Hey, Snake—Rattle This!

Some furry little creatures are born to taunt rattlesnakes

By SUSAN MILIUS

Your basic hairy-chested guy who wrangles rattlers may find himself out-machoed by a half-pound of cute, wiggly-nosed fluff.

When California ground squirrels spot a rattlesnake, they get "feisty," according to Ron Swaisgood, who's observed plenty of whiskers-to-fang confrontations in the wild and in a laboratory at the University of California, Davis. The ground squirrel behavior confounds scientists. "It's not your typical predator-prey interaction," Swaisgood says.

"After a few minutes of inspection, the squirrels come in with more confrontational tactics," he recounts. "They'll lunge at the snake. They'll kick dirt at the snake. They'll get really close and kick pebbles. I've even seen them partially bury a snake." Ground squirrels also have been known to nip at rattlesnakes, and twice Swaisgood has seen a squirrel kill a small rattler by biting it.

All this attitude, not surprisingly, provokes a snake to rattle and occasionally attack ground squirrels, says Swaisgood, who now works at the San Diego Zoo.

"If it strikes, they have an evasive leap where they jump back dramatically, a kind of a sideways flip, out of the snake's way," he says. "[The snakes] strike extremely fast, but the squirrel jumps even faster."

It's unlikely that a snake could kill adult ground squirrels, although it can inflict serious injuries, taking out an eye or causing a debilitating wound, Swaisgood says. However, some 40 percent of squirrel pups get eaten by snakes.

Swaisgood's work is the most recent in a rich history of studies on squirrel-snake spats. One of the pioneer analysts of rodent moxie, Don Owings at Davis, says, "The ground squirrel–snake relationship is an interesting one in its own right. But it's a nice system to study broader issues."

Studies of snake teasing have led scientists to consider a wide range of topics including evolutionary arms races, ghosts of bygone predators, and a fear-fascination reaction to snakes that may be shared by people.

Coss

Beginning cautiously, two adult California ground squirrels check out a rattlesnake.

Owings started his research career studying the nocturnal kangaroo rat's aversion to moonlight. Ground squirrels, however, charmed him away from that project in the early 1970s—in part, because he could watch them in daylight. He found a few descriptions of brash squirrel behavior in journal articles from the 1940s but no reports of experiments. Ranchers and rangers he talked to often had never heard of the phenomenon. "It was in the literature but not in the lore," he says.

He, his Davis colleague Richard G. Coss, and their students staged snake-squirrel encounters in their laboratories, witnessing taunts and hair-breadth escapes that set the human observers' hearts racing. "The tension was agonizing," Owings remembers.

The performances were also astonishing. Coss remembers seeing an adult female fail to flip out of the way fast enough and take a full strike from a rattlesnake. Backing away, "she rubbed her face, and that was it. She came back for more," he says. He's even seen an adult ground squirrel pry itself free of snake fangs in its neck.

Other research suggested that some other rodents have some resistance to snake venom. So, Coss and Naomie Poran, now president of SemioChem in Raleigh, N.C., checked the California ground squirrels that he had been studying and discovered proteins in their blood that inactivate the venom of Northern Pacific rattlesnakes. "They can tolerate enough to kill a human," he says.

However, the pups prove vulnerable; they don't yet have enough of the protective proteins, the researchers found.

Unraveling how the lifesaving biochemistry works has intrigued graduate student James E. Biardi at Davis. He's refining biochemical assays to explore such questions as whether the protective factor sabotages the venom's ability to dissolve its victim's proteins.

Even among California ground squirrels, populations vary in antivenom functions, according to Biardi. In an article that will soon be published in TOXICON, he and his colleagues compare two ground squirrel groups in very snaky terrains with two that rarely, if ever, confront a rattler.

Some of the variation makes immediate sense. Ground squirrels from a rattlesnake heaven near Winters, Calif., can laugh off the venom of the Northern Pacific species—the one that lurks in their home range—but are much less, or not at all effective against two other rattlesnake species.

In a virtually rattlerfree site in the Sierra Nevadas in California, ground squirrels have lost venom resistance to Northern Pacific rattlesnakes. When Biardi tested these squirrels' blood against a menace new to them, the Western diamondback, something in the rodent blood actually exaggerated the venom's destructiveness. Snakes may have evolved means to hijack some of their prey's own protein-dissolving compounds, Biardi muses. Beyond those points, "it's a really confusing pat-

Photos: Coss

On its first day out of its burrow, a pup immediately recognizes a rattlesnake and does a creditable version of an adult's snake taunting.

tern," Biardi admits.

He and Coss are now expanding their venom analysis to rock squirrels in New Mexico, collaborating with Owings and Matt Rowe of Appalachian State University in Boone, N.C. These squirrels contend with four or five rattler species, and Biardi predicts some kind of broad-spectrum protection. His preliminary results do show some activity against at least three species' venoms, he says.

When Coss and Owings began examining ground squirrel populations for venom resistance, they stumbled onto a surprise. Squirrels that have lost their resistance to venom still taunt snakes.

In prime rattler territory, such as the Folsom Lake area of the Sierra Nevada foothills, ground squirrels and snakes have been battling it out since at least the last ice age, and the adult squirrels there display high resistance to venom. On Mount Shasta in northern California, however, ground squirrels and rattlesnakes haven't met socially for 300,000 years. When researchers tested the Shasta squirrel population, they found the animals had lost their resistance to snake venom. Yet when exposed to a snake, the unprotected animals still watched tensely, snapped their tails from side to side, and then taunted the snakes.

If anything, the Shasta squirrels turned out to be more aggressive provocateurs than the animals that see snakes all the time, Coss says. He speculates that ground squirrels that live around snakes tend to get yanked out of the gene pool if they're extremely brash, whereas rodent lineages in snake-free zones can drift toward recklessness with no reality check.

Not until the researchers tested Arctic ground squirrels, which haven't encountered rattlesnakes during the past 3 million years, did they find a ground squirrel without snake-taunting behaviors.

Venom resistance and brashness might work well together in snake-infested areas. However, take away the real snakes and one system seems to decay rapidly while the other remains in full force, notes Coss.

Thus the ground squirrel–snake system is a classic example of so-called relaxed selection. In this upside-down evolutionary process, traits deteriorate, often at different rates, after their driving cause vanishes.

The snake-squirrel interaction reminds Swaisgood not so much of predator-prey conflicts but of two rivals of the same species sizing each other up. In swaggering moments of bluster, rivals calculate each others' strengths and decide whether to fight or back down. The data thus gathered reduce an animal's risk of getting trashed in a contest it could never have won or permits it to pick the moment when its tough rival is vulnerable.

Classic research has demonstrated such testing periods within a species. When rival toads of one species meet, for example, they croak and assess each other's fighting potential by the pitch. A deeper pitch means a bigger, tougher toad. By playing back the deep boom recorded from a large toad, Nick Davies of the University of Cambridge in England and Tim Halliday of the Open University in Milton Keynes, England, got other toads to defer to a tiny, insignificant intruder.

In another example, spiders on a web take turns jiggling the strands. The spider that displaces the web the most, presumably the biggest, gets precedence. The other spider, even if it had made the web, often flees. Susan E. Riechert of the University of Tennessee, Knoxville turned a tiny spider into a world champion by fastening a little weight to its body so that it gave webs a powerful shake.

Swaisgood wondered, Could snake taunting lead to this kind of information gathering by ground squirrels? Earlier work by Rowe and Owings had already established that not all rattlesnakes are equally menacing. Bigger snakes strike farther and faster, and they can hold on longer when they've sunk their fangs into prey. Temperature also makes a difference. A warm snake hesitates less before it strikes and hits its target with greater accuracy than a cold snake does.

In theory, a ground squirrel could figure out a snake's size and body temperature from the sound of the rattle, Swaisgood has shown. Bigger snakes sport bigger rattles and shake them harder, making a louder, lower-pitched sound. Warm snakes rattle faster than cold, sluggish snakes do. "It's pretty dramatically different," he says.

To see whether ground squirrels hear these differences and whether they pay attention to them, Swaisgood played snake recordings to squirrels in a metropolis of burrows in Camp Ohlone, a wilderness park on the fringes of the San Francisco Bay Area. "They definitely associate these sounds with rattling snakes," he says. As soon as the rattle burst out of a speaker, nearby squirrels backed away, fluffed up their tails, and reared on their hind legs. "Basically they acted snaky," Swaisgood says.

The squirrels indeed responded differently to rattles from various snakes. The sounds of big, warm snakes, the most dangerous ones, inspired the most concern and caution. For these alarming sounds, squirrels closed in on the speaker more slowly than they did for sounds from small, cold snakes.

Provoking a snake to rattle provides useful information about how big a threat the snake is, Swaisgood points out. In the darkness of a burrow or in a tangle of vegetation, that noise might be the best way to get an idea of the snake's potential. It's not necessarily in the snake's best interest to reveal its vital statistics as it tries to snatch a pup, but the teasing squirrels may drive it to indiscreet rattling.

"The snake is leaking this information," Swaisgood says. He, Owings, and Rowe described the phenomenon in the June ANIMAL BEHAVIOUR.

Swaisgood estimates that perhaps 1 in 10 face-offs ends with the snake slinking away. However, all the fuss seems to put the rest of the colony on snake alert. "It's dramatic, and it catches your eye from a distance," Swaisgood

After watching from a safe distance, an adult ground squirrel gets scrappy and moves in to kick sand at a rattlesnake.

notes. He wasn't surprised to find that mothers with pups devoted an unusual amount of time harassing snakes.

Taunting sabotages a snake's hunting strategy, agrees Jan A. Randall of San Francisco State University. Snakes usually hunt by hiding and waiting, she says. Having a prey jumping around, flapping its tail, and making a commotion pretty much ruins the hiding part.

The energetic reaction to snakes may be common among rodents, Randall speculates. Other scientists would extend that speculation to primates.

Randall has analyzed snaky reactions in the banner-tailed kangaroo rat. In testing these animals, she chose not to work with their local rattler, the Mojave, which is the deadliest one in North America. Instead, she used gopher snakes, which don't inject venom but kill by constricting their prey.

Gopher snakes can nab a rodent with surprising speed. In Randall's tests, the kangaroo rats showed a great interest in the snake, watching it intensely and then making a fuss by drumming their feet. Since publishing that study, she and her students have found two more species of kangaroo rats that drum their feet at snakes.

Denise Boltas

A gopher snake flees from a desert kangaroo rat that has kicked sand at it (top), even though this type of snake (bottom left) can kill a kangaroo rat (bottom right).

When Randall went to Uzbekistan and Turkmenistan to study the great gerbil, she found that it too, reacts, to snakes. "I really didn't expect the gerbils to do this," she says. Yet when she tethered a local constrictor, she found that the gerbils whistled, warily approached, and thumped the ground with their feet.

The "Yikes, it's a snake!" reaction may not be limited to rodents. She points out that vervet monkeys give alarm calls and cluster around, fussing, when a snake slides among them.

Owings goes even further. He has spent decades watching ground squirrels grow wide-eyed and tense around snakes, edging forward but spring-loading their muscles to shoot themselves out of range.

"It's kind of the way humans respond," he says. "Humans are fearful, but they're fascinated." People have been known to get feisty, too, yelling to friends, poking snakes with sticks, and even wrangling rattlers as bravely as a squirrel. □

Biology

Just say NO (or yes?) to aggression

Two new studies of mice lacking enzymes that make nitric oxide (NO) should help scientists better understand the role of the compound in regulating rodent aggression and perhaps clarify its influence on human behaviors.

Once dismissed as a mere air pollutant, nitric oxide has proved to be a versatile molecule in the human body, providing services including the triggering of penile erections and helping the immune system battle microbes. The compound also is one of the many molecular signals that enable brain cells to communicate.

About 4 years ago, researchers created mice lacking the enzyme that synthesizes nitric oxide in nerve cells. Male mice of this mutant strain constantly attacked other males and kept trying to mate with females that had rejected them. This behavior, the investigators concluded, implied that the gas plays a part in the brain signals that dampen aggression.

Although nitric oxide may make male mice mellow, it seems to act in the opposite manner in mother mice. Female mice are normally docile, except when they've just given birth. Then, they'll challenge strange males that approach their pups. Yet mothers from the mutant strain, deficient in nitric oxide, are much less vigorous at defending their pups, Stephen C. Gammie and Randy J. Nelson of Johns Hopkins University in Baltimore report in the Sept. 15 JOURNAL OF NEUROSCIENCE.

The results suggest that nitric oxide is essential to brain signals for maternal aggression. "I didn't expect this outcome," says Gammie.

The confusing interplay of nitric oxide and aggression doesn't end there. Gregory E. Demas of Georgia State University in Atlanta and his colleagues, including Gammie and Nelson, recently studied mice lacking a different enzyme that some cells, primarily in blood vessels, use to make nitric oxide. Males of this strain are less aggressive than normal males, the researchers report in an article published online Sept. 16 by the JOURNAL OF NEUROSCIENCE.

The behavioral shift was unexpected since the second enzyme isn't in nerve cells, says Gammie. Demas speculates that nitric oxide made by blood vessels in the brain may diffuse to nearby nerve cells, or the compound may dilate blood vessels and increase blood flow to brain regions involved in aggression. Scientists might resolve the role of nitric oxide in aggression by breeding the two mutant strains to make mice lacking both of the nitric oxide–making enzymes, says Demas. —*J.T.*

Two genes for the price of one?

Several companies, as well as an international consortium of scientists, are racing to decode the human genome and may finish next year. One of those companies, Incyte Pharmaceuticals of Palo Alto, Calif., now suggests that people possess as many as 142,000 genes, far more than the usual estimates.

"That's about twice the number of genes predicted for the human genome," Randy Scott, president of Incyte, told an audience at the International Genome Sequencing and Analysis Conference in Miami on Sept. 20.

Scott and his colleagues derived their number in two ways. In one calculation, they gauged the size of the human genome by using expressed sequence tags (ESTs), bits of DNA from genes that are active in cells. Incyte scientists and other researchers have found more than 4.7 million ESTs, which they believe represent about 130,000 genes.

The second method made use of the observation that about half of all known human genes have a DNA sequence called a CpG island. Incyte's data predict that the human genome contains 75,596 CpG islands, which translate into 142,634 genes, says Scott. The greater-than-expected number of genes shouldn't slow their identification, but Scott suggests that it may add to the effort required to understand how all the genes in the human body interact. —*J.T.*