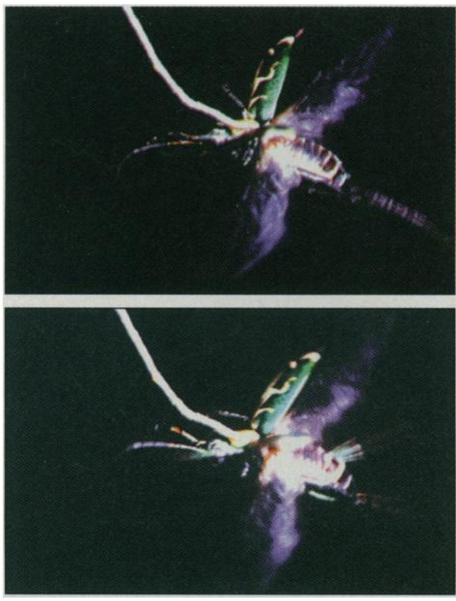
Zoologists Flock to U.S. Capital for Annual Assembly

The American Society of Zoologists (ASZ) underwent a metamorphosis at its recent annual meeting, held from 26 to 30 December in Washington, D.C. Arriving as a group of zoologists, they left as the Society for Integrative and Comparative Biology, reflecting the widespread interests of members, who often belong to several of the society's 10 divisions. Reports show that metamorphosis was also under scientific consideration at the meeting, as were topics such as bat-evading beetles and a real hero shrew.

Beetle Ears Befuddle Bats

Ever since bats appeared and started hunting insects some 50 million years ago, the fossil record indicates that insects have been evolving ways to get away. Some, such as the green lacewings, evolved whole new sensory organs—ears—to warn them of an approaching bat. And at the ASZ meeting, neurobiologists reported some of the first evidence that this biological arms race has also shaped the anatomy and behavior of members of another large insect group: beetles.


PHOTOS BY D. YAGER

Evasive action. A flying tiger beetle *(top)* is startled by bat sounds *(bottom)* and jerks its elytra (wing shields, green) back against its wings, causing an abrupt dive.

Previously researchers hadn't known that beetles tried to evade bats. Now, in two beetle species, scarabs and tiger beetles, investigators have discovered specialized ears that alert the insects to bat attacks and activate an array of evasive countermeasures. Tiger beetles even create a "sonar jamming" noise to confuse their attackers. Researchers hearing the talks were intrigued not just by this new dimension in beetle biology but also by evidence that the anti-bat measures evolved from pre-existing anatomy and behavior. "The exciting thing is that animals can achieve a new [system] in an ad hoc way, making use of bits and pieces," notes John Edwards, a neuroscientist from the University of Washington, Seattle, who is working for a year at the National Science Foundation.

Scientists stumbled across the scarab beetle ear when the beetles stumbled into a trap. Tim G. Forrest and Ronald H. Hoy from Cornell University in Ithaca, New York, were testing the effects that recordings of ultrasonic bat echolocation clicks had on mating crickets, when they noticed that the clicks had startled a large number of flying beetles, who fell into a trap.

Bat clicks, the scientists observed, prompted flying beetles to close the elytra—hard coverings that shield the wings when retracted—on their flapping wings, causing the beetles to drop to the ground. In the lab, walking beetles were also startled by recordings of bat clicks, and pulled their legs up and twisted their heads around. But only insects that had extended their heads from their hard outer coats reacted to the clicks.

There was a good reason for this: Their ears turned out to be in the neck membranes. Apparently, Forrest says, the ears' neural connections were co-opted from the beetles' chordotonal organs, which are older sensory systems designed to monitor body position and the stretch of various membranes. David D. Yager, a neurobiologist from the University of Maryland, College Park, says this is par for the course for insects, which seem to have reinvented ears many times over in different species in this manner. "You don't necessarily need to build truly new circuits," he says.

Yager should know: He reported on a similar case of conscription from his own work. Several years ago, he had been studying bat avoidance behavior in the praying mantis when a colleague, Hayward Spangler from the U.S. Department of Agriculture Carl Hayden Bee Research Center in Tucson, Arizona, found that tiger beetles had ears. Spangler and Yager wondered if the beetles used them to avoid bats.

So last year the two set up a series of experiments. They tethered a beetle to a stick, then played bat sounds through a speaker. During normal flight, a tiger beetle raises its elytra, spreads its wings, and stretches its head forward. But the sound of bat clicks causes the beetle to roll its head to one side and jerk its elytra back, slamming them into the wings. At the same time, the wings beat faster and the legs kick to the side—all within about 150 milliseconds. These actions, Yager says, change the beetle's course and throw it into an abrupt dive, presumably to foil the bat's interception efforts.

When the wings hit the elytra, moreover, they make a clicking sound similar to one made by bat-evading moths, which have a special organ on the side of the thorax to make the clicks. These clicks often appear to startle or confuse the bat, enabling moths to avoid capture. Tiger beetles, Yager suggests, are doing the same thing, but without the specialized equipment.

What he finds most striking, however, is the similarity between this evasive strategy and the one the tiger beetle follows to avoid capture by airborne robber flies, one of the more common beetle predators. The beetle jerks back its elytra to make a quick landing and to shield its soft back from the fly's sharp proboscis. As the flies presumably predate the bats, the beetles appear to be turning an old behavior pattern to new use. "Specific new behaviors may build on existing structures," Yager concludes.

–Elizabeth Pennisi

Missing Metamorphosis

Some frogs and other amphibians hop right over their tadpole stage. Departing from the traditional path of embryo to fishlike tadpole to terrestrial adult—the ancestral form of amphibian development—some more recent lineages go directly from embryo to adult form. The invention is a popular one: Vertebrates such as mammals do it, possibly expanding their range of habitats because they don't have to spend part of their lives as fish. But just how direct developers evolved has remained a slippery issue. Now, aided by studies of one larva-leaping frog species, *Eleutherodactylus coqui*, biologists are beginning to get a handle on it.

At the zoology meeting, evolutionary biologist James Hanken of the University of Colorado, Boulder, described new studies in which his team compared developing embryos of *Eleutherodactylus* to those of several of its metamorphosing relatives. The researchers have uncovered clues to endocrine and genetic differences that may underlie the differing developmental patterns, information that may eventually help biologists understand how direct development evolved. If so, that would be a welcome advance, says developmental biologist Rudolf Raff of Indiana University in Bloomington. The link between development and evolution "has been a speculative one for much of this century," he says. "But Hanken's lab is one that's taking it from speculation to experimental science."

To get a finely detailed picture of skeletal development in the early *Eleutherodactylus*

J. HANKEN

Leaping over the larva stage. Skeletal development of an *Eleutherodactylus coqui* frog embryo shows limb buds and an adult jaw; the embryo doesn't develop into a tadpole, but grows adult features.

coqui embryos, Hanken and Colorado colleague Michael Klymkowsky stained the embryos using tagged antibodies to type II collagen, a protein that becomes part of the framework for the burgeoning skeleton. This revealed that the *coqui* embryos lacked many larval features found in metamorphosing creatures such as the clawed frog *Xenopus* or the fire-bellied toad *Bombina orientalis*; they had no larval jaws, for example, or gill skeleton. But 13 of the 17 adult skull bones do form in *coqui* embryos, features that do not occur in embryos of the larval developers.

But what makes *coqui* embryos so precocious? In metamorphosing larvae, the appearance of adult features is triggered by endocrine activity, chiefly from an axis involving the brain and pituitary and thyroid glands. But studies done in the 1950s failed to show that this relationship had been moved back into the *coqui* embryo, suggesting that the adult features may emerge without the influence of the thyroid.

Hanken and graduate student David Jennings, however, decided to revisit the question by using sensitive antibodies to look for thyroid axis products. They detected signs of colloid, a thyroid secretion, by stage 10 of the 15-stage *coqui* embryo development. That was intriguing, because shortly after that stage the skeleton supporting the adult tongue, whose formation is controlled by thyroid hormones in metamorphosing species, begins to shape up. The researchers also found evidence for thyroid-stimulating hormone, which is made by the anterior pituitary gland, by stage 9. Although the evidence isn't conclusive, Hanken says those findings suggest that the thyroid axis may be active in the embryo after all, prompting the development of adult forms.

Because the timing of *coqui* development might be different from that of frogs with larval stages, Hanken wondered if the patterning of developing features was altered as well, perhaps by subtle differences in gene expression. Hanken and postdocs Lennart Olsson and David Moury found tentative evidence of this in the neural crest, embryonic tissue that gives rise to bone and many other cranial tissues: *Coqui* neural crest cells make human natural killer (HNK) glycoprotein, which in other vertebrates is involved in the migration of neural crest cells as they journey to their specialized fates. Neither *Bombina* neural crest nor that of any other metamorphosing frog the researchers studied appeared to express HNK, however.

Whether HNK is involved in cell fate and direct development in *coqui* is still not clear, Hanken says. But he adds that the new results have given the team leads to more specific systems on which to target further efforts. They are currently developing methods to test *coqui* neural crest cells for bone morphogenic proteins, which are involved in bone development. Finding out just how direct and indirect developers differ in the genes affecting the thyroid system and neural crest might reveal how such differences evolved. And in the field of vertebrate development, that would be a great leap forward.

–Joshua Fischman

Superhero Shrew

The 1960s cartoon character Mighty Mouse was a tiny hero with super strength. But its creators didn't need to resort to a fictional small mammal. They could have used a real one: the hero shrew. Just 23 centimeters long, the shrew reportedly can bend itself into a U shape, nearly touching its hind feet with its snout—and bear the weight of a 73-kilogram man on its back.

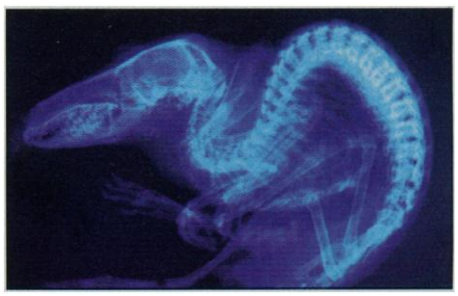
The few investigators who knew of the hero shrew have been baffled by its Herculean powers, but at the ASZ meeting Dennis Cullinane, a graduate student at Cornell University, detailed the shrew's secret: a backbone equipped with extra joints for flexibility and large bony buttresses that may be the key to its unusual strength. No other mammal has these features. "The animal is absolutely, totally weird," says Susan W. Herring, a vertebrate morphologist from the University of Washington, Seattle. "There isn't anything else like it."

The shrew, *Scutisorex somereni*, ranges across southwestern Uganda, eastern Zaire, and northern Rwanda. Biologists took note of the animal early in this century when one naturalist observed a ceremony in which a man stood on the shrew with one foot, then released it—and the shrew, apparently uninjured, ran off. When Cullinane came across a description of this event and the shrew's spine—in one of the only two papers ever published on the shrew—he decided to learn more about the animal. So he raised money for a trip to Uganda and brought one shrew back to the United States.

There he constructed a habitat of plastic tubes and boxes, and made movies of the shrew as it moved about. The films showed the shrew could bend 180 degrees to its side in a tube little wider than the animal itself. It began by bending sideways and then twisted its pelvis and lower back so its snout nosed up against its back feet. "This was remarkable," says Herring. Typically, the lower mammalian spine is very stiff, to accommodate forces generated by the hind legs. X-rays revealed what may be the source of this flexibility: While most shrews have five vertebrae in the lower spine, the hero shrew has 11, giving it extra bending points.

But that flexibility seems to be combined with extreme strength, if those early observations were correct. Cullinane isn't certain the spine really is superstrong, but he plans to use force transducers to measure the load the spine can take. If it does have heroic strength, the key may be the large bony buttresses, or tubercles, that stick out to the sides of each vertebra. The tubercles make each vertebra three times wider than those of the typical shrew, and they overlap and interlock. "It increases the spine's ability to resist bending and compression," Cullinane says.

It may take a while for Cullinane to test these ideas fully, because his animal died on Christmas Eve. So until he raises the money



D. CULLINANE

Showing some backbone. An x-ray of the 23-centimeter-long hero shrew shows its unusual spine, equipped with extra vertebrae and supported by bony buttresses, which may be responsible for the animal's extraordinary flexibility and strength.

to go after more shrews, he's making do with testing preserved specimens. The study of these unusual features could prove invaluable, Herring says, because the extreme adaptation could yield clues about the forces driving the evolution of more ordinary spines. But the shrew holds interest for another reason as well. "We study [these] things, frankly, because they are weird and wonderful," Herring admits. "It enriches our life."

–E.P.

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