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VAMPIRE BATS – The Good, the Bad, and the Amazing

Vampire bats are *sanguivores*, organisms that feed upon the blood of other animals. They are the only mammals that feed exclusively on blood. Despite horror-movie depictions, vampire bats very rarely bite humans to feed on their blood. They feed primarily on domestic livestock, due to their abundance, and to a lesser degree on wild mammals and birds. They are very small animals, with wingspans of about 12-15 inches, and weigh less than 2 ounces.

SPECIES AND DISTRIBUTIONS

Three species of vampire bats are recognized. Vampire bats occur in warm climates in both arid and humid regions of Mexico, Central America, and South America.

Distribution of the three species of vampire bats.

Common Vampire Bat (*Desmodus rotundus*)

This species is the most abundant and most well-known of the vampire bats. *Desmodus* feeds mainly on mammals, particularly livestock. They occur from northern Mexico southward through Central America and much of South America, to Uruguay, northern Argentina, and central Chile, and on the island of Trinidad in the West Indies.

Common vampire bat, Desmodus rotundus.

White-winged Vampire Bat (*Diaemus youngi*)
This species feeds mainly on the blood of birds. They occur from Mexico to southern Argentina and are present on the islands of Trinidad and Isla Margarita.

White-winged vampire bat, Diaemus youngi.

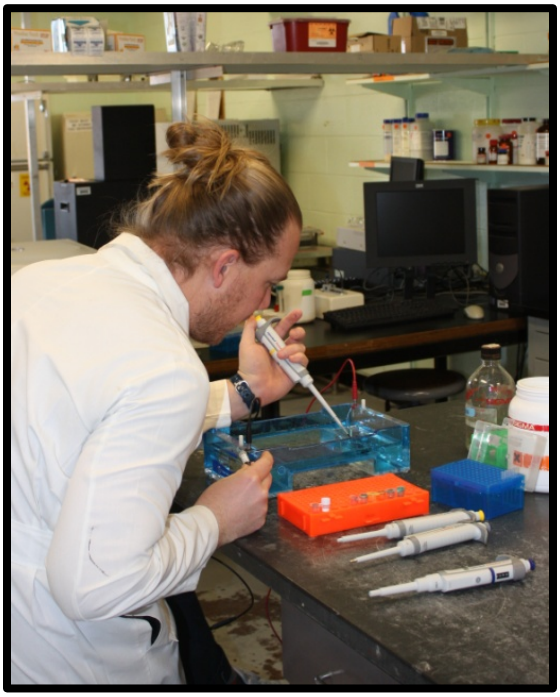
Hairy-legged Vampire Bat (*Diphylla ecaudata*)
This species also feeds mainly on the blood of birds. They occur from Mexico to Venezuela, Peru, Bolivia, and Brazil. One specimen was collected in 1967 from an abandoned railroad tunnel in Val Verde County, Texas. This specimen (now in the Museum's Mammal Collection of the Natural Science Research Lab) is the only record of a vampire bat ever documented from the United States.

Hairy-legged vampire bat, Diphylla ecaudata.

The White-winged and Hairy-legged Vampire Bats are less abundant and less is known about these species than is known about the Common Vampire Bat, *Desmodus rotundus*. **The information in the remainder of this exhibit pertains specifically to the Common Vampire Bat, *Desmodus rotundus*.**

THE EVOLUTION OF BLOOD-EATING

At Texas Tech University, Horn Professor of Biology and Curator of Mammals Dr. Robert J. Baker and post-doctoral fellow Dr. Caleb D. Phillips are using cutting-edge technologies to investigate the origin and evolution of blood-eating in bats.



Caleb Phillips, Post-doctoral Fellow, Department of Biological Sciences.

Vampire bats are members of a large and diverse mammalian Family known as Phyllostomidae (New World Leaf-nosed Bats). At least 160 known species of bats are in the phyllostomid family. Most of the phyllostomid species feed primarily on fruit and other plant material, while others feed on insects, nectar, frogs, or are omnivores. Only the three vampire species feed on blood.

When, how, and why did this specialized diet, and the unique behaviors and physical adaptations that make it possible, evolve? For many years, researchers have investigated and debated this question. Recent genetic studies have determined that the vampires diverged from the remainder of the Phyllostomid family about 26 million years ago. Blood-feeding is thought to have evolved only once, in a common ancestor that is shared by the three vampire bat species of today.

Some researchers suspect that the first vampire bats may have evolved from insect-eating bats that were feeding on the parasites of birds and mammals. Thus, the bats were consuming a partial diet of blood (the blood that the parasites had eaten), and when they pulled the parasites off the bird or mammal, they were further exposed to blood at the attachment site. Behaviorally, it would not be a large leap for the bats to begin feeding directly on blood. This view is supported by observing other animals that feed in a similar manner. For example, although obligate (meaning compelled or constrained, required to survive) blood-feeding has evolved only once among vertebrates (vampire bats), some species of bird, such as the vampire finch, also feed on the ectoparasites of other birds and occasionally consumes some blood at the site where the ectoparasites were attached.

Micronycteris *Desmodus*

Micronycteris is a present-day example of an insectivorous bat. A similar bat may have given rise to the vampire bats approximately 26 million years ago.

Research indicates that the vampires evolved from insect-eating bats to obligate blood feeders over a period of a little more than 4 million years. A tremendous variety of specializations occurred during that time, including the evolution of anticoagulants in the saliva, modifications to the teeth, physiological adaptations for digesting blood and excreting excess water, anatomical changes to facilitate preying on sleeping mammals or roosting birds, and sensory adaptations to detect prey and blood flow sites. The evolution of these traits undoubtedly involved many genetic changes to result in these unique and fascinating mammals.

Recent work conducted in the laboratory of Dr. Baker has provided a new understanding of the genetic basis of how vampire bats evolved. By comparing the proteins expressed in the saliva of vampire bats, insectivorous bats, and medicinal leeches, Drs. Baker and Phillips have shown that many of the salivary proteins important for blood-feeding, such as anticoagulants, are found in both vampire bat and leech saliva. One of the remarkable aspects of this discovery is that the evolutionary lineages that led to vampire bats and leeches diverged more than 500 million years ago, during a period of rapid origination of animal diversity known as the Cambrian Explosion. Drs. Baker and Phillips discovered that many of the salivary proteins found in vampire bats and leeches have been recruited to adaptive roles in blood-feeding from gene families that were present in their common ancestor.

Leeches and vampire bats, species that have been evolutionarily separate for 500 million years, share a common gene that has been modified, through a process known as gene recruitment, to serve a new function in the saliva of these species. This genetic change has resulted in the anticoagulant properties of leech saliva and vampire bat saliva that prevent blood from clotting at the wound site of a victim.

The term *gene recruitment* refers to the phenomenon of using genes that originally evolved for one function for a purpose in a new biological function. In the case of vampire bats (and leeches), genes have been recruited from normal hemostatic processes (that is, the regulation of blood coagulation) that are widely shared among animals, to novel roles as anticoagulants. For example, animals (including humans) express the protein version of a gene called Entpd1 on the inside of blood vessels of the circulatory system. Normally, Entpd1 inhibits blood coagulation and helps to keep blood flowing through the circulatory system. However, when a person or an animal is cut or wounded, Entpd1 is removed from the area of the wound by cells in that location. By removing Entpd1 from the wound site, blood clotting is allowed to take place. A wound created by a bite from a vampire bat, however, bleeds for a considerable amount of time. This is because Entpd1 is expressed in vampire bat saliva. So, even though the normal physiological response of the bitten animal is to begin blood clotting by removal of Entpd1, the presence of vampire bat saliva (and the vampire bat version of Entpd1) in the wound site prevents the blood from coagulating. This is an evolutionary adaption (by gene recruitment) to help vampire bats consume considerable portions of blood at a single feeding.

Further research currently underway in the laboratory of Dr. Baker is focusing on comparing the salivary proteins found in each of the three species of vampire bat. Because each vampire bat species has its own unique evolutionary history and prey items, this work will lead to new discoveries about the adaptations that each species has evolved to be successful in their own specialized ecological niches.

WHAT'S IN A NAME?

The scientific names of vampire bats do not directly describe their blood-feeding habits. *Desmodus* literally means "fused tooth" and refers to the highly modified dentition of vampire bats that is an adaption to aid in efficiently cutting the flesh of victims. Other bats, however, that do not feed on blood, such as *Vampyrum* (a carnivorous bat), have names suggesting they are vampires. The reason that non-blood-feeding bats have vampire-like names is the result of early zoologists who incorrectly claimed to have captured the mysterious blood-feeding animals reported by European explorers of the New World. In 1810, the common vampire bat was named *Desmodus* by Étienne Geoffroy Saint-Hilaire, but no indication was given in his description of the species that *Desmodus* was in fact the vampire bat. It was not until 1832, when *Desmodus* was caught in the act of blood-feeding by Charles Darwin during the famed Beagle voyage to South America, that the first correct identification of a vampire bat was made.

PHYSICAL ADAPTATIONS FOR FEEDING

Like most bat species, vampire bats use both echolocation and vision to navigate and find prey. They also use smell and sound to locate prey. Vampire bats, however, have evolved many unique characteristics for their specialized feeding behavior.

Typical feeding behavior involves landing on the ground near its intended victim, usually while the individual is sleeping. Research has shown that in vampire bats, *an area of the brain that processes sounds has become specialized to detect the deep, regular breathing of sleeping animals*. The bat then climbs up the animal's body to find a suitable place to bite. Vampire bats have highly specialized *heat-sensing "pit organs" near its nose* that allow the bat to detect variations in body temperature due to blood flow near the surface of the skin. Once a suitable site is chosen, the bat uses its *thin, broad, blade-like incisors* to make a very small incision (3-5 mm wide and deep) in the skin of its victim. The teeth are so sharp, the animal rarely knows it is bitten, and *special proteins that function as pain killers* have been identified in vampire bat saliva that help to keep victims unaware that they have been bitten and are being fed upon. The bat does not suck the blood, but quickly laps it up with its *specialized tongue* that has two lateral grooves on the underside that expand and contract as the bat feeds. *Anticoagulants in the saliva* of the vampire bat prevent the blood from clotting at the wound site. This anticlotting allows the blood to keep flowing until the bat has had its fill, a process that may take about 20 minutes. Vampire bats require about 20 grams (about 2 tablespoons) of blood per day, and they cannot survive more than two or three days without a meal.

The *digestive tract, circulatory system, and kidneys* of the vampire bat are especially developed for rapid processing and digestion of blood. The stomach lining rapidly absorbs the blood plasma, and the plasma is transported quickly to the kidneys and then the bladder for excretion. A common vampire bat begins to excrete very dilute urine within two minutes of feeding. This shedding of much of the water-weight from a meal is necessary to allow the bat to fly and return to its roost.

The limbs of the vampire bat also are specialized and different from those of other bat species. The *thumb of the wing is especially long and well-developed* and their *wings and hind legs are strong*. Unlike other bats, they can walk, run, and jump using their legs and the thumbs of their folded wings, and they are quite agile and stealthy. These abilities allow vampire bats to stalk and attack prey from the ground. The vampire bat's ability to jump almost vertically also allows it to launch its heavy body into flight after a large meal, when wing-power alone might not be enough for take-off!

Desmodus have particularly long and powerful thumbs to aid in climbing on victims and in launching from the ground into flight. Their wings and hind limbs also are strong and adapted for walking, running, and jumping.

The braincase of Desmodus is large and accommodates a highly specialized brain. The upper incisors and canines of Desmodus are large, flat, blade-like, and razor sharp for biting their prey. Unlike the teeth of most mammals, the teeth of vampire bats do not have enamel. This adaptation allows the teeth to stay especially sharp and not wear down from use.

The specialized tongue of Desmodus has two lateral grooves on the underside that expand and contract to help draw blood into the mouth as the bat licks the site. Anticoagulants in the saliva prevent the blood from clotting at the wound site while the bat is feeding.

Vampire bats have heat-sensing "pit organs" near its nose that allow the bat to detect blood flow near the surface of the skin. The lower lip is curved downward in the center to accommodate the tongue as it licks up blood. Also note the large thumbs that aid the vampire bat in walking, climbing, and jumping.

SOCIAL BEHAVIOR

Vampire bats are social animals that live and hunt in groups. Their colonies typically range in size from 20 to 150 individuals, but much larger colonies occasionally have been reported. They roost most commonly in caves, but also in tree hollows, mine shafts, abandoned buildings, and frequently under highway bridges and culverts.

Within the roost, females tend to form groups of 8-12 individuals that roost close together on a regular basis. The males roost separately, with each defending a small territory from other males.

Desmodus can breed year-round, but each female breeds just once per year. After a gestation period of seven months, a single well-developed young is born (twins occasionally occur). The young weigh about ¼ of an ounce at birth! They feed strictly on their mother's milk for the first month of life, during which time their weight doubles.

At two months of age, the young bats are introduced to their blood diet by receiving regurgitated blood from their mothers. The young begin accompanying their mothers on hunts and feeding on living prey when they are about four months old. By five months, they are fully grown, but they may continue to nurse for up to nine months. Vampire bats in captivity have been known to live 20 years, although the average lifespan in the wild is estimated to be 9-12 years.

Female vampire bats exhibit the rare behavior of food-sharing with other adult females. When the bats return to the roost after an evening of hunting and feeding, they often begin socially grooming each other. During this grooming process, females that have fed may regurgitate small amounts of blood for roost mates that were unsuccessful in feeding that night. This mutual feeding, a unique example of *reciprocal altruism*, ensures the survival of individuals and strengthens the colony as a whole.

CAPTURING BATS FOR RESEARCH

Vampire bat captured in a mist net.

Mist nets are used by bat biologists to harmlessly capture bats for research purposes. The nets are made of fine nylon or polyester mesh suspended between two poles. The size of the mesh varies depending on the size of the species targeted for capture.

The nets typically are placed where bats search for food, over water sources where the bats drink, and near the mouths of caves or other roosting locations to capture the bats as they leave their roost each evening. Efforts to capture vampire bats, in particular, may include baiting with a live domestic animal, such as a goat or donkey, and setting up mist nets near the bait. Trained personnel monitor the nets and promptly remove any captured bats as they become entangled in the fine mesh.

VAMPIRE BATS AND RABIES

The Common Vampire Bat is one of the few species of bats that is considered an agricultural pest. Its pest status is due to its feeding on domestic livestock and spreading of disease, including rabies. Losses to the cattle industry due to rabies in Latin America amount to many millions of dollars every year.

Desmodus rotundus feeding on blood from a pig's snout.

Although cases are rare, humans can contract rabies from vampire bat bites. Despite the fact that such incidences are uncommon, recent cases have led to wide-scale eradication attempts, including burning, gassing, and dynamiting of potential roosts. Unfortunately, these control programs have resulted in considerable losses of harmless or beneficial bat species such as fruit bats, as well as other cave-dwelling animals.

Strategies to control rabies transmitted by vampire bats include vaccination of humans and livestock and reduction of bat populations by culling. Vaccination of livestock is effective, but is impractical and too costly in the developing countries where vampire bat rabies problems are most severe. For humans, vaccination also is cost-prohibitive for many people in these regions, and vaccination efforts typically are initiated only after a death is reported in an area.

Human rabies vaccine.

Large-scale culling of vampire bats began in the 1970s with the development of vampiricide, an anticoagulent paste applied to captured bats and spread to the colony by mutual grooming after the treated bats return to the roost. Despite four decades of culling in many Latin American countries, rabies cases continue to occur in livestock, suggesting that vampiricide is insufficient for vampire bat rabies elimination. Recent studies have shown an actual increase of vampire bat populations and the number of rabies-infected vampire bats after culling programs. The reasons for this increase are unknown, but may include immigration of bats from neighboring colonies to fill vacant roost space, selective removal of adults that perhaps had protective immunity to rabies, or an increase in birth rates of bats following the relaxation of resource or space limitations.

Vampiricide, a mixture of poison and petroleum jelly, is applied to the bodies of captured vampire bats in an attempt to control their populations and the spread of rabies. When the bats are released and return to the roost and groom themselves, and each other, the bats are poisoned and die.

VAMPIRE BATS HELPING HUMANS

The unique properties of the vampire bats' saliva have found some positive uses in medicine. A genetically engineered drug called desmoteplase that uses the anticoagulant properties of the saliva of *Desmodus rotundus* has been utilized in trials as a treatment for acute ischemic stroke (blood clot in the brain). The drug has been shown to work more quickly and effectively at breaking up blood clots than traditional treatments and extends the time window for treatment following a stroke. The drug is in the final stages of clinical testing and is expected to be submitted for approval in 2014.

VAMPIRE BATS IN FOLKLORE

Vampire bats and mythological creatures termed vampires find prominence in both current and historical culture and folklore. Folklorist Stu Burns indicated that the word *vampire* is derived from the early Slavic word *upir* found an 11th century Russian manuscript. The word *upir* was westernized to *vampyre* in the 18th century.

The word *vampire* refers to a corpse that has arisen from the dead to drink the blood of the living. Stories of blood-feeding monsters are common among many different cultures worldwide. Early doctors and researchers even blamed vampire attacks as the cause of various diseases such as anemia and the Black Plague.

But how did the vampire come to be associated with bats? After early reports by New World explorers of blood-feeding bats, folklore surrounding vampires rapidly incorporated “winged creatures of the night” into these myths. The elusiveness, mystery, and nocturnal habits of both bats and these mythological creatures contribute to this folklore connection. Bats and vampirism were connected permanently upon the publication of Bram Stoker’s classic novel *Dracula* in 1897.

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