ScienceNews

FEATURE ANIMALS

Being a vampire can be brutal. Here's how bloodsuckers get by.

What's most remarkable about real-life bloodsuckers doesn't show up in movies

VAMPS Creatures that feast on blood have evolved surprising ways to deal with all that fluid and protein, and to get the nutrients blood doesn't offer.

MATT GRIFFIN

By Susan Milius

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Jennifer Zaspel can't explain why she stuck her thumb in the vial with the moth. Just an after-dark, out-in-the-woods zing of curiosity.

She was catching moths on a July night in the Russian Far East and had just eased a *Calyptra*, with brownish forewings like a dried leaf, into a plastic collecting vial. Of the 17 or so largely tropical *Calyptra* species, eight were known vampires. Males will vary their fruit diet on occasion by driving their hardened, fruit-piercing mouthparts into mammals, such as cattle, tapirs and even elephants and humans, for a drink of fresh blood.

Zaspel, however, thought she was outside the territory where she might encounter a vampire species. She had caught *C. thalictri*, widely known from Switzerland and France eastward into Japan as a strict fruitarian.

Before capping the vial with the moth, "I just for no good reason stuck my thumb in there to see what it would do," Zaspel says. "It pierced my thumb and started feeding on me."

Make that eight-plus vampires. Zaspel, an entomologist now at the Milwaukee Public Museum, is still puzzling over the genetics of the moths at the two Russian field sites she visited in 2006. Males there will bite a researcher's thumb if offered, yet genetic testing so far shows the moths are part of a vast, otherwise mild-mannered species.

Which is just as well. As vampires go, these moths are not stealth biters. "I would compare it to a bee sting," Zaspel says. For the sake of moth science, one of Zaspel's colleagues voluntarily documented the experience, noting that a moth will feed as long as 20 minutes. Such moth bites definitely get noticed. For these moths and other real-life vampires, being smacked to a smear is a bigger danger than getting staked through the heart.

The tubelike mouthpart of a *Calyptra thalictri* moth extracts blood from a researcher. Long thought to be a strict fruitarian, the moth is better adapted to pierce a plum than a thumb.

J. ZASPEL

Nabbing the occasional red lunch, or managing to survive on nothing but blood, is far more difficult than it looks in the movies. The relatively few animals that manage the lifestyle are indeed remarkable: some insects and other arthropods, a few mollusks, some fishes, birds on occasion and, of course, three kinds of bats.

Blood is not an easy food. There are pressures to gorge as much as possible at each meal. At these heroic volumes, however, blood can be outright toxic. At the same time, a blood meal is insufficient, missing some basic nutrients. Surviving this way takes guts as well as other specialized physiology. Modern tools of genetics and molecular biology are revealing the hidden specializations required for blood feeding and helping make sense of lifestyles that go to different extremes, even mouth-to-mouth blood donation. Though many of these biological

adaptations would never fit among the showy strengths of the immortals of *Twilight* or *True Blood*, they could certainly count as superpowers.

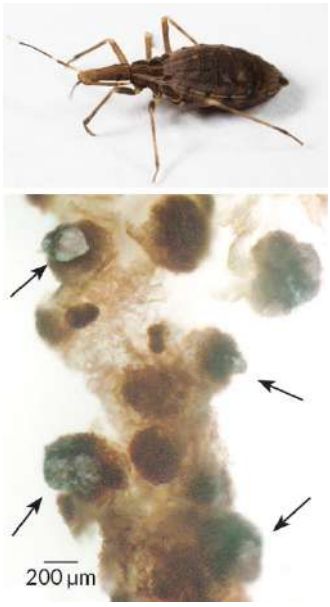
Big dinner

To grasp the risks real vampires take, imagine an animal 35 million times your weight. Now bite it hard enough to make it bleed.

And make it mad. "You can easily get killed by the host," says insect molecular physiologist Pedro L. Oliveira of the Federal University of Rio de Janeiro. The 35 million multiplier applies for a 2-milligram female mosquito attacking a 70-kilogram human, measurements from an article he coauthored on nutritional overload in bloodsuckers in the August *Trends in Parasitology*.

Finding that giant blood source isn't easy. "If you go into a forest, you have hundreds of meters separating one vertebrate host from another, and hundreds of meters would be several kilometers for us," Oliveira says. Then the tiny vampire has to find a capillary for biting within just a few millimeters of the skin surface. On a human victim, Oliveira estimates, only about 10 percent of the skin acreage will do.

Considering the dangers and difficulties that blood feeders face, "most of these guys try to minimize the number of visits," Oliveira says. They drink fast, and they drink big. A young kissing bug, with its deceptively friendly nickname and the ability to spread debilitating and possibly fatal Chagas disease, needs only minutes to down about 10 times its weight in blood.



A blood-sipping pro, the *Rhodnius prolixus* kissing bug (above) has enzymes in its gut that keep tyrosine in a meal from crystallizing and puncturing tissues. Arrows at bottom show white gut crystals that form when the enzymes are blocked.

RAY WILSON/ALAMY; M. STERKEL *ET AL*/*CURRENT BIOLOGY* 2016

To relate this to human physiology — forget it. There are people who intentionally drink blood, which is another story, but even small amounts in vampire terms, such as the amount of swallowed blood from a long nosebleed, can give a human diarrhea, says Tomas Ganz of the David Geffen School of Medicine at the University of California, Los Angeles. Fresh blood is difficult for the human gut to process, and

too little of the water in blood gets extracted and routed to the kidneys. For its water-content challenges, Ganz compares fresh blood to the solutions people drink to clear their intestines, swiftly and unpleasantly, for a colonoscopy.

With such big blood meals, ingredients that would be harmless or healthful in small amounts can be toxic. “The dose makes the poison,” Oliveira says.

Remove the water in blood, and what’s left is almost 90 percent protein. Oliveira got an inkling of something perilous in that protein when his lab was exploring the genetics of one of the Americas’ kissing bugs, *Rhodnius prolixus*. With a rounded rear that stretches and narrows at the head like a railroad-track penny that almost escaped, the bug lurks in crevices indoors or out. At night both males and females search out humans, their pets or other vertebrates pulsing with a good blood dinner. The bug has vampire superstealth and outdoes the vampire moths by biting without waking a sleeping blood source. Unlike mosquitoes and ticks whose bites deliver pathogens in saliva, a kissing bug delivers the Chagas disease parasite through its excrement, which the bug leaves on the host.

Of all the amino acids detected in that huge drink, only tyrosine meets a massive special array of enzymes ready to break it down as it washes into the kissing bug gut, researchers showed in 2014. Finding tyrosine-busting enzymes in the gut is “kind of strange,” Oliveira says. In mammals, the liver and kidneys are the only organs with enzymes that break down tyrosine. Then again, most mammals don’t flood their guts with overwhelming protein.

When researchers messed with the kissing bug to sabotage tyrosine breakdown, either by disabling genes or chemically blocking the enzymes, the bugs died after dining, Oliveira and colleagues reported in *Current Biology* in 2016. Some of the dead bugs had crystals of tyrosine stabbing through the gut lining, and gut contents had leaked into the body cavity. This discovery, researchers propose, might someday give molecular biologists their own drug to serve as a vampire-killing stake.

Blood feeding in arthropods has evolved independently multiple times (some say 21), but often the vampires have solved the same challenges with different quirks of biochemistry. The challenge of detoxifying tyrosine, however, might be a problem that a lot of lineages have solved in unusually similar ways, Oliveira proposes.

First stabs at a weapon to disable the common chemistry are compounds that inhibit an enzyme called HPPD. The enzyme shuts down tyrosine breakdown, not just in the kissing bug but also in a kind of tick and in the female Zika-spreader *Aedes aegypti* mosquito. When tested, the treatment didn't harm milkweed bugs or mealworms.

Story continues below image

The common vampire bat is a blood licker. Razor teeth nick flesh so the bat can lick up the gently welling blood.

Bad blood

Tyrosine is just one of the nutrients turned toxic by the massive size of blood binges. In the real world, a vampire's ability to excrete wastes is much more important than some fictional power to hoist trucks.

Nephrologist Jonas Axelsson of the Karolinska Institute in Stockholm and colleagues are studying kidney function in vampire bats versus cousin species that live on fruit or nectar. Human diets typically feature some 50 to 120 grams of protein a day, but eating like a vampire bat would boost a 70-kilogram human's intake to some 6,000 grams of protein a day. That protein overdose means these bats have blood concentrations of protein-metabolism waste products such as urea that would be a short route to kidney failure in humans.

Yet the vampire bats are fine. Their kidneys are about the same size as other bats' kidneys, Axelsson says. Vampire bats devote more of their space to the long tubules that deal with reabsorbing useful substances from just-made urine, he notes.

Much of the protein in blood is hemoglobin, the iron-containing marvel molecule that ferries oxygen around the body and helps vertebrates live big and bold. Yet digesting so much hemoglobin in a hurry can free a massive, potentially poisonous dose of iron into the bloodstream. A healthy man makes his doctor happy with blood iron concentrations around 127 micrograms per 100 milliliters. Yet concentrations up to 200 times higher don't seem to harm fishes called lampreys during their larval years, measurements from various species suggest. The larvae pick up iron while burrowing and eating anything that floats along. When sea lampreys (*Petromyzon marinus*) mature, growing their jawless toothy gapes and sucking blood of other fishes, iron concentrations in blood drop — to about 10 times healthy human levels.

At first, a lamprey sticking to skin feels like "a moistened suction cup on your face," says lamprey biologist Margaret Docker of the University of Manitoba in Winnipeg, Canada. She has permitted one exploratory kiss on her cheekbone from a blood-feeding silver lamprey (

Ichthyomyzon unicuspis

) found in North American lakes and streams. Only half the world's 38 lamprey species suck blood.

Even scarier than the blood-sucking sea lamprey's teeth are the secretions that keep a victim's blood from clotting.

T. LAWRENCE, GLFC

Lampreys can generate a good grip; some even mouth-suck their way up vertical waterfalls or dams. In the very unlikely event of a fish on the face, "the key is to dislodge it ... before it starts to rasp in with the teeth on its tongue or oral disk and before it secretes its anticoagulants," Docker says. A little prying with a fingernail breaks the suction.

Lampreys may have gone parasitic early in the history of vertebrates and so have had a long time to evolve their vampiric specializations. A small fossil from Devonian times, some 360 million years ago and long before dinosaurs arose, shows an oral disk with 14 evenly spaced teeth, already looking very capable of draining blood.

Studies of the modern species' blood-feeding physiology got a solid source of new data in 2013 when an international team decoded the genetic instruction book of the sea lamprey, a notorious invader of the Great Lakes. Docker hopes for more work on lamprey detox tricks, such as the liver enzyme superoxide dismutase, which increases as concentrations of iron in the liver rise in adult pouched lampreys. At this stage, liver cells are akin to those in people suffering from a potentially fatal iron-metabolism disorder called hemochromatosis. Another big reason for studying real vampires, as if scientists need another, is the possibility of finding new insights into human metabolic disorders.

Not enough

Blood may have lethally too much of some things, but lethally too little of others. "Vampires don't really have it that easy," muses ecological microbiologist Rita Rio of West Virginia University in Morgantown.

Blood lacks B vitamins, she explains. Animals need these as essential nutrients for a wide range of basic bodily chores, such as gene regulation, cell signaling and amino acid breakdown. Yet animals can't make their own supplies. Rio's favorite vampire flies get around this problem with tiny live-in help.

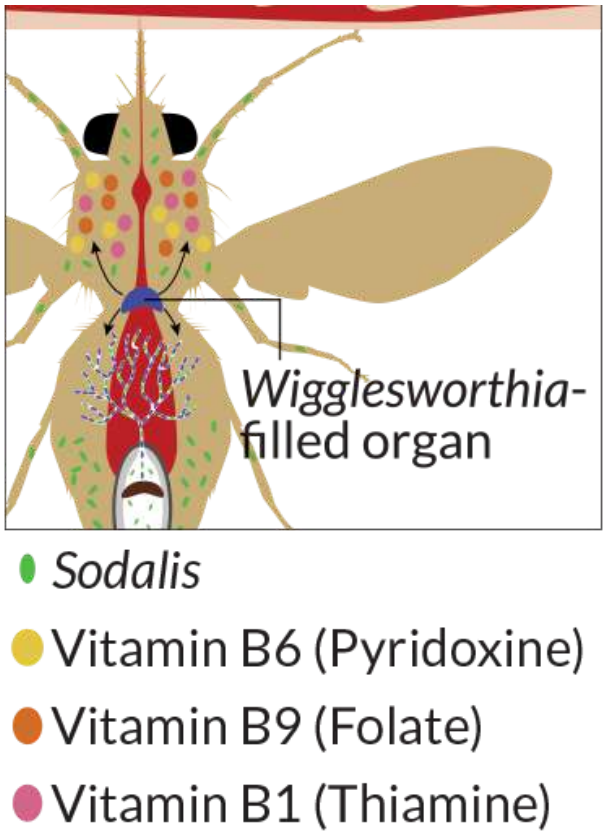
"I have loved tsetse flies ever since I first learned about them," she says. She's speaking of sub-Saharan Africa's *Glossina* flies' "really cool biology," not their ability to spread the parasite that gives humans and some other vertebrates potentially fatal sleeping sickness.

Tsetse flies look like robust house flies but live very differently. Instead of the typical low-involvement insect motherhood of laying many little eggs and leaving them to their luck, a female tsetse fly has just one offspring at a time. A single egg hatches inside her, and as it grows, it draws sustenance from "milk" glands inside the mother fly. "You'll see her getting chubbier and chubbier," Rio says. A mother sometimes gives birth to a youngster bigger than she is. The youngster at that point has only its pupal stage to go before it reaches sexual maturity. "It would be like me giving birth to a 12-year-old," Rio says.

Little helpers

GEOFFREY M. ATTARDO

Tsetse flies (pregnant female, above) can survive on an all-blood diet thanks to symbiotic bacteria. In an organ (blue, bottom) ringing the fly midgut, *Wigglesworthia* bacteria churn out B vitamins, including B1. Both the fly and resident *Sodalis* bacteria need this vitamin, also called thiamine.



R. RIO *ET AL/TRENDS IN PARASITOL.* 2016

As the mom fly gives her tween a pampered start in life, she also passes along an infection the youngster will need to reproduce on its nutritionally sketchy, all-blood diet. Each larva emerges with its own rod-shaped bacteria called *Wigglesworthia*, a bit on the chubby side themselves. The bacteria churn out B vitamins and flourish inside a special organ that grows inside the fly. The tsetse fly version of this organ, called a bacteriome, "looks like a little doughnut around the digestive tract," Rio says.

The interplay between fly and microbes has come to fascinate evolutionary biologists, as genes in both bacterium and host change across generations, sometimes breaking down or taking on odd functions, depending on what the other partner is doing. In the September *Genome Biology and Evolution,* Rio and her colleagues published a study of the molecular activity of both tsetse flies and their *Wigglesworthia* in the wild.

Low-fat bats

Another downside of blood is its low fat content, at least from the vampire bat point of view. Extra cargo on a small flying mammal is limited to a mere 20 to 30 percent of the animal's predinner weight, so a small, low-fat meal won't fuel the bat for very long. A common vampire bat (*Desmodus rotundus*) can't survive three days without drinking blood, says evolutionary biologist Gerald Wilkinson of the University of Maryland in College Park. That's one of the forces pushing the bats to develop social networks of blood regurgitators.

Needing backup blood is no slur on this vampire's superb adaptations to feeding on large vertebrates. The razor-toothed mammal is one of three blood-feeding bat specialists, all native to the warm latitudes of the Western Hemisphere. The first wild *D. rotundus* Wilkinson studied, on a ranch in Costa Rica, "would often just fly up and land on the back of a horse," he says. The bat has a fleshy little nose, "like a pig," with heat-sensing ability useful in finding where warm blood flows close to the body's surface. Actually getting that blood "was a very non-trivial thing" for the bats, he says. A bat routinely spent half an hour selecting a spot, clipping down horse hair if necessary, nicking out a tiny divot of flesh and then licking the wound, often while urinating, all without waking the horse. Revisiting a wound on another night appeared to be faster than prepping a new site. Wilkinson realized one night that the bat he was watching was feasting on the same horse it had fed on the night before, even though the horse had been moved to a different pasture.

The bat's saliva has impressive anticoagulant powers, Wilkinson reports. "I've been nipped a few times and the blood was hard to stop," he says. "People who have been fed on will wake up and there's a pool of blood — and the blood is often from after the bat left."

Compared with bats of other species, the common vampire bat may even seem to have superpower moves: Instead of just flying, it easily runs on the ground.

When a hungry bat can't find a meal for a night, the accomplished blood seeker may get a bit of blood from a luckier roost mate. Positioned facing each other mouth to mouth, "one animal is motionless and the other animal is licking," Wilkinson says.

In his early experiments with captive bats, he found animals willing to regurgitate on occasion for a hungry bat with no kinship connection. For decades, researchers have debated whether it's fair to consider vampire bats as examples of natural altruism. For the latest published experiments, Wilkinson's student Gerald Carter, at the Max Planck Institute for Ornithology in Konstanz, Germany, as of November, put together bats from unrelated zoo populations. He fed them blood (collected from a slaughterhouse, not anybody's favorite part of doing science) and then created short artificial food crises, recording dozens of observations of blood sharing.

Looking at all these examples of sharing, kinship didn't matter, Carter and Wilkinson concluded. In captivity at least, a vampire will help a starving roost mate who's not a relative.

Carter even did an elaborate test of how a starving vampire reacts when its main go-to pal for emergency regurgitation "betrays" it by not helping. To simulate betrayal, Carter removed the potential helper from the group so it did not feed its starving roost mate. Then on another night, he flipped the roles. The bat that had not helped its pal was now the hungry one in need of that pal's regurgitation.

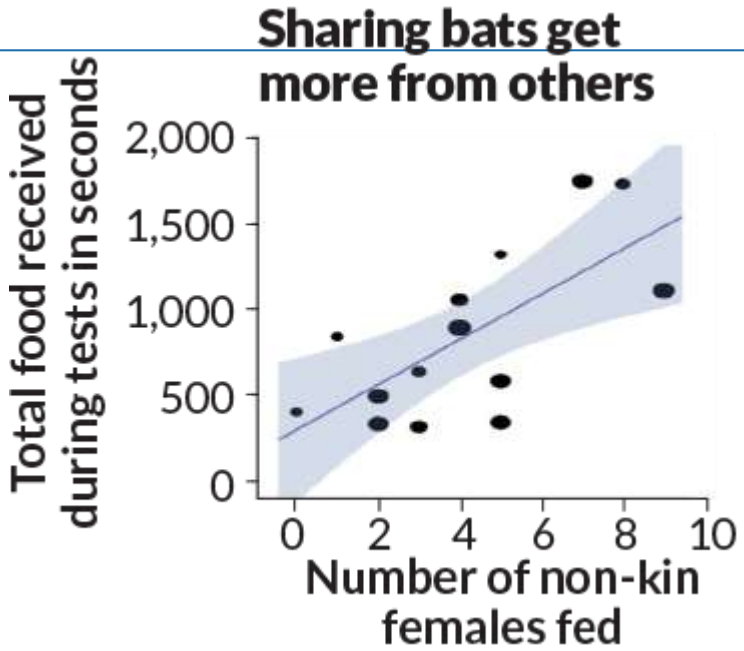
In general, no hard feelings. The partner who was forced to defect often got fed regardless. The evidence so far looks as if vampires are hedging their bets in sharing blood, Carter, Wilkinson and Damien Farine of Max Planck proposed in the May *Biology Letters*. Bats that shared with many partners over the long run ended up receiving more blood when it was their turn for trouble. In an uncertain world, this advantage might favor helping non-kin. Vampirism may work as a force for generosity.

Story continues below sidebar

Networking

Captive vampire bats that shared blood with non-kin reaped benefits. Hungry females that donated to more bats tended to receive more regurgitated blood from others later (left). The diagram at right shows one bat's feeding network. Red circles are bats that a hungry bat (star) had donated to in the past. Two-way arrows show reciprocity.

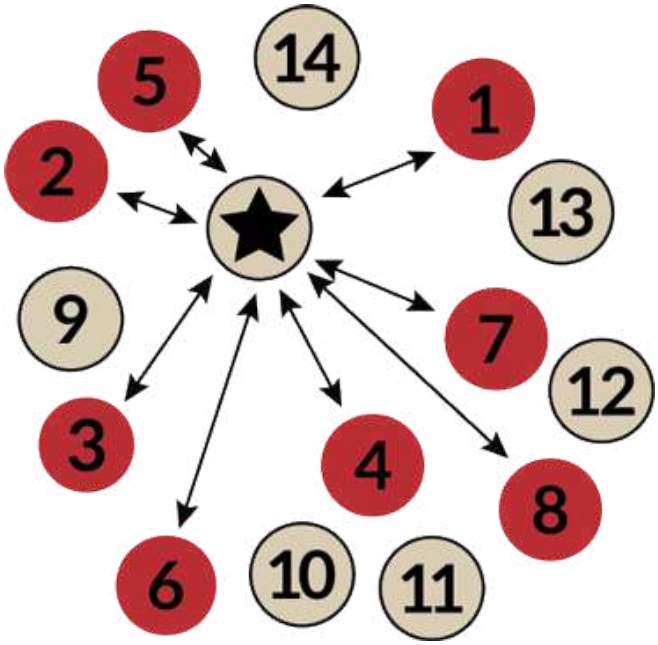
G.G. CARTER AND G.S. WILKINSON/*PROC. ROYAL SOC. B.* 2015



Way beyond bats

Baby vampire bats go for blood right away, licking their mothers' mouths for red regurgitation within minutes of birth. And there are many more vivid variations on vampirism (see sidebar).

There's blood feeding as a mix of practicality and mate monopolization in a vast dark and dangerous ocean. In some deep-sea ceratioid anglerfishes, males stay miniature and upon finding a female meld tissue with her giant body and thereafter live off her circulatory system. The male essentially makes her a hermaphrodite with a sperm organ ready when she needs it.



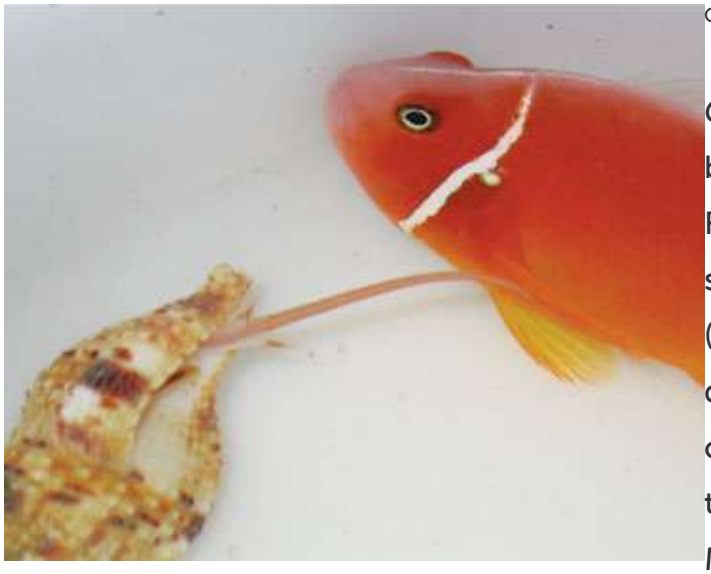
There's also blood feeding by proxy. The jumping spider *Evarcha culicivora* hunts mosquitoes, preferably those engorged with human blood. There's even blood feeding as an impossible dream. Male mosquitoes sip flower nectar, but when scientists served the mosquitoes blood soaked cotton, they ate readily. Given nectar as an alternative, males still went for blood instead, even though they died early.

And there could be even more vampires out there that science hasn't discovered yet. All it might take is someone sticking a thumb into a collecting vial.

Many shades of vampire

The real world of blood feeding is much more varied than fictional vampires' all-or-nothing menus. Drinking blood can be a full-time or a sometimes urge.

Cast a spell



COURTESY OF M. OLIVERIO

Colubraria muricata snails are experts at sucking blood from fish. Found from South Africa to French Polynesia, the snail creeps toward a sleeping fish and extends a long feeding tube (shown), with fish blood pressure probably delivering the meal. The snail secretes a complex cocktail that may include an anesthetic to keep the donor passive for the duration of a drink, says Marco Oliverio of Sapienza University in Rome.

Furtive drinkers

ANDREANITA/ALAMY

Sometimes considered helpful partners, Africa's oxpeckers (*Buphagus*) glean ticks and other arthropods from African grazing animals. Red-billed oxpeckers (*B. erythrorhynchus*, shown) also eat earwax, dung, urine — and blood. In food tests on donkeys, birds chose to feed on wounds even when the birds' favorite ticks were offered, Tiffany Plantan of University of Miami in Florida and colleagues found.

Kids' stuff

M.B. LABRUNA *ET AL/J. PARASITOL.* 2012

An adult *Antricola marginatus* tick probably feeds on bat guano, but youngsters riding on mom's back (shown) readily leap off to drink blood if warm mammals are nearby. A mom may "feed" her young by climbing near bats, Marcelo Labruna of the University of São Paulo in Brazil and colleagues proposed after observing moms and young in a Yucatán bat cave in Mexico.

This article appears in the October 28, 2017 issue of Science News *with the headline, "Real Vampires of Planet Earth: It's not easy sucking blood."*

A version of this article appears in the October 28, 2017 issue of *Science News*.

CITATIONS

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