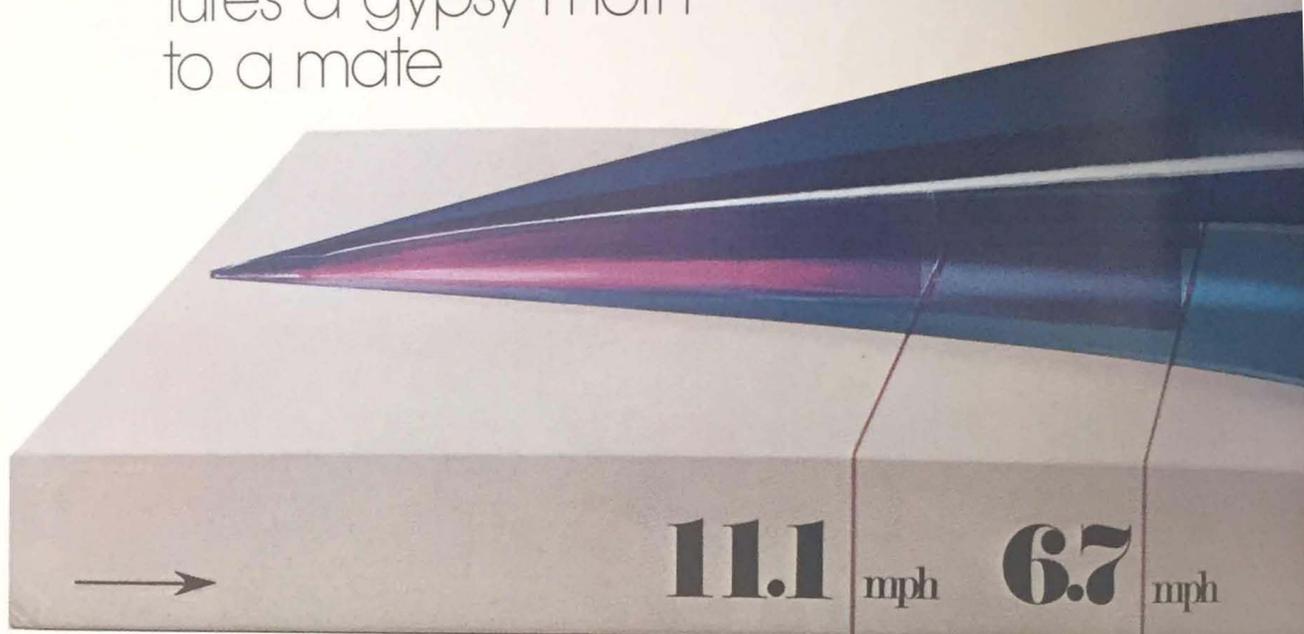
Humans don't go around speaking phonemes to one another: They deliver whole messages. We can assume that animals don't spend much time giving incomplete signals either. The basic units of communication—the level at which function becomes apparent—are revealed by the ways animals combine and shuffle gestures, movements, sounds, or touches to make messages. If an animal always puts together what at first appear to be two different signals, never giving one without the other, we can be fairly sure that both parts are required to give the message accurately and completely.

The chirps of field crickets can be subdivided into sound pulses made by individual strokes of the wings. But playbacks of individual pulses do not cause other crickets to respond. Only certain minimal groupings and patterns of pulses make a complete message. As early as 1913 a German biologist, Johann Regen, sent the chirps of a male European field cricket through a telephone and observed that a female was attracted to the receiver. The experiment has been repeated with other species and refined with modern sound equipment. We now know also that female crickets respond only to the chirps and trills of males of their own species.

The only way a cricket can make his sounds is by stroking his wings back and forth. He produces a pulse by rubbing a row of teeth against a scraping edge, which together make up a "stridulatory" apparatus. More than 2,000 cricket species make sound this way; sometimes as many as 30 live in a single small field or forest. Only rarely, and only when they do not breed at the same time, do different species have the same pulse pattern. The patterns thus provide a rich signal grammar, or syntax. Comparative studies through analyses of recorded cricket songs reveal how messages are constructed and what are rough equivalents of phonemes and morphemes in human language.

Most of the examples used in biology to describe signal function come from insects. A major reason, I believe, is that higher animals with more complex behavior use many

Windborne odor lures a gypsy moth to a mate



different kinds of signals in quick succession or simultaneously. The functions of insects' signals are relatively easy to analyze.

Crickets are not only cheerful laboratory companions, they also make excellent subjects for study. They are easily reared in captivity. Different species can be hybridized (even though they rarely crossbreed in the wild). Surgery can easily be performed on them. Biologists have thus been able to study the development and neurophysiology of signals in crickets more thoroughly than in other animals. We know, for example, that 19 pairs of muscles help produce each pulse of cricket language. Those muscles are coordinated with a single impulse from a clump of nerve cells making up a pacemaker in the central nervous system. Other pacemakers modulate the stream of pulses into groups, or bursts, of pulses. These patterns, usually called chirps or trills, are the actual messages, comparable to morphemes. Each species has a distinctive repertoire, from one to six different signals.

Studies involving hybridization show that differences in the pacemaker rate which shape the distinctive species signals are inherited. A cricket gives the right chirps for his species the first time he tries. Unlike birds and mammals, most crickets hatch long after the previous generation has died. This means there is no "culture" involved in an individual's chirping—no learning from hearing a parent's song. Neither in a laboratory that is sometimes a cacophony of chirp and trill nor out in a world of even more alien noises has anyone yet been able to change a cricket's tune. There is much we do not know about how a cricket acquires his song, but we do know he does not learn it by listening.

How can we generalize the roles of animal signals?

Basically, the life function of every organism is reproduction. All its activities can be viewed as a means to that end. In order to live to reproductive age an animal must be able



TASI GELBERG PESANELLI, INC. INSETS: ROBERT S. OAKES, NATIONAL GEOGRAPHIC PHOTOGRAPHER

Written on the wind, the volatile scent of a female gypsy moth advertises her readiness to mate. A male (below) reads the message with his feathery antennae and moves upwind to find her. The potent alcoholic substance, called gyptol, attracted males from 2.8 miles away when wafted on a gentle wind of 2.2 miles an hour. Stronger winds scatter the odor, shortening and narrowing the effective area, shown by conic sections in model at left. In still air, some males detect odor but cannot find the source.

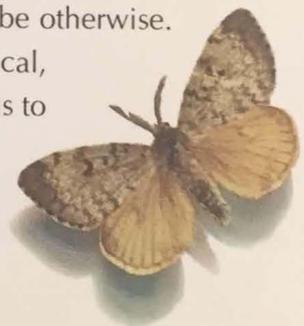
Gypsy moth larvae defoliated 1.4 million acres of American forests in one year. Decoy scents to keep males from finding females may offer a nontoxic way of curbing moth populations.

to get food, to avoid predators and disease, and to remain or go where the climate suits it. Then the animal must produce offspring that are able to do the same things. Some of these activities do not necessarily involve more than a single animal of the species. But in all sexual species, at least the last activity—production of offspring—takes two and therefore requires that male and female communicate.

Sexual activity begins with finding a suitable mate and producing a fertilized egg. In some cases it ends only after a long period of parental care of the offspring. Pair formation is therefore the most nearly universal context of cooperation and competition. And sex signals are the most prominent and diverse in the animal kingdom. They also appear often to form the basis of communication used in aggression, territoriality, and alarm.

Sex signals include not only the familiar bird songs, cricket calls, and firefly flashes but also the less obvious odors of a female moth or of a bitch in heat. Chemical signals, though perhaps the least perceived by man, are among the most ancient and the most widely used in the animal world. Odors of female moths can be enormously powerful stimuli. In one of the pioneer studies of sex signals in insects C. V. Riley more than 75 years ago released a marked male silkworm moth 1½ miles from a caged female. The male was on her cage the next morning. Recent work indicates that in a slow, steady wind the female's potent sex pheromone may recruit male moths at even greater range.

As one might predict, the signals responsible for forming pair bonds are never alike between species that live together, no matter how similar the species may be otherwise. Human beings rely upon whole constellations of signals of a visual, acoustical, and chemical nature, and form long-term pair bonds. It is thus not easy for us to understand the importance of distinctiveness in the sex signals of species that rely chiefly or entirely upon a single signal—an odor, a flash, or a chirp—and whose pair bonds may last only as long as a single copulation.



Some insect species are so much alike that biologists can find scarcely any way to distinguish them except by their dissimilar sex signals. Similar species may avoid mix-ups by signaling at different times of day or in different seasons. Or they may live in different habitats in the same geographic region. Those active in the same place at the same time evolve different signal structures.

Pair-forming signals operate in two ways. In the first system one sex, when ready to mate, stays in place and broadcasts a signal. The other sex cruises about, either homing in on an intensity gradient of the signal, or in the case of chemical signals sometimes simply moving upwind or upstream. In crickets, frogs, and most birds, the male takes a calling station and the female is the rover. In moths the female is a stationary chemical signaler and the male moves to her. Females of some moth species have lost their wings and legs and evolved into little more than bags of eggs and scent.

In the second major system both sexes signal. One begins with a long-range signal; the other responds. Thus they set up a reverberation of signals and responses and gradually move together. Fireflies and katydids start courtship this way.

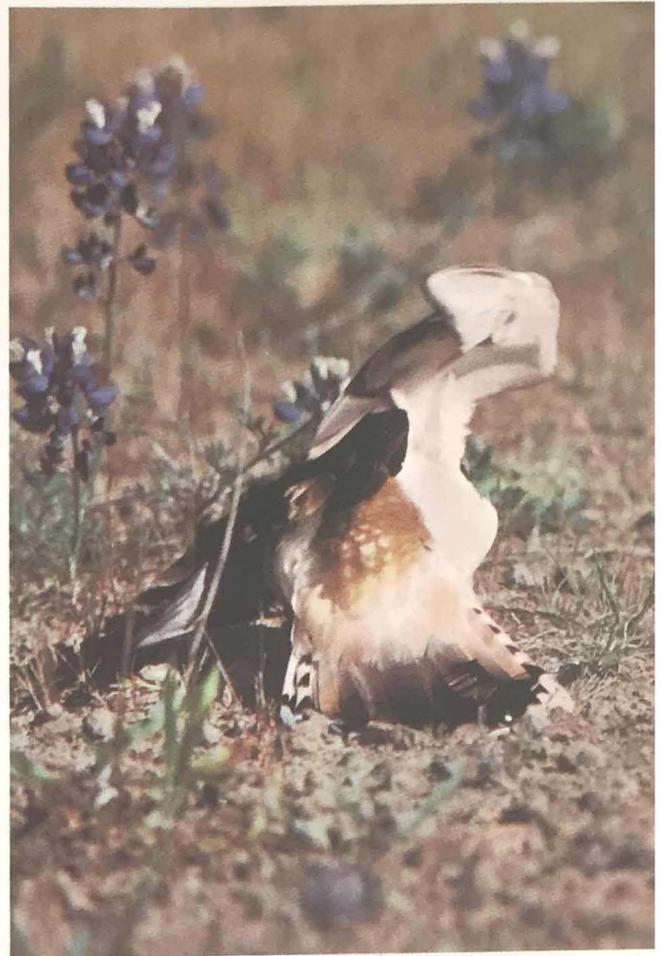
The insect that stays in one place and emits a sound would seem especially likely to be eaten by a predator. It is not surprising that most insects signal only at night, when few insect-eating birds are active. Generally, those that venture daytime noises either call from burrow entrances, as with field crickets, or have excellent vision and flying ability, as with grasshoppers and cicadas.

In the cricket family, those that live in trees tend to sing only at night. The correlation is so close that in some sister species the one living in the grass sings much in the daytime, but its tree-dwelling relative almost never does. Bird predation is a fact of life for tree crickets, shown also by their close color match with the leaves and twigs of the host trees. The pine-tree cricket of eastern North America not only has a reddish head and green body to match the sheath and needles of pine foliage, but when disturbed it positions itself so it looks almost exactly like a pine needle.

Whatever an animal's means of signaling, it seldom finds a clear channel. The world is full of competing sights, noises, and smells. As a result, some animals have evolved ways of sending signals that carry great distances, can be continued for hours, and are essentially flawless from a physical point of view. The enormous larynx of a howler monkey, the hollow abdomen of a male cicada, and the balloonlike vocal sacs and larynx of a frog all act as loudspeakers to increase the power of the emitted signals.

"All's fair in love" seems to be true even at the insect level. Take the "false katydids." During an evening of sexual activity a male flies from one singing spot to another, stopping briefly to signal. When a female answers, he alternates signals with her and slowly flies and walks toward her. He holds his forelegs, bearing his auditory organs, in odd positions. He slowly tilts and waves them, listening directionally.

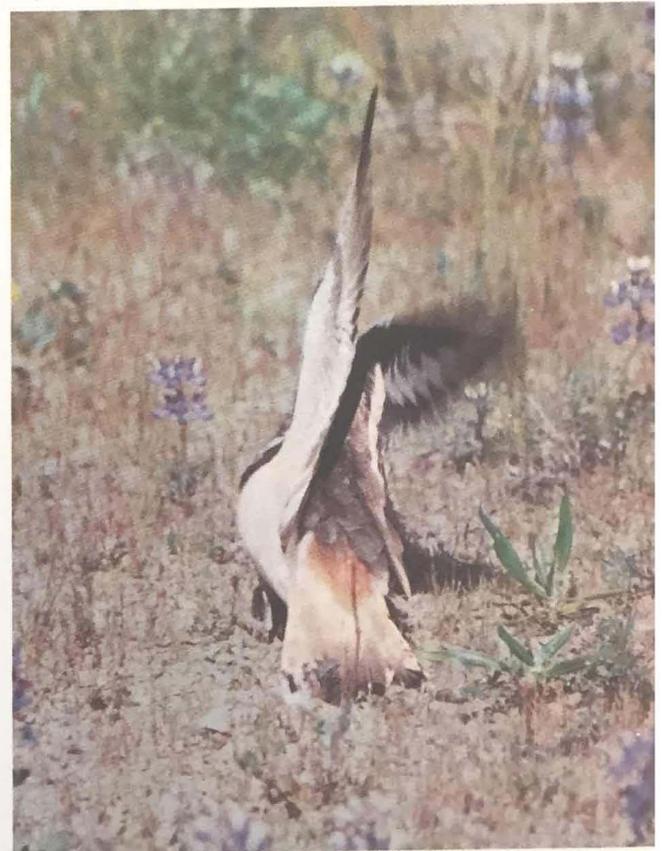
John Spooner, who worked out how these katydids form pairs, gave me an impressive demonstration one night in my backyard in Michigan. For a while he answered a signaling male by striking the blade of a pocketknife against a baby-food jar. Then he told me to turn on my flashlight and look around. I was amazed to see half a dozen other katydid males forming an arc in front of us, slowly waving their forelegs and moving silently in



EDWARD S. ROSS

Parental ploy: A killdeer performs a "broken-wing" display that may save its nest from plunder. Predators, seeking the easy mark, have evolved the ability to detect when birds are hurt. Nesting killdeers exploit the exploiter. The robin-size plover lays its eggs on open ground. Male and female share incubation duty. When an intruder comes near, the nesting bird, perhaps alerted by the alarm call of its mate, hurries away. It flops about, beats the dust, and, dragging a wing as if it were broken, leads the interloper directly away from the nest. When the predator closes in for the kill, the faker flies away. If the brood has hatched, the parental maneuver—a step removed from an alarm signal—may save lives by causing the young to freeze or squat out of sight.

Some animals employ an opposite kind of mimicry, pretending to be armed when actually helpless. Certain tenebrionid beetles can spray a noxious chemical to keep from being eaten. A similar-looking beetle lacking scent glands fools some predators by mimicking the headstand position its armed relative assumes when about to spray.





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Wet and woebegone trio of month-old coyote pups—survivors of a flooded den—and an adult that has found winter food celebrate two of many howling occasions. Members of the genus Canis command a rich repertoire of social whimpers, barks, and growls as well as the long plaintive howl reminiscent of a prairie party line. Said one writer who found music in the calls of wolves: "Like a community sing, a howl is . . . a happy social occasion. Wolves love a howl. . . . troop together, fur to fur."



our direction. Evidently they were creeping toward the responding "female" whose location was exposed by the one male alternating calls with her.

It may be to the female's advantage to broadcast her responsiveness to every male in the vicinity and let the "best" win. It is not clear how a male fights such competition. But in alternating with a female he does throw in an odd little noise much like that of the female, so quickly after her signal that it seems a part of her sound. This little confuser perhaps gives some trouble to the males freeloading on the signaler.

A different kind of opportunism confronts some firefly species. James Lloyd has discovered that some females of the genus *Photuris* are capable of answering the flash code of males of the smaller *Photinus*. When boy meets girl, however, the *Photuris* females seize the responding males and eat them.

Long-range mating signals probably evolved from close-range courtship. Courtship signals are usually softer, less distinctive, and more erratically delivered than long-range pair-forming signals. When two tree crickets are courting at close range, the male raises his forewings, exposing a chemical area on his back which attracts the female into mating position. Vibration of some ancestral male's body as he lifted his wings in courtship was probably the evolutionary forerunner of stridulation.

The signals that reproductive individuals or pairs use to secure and hold territories are also associated with sex. The functions of a territory differ with various animals. In crickets the territory is the area from which a male excludes other males which might compete with him for mates. Females have little stake in such a territory.

In birds, on the other hand, male and female commonly cooperate in a monogamous unit to raise as many healthy babies per clutch of eggs as they can. In many songbirds, each parent must make dozens of insect-capturing trips each day. Keeping other birds out of the nesting area forestalls attacks on the young and also saves the nearby food for the nesters' use. Although surprisingly little is known of the significance of the males' songs for their females, the songs are known to be aggressive signals between males.

Just past midnight one summer several years ago, I was driving through Shiloh National Military Park in southern Tennessee. On an impulse I stopped among the shadows of its great oak trees. The park was bathed in moonlight so bright I could read the inscriptions on the pedestals telling of the events of April 1862, when Union and Confederate forces fought here. It was easy, standing alone in the moonlight, to envision the battle scene. Off to my left I could hear two nightjars—a northern whip-poor-will and a southern chuck-will's-widow—posted very near one another and calling in a furious and rapid antiphony. As I read from the plaques and glanced across the slopes reconstructing the battle, I was suddenly chilled by a tremendous boom and rumbling roll of sound across the woodland to my right. Seconds passed before my mind came back to the present and accepted the noise as a sonic boom from a jet plane now fading into the night sky.

As I climbed back into my car, though, the thing that kept ringing through my mind was the symbolism in the aggressive interaction of those two birds, Yankee and Rebel, that happened to overlap ranges here. So easy for soldiers on night duty to borrow their signals, I thought. And I wondered whether some innocent, feathered tops-of-posts hadn't been blasted into eternity during those few fateful days a hundred years before.

Man discusses, debates, argues—and worse. Animals also wield signals in competing for commodities having reproductive value: food and water, shelter, mates, and territory. For many animals, sex signaling ends with copulation. Other species care for their babies: organisms as diverse as burying beetles, honeybees, salamanders, toads, snakes, and almost all birds and mammals. Individuals in these species have more survivors by using part of their reproductive effort to reduce mortality of their young.

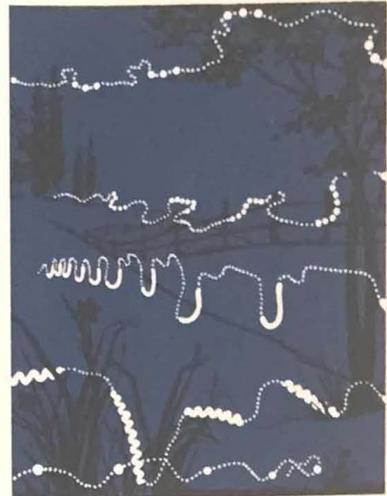
Some of the shift in effort is almost certain to involve the development of special communication between parental animals and their offspring. Such signals are constantly before us: the exchanges of whinnies and bellows and bleats and grunts by mares and colts, cows and calves, ewes and lambs, sows and pigs. The signals help parents and young stay together or find each other if separated. In some large social groupings, they help parents to distinguish their own offspring.

Until a few years ago it was generally believed that orphaned birds in large colonies were fed by other adults, and even that adults fed young indiscriminately, not knowing their own. In each case studied carefully, however, parents were shown to recognize their offspring by its voice or by sight and sound together. Obviously the parent who refuses to feed any but its own young will have a reproductive advantage. Herdsmen have long had trouble getting ewes or cows to adopt orphans. Sheep raisers sometimes pull the skin of a dead lamb over an orphaned one to get the bereft mother to adopt it.

Forewarned is forearmed in animal as well as human society. An individual that detects another's reaction to danger has more time to flee or ready its defense. An animal giving an alarm signal in some cases also increases its own safety. A bird sounding an alarm call may cause the flock suddenly to take to the air or scatter, so confusing the predator that it does not attack. A young baboon that screams when it sees a leopard may attract adult male baboons that can successfully bluff or repel the predator. But usually the individual giving a danger signal attracts the predator's attention; the alarm-giver takes a risk. Such behavior is often thought of as altruistic; that is, the signaler endangers himself in order to save his fellows.

How can natural selection favor such behavior? For the "selfish" individual that does not endanger itself for others seemingly would be safer, would produce more descendants, and eventually would be the only kind of individual left in the population. But when parents signal to protect their offspring, they may increase their reproduction over parents that do not. Even though a parent is sometimes killed by the predator, its signal may save a number of offspring. Similarly, a signaler may be preserving his own genes by saving his pregnant or brooding mate. An individual helping close relatives could feasibly benefit in terms of saving his own genetic material. Biologists call such partiality to relatives "kin selection." In humans we call it nepotism.

Alarm signaling is not confined to the breeding season nor to groups known to be composed of close relatives. In some cases, however, there is reason to believe the signaling is an outgrowth from parents protecting babies. A parent-offspring signal that is useful most of the year may, on rare occasions, be given in disadvantageous situations because greater precision in its use has not yet evolved. Even for the alarm-giver, a well-alerted flock is a safer place to be than a poorly alerted one.



Built-in beacon gives the firefly a visual signaling system that works in the dark. While most night creatures call on other sensory channels—chiefly sound and smell—luminous beetles of the family Lampyridae blink their abdominal lanterns. A compound, luciferin, interacts with an enzyme, luciferase, and oxygen to make cold light. Larvae as well as adults can emit a glow, but most fireflies studied flash only during pair formation or when disturbed. Flight paths of flashing males vary; some species can be identified by their J-shaped swoops or periodic wagging.

Beaded trails of light (above) show paths and rhythmic flashing of five species in the American genus Photinus, as they might appear in a time exposure. A male begins the signaling. When a female turns on at the proper interval, he flies toward her, exchanging signals periodically. Attraction is based entirely on the flash code; females of various Photinus species put in airtight glass cages attracted males as in the open.

Males of some Southeast Asian fireflies, including Pteroptyx malaccaea (left), synchronize flashes. Pooling their luminosity may increase their ability to attract females.

Most alarm signals probably begin when simple fright behavior of one animal is used by another to avoid the same danger. Once such an action takes on signal value, and it also helps the actor in some way, it may spread through the population.

Animals of different species sometimes benefit from one another's alarm signals. Baboons and impalas, for example, often forage together. Baboons have keen eyesight; impalas have keen senses of smell and hearing. Thus each can profit from the alarm signals of the other. When two animals gain from each other's presence, they develop not only social tolerance but also better ways of communication in succeeding generations.

Such mutual aid, or "reciprocal altruism," is prominent among animals that interact in social groups. Some animals recognize one another individually and are thus able to identify and discriminate against cheaters that do not act for the benefit of others when it is their turn. Some of the complex social communication of human beings seems to fit such a model. Trying to explain alarm signals in terms of natural selection is a topic of great current interest to biologists. Different theories have been offered, and important questions remain unanswered. But alarm signals are sure to figure prominently in the future study of animal communication.

By coincidence the peculiar beeping signal transmitted back to earth from one of man's first orbiting satellites sounded remarkably like an intriguing and seldom-heard animal communicative signal: the piping of a new queen bee still in her pupal cell. The piping coincides with the departure of the old queen and some of her workers to a new site. Listening to the one signal and thinking of the other, I was struck with how much man, the super-communicator among all organisms, has learned about signals and their meanings and how much he has yet to discover.

Satellite beeps and honeybee piping have more than their sound in common. Each signifies a beginning: for man an era of direct exploration and dispersal into unknown regions of the universe; for the honeybees a new era in the life of the colony.

The beeps and piping are each products of an enormous amount of social cooperation. And each is inextricably linked to that complement of cooperation, social competition. No satellite is launched without the power and coordination generated by thousands of people working together. No queen honeybee is produced without the cooperation of thousands of bees. But we can legitimately wonder how long it would have taken a single nation without a competitor to make those initial probes of space. And no biologist doubts that it has been the constant reproductive competition between honeybee colonies that has produced their complex, almost bizarre social existence.

Competition results in change, whether good or bad in the long run. In a social organism cooperation is a vehicle of that change. These two interwoven facets of behavior are the key to the fascinating and complex patterns of interaction in the animal world. Communication, because it is the sole means by which social competition and cooperation are carried out, is the essence of social existence.

Galaxy of fireflies sets a mangrove tree aglow. Here in tropical Malaysia swarms of Pteroptyx perform each night. A single male begins flashing; gradually others pick up the rhythm until nearly all are blinking in unison. Responding females emit dimmer, unsynchronized flash patterns. Signaling mechanisms that benefit an animal pass on to new generations, refueling the torch of life.

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