



Topic
Science

Subtopic
Biology

Field Guide to North American Wildlife

Course Guidebook

David Mizejewski



**NATIONAL
WILDLIFE
FEDERATION**



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4840 Westfields Boulevard, Suite 400
Chantilly, VA 20151-2299
USA
1-800-832-2412
www.thegreatcourses.com



David Mizejewski

David Mizejewski is a naturalist with the National Wildlife Federation and the author of *Attracting Birds, Butterflies, and Other Backyard Wildlife*. He has appeared on shows such as *The Martha Stewart Show*, *Conan*, *The Wendy Williams Show*, and NBC's *TODAY*, and he has hosted series on Animal Planet and Nat Geo WILD. He earned a BA in Human and Natural Ecology from Emory University.

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1

Where the Red Wolf Still Roams

Many people love the idea of the wild and feel a strong connection to nature and wildlife. And yet, a strange paradox exists where many people don't want to accommodate wild animals or don't realize how their actions can negatively impact animals—to the point where humans have driven many to the brink of extinction. But the ecosystems that humans rely on for their own survival need healthy wildlife populations. The National Wildlife Federation's mission is to ensure that wildlife and people thrive in the rapidly changing world. This course explores some of the fascinating species that populate North America, illuminating what makes them so remarkable and why they're so important to the ecosystems they share with humans. This journey begins with the red wolf.

Taxonomy and Evolution of Canids

The incredibly rare red wolf—*Canis rufus*—once ranged across a wide swath of the southern and eastern United States. But humans have eradicated wolves from most of their former range, and the red wolf is now one of the world’s most endangered species. The fact that they exist at all is nothing short of a conservation miracle.

Red wolves are large wild dogs that measure around 3 to 4 feet in length from nose to tail and weigh around 65 pounds, with males being larger than females. They’re comparable in size to a German shepherd dog. Their fur is a combination of colors, including brown, gray, black, tawny, buff, and the rusty red color that gives the species its name. Red wolves tend to have lighter fur on their face, chest, underbelly, and legs and have black-tipped tails—but there’s considerable variation among individuals.

Red wolves are mammals that belong to the order Carnivora (carnivores) and, within that, the family Canidae—generally known as the canids or wild dogs. The Latin words come from the international classification system for all living organisms. The name for the red wolf in that system, *Canis rufus*, consists of the animal’s genus, *Canis*—that’s the group of related species to which it belongs within its family—and its species modifier, *rufus*—which distinguishes it from the other species in its genus.

Canids first evolved in North America some 40 million years ago. Around 8 million years ago, they crossed the Bering Land Bridge into Asia, where they radiated westward and southward. From there, they spread into Europe and Africa. Around 3 million years ago, they made their way into South America. Along the way, canids evolved and diversified into many different species. Most are now extinct, but there are about 37 modern species living today, including wolves, foxes, jackals, coyotes, and several other lesser-known species, such as bush dogs, raccoon dogs, dholes, and painted dogs.

Generally, canids have long muzzles and legs, upright ears, and long, shaggy tails. They come in a variety of colors and sizes and have developed a wide range of skills and behaviors suited to the environments they occupy. Most

canids are exclusively terrestrial, but some regularly climb trees, and others swim in the ocean. Some live socially and hunt in packs, while others are more solitary outside of the breeding season.

Gray wolves, red wolves, and coyotes are the species in the *Canis* genus found in North America. The gray wolf, *Canis lupus*, has (or at least had) one of the widest distributions of any terrestrial mammal, historically found across most of the Northern Hemisphere in North America, Europe, and Asia. Because gray wolf populations in different ecosystems can look and behave quite differently from one another, biologists initially believed that there were many different species of wolf in different regions of North America—arctic wolves, timber wolves, Mexican wolves, Great Plains wolves, and so on. But today, these populations are all considered to be subspecies of the gray wolf, as are the wolves that survive in Europe and Asia.

The red wolf, however, has been determined not to be just another gray wolf subspecies. And they aren't just hybrids between gray wolves and coyotes, either. According to recent genetic studies published by the National Academy of Sciences, the red wolf is a separate species. This continues to be a subject of debate, but most authorities, including the US Fish and Wildlife Service, recognize red wolves as a distinct species—one that has been present in North America for approximately 150,000 years. Still, both gray and red wolves are closely related enough to coyotes that they can and sometimes do interbreed, which could have serious consequences for the dwindling red wolf species.

Under ordinary circumstances, animals of two different species don't mate, and if they do, they don't produce fertile offspring. But there are exceptions to every rule, particularly when circumstances aren't ordinary—and that's especially true for the red wolf.

There are canids on every continent except Antarctica, living in a variety of environments. Their vast distribution reflects their adaptability as a group.



Red Wolf

Canis rufus

ENDANGERED

HISTORIC RANGE



MODERN RANGE



The Albemarle Peninsula in eastern North Carolina is the only place in the world that wild red wolves are still found.



Gray Wolf

Canis lupus

ENDANGERED*

*Some gray wolf populations have recovered and have been delisted.

HISTORIC NORTH AMERICAN RANGE



MODERN NORTH AMERICAN RANGE



1. Where the Red Wolf Still Roams



Coyote

Canis latrans

LEAST CONCERN

Behavior and Communication

Like gray wolves, red wolves are social animals, living in family groups or packs comprised of a breeding pair and their offspring. Pack size varies, but on average, a pack includes around five to eight animals. Living in packs allows them to take down larger prey on occasion, but since their diet is mostly made up of smaller prey, they often hunt alone or in pairs. They require an average of 2 to 5 pounds of food per day and can range as much as 20 miles a day in search of prey to meet their caloric needs. Red wolves are generally crepuscular, meaning they are most active at dusk and dawn, but they can be active at any time of the day or night.

Social animals generally have complex forms of communication, and red wolves are no exception. They use a variety of vocalizations, including barks, growls, and howls. They also communicate with body language; their facial expressions and body posture and the position of their ears and tails can indicate what they're feeling. In addition, wolves chase and mount each other in displays of dominance, and they bite and even aggressively attack each other—although attacks are usually reserved for non-pack members encroaching on their territory.



Red wolves also communicate through scent. They mark the boundaries of their territory with urine and scat, or droppings, and can detect mating receptivity in other wolves via pheromones. They generally mate for life. A male and female will stay together and continue producing litters once a year in their home territory. However, if one dies, the other will readily pair up with another individual. On average, red wolves in the wild live to about 7 years of age. In captivity, they can live to 14 years.

Populations Today

The range of the red wolves in the United States once extended from East Texas north and eastward up to the lower Great Lakes region, east through Pennsylvania and southern New England to the Atlantic Coast, and south through Florida and across the Gulf Coast. They occupied a variety of ecosystems throughout that range but seemed to prefer bottomland forests and wetlands where prey was abundant.

Over the course of the last century, however, the red wolf's range shrank as a result of the same factors that wiped out much of the gray wolf population—aggressive antipredator campaigns, demonization of the species, unregulated hunting, and habitat loss. And unlike gray wolves, which remained abundant in rural Canada and Alaska, much of the red wolf's habitat was considered prime real estate for people, for either agriculture or development. As a result, red wolves today inhabit just a single area known as the Albemarle Peninsula in eastern North Carolina.

The red wolf's survival in the wild took a major conservation effort. That effort has been underway since the 1960s and at one point involved the US Fish and Wildlife Service taking all remaining red wolves into captivity before they went extinct—to build their numbers through captive breeding and to reestablish a sustainable wild population.

Red wolves' ecosystem depends on them as much as they depend on it. They help keep populations of their prey in check, from rodents and raccoons to rabbits and white-tailed deer. This has a ripple effect. For example, with fewer raccoons to predate the eggs and young of nesting birds, more birds survive.

Predation by red wolves can also help minimize damage to crops, protect native plant populations, and reduce dangers to humans, like tick-borne diseases and car strikes that increase with deer overpopulation.

Unfortunately, the situation of the red wolf today remains dire. As of the writing of this course, only around 20 red wolves are believed to still survive in the wild, with some 250 individuals living under human care in zoos.

Adult red wolves have no natural predators. Humans are the primary threat to the species—through direct action, such as illegal shooting or poisoning, and indirect impacts, such as automobile collisions, which can occur when wolves are forced to cross roads that crisscross their habitat.



The sad truth is that some 70% of red wolf deaths are attributable to humans—even though red wolves have been federally protected as an endangered species since 1967.

1. Where the Red Wolf Still Roams

The species is also in danger of erasing itself through interbreeding with coyotes. Normally, red wolves and coyotes have an adversarial relationship, with the larger red wolves driving out or even killing coyotes. But sheer desperation from lack of available mates has driven some red wolves to mate with coyotes, creating hybrid animals. The problem is that hybrid pups pose a risk to the genetic integrity of the tiny remaining wild red wolf population. If hybridization with the much more abundant coyote continues, red wolves will simply cease to exist as a distinct species.

The US Fish and Wildlife Service continues to manage the red wolf wild population and a captive breeding and reintroduction program. Conservation organizations like the National Wildlife Federation and its state affiliate, the North Carolina Wildlife Federation—among others—continue to advocate for continued protections and conservation of these unique North American animals found nowhere else in the world.



SIGNS OF A RED WOLF

TRACKS

- four toes and a central footpad between which an X can be drawn
- front feet slightly larger than back feet
- claw marks in the tracks
- longer than most dog tracks and larger than coyote tracks



SCAT

- cigar-shaped, sometimes segmented or in smaller pieces, and pinched off at the end
- usually about 4 to 5 inches long and containing indigestible fur and bits of bone of prey
- often very dark in color and larger than coyote scat





REMAINS OF KILLS

- bones with gnaw marks on them (often hard to differentiate from a coyote's kill)

HOWLS

- longer in duration than the short, yipping howls of coyotes

Reading

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2

The Resurgent American Alligator

One of the more intimidating species you're likely to meet in North America is the American alligator. But it wasn't so long ago that it was endangered. Today, it's bounced back and then some. But with the alligator's return have come some difficulties, mostly because people don't always exercise common sense when encountering it or visiting the places it inhabits. In this lecture, you'll take a close look at the alligator's habits and remarkable abilities so that you can appreciate this resilient reptile, stay safe when it's around, and be aware of the species' vulnerabilities.

Taxonomy and Habitat

Alligators belong to the reptile order Crocodylia, which includes the crocodiles, caimans, gharials, and alligators. The ancestors of these crocodylians appeared some 247 million years ago, with the modern forms evolving around 95 million years ago. There have been terrestrial crocodylians and marine species, but today, all living crocodylians live amphibious lives around freshwater or coastal areas. Many have remained essentially unchanged for quite a long time, including the American alligator, *Alligator mississippiensis*, which has existed in its present form for at least 8 million years.

The American alligator is found only in North America and almost exclusively in the United States. It ranges from East Texas north into the southeastern corner of Oklahoma and east across portions of Arkansas, Mississippi, Alabama, Georgia, South Carolina, and North Carolina. It's also found throughout both Louisiana and Florida, where alligator populations are greatest.

Alligators live in subtropical to temperate climates. They inhabit freshwater wetlands, including marshes, swamps, coastal wetlands, estuaries, ponds, lakes, slow-moving rivers, and human-made water bodies such as canals. Sometimes, they venture into brackish water and are occasionally seen in the ocean or on beaches in coastal areas, but they generally avoid salt water.

Like all reptiles living today, alligators are ectothermic, or cold-blooded, meaning they don't produce their own heat internally as mammals and birds do. Instead, their body temperature is dependent on the outside environmental conditions. As such, alligators are most active when it's relatively hot out, in the temperature range of 82° to 92° Fahrenheit. In cooler temperatures, alligator metabolism slows down, and they haul onto land to bask in the sun to heat themselves.

Though they don't truly hibernate, during extended periods below 55° Fahrenheit, they will enter a seasonal dormancy called brumation in deep burrows in the muddy banks. At the northern edge of their range, their wetland habitat sometimes freezes over, and alligators react by moving into the shallows—staying motionless with just their nostrils sticking out of the ice.

ALLIGATORS VERSUS CROCODILES

ALLIGATORS



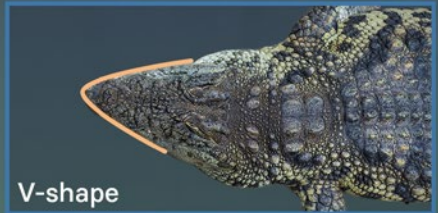
U-shape



Lower teeth hidden

- Broad, U-shaped jaw
- Top teeth visible when mouth is closed
- Largely restricted to fresh water
- Can live in more temperate climates (higher cold tolerance)
- Lack bony eye ridges

CROCODILES



V-shape



Lower teeth visible

- Narrow, V-shaped jaw
- Teeth protrude from upper and lower jaws when mouth is closed
- Can live in salt water (some species)
- Restricted to tropical or semitropical environments
- Have bony eye ridges



American Alligator

Alligator mississippiensis

THREATENED*

*Species is stable but listed due to similarity in appearance to the endangered American crocodile.

Anatomy

Alligators are well adapted to the wetlands they inhabit. The location of their eyes, ears, and nostrils on the top of their heads allows them to lie in wait hidden just beneath the surface of the water but still see, hear, and breathe. They don't have external ears but ear canal openings behind their eyes. They can close these ear openings and their nostrils when submerged. A clear third eyelid called a nictitating membrane closes underwater to protect the eye while still allowing alligators to see underwater. They can also close the back of their throats, allowing them to hunt underwater without water rushing into their lungs.

Their coloration—dark above and light below—is a kind of camouflage known as countershading. From above, they're hard to see in the dark water, and from under the water looking up, their light bellies blend with the sky.

One of the many factors that make alligators such good hunters is that they can detect minute changes in pressure and vibrations in the water around them with tiny sensory organs along their jaws, around their teeth, at the tip of their snouts, and inside their mouths. These are called integumentary sensory organs, and they help alligators to detect prey and navigate their surroundings when visual and auditory cues are absent.



Alligators have four-chambered hearts that function more like the hearts of warm-blooded birds and mammals than other reptiles, as well as a series of shunts that control the mixing of oxygenated and unoxygenated blood. This helps alligators hold their breath underwater for extended periods of time and regulate their metabolism based on temperature. They typically stay submerged for only 10 or 15 minutes before returning to the surface for a breath but can stay underwater for 30 minutes.

At the back of each eye, a mirror-like membrane called the tapetum lucidum reflects light, giving alligators the ability to see well in the dark. This is what causes their eyes to shine an eerie red in the glow of a flashlight.

Prey

Alligators' legs are positioned on the sides of their body and angle outward rather than directly down. This gives them a distinctive waddling, side-to-side gait when they move on land. While on land, alligators are generally slow moving and lumbering, but they can run surprisingly fast over short distances. Usually, this happens when they're fleeing from danger toward the safety of the water. They don't run after prey on land, although they will burst from the water toward prey at the water's edge.

An alligator's cone-shaped teeth are designed for holding prey, not for cutting or chewing. Prey are dispatched not by being impaled on the teeth but by the bone-crushing force of the alligator's incredible bite—which can exert more than 2,000 pounds of pressure per square inch. If that doesn't do the job, the alligator will thrash prey violently back and forth, breaking the prey's neck or spine. They also sometimes drown their prey by holding it in their jaws and submerging until the animal expires.

Once prey has been killed, the alligator will swallow it whole or thrash it around again to rip off more manageable chunks. They often stash the carcass underwater for a few days, which softens it and makes feeding easier.

Alligators are wholly carnivorous. As adults, they feed on most anything that moves, from fish to birds to deer. They are also cannibalistic, with large individuals preying on smaller ones. This not only provides a food source for large alligators but also reduces competition for habitat, food, and mates.

One of the biggest threats to young alligators is larger alligators.

Mating and Reproduction

Alligators exhibit some impressively complex social behavior. Although they don't live in family groups, many individuals can inhabit the same wetland. Males can patrol territories up to 1,000 acres and will attack each other to assert their territorial rights.

Both sexes communicate vocally with grunts, growls, and bellows, which convey their physical size, condition, and dominance. They can also vocalize in infrasound—below the range of human hearing. When irritated, alligators emit a loud warning hiss. If pressed, they'll lunge with their jaws open to drive away or kill a threat. They can also spin around quickly and will thrash their tail, which can pack quite a wallop.

They engage in courtship and mating in the spring months between March and June. Males put on displays to intimidate other males and to show their fitness to potential mates. Mating takes place in the open water. Afterward, the female will construct a large, mounded nest of vegetation and mud, where she will lay her eggs and cover them. Nests are typically set back about 15 to 20 feet from the water, far enough away to prevent flooding but close enough that the mother can keep a watchful eye while immersed.

To incubate the eggs, the nest needs to remain warm. Temperature is also the main factor in determining the sex of the offspring. At about 93° Fahrenheit and above, eggs produce mostly male alligators. At about 86° Fahrenheit or below, the eggs produce mostly females. Some nests produce all males, some all females—but most produce a mix.

The parental care of the female alligator is something that few reptiles provide. Even so, it's estimated that in a growing alligator population, of an average nest of 38 eggs, approximately 24 will successfully hatch, 10 will make it past their first year, and only 5 will make it to sexual maturity at 6 feet in length, which could take between 8 and 15 years.

At hatching, alligators are roughly 10 inches in length. Female alligators typically grow to about 9 feet in length. Though mature male alligators generally max out around 12 or 13 feet, they can get bigger. The record is held by a male alligator killed in Louisiana in 1890 that measured more than 19 feet long.



Young alligators have yellow bands across their dark bodies that gradually fade with age. Adults have greenish-gray to black skin with pale yellowish-white undersides. Their skin is leathery and covered in tough scales called scutes.

Ecological Importance and Conservation

Alligators are a keystone species: Their ecosystems depend on them and might not survive without them. As top predators, they are an important ecological check on the populations of their prey species—which include themselves!

At the same time, young alligators are on the menu for a wide range of other predators. Raccoons are the most common nest raider. Once they've hatched, young alligators are preyed on by just about any predator larger than themselves until they reach several feet in length. At that size, larger alligators are their main natural threat.

The nests of alligators are often used by turtles and snakes as a place to lay their eggs. Turtles and most snake species don't care for their own young, but the presence of the mother alligator protecting the nest provides some insurance against nest predators.

During dry times, as water levels drop, alligators excavate the mud and debris at the bottom of the body of water where they live to allow more water to be stored. These "gator holes" not only give the alligators a place to remain submerged and hunt but also serve as habitat for many other water-dependent species.

Despite the alligators' vital role in their ecosystems, humans almost drove them to extinction. After centuries of unregulated hunting and major destruction of their wetland habitat for development, alligator populations plummeted by the mid-20th century. They were one of the first species to be protected under the Endangered Species Act in 1973. Those protections stopped unsustainable hunting, and that, coupled with captive breeding and reintroduction programs and public education efforts, helped the species rebound. By the mid-1980s, the American alligator was fully recovered to a sustainable level, and in 1987, it was officially downgraded from endangered to threatened.

Generally, alligators fear and avoid people. If someone deliberately enters their habitat, however, especially at times when they're actively hunting, chances of an aggressive encounter increase. This is easily avoided by not swimming in known alligator habitat between dusk and dawn, when they're most active. Also avoid feeding alligators, which can cause them to lose their fear and begin approaching people looking for food. And of course, don't get close to an alligator to take a selfie.

Now that they're no longer at risk of extinction, alligator populations are managed by state wildlife agencies. In most states where they occur, alligators can be hunted legally, with hunting permit fees going to fund wildlife conservation in the state. Unlike in the past, wildlife managers set hunting limits so that the populations will remain healthy. In 2021, the Florida alligator population was an estimated 1.3 million, so the species is doing quite well.



Alligators are still listed and protected as threatened at both the federal and state levels to protect the similar-looking American crocodile, whose range partly overlaps with that of alligators in southern Florida.

SIGNS OF AN ALLIGATOR

TRACKS

- tracks in muddy areas where the shoreline vegetation is missing
- trails between footprints caused by an alligator dragging its tail



SCAT

- oval-shaped scat with a smooth texture (brown when fresh but white when dry) and no segments or identifiable remnants of prey visible



HABITAT

- burrows in muddy banks and alligator holes in dryer times
- nests that look like backyard compost piles

SOUNDS

- bellowing sounds, especially during the spring courtship and mating period

OTHER SIGNS

- red eyeshine reflected in the beam of your flashlight at night

Do not approach a nest during the summer nesting season, or you risk meeting up with an angry mom. Be smart, be safe, and just leave alligators alone.

Reading

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3

What You Probably Don't Know about Bees

This lecture explores a group of wildlife that includes thousands of individual species: bees. Although they're smaller than your little finger, bees are so critically important that if they were to suddenly disappear, most terrestrial ecosystems would soon crash. It's not hyperbole to say that bees are collectively responsible for keeping life as we know it functioning on this planet. The focus in this lecture will be on the wild native bees of North America—not just because they're fascinating but also because they need our help.

Bee Diversity

Of the 20,000 species of bees found on Earth, the one you may be most familiar with is the honeybee. But you might not know that honeybees are an introduced, nonnative species in North America. They were brought here by colonizing Europeans for crop pollination and the production of honey and beeswax.

Today, most honeybees in North America live in hives managed by the agriculture industry or hobbyist beekeepers. Those that have escaped and established themselves in the wild are technically feral animals. And they're competition for the approximately 4,000 wild native bee species that have existed on the continent for millennia.

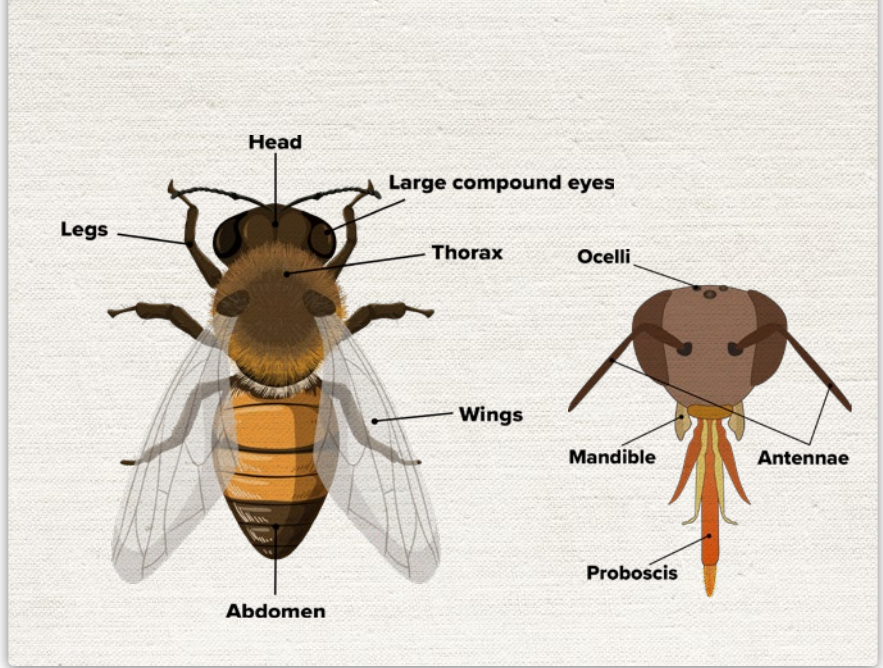
North American bees come in a wide range of sizes and colors. Most but not all species are somewhat fuzzy, and the degree varies between species. And in most bee species, the females have stingers, but when and how they use them varies. There are also some stingless species. Males in all bee species lack stingers.

As for their behavior, all bees visit the blooms of flowering plants to feed on nectar, and most also collect pollen to feed their young. But which plants they visit depends on the species, as does what time of year they're active. Some bees live communally and form hives, but many more species live solitary lives. So, with such diversity, what makes a bee a bee?

Anatomy and Evolution

All bee species are insects and have the typical insect body structure of head, thorax, and abdomen. They have six legs, a double pair of wings attached to their thorax, and two jointed antennae on their heads. On the sides of their heads, they have large compound eyes that consist of thousands of individual lenses, and on the top, they have three single-lensed eyes called ocelli. Their mouths have two mandibles, or jaws, and a tongue-like proboscis.

They all start life as eggs that hatch into larvae, which pupate and emerge as adults. Male bees are generally smaller than females. Flower nectar and pollen are the primary food sources for most bee species.



To understand bees' essential nature, it's important to explore their origins. Their story starts with two things: wasps and the emergence of flowering plants. Wasps are believed to have appeared about 240 million years ago. Bees evolved later from a group of carnivorous wasps approximately 120 million years ago, around the same time that flowering plants began to spread on this planet.

It's been hypothesized that the switch from insect prey to nectar and pollen might have been the result of wasps consuming prey insects that had visited flowers and were dusted in pollen. As certain wasp species evolved to take advantage of the protein-rich pollen and flower nectar as food sources, they became something new and different: bees.

In the beginning, bees were largely pollen specialists, only able to feed on the pollen of certain plant species. Later, new bee species emerged that were generalists, able to feed on a variety of plant pollen. But the life cycles and pollination ecology of flowering plants and all bees have become so intertwined that these two groups of living things really cannot exist without each other. And humans cannot exist without them, either. To understand why, it's helpful to review what exactly pollination is and why it's important.



Rusty-Patched Bumble Bee

Bombus affinis

ENDANGERED*

*The rusty-patched bumble bee is listed as endangered. Other bee species are declining, too.

Why Pollination Is Important

In order to reproduce, plants must find a way to get their male reproductive material, pollen—which is produced in a structure called a stamen—to the female reproductive structure, a pistil, of a flower of the same species. But unlike animals that can move about to find mates, plants are stuck in one spot, so they've evolved some clever ways of achieving pollination. Some rely on the wind, some can self-fertilize their own flowers, but most rely on animals as their reproductive vehicle.

When a bee visits a flower, it gets covered in pollen as it feeds. When it moves to another flower, some of the first flower's pollen sticks to the pistil on the second one, and it becomes fertilized. It then grows seeds, which are often packaged in berries, nuts, or other fruiting bodies. These bodies protect the seeds and are designed to attract a different set of animals—typically birds, mammals, and reptiles—that eat the fruit and deposit the indigestible seeds in their droppings away from the parent plant where the seeds can become new plants.

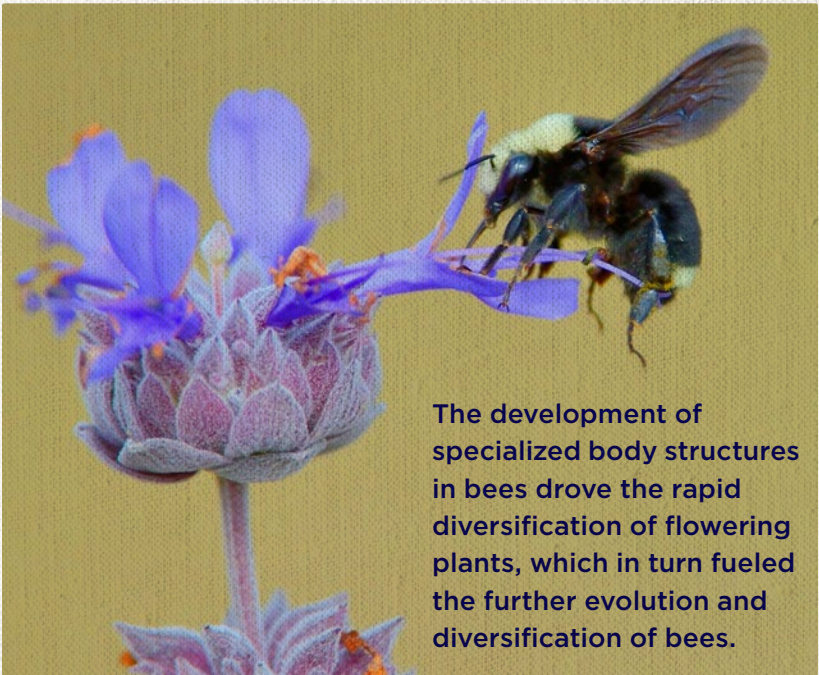
Many different animals are pollinators, but the majority are insects. In the United States, around 80% of flowering plants require an insect pollinator. If pollinators disappeared and the plants could no longer reproduce or produce the seeds and fruits that feed so many other species (including humans), life as we know it would cease to exist.

Plants evolved flowers specifically to attract animal pollinators. Plants produce sugary nectar and pollen as food sources for these animals and lure them in with bright colors and appealing scents. The animals are not aware of their important role in ensuring the future of the plant species they visit.

How Bees Find and Transport Pollen

Of all pollinators, bees are especially suitable for the job. Their fuzzy bodies and structures called pollen baskets allow for maximum efficiency in moving pollen from one flower to another to ensure fertilization. The act of feeding starts with their eyes. Bees fly through the landscape looking for flowers. In general, they show a preference for purple flowers, then blue, and then yellow.

Some flowers have evolved shapes designed to support bees. Daisy-shaped flowers, such as sunflowers, asters, purple coneflowers, and black-eyed Susans, are especially easy for bees to land on, feed from, and pollinate.



The development of specialized body structures in bees drove the rapid diversification of flowering plants, which in turn fueled the further evolution and diversification of bees.

Bees use their antennae to touch and investigate their surroundings, but the antennae also contain olfactory organs responsible for their sense of smell. And scent is more important than sight for bees in determining which flowers have nectar with the highest sugar content. For bees that are pollen specialists, scent also helps them find their specific pollen plants.

Bees eat some pollen directly, but mostly, they collect it to bring back to their nests for their young. The pollen sticks to bees' fuzzy bodies. Most have specialized hairs called scopal hairs on their legs or underbellies. The pollen baskets that some species have on their legs hold even more pollen.

Bumble bees, as well as some other species, also engage in buzz pollination. This is when the bee attaches itself to a flower and rapidly vibrates its flight muscles, causing the entire flower to vibrate. This causes the pollen to flow out, where it can be collected by the bee.

Nesting and Mating Behaviors

Nesting behavior is a critical element in bee reproduction and one of the most important areas of difference between wild native bees of North America and European honeybees. Honeybees live in hives founded by a queen, who produces worker bees. The worker bees, which are female, have many roles, from foraging to honeycomb building to protecting the hive. The queen is the sole reproductive female; her only role is to mate and lay eggs. Male honeybees' only role is to mate with the queen, an act that kills the male. This kind of social grouping, called eusociality, is uncommon, with only approximately 2% of bee species exhibiting this reproductive behavior.

Other species are classified as social. They don't have a queen, but the females create communal nests with their sisters and help protect each other's eggs and young. This kind of social behavior is also not very common.

Most wild native bee species in North America are solitary. Individual male and female bees mate, and the female lays eggs in a series of chambers in a nesting tunnel. She provisions each egg with a ball of pollen and nectar mixed with her saliva, seals each chamber, and leaves her eggs to hatch and develop on their own.

Some 75% of these solitary bees nest in tunnels in the ground. The rest nest in tunnels in dead wood or hollow plant stems. Some create their own nesting tunnels, while others use existing holes created by other wood-boring insects or drilled by woodpeckers.

Stinging is a defensive behavior related to nesting. Only female bees have stingers, and that's because the stinger is a modified ovipositor—the structure through which female insects lay eggs. Eusocial bees have a hive system filled with honey, their queen, and hundreds of young to protect, so they're prone to defend those resources by stinging if they feel threatened. The females of solitary bee species can also sting, but they rarely do.

When a honeybee worker stings, its barbed stinger rips out with the venom sac—killing the bee but making the sting a particularly painful deterrent. But like wasps, native bees don't have barbed stingers, so they don't die when they sting and can sting more than once if provoked.

COMMON NATIVE BEES

Native bees are found in every region and ecosystem on the North American continent. Wherever there are native flowering plants, there are native bee species. Here are some common ones to look for in your neighborhood:

BUMBLE BEES (EUSOCIAL)

- They are large, furry, and mostly black with stripes of yellow, white, or bright orange.
- They have distinctive pollen baskets on hind legs.
- Queens nest in hives in the ground.



CARPENTER BEES (SOLITARY)

- They are large and black, and many species also have yellow coloration.
- Their upper abdomen is hairless and can appear glossy.
- They nest in wood.
- Defensive (but stingless) males chase threats away during spring courtship.



BLUE ORCHARD MASON BEES (SOLITARY)

- They are small to medium-small and can be metallic black, blue, or green.
- They collect pollen on the underside of their abdomen.



- They are a commercially important pollinator of apples, almonds, cherries, and plums.
- They nest in tunnels in dead wood or plant stems.



SWEAT BEES (MIXED NESTING)

- They are sometimes drawn to moisture and minerals in human perspiration (hence the name).
- They are the most common group of bees in the Northern Hemisphere.
- They vary in size and color—some are metallic green, while others can have black-and-white striping.
- Most nest in tunnels in the ground, though some have queens and hives, and others are solitary.



You can explore many other bees by getting a field guide or downloading a bee identification app.

Decline of Native Bees

Wild native bees provide billions of dollars of pollination services to the economy each year. Moreover, they're an important food source for countless other wildlife species. Yet more than 700 of the 4,000 bee species native to North America are in decline, and nearly 350 of those are at risk of extinction.

Loss of plant diversity is a primary cause of native bee decline. It puts the 20% to 45% of bees that are pollen specialists at particular risk. If the host plants for these bees disappear from an area, so do those bee species, perhaps forever. Other contributors to native bee decline include habitat loss and fragmentation, climate change, heavy pesticide use, diseases introduced by nonnative species, and competition with such species—including domesticated honeybees.

Here are three simple things you can do in your own yard and neighborhood to support wild native bee species in North America:

- plant native plants,
- stop using pesticides, and
- provide nesting habitat.

With easy measures like these, you can help sustain not only bees but also the ecosystems on which everyone depends.

The American bumble bee population has declined by 90% in the last 20 years. It's strongly suspected that they were infected with a deadly virus when European bumble bees were introduced to North America.

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4

The Monarch Butterfly's Astonishing Journey

Many people can identify the beautiful monarch butterfly, *Danaus plexippus*, at a glance, but few realize just how extraordinary this creature is. This lesson explores the complex relationship between this fascinating insect and its environment and follows it on its astonishing annual migration—during which an individual butterfly might fly up to 3,000 miles!

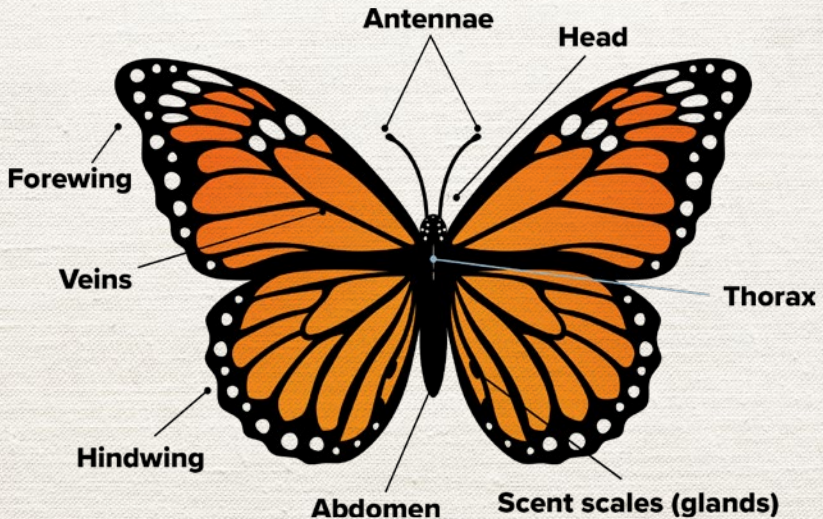
Anatomy and Evolution

Monarchs have the typical insect body structure of a head with antennae, a thorax with six legs and wings, and a long abdomen. Their wings are a striking deep-orange color with black veins and white markings along the edges, and their wingspan measures 3 to 4 inches. Monarchs' bodies are black and have bright white speckles.

Given their showy coloration, you might wonder how butterflies hide from the many animals that prey on them. In short, they don't. To understand why and how that came about, it helps to know a bit about butterfly evolution.

Butterflies, along with moths, form the insect order Lepidoptera, which includes some 180,000 species.

Butterflies evolved from moths, which are largely nocturnal, to take advantage of the benefits of being diurnal, or active during the day. This allowed them to exploit an abundant food source: flower nectar. Because bees, the primary pollinators of flowering plants, are active during the day, most flowering plants focus on offering nectar during the day to attract them. So, in a way, we have bees to thank for butterflies!



Monarch Populations

There are three different monarch species and several subspecies. The species found across North America, from southern Canada to Central Mexico and on some Caribbean islands, is *Danaus plexippus*. The second species is the southern monarch, *Danaus erippus*, found in South America. The third is the Jamaican monarch, *Danaus cleophile*, found only in the Caribbean islands.

In recent centuries, though, populations of *Danaus plexippus* have also established themselves in the Pacific region—in Hawaii, Indonesia, Australia, and New Zealand—as well as in Europe, specifically Spain. It's unclear whether they did so through natural dispersion, hitching rides with human beings, deliberate release, or a combination of ways. But they couldn't have formed breeding populations in these new places without the presence of caterpillar host plants, which, in some cases, were introduced by people to the new regions.

In continental North America, there are two main subspecies of *Danaus plexippus*: the nonmigratory monarch, found in southern Florida, and the migratory monarch, found throughout the rest of the continent.

Migratory monarchs themselves are divided into eastern and western populations, separated by the Rocky Mountains. Though geographic location means their migratory routes and wintering grounds are different, there's no genetic difference between these two populations. The eastern population is far larger than the western, making up more than 95% of the overall migratory monarchs on the continent.

Butterfly colors and patterns can serve many purposes, such as helping butterflies blend in with colorful surroundings, making them more recognizable to potential mates, scaring off predators, or warning predators that the butterfly is inedible. Monarchs fall into this last group.



Most monarchs in North America belong to the migratory subspecies of *Danaus plexippus*.

Monarch Butterfly

Danaus plexippus

DECLINING*

*Monarchs are currently under review for endangered listing by the US Fish and Wildlife Service.

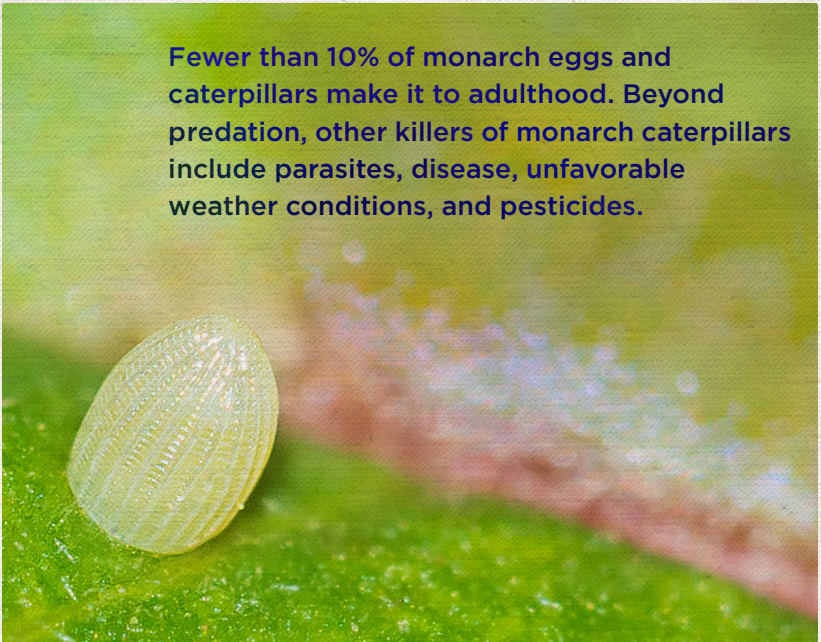
Monarch Life Cycle

Like all butterflies, monarchs undergo metamorphosis—basically, the transformation of their bodies and behavior into something quite different. Butterflies do that in four phases: egg, larva, pupa, and adult. The total transition time from egg to adult is temperature-dependent, taking as little as 25 days in warm weather and up to 50 days in cooler conditions.

Egg and Larval Phases

Female monarchs can lay 300 to 1,000 eggs over the course of 2 to 5 weeks. They lay eggs one at a time on the underside of milkweed leaves.

Fewer than 10% of monarch eggs and caterpillars make it to adulthood. Beyond predation, other killers of monarch caterpillars include parasites, disease, unfavorable weather conditions, and pesticides.



4. The Monarch Butterfly's Astonishing Journey



About 3 to 5 days later, the eggs hatch into tiny caterpillars, which feed on foliage. The larval stage includes five phases of molting, called instars, as the caterpillar eats and grows. Each instar lasts between 3 and 5 days. Monarch caterpillars start out a light yellowish green and then develop black, white, and yellow bands along their bodies as they grow. They can reach almost 2 inches in length in their final instar.



Generally, plants don't want insects feeding on their leaves, so they've developed chemical defenses that make their leaves unpalatable or even toxic to insects. In turn, butterflies and their moth relatives developed an immunity to these chemicals. But it would be impossible to become immune to every plant chemical defense, so these insects became specialists, developing immunity to the chemicals of only certain plants. While some butterfly species can feed on several different kinds of plants as caterpillars, others are so specialized that they can only feed on one kind. Monarchs fall into this latter category.

Monarch caterpillars can feed only on the leaves of milkweed plants, which in North America include 76 species of herbaceous perennials and some related honeyvines. These plants are quite toxic to most species, but by evolving an immunity, monarchs secured a food source that few other things can eat, reducing competition. The flip side of this benefit is that without milkweed, monarchs can't complete their reproduction cycle and their populations disappear.



Beyond nourishment, milkweed offers another benefit to monarchs. Caterpillars incorporate its toxic chemicals into their exoskeletons, which in turn makes them taste incredibly bad to vertebrate predators such as birds. Adult monarchs do not feed on the toxic parts of milkweed plants but retain some protective toxicity from their caterpillar days. Their bright orange-and-black coloration signals to would-be predators that monarchs are toxic and not good to eat. The signal works well enough that other insect species that feed on milkweed also display this same color pattern!

Pupal Phase

After the fifth instar, the caterpillar is ready to pupate. Generally, it will crawl away from its milkweed host plant and climb up a nearby plant or other object. There, it spins a silk pad onto which it latches and hangs upside down in the form of the letter *J*.

After hanging for 12 to 24 hours, it sheds its caterpillar skin to reveal a pupa about the size and shape of a large bean—called a chrysalis. The chrysalis is seafoam green with a half-moon band of black and gold at the upper end and additional gold dots toward the bottom. Beneath the surface of the chrysalis, the monarch's body begins the process of transforming into an adult butterfly, which usually takes between 11 and 14 days.

Under its chrysalis exoskeleton, the insect essentially dissolves into a soupy liquid and then reforms into the shape of an adult butterfly. Toward the end of that process, the chrysalis becomes translucent, revealing the insect's bright orange-and-black coloration, and eventually splits open to release the adult butterfly.

Adult Phase

When the adult butterfly first emerges, its wings are folded, crumpled, and soft. The butterfly pumps fluid into its wings for several hours as they dry and stiffen. Its mouth is also not quite ready for use—the proboscis is in two parts. The monarch repeatedly coils and uncoils each half to zip them together, forming a tube through which it will suck up nectar.

At this point, its goals are to feed and to mate. It uses its senses of sight, smell, and taste to find flowers. Its antennae are filled with scent receptors. Most of its taste receptors are in its feet, which female monarchs use to find the highest-quality milkweed plants on which to lay their eggs.

Within about 3 to 5 days of emerging from the chrysalis, a monarch reaches sexual maturity and sets about finding a mate. Mating can last several hours and starts in the air with a male pursuing a female and driving her to the ground, where mating takes place. The female stores the male's sperm internally and fertilizes her eggs as she's laying them.

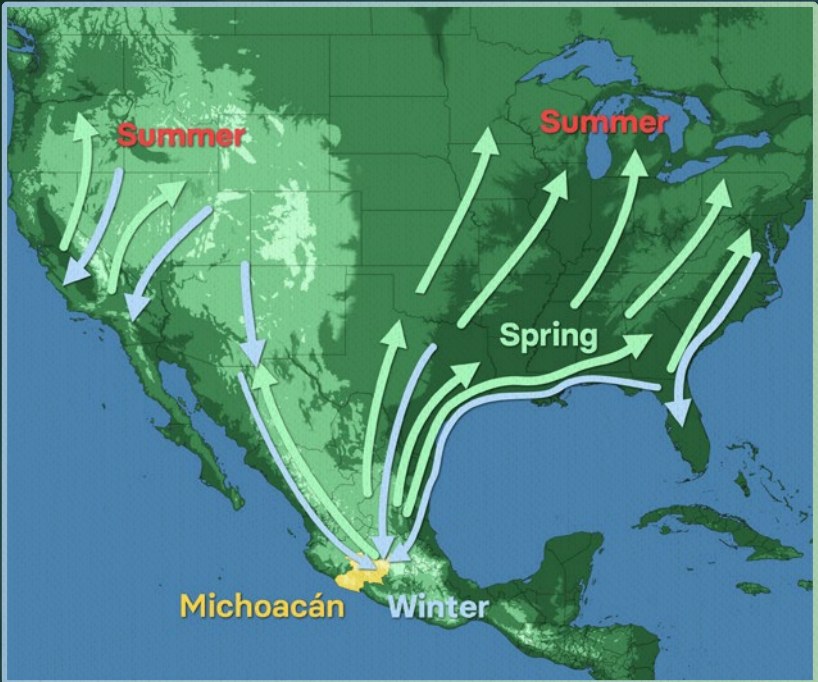


In most cases, the monarch lives in its adult, butterfly form for only a few weeks—long enough to complete the reproductive process. The generation of monarchs that migrates, however, is an important exception to this rule. It is a kind of super generation, living some eight times as long as the previous generations.

Monarch Migration

The migration—which is driven by instinct rather than memory—is triggered when the days get shorter, temperatures drop, nectar sources begin disappearing, and the nutritional value of aging milkweed leaves declines. Monarchs migrate during the day and use the sun like a compass to determine direction. They augment this sun compass by sensing magnetic fields to determine how far in a specific direction to fly from the sun.

MIGRATION PATTERN



The monarchs' migration is unique in nature. Other butterfly species make shorter round trips or one-way migrations, but only the migratory subspecies of the monarch butterfly makes such a long journey, with the same individuals that flew south in the fall also returning partway northward in the spring.

On average, they can travel about 25 to 30 miles in a day. Along the way, monarchs must feed to fuel their journey. Late-blooming native wildflowers, such as goldenrods and asters, are particularly important to them.

The goal for the eastern monarch population is to reach an area in the Mexican state of Michoacán. There, they cluster in huge numbers in just a dozen or so spots in oyamel fir trees that grow in the mountains almost 10,000 feet above sea level. The area has been designated the Monarch Butterfly Biosphere Reserve. These forests create the perfect conditions for the monarchs to overwinter. For the western monarch population, some from Arizona also head southeast to join their eastern counterparts in Mexico, but the majority overwinter in scattered clusters along a 620-mile stretch of the central California coast.

When lengthening days and rising temperatures signal spring's approach, the changes trigger the monarchs' hormones to release, and the migratory generation finally reaches sexual maturity. The monarchs mate and begin the return to their breeding habitat to the north. This usually happens in late February or early March.

They'll make it as far as Texas, just when the native milkweeds are emerging. There, before dying, the females lay their eggs. Once the offspring complete their metamorphosis, they'll continue the journey north. Three to five generations of monarchs will hatch, mate, and disperse throughout the US and into southern Canada before the end of the summer, when a new super generation will undertake the southern migration once again.

Causes of Decline

Unfortunately, monarch butterfly populations have plummeted in recent decades. While numbers vary from year to year, the eastern monarch population has dropped by as much as 90% in some years from population highs recorded in the 1990s. The western monarch population has fallen by more than 99% in some years.

A major cause of the decline in the US is destruction of monarch breeding habitat, resulting from urbanization, agriculture, and the associated use of insecticides and herbicides. Meanwhile, logging threatens the monarchs' overwintering sites in Mexico. Even though the Monarch Butterfly Biosphere Reserve is protected, logging of surrounding forest affects the microclimate the monarchs need to successfully overwinter and gives predators easier access to them.

Climate change, too, is taking a toll. Greater frequency of extreme weather, including freezing events and heavy precipitation, is disrupting monarch migration and increasing mortality during the journey and at the wintering grounds. The increase in extreme heat days also affects breeding populations. The US Geological Survey estimates say that there is nearly a 60% chance the monarch's migration in the eastern half of the country could completely collapse within the next 20 years.

But people and communities can play a part in helping monarchs recover by just giving them some habitat. If each person planted a patch of native milkweed and nectar plants, monarch habitat would increase exponentially overnight. It's a small act that can make a big difference.

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5

The Tiny but Fierce Screech Owl

Screech owls live all around us in the United States throughout the year, pretty much anywhere you can find trees—even in urban parks. They're beautiful and agile, and their lives are complex and fascinating. Because they are small, they are constantly looking out for predators, including larger owls. Nevertheless—and despite all the natural habitat humans have destroyed—both the eastern and western screech owl have managed to thrive. So, what's their secret? To find out, let's consider this plucky little creature more closely.



Eastern Screech Owl

Megascops asio

LEAST CONCERN

Anatomy and Behavior

Screech owls are in the genus *Megascops*, from the Greek *me-gas*, meaning “great” and *skopos*, meaning “watcher.” Together, the name means “great little owl,” with *great* probably referencing the bird’s bold personality rather than its size! They grow to be around 7 to 10 inches tall, with females slightly larger than males. In general, they’re brown, gray, or sometimes reddish orange in color. Their body feathers are heavily barred or streaked, which makes for excellent camouflage when pressed up against the bark of a tree.

Screech owls have disproportionately large, round eyes, which are always a strikingly bright yellow. Like other owl species, they can’t move their eyes from side to side, so to look left or right, they turn their entire head, which can rotate 270°. They have ear tufts at the top of their heads that they use for signaling to other owls. Their real ears do not have external structures and are simply small holes in the side of the head. In many owl species, one ear hole is positioned slightly higher than the other, which helps the owl pinpoint the source of a sound with extreme accuracy.

Unlike many owls that hunt at night, screech owls are more crepuscular—active at dawn and dusk, when both their eyes and ears are valuable tools for hunting and when they’re less likely to be targeted by larger, fully nocturnal animals like the great horned owl.

Habitat

Separated by the mighty Rockies, North America’s two species of screech owls have developed a few notable differences. The eastern screech owl, *Megascops asio*, favors lowland forests, mountainside woodlands, and desert scrub but can also be found in suburban neighborhoods. Eastern screech owls have two color morphologies, or morphs: rufous, which is a rusty red, and gray. The rufous morph is more common in the southeastern United States, while the gray morph is more common farther north and west.

The western screech owl, *Megascops kennicottii*, lives west of the Rockies, primarily in coastal forests or riparian areas—that is, by rivers and streams. It's one of the most common owls in low-elevation woodlands and deserts from Central Mexico north along the Pacific coast and is also often found in suburban areas. Western screech owls are brown or grayish brown in the Northwest, with populations in the southern deserts more of a light gray. Their feather patterns tend to be more heavily barred or streaked than those of eastern screech owls, to help with camouflage in the West's comparatively dense and tangled forests.

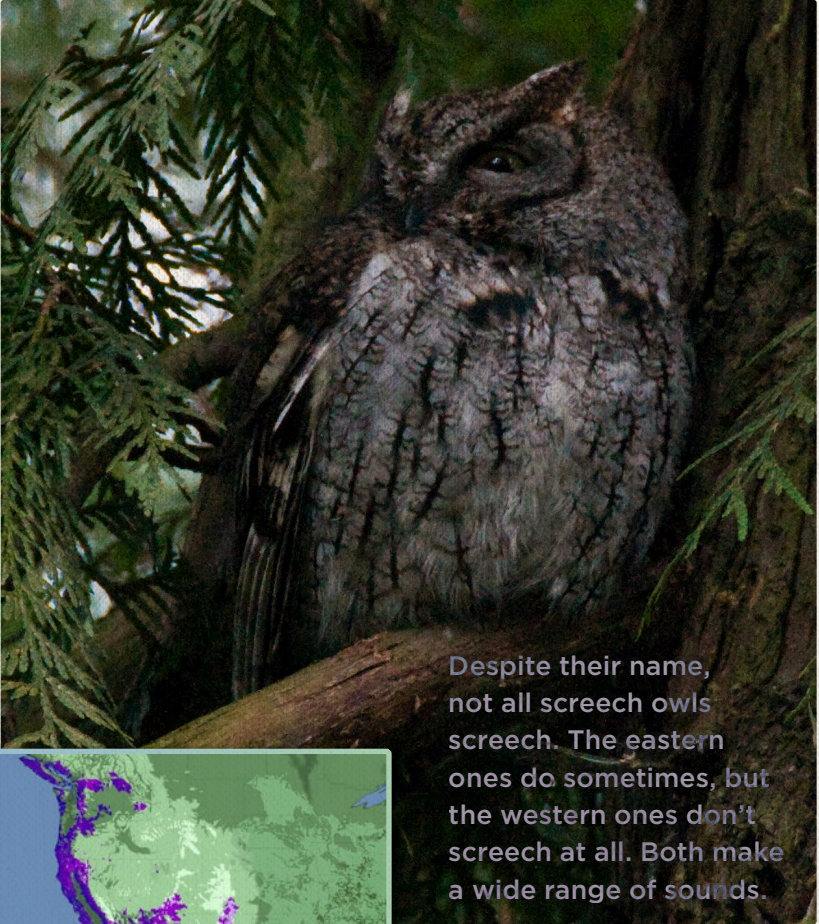
There's currently only one place in the world where you can find wild eastern and western screech owls living in the same space. The two species meet in an approximately 3,800-square-mile stretch of southwest Texas, where they sometimes hybridize. But hybrids are rare and haven't been documented since 1973.

Evolution

Owls are birds, and birds first appeared during the Jurassic Period, around 165 million years ago. Birds evolved from one lineage of dinosaurs and, as such, could be considered modern dinosaurs. In fact, they're the only living representatives of the dinosaurs' lineage.

Almost all dinosaurs were wiped out in a mass extinction event 65 million years ago—now believed to have been caused by a massive asteroid colliding with Earth. But birds were able to survive, largely because they could fly, an ability that had evolved in them only a few million years earlier. It's likely that flight evolved from the ability to generate lift, which assisted ground-dwelling dinosaurs when they climbed up trees to escape predators.

We can see birds, including owls, using this tactic today. It's called wing-assisted incline running. Young birds without fully developed wings will flap their arms to generate lift when walking up trees or other steep slopes as a way of making climbing easier.



Despite their name, not all screech owls screech. The eastern ones do sometimes, but the western ones don't screech at all. Both make a wide range of sounds.



Western Screech Owl

Megascops kennicottii

LEAST CONCERN

Owls most likely evolved not long after the dinosaurs were wiped out and have existed for at least 57 million years. The earliest fossil records we have of screech owls come from cave deposits in New Mexico and might be as old as 129,000 years.



Along with eagles, kites, falcons, hawks, ospreys, and some vultures, owls are predatory birds that capture prey with their feet rather than with their beaks. Today, these different bird groups are collectively known as raptors.

Prey

Eastern screech owls have the most diverse diet of any North American owl. That undoubtedly contributes to their staying power as a species. They eat at least 138 species of vertebrates, including small rodents, lizards, snakes, and fish. They're capable of killing prey far larger than themselves—including birds as big as pheasants and waterfowl!

Despite their varied diet, screech owls are most fond of eating invertebrates, which make up about 75% of their diet. Given their affinity for both insects and small rodents, screech owls provide pest removal services for agricultural fields and suburban homes alike.

Under certain extreme conditions, screech owls will cannibalize their own young. This happens only during harsh weather conditions with low food supply, when the young aren't likely to survive anyway. Screech owls like to store extra food in their nests when prey is abundant as insurance against lean times, so cannibalization is rare.

Screech owls are perch-and-pounce predators. Instead of actively flying around in search of food, they will take a high perch and wait for prey to come within range, at which point the owl will silently drop onto the animal from above.

Like all owls, screech owls have incredibly soft feathers that allow them to fly in almost complete silence. This offers a huge advantage during ambush. Their wings have low aspect ratios, meaning they are relatively short and broad. This shape gives them high maneuverability, although at the cost of speed.

Owls can rotate one toe on each foot so that it's facing forward or backward. As a result, their tracks can be in two configurations: three toes forward and one backward or with two toes forward and two backward in a sort of *X* shape. The latter configuration is most often used while hunting because it gives the bird a stronger grip and more control over captured prey.

Nesting, Mating, and Parenting

Screech owl nests don't look much like a typical bird's nest. Instead, they seek out cavities to raise their young in and lay eggs directly on whatever debris happens to be at the bottom. They often use old nests excavated by woodpeckers or tree cavities that form naturally when branches break off.

They usually maintain what are known as polyterritories, or territories with more than one nest cavity available for use. This is important because some particularly smart predators, like crows and raccoons, are known to raid owl nesting cavities and to return to those they've predated before. To avoid repeat raids, screech owls will choose a new cavity within their polyterritory the next time they nest.

Screech owls are nonmigratory, living in and defending their territory throughout the year. They're socially monogamous, meaning the parents stay together after mating to care for and raise the young. They're also genetically monogamous, meaning the adults don't usually attempt to mate outside of established socially monogamous breeding pairs. Most birds show social monogamy, but genetic monogamy is quite rare.

Breeding usually begins in March or April, when females lay between three and five eggs in a selected cavity. The female incubates the eggs by herself until they hatch (in about a month) while her mate brings her food. Once they've hatched, the male feeds both his mate and his offspring until the young are about 3 weeks old. At this point, the female must also begin hunting to provide for the rapidly growing owlets.

By the fourth week after hatching, nestlings often pounce on inanimate objects and cached dead prey. Fledging, or leaving the nest for the first time, always occurs at night and with adults in attendance. It's an extremely vulnerable time for the young owls—now known as fledglings. They stay close to their parents, who continue to look out for them for about 5 weeks after they leave the nest cavity. Once they've mastered flight, screech owls have a relatively high rate of survival, with about 73% living to disperse at the end of the summer.

5. The Tiny but Fierce Screech Owl



SIGNS OF A SCREECH OWL

- mobbing or diving songbirds that may be trying to scare off a potential ambush predator
- regurgitated pellets of undigested bits of animal in or near a nesting cavity
- small, slender, and often shallow tracks with three toes forward and one backward or with two toes forward and two backward in an X shape
- pounce imprints with wing prints around the edge of the footprints



Threats to Screech Owls

Even though both western and eastern screech owl populations are considered species of “least concern” by conservationists, they still face some threats. Like other owls, they are vulnerable to vehicle collisions, blinded by headlights while they’re hunting for prey along the grassy roadsides. They’re also threatened by illegal shooting and trapping, predation by dogs and cats, collisions with windows, and insecticide poisoning.

The riparian habitats of western screech owls are often negatively impacted by human development, especially in southwestern deserts. These owls have also suffered intense regional declines in areas where barred owls have moved in. Barred owls, which prey on screech owls, have expanded their range as humans have altered the landscape, particularly in the Pacific Northwest.

Although this “great little owl” contends with many challenges, including some serious ones created by humans, so far, it persists well enough that you may find signs of one not far from your home.

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6

The Arduous, Important Lives of Salmon

Today, North American salmon are found primarily in Maine, the Pacific Northwest, and Alaska. They have become a staple of the American diet, both because of their distinctive taste and because a huge industry has developed to catch or farm them. The famous annual migration of wild salmon up rivers to spawn is celebrated as one of nature's great wonders. But you may not realize just how complex and challenging life is for wild salmon or how important they are to our ecosystems—not only in our oceans and rivers but on land as well.

Taxonomy and Diversity

The word *salmon* comes from the Latin *salire*, meaning “to leap,” and refers to the behavior of these large fish as they make their way from the ocean upriver to spawn. Their ability to transition from fresh water to salt water and back is called anadromy, and it’s a key defining feature of salmon as a group of species, though not all anadromous fish are salmon.

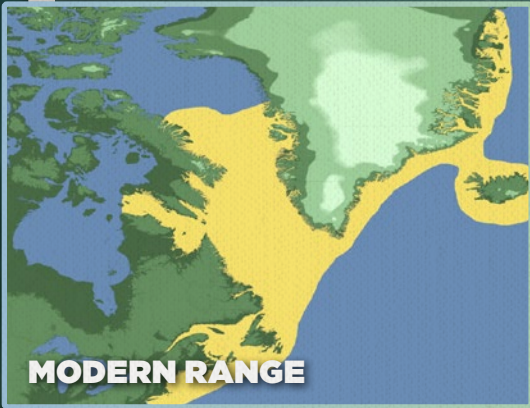
All salmon belong to the family Salmonidae, which appeared about 88 million years ago. Within this family, the genus *Salmo* includes the Atlantic salmon, which is more closely related to European trout than to the salmon found in the Pacific.

All other North American salmon species are native only to the Pacific, and they include the Chinook (or king) salmon, chum salmon, pink salmon, sockeye salmon, and coho (or silver) salmon. These species belong to the genus *Oncorhynchus*. The masu and amago salmon of Asia also belong to this genus. The divergence between this Pacific group and Atlantic salmon occurred between 10 and 20 million years ago.

Salmon species vary in size and are primarily silver or brown for most of the time they’re in the ocean. They become distinctively colorful, though, once they reach their upriver spawning grounds. Adult Atlantic salmon are large fish, averaging almost 4 feet in length and weighing more than 120 pounds. Breeding adults are bluish green on their backs, becoming silvery along the sides and white underneath, sometimes with black spots but none below the midline.

Chinook salmon are the largest Pacific species, averaging just over 2 feet as adults but sometimes reaching almost 4 feet and weighing up to 135 pounds. During the breeding season, their coloring changes to olive brown, dull red, or purplish gray.

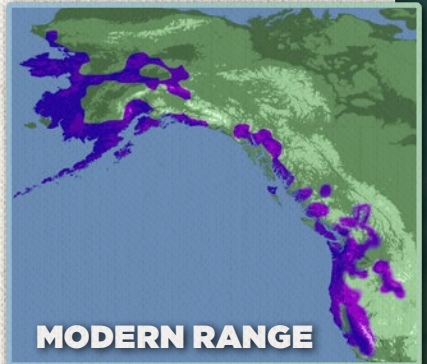
Perhaps the most easily identifiable is the sockeye, which averages just under 2 feet in length and doesn’t usually grow heavier than 16 to 17 pounds. At spawning, males change color more noticeably than any other species. Their head becomes olive green with black on the hooked snout and upper jaw. The rest of the fish turns bright, blood red.



Atlantic Salmon

Salmo salar

LEAST CONCERN



Pacific Salmon

Oncorhynchus

ENDANGERED and **THREATENED***

*Several populations of salmon in North America are listed, others declining.

Pre-spawning Life

Salmon begin their lives in fresh water. Rivers and streams provide gravelly bottoms that shelter the eggs and young salmon from predators, and the cold running water is rich with oxygen that helps them develop.



After about 3 months of development, an egg will hatch into what is known as an alevin—a tiny fish that has no mouth. It relies on a yolk sac that's attached to it for nourishment. At 5 to 10 weeks of age, the alevin has fully absorbed its yolk and developed a mouth. At this stage, it's called a fry and begins feeding on tiny aquatic insects, mollusks, crustaceans, and smaller fish. Over several more weeks, it grows larger and becomes a parr. Parr are large enough to make a decent meal for some birds and other fish, so they develop distinctive striping as camouflage.

The amount of time that young salmon stay in fresh water depends on the species. Atlantic salmon may take up to 6 years to begin migration to the ocean, while chum and pink salmon tend to head for the Pacific within 1 year.

During smoltification, hormones cause changes to the fish's gills, increasing their capacity to excrete salt, an ability necessary for breathing in salt water.

When a salmon parr is ready to migrate downstream to the ocean, it begins to undergo smoltification—a process that prepares it for life in the sea. Until smoltification is complete, juvenile salmon venture no farther toward the ocean than the somewhat salty water near the mouth of a river. This allows their systems to adjust to processing salt water through their gills.

By the time a salmon enters the ocean, it's an adult capable of reproduction. Its primary focus, though, is on feeding, growing, and building strength for the dangerous return trip to the spawning grounds. Rich in nutrients, the open ocean provides salmon with plenty of food to grow, including squid, shrimp, and other fish. The smaller Pacific species also eat substantial amounts of small crustaceans called copepods as well as plankton.

Migration to the Spawning Grounds

Adult salmon can remain in the ocean anywhere from 1 to 6 years. When they're ready to spawn, they usually return upriver sometime between June and November, depending on the species and the region. Males undergo more physiological changes at this stage to prepare them for breeding. For some, hormones such as cortisol transform their bodies. Depending on the species, they may grow a hump or develop a pronounced curvature of the jaws, called a kype. They may also develop canine-like teeth. Traits such as a larger hump and redder coloring signal fitness to females when choosing a mate.

Only the strongest, fittest, and luckiest salmon will survive the journey back to the spawning grounds. Adults may need to migrate up to 1,800 miles upstream and climb 7,000 feet in elevation, all while dodging a slew of dangers, including marine, terrestrial, and airborne predators.

It's likely that a salmon will need to cross a dam on its journey, too. Dams alter the salmon's habitat, making migration much more difficult. Salmon can exhaust themselves to death trying to pass dams. Some dams are completely impassible, halting the salmon spawning process.

To alleviate this problem, "fish ladders" have been installed on some dams to help salmon. While they do make things easier, they can become blocked by the sheer number of salmon trying to pass. Salmon are also at higher risk of predation while waiting to pass through fish ladders. Fortunately, state governments are currently working to make dams safer for salmon migration or, in some cases, entirely removing the dam.

If a migrating salmon manages to survive the journey, it will almost always return to the location where it hatched. Salmon navigate first by using the earth's magnetic field like a compass and then by using their sense of smell and scent memory.

There are so many dams in the northeastern United States today that most salmon can no longer reach their spawning grounds. Similarly, in the Columbia River basin on the West Coast, dams block more than 55% of spawning habitat historically available to salmon.

The Spawning Process

Once at her natal spawning site, a female salmon will dig a depression, called a redd, in the river's gravelly bottom and lay her eggs. Meanwhile, a male salmon will wait nearby, guarding the female and fending off other males. After she lays her eggs, the male will release his sperm, called milt, over the eggs as a cloud. Once the eggs have been fertilized, the female covers them with a thin layer of gravel for protection.

Females may dig several redds and spawn with several males over a few days, releasing between 700 and 25,000 eggs total. Only 1% to 10% of young salmon will make it past their first year.

The spawning period usually lasts only a week or two. By that point, most male salmon are utterly spent, having devoted so much energy to their migration and more to fighting off other males while breeding. In a matter of days, or weeks at most, the salmon's muscles and organs deteriorate, and its body rots from the inside out. It essentially becomes a living corpse, sometimes called a zombie fish.

Females are not exposed to as much stress as males during breeding. Although many of them die at the end of spawning, too, some females will survive and return to the ocean. Some may repeat the upriver migration to spawn again for up to six seasons, though most won't make it past their second attempt. But the death of salmon isn't the end of their important role in the web of life.

Ecological Importance beyond Death

Nitrogen is an essential macronutrient for plant function and growth, and trees employ a variety of strategies for getting the nitrogen they need, depending on where they grow. But it turns out that around rivers where salmon spawn, 40% to 80% of the nitrogen in shrubs and trees originates in the open ocean, having been carried to the forest within the bodies of salmon! How does this happen?



In these spawning locations, many predators, especially brown bears, capture salmon and carry them into the forest to eat. Often, bears eat only certain parts of the fish and leave the rest on the forest floor. As the salmon decompose, the nutrients in their bodies seep into the soil, where they can be used by surrounding flora.

Most surprisingly, spruce trees located up to 1,600 feet in elevation from a stream where brown bears hunt for salmon have been found to contain nitrogen originating from the ocean. It gets there via the food web. A fly may feed on decaying salmon flesh on the forest floor and may later be eaten by a spider. The spider may be eaten by a bird. The bird, now carrying the nitrogen from thousands of spiders and insects it has eaten, may later die on a mountaintop—and the nitrogen may enter the soil there. Repeated over and over, such processes distribute substantial amounts of the nutrients gathered by salmon over great distances, nourishing forestland far and wide.

Causes of Decline

While Atlantic salmon are still widespread, habitat destruction and overfishing have caused many of their wild breeding populations to plummet. Only nine such populations now remain in the United States—all of which are in the Gulf of Maine and are listed as endangered. Along the Pacific coast, there are also many threatened or endangered populations. The US still commercially harvests about 1 million tons of wild salmon every year, amounting to as many as 240 million fish in some years. About 80% of that harvest is in Alaska.

Fisheries' conservation efforts, fish farming, and hatchery releases have reduced pressures on wild salmon populations, but they can also create new problems, especially when farmed salmon escape and breed with wild fish.

Pacific salmon species have progressively become smaller and younger on average when spawning. Some scientists think this may be because the wild fish must now compete with highly abundant hatchery-released fish. The focus on harvesting the biggest fish, which are the most valuable, is also likely a contributing factor, as that can interfere with natural evolution and sexual selection by overloading breeding populations with younger, poorer-quality breeders.

HOW CLIMATE CHANGE AFFECTS SALMON

- Warmer waters make salmon more prone to disease and predation.
- Loss of snowpack reduces stream flow and makes migration more difficult.
- Wildfires kill trees that keep spawning rivers cool by shading them.
- Extreme weather and resulting flooding can scour away the small gravel salmon use for spawning and erode root systems that keep streams in place.
- Ocean acidification caused by atmospheric fossil fuel pollution dissolves the shells of mollusks, an important food resource for salmon.

Reduced physical size and population numbers may also be a result of climate change, which is affecting salmon in a variety of ways. Research shows that pink salmon, at least, are currently adapting to warming temperatures in Alaska. They have been migrating earlier to take advantage of earlier warming temperatures—a move that increases their chances of spawning in ideal conditions.

Salmon aren't just an essential food source to other species. Humans, of course, benefit greatly from them as well. They contribute high-quality nutrients to our diets and millions of dollars to our economies. With a little effort on our part to protect salmon habitat and employ smart conservation practices, they will remain with us long into the future.

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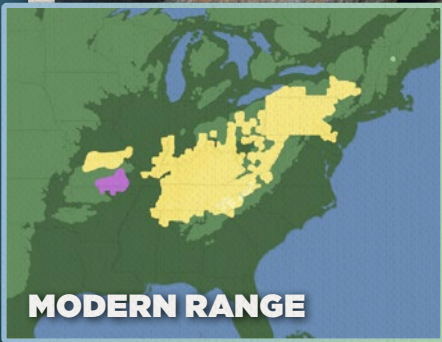
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7

The Giant Hellbender Salamander

If the word *salamander* calls to mind cute little creatures that you might have spotted while hiking in the woods, the hellbender requires a rethink. As the largest salamander in North America, it has collected some intriguing nicknames: devil dog, snot otter, and lasagna lizard. And while it may not be everybody's idea of cute, it's got some amazing traits—including the ability to breathe through its skin! So, let's meet this wonderfully weird creature that lives in clear, cold streams in parts of the eastern and central United States and nowhere else on the planet.



Hellbender

Cryptobranchus alleganiensis

ENDANGERED

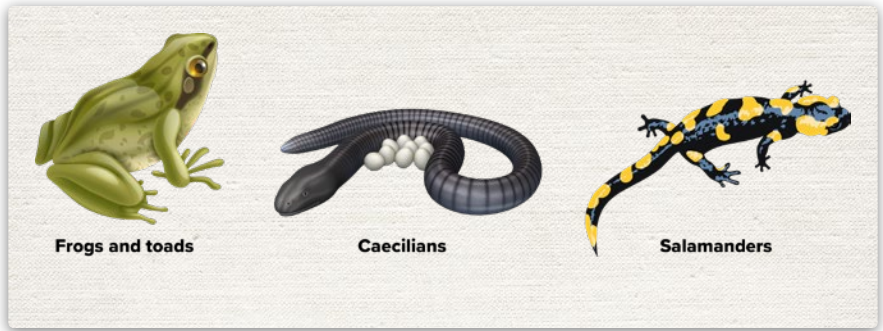
Evolution of Amphibians

There are at least 150 salamander species native to North America. Salamanders are amphibians, a very important group of wildlife that evolved around 365 million years ago from fish ancestors that were the first vertebrates to emerge from the water onto land. To survive outside of water, these fish developed adaptations such as legs with feet for walking rather than just swimming, lungs for breathing air, and special permeable skin that can exchange gases and liquids directly from the animal's environment.

The move from living in water to living on land was one of the most significant evolutionary events in the history of life on our planet so far. The emergence of amphibians was a crucial first step in the development of tetrapods, or four-legged animals, whose body type is the standard today for vertebrates that live on land.

Amphibians became the first vertebrates to dominate life on land, but they're still inextricably tied to water. This dual connection to both land and water is reflected in the name *amphibian*, which is rooted in ancient Greek and means "living both kinds of life." Some species, including the hellbender, have evolved back to being fully or mostly aquatic, living their entire lives in water but also having lungs and four limbs like land animals.





Eastern and Ozark Hellbenders

There are three groups of modern amphibians: frogs and toads; caecilians, which are blind, worm-like animals that live underground; and salamanders. The largest salamander species on the planet are found in China and Japan, the biggest of which can reach lengths greater than 5 feet. Though the hellbender is significantly smaller at just 2 feet, it's the American cousin of these hulking giant salamanders and the only member of the family found outside Asia.

Hellbenders, also known as *Cryptobranchus alleganiensis*, emerged around 150 million years ago. Today, there are two recognized subspecies, the eastern hellbender and the Ozark hellbender—although recent genetic analysis suggests they may be different species altogether. The eastern hellbender gets a bit larger than the Ozark hellbender, has slightly larger gill openings, and has a uniformly colored chin compared with the Ozark's mottled one.

The exact origin of the hellbender's common name isn't fully clear, but it undoubtedly relates to its bizarre appearance. They have big heads with wide mouths, tiny beady eyes, and one gill slit on each side. Their bodies are flat and long with four limbs and a large, paddle-like tail. Hellbender skin ranges from gray brown to pea-soup green, often with black speckles or orange mottling. Their skin also has a saggy, baggy appearance, wrinkling and folding along the animal's sides.



The nickname lasagna lizard makes some sense, even though lizards are reptiles and hellbenders are not. The hellbender's floppy skin folds do look a bit like the fluted-noodle edges and layered appearance of a lasagna.

Habitat and Diet

The eastern hellbender is found along the Appalachian ridge, starting in southern New York, where it lives in the basins and tributaries of the Allegheny and Susquehanna Rivers. From there, it ranges west through Ohio and into Illinois and south, following the trajectory of the Appalachians through Pennsylvania, Maryland, West Virginia, Kentucky, Tennessee, the western parts of Virginia and the Carolinas, and on into northern Mississippi, Alabama, and Georgia. There's a separate, unconnected population of the eastern hellbender in eastern Missouri. The Ozark hellbender is also found in Missouri and in Arkansas.

Hellbenders are found only in cool, clear streams with large, irregularly shaped boulders on the gravelly stream bottom. These boulders provide the crevices where hellbenders hide. Cold, swift-moving water is a necessity because it contains high levels of dissolved oxygen that hellbenders need to survive.

Like most other amphibians, hellbenders eat any other creature they can fit into their large mouths and swallow. That includes a variety of aquatic invertebrates from worms and insects to crayfish, along with vertebrate prey such as fish and other amphibians, including smaller hellbenders. They are harmless to humans.

Anatomy

Even though adult hellbenders have gill slits, they don't use them to breathe. In their juvenile phase, like most amphibians with an aquatic larval period, hellbenders do breathe through gills—but they are reabsorbed into their bodies when the animals reach maturity. At that point, they develop a set of lungs, but they don't use those to breathe, either. Instead, they use them for buoyancy. To breathe, adult hellbenders absorb dissolved oxygen directly from the water through their skin. Their saggy, folded skin is an adaptation that increases the surface area for gas exchange to happen underwater. The swift current of the stream makes that gas exchange possible by constantly washing oxygen-rich water over their skin.

Hellbenders almost never leave the water. Their legs aren't strong enough to support their weight or move any real distance on land, and neither their lungs nor their skin can provide sufficient oxygen from the air. But hellbenders are perfectly adapted to their underwater environment. Their flat, slimy bodies are streamlined for easy movement through the water. Because swimming can be difficult in swift stream currents, they generally walk along the stream bed. Their toes have rough pads on the tips, making them ideal for gripping the stream bottom.

The hellbender's slimy skin serves several purposes:

- It provides a barrier against disease and contaminants in the water that they could absorb through their skin.
- It reduces drag in the water so that they can move more efficiently and easily slide into crevices in and under the rocks, where they hide from predators and make nests.
- It offers a defense against predators by making hellbenders difficult to grab onto.

Hellbenders are nocturnal and don't have particularly good eyesight. But they do have light receptors all over their body—particularly on their tail. It's thought that these allow the hellbender to sense whether its tail is safely tucked under a rock—out of the light—rather than sticking out and visible to predators. Hellbenders also have a system of sense organs known as a lateral line, similar to what fish use to navigate. This allows them to detect movement and pressure changes in the water around them.

Life Cycle

Like most amphibians, hellbenders start out as soft eggs. The breeding season begins in late August or early September and can continue as late as November. Males excavate a saucer-shaped nest depression under a large rock or log in the water, with the entrance pointing downstream. The male waits at the entrance for a female to find him, then leads her into the nest. There, she'll typically lay a double strand of 100 to 500 eggs for the male to fertilize.

The male hellbender will guard his mate until fertilization is over but will also encourage other passing females to lay eggs in his nest. Once fertilization has occurred, the male drives each mate away and guards the nest by himself, fending off predators. This incubation period lasts between 45 and 75 days, when the eggs hatch into small, fish-like larvae about an inch or so long. The larvae are little more than heads with a long, limbless body, external gills, and a large yolk sac that provides nutrients.



After hatching, the larvae leave the nest area to strike out on their own. They'll receive no further parental care. They need to dodge predators such as fish, turtles, snakes, and larger hellbenders. Fortunately, they grow rapidly. They absorb the yolk sac and grow two tiny pairs of legs. They hide under rocks and within the gravelly stream bottoms for safety and begin hunting for tiny invertebrates.

When hellbenders reach one and a half to two years old, they go through metamorphosis into their adult form. They already have legs, and they retain their long tail. But their feathery external gills disappear, they develop lungs for buoyancy, and they start breathing entirely through their skin.

Following this metamorphosis, hellbenders will claim a home territory with suitable crevices in the rocks to hide under during the day. They reach sexual maturity at 6 to 8 years old, but outside of breeding, they'll live generally solitary lives.

Adult hellbenders are large enough that they have few predators. But when threatened, they can secrete a milky, gelatinous substance that often makes attackers change their minds.

The exact life span of hellbenders is uncertain, but they've been documented to live to 30 years in captivity, and it's estimated that in the wild, they might live for more than 50 years. They grow throughout their lifetime, although that growth slows significantly as they age.

Decline of Hellbenders

It's especially important not to disturb hellbenders because they are rapidly disappearing. The Ozark hellbender population has declined around 75% since the 1980s, with less than 600 individuals remaining in the wild. It's federally listed as endangered by the US Fish and Wildlife Service under the Endangered Species Act, as is the Missouri population of the eastern hellbender.

Across the rest of its range, the conservation status of the eastern hellbender is under review by the Fish and Wildlife Service as of the writing of this course. But hellbenders are listed and protected at the state level in some states within their range.

Here are some tips for spotting a hellbender in the wild:

- Look in clear, fast-flowing streams with rocky rather than silty substrate.
- Look at night, when they're typically active, or at dawn or dusk if looking during daylight hours.
- Look for its body shape against the stream bed (as opposed to movement in the water); hellbenders typically rest facing upstream, often in an S formation, and they're easier to spot on gravel.
- Keep an eye out for a strange "rock" with black markings unlike the color patterns of nearby rocks; it might be a hellbender!

Always treat them and their habitat with care:

- Don't try to pick up a suspected hellbender. It could be harmful to the animal.
- Don't flip rocks over to find them. You might disturb a nest or permanently destroy the animal's home habitat.
- Don't gather rocks to stack along the stream banks or shallows. Hellbenders may abandon their home range if the rocks are removed or disturbed, and that puts their survival at risk.

The biggest threat to hellbenders is sedimentation, which happens when soil and other organic matter runs off into streams, building up on the bottom. It's caused by development, agriculture, clear-cutting of forests, and the removal of streamside vegetative buffers. Sedimentation destroys hellbenders' habitat, and it can increase water temperature and reduce dissolved oxygen—two things that hellbenders can't survive.

Pollution is another major factor in hellbender decline. Its range overlaps with active coal-mining facilities in many states, and acid-mining drainage and heavy metal waste are destroying hellbender habitat in many places. Pesticides and other chemicals that run off from agricultural fields and lawns can kill hellbenders, as can nutrient pollution from livestock waste and fertilizers, which can cause algae to bloom, robbing the water of oxygen.

Climate change is affecting populations as well due to the resulting increase in stream temperatures and extreme weather events. Droughts can dry out their habitat, while flooding can wash it away and cause sedimentation.

Hellbenders are also susceptible to diseases caused by bacteria, viruses, and fungi, which are sometimes spread by human activity. And overcollection for research or for the pet trade can affect populations. Stocking streams with fish such as rainbow and brown trout may seem harmless, but those fish prey on juvenile hellbenders and compete with the adults for food.

But there's hope: In some areas, conservation efforts are helping, including habitat protection and restoration, use of artificial underwater nesting boxes, and captive breeding and reintroduction programs. And you can help. The more you know and share with others about these unique amphibians and the more care you show them if you encounter them, the better their chances are for survival.

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8

Neither Pig nor Rodent: The Tusked Javelina

The javelina, also known as the collared peccary, is often mistaken for a pig, but beyond superficial similarities in appearance, the two animals are remarkably different. This lecture explores the history and characteristics of the javelina, an intelligent animal that few Americans know about outside the Southwest, where they're found.

Taxonomy and Evolution

Peccaries and pigs are not closely related, but they resemble each other because they share a common ancestor, one that emerged some 50 million years ago. They're both even-toed ungulates—a taxonomic order that also includes deer, antelope, giraffe, camels, hippos, pronghorn, goats, sheep, and cattle. But the two lineages split from each other around 35 to 40 million years ago. Peccaries are in the taxonomic family Tayassuidae, while pigs are in the family Suidae.

Peccaries first evolved in Europe. From there, they expanded through Asia into North America 30 million years ago, using land bridges such as the Bering Land Bridge that no longer exist. Around 3 million years ago, those ancient peccary species made it into South America. Today, peccaries no longer exist in Europe or Asia and are found only in the Americas.

In contrast, both domesticated and wild pigs can be found today in Eurasia, Africa, and the Americas. But the wild pigs of the Americas were brought here much more recently by humans, beginning with Spanish colonizers in the 1500s and continuing ever since.

Today, there are three living species of peccary. The white-lipped peccary ranges from Mexico south through South America into Argentina. The Chacoan peccary is also found in South America, living only in the Gran Chaco region of Paraguay, Bolivia, and Argentina. The collared peccary ranges through most of South America northward into the desert Southwest of the US in Arizona, New Mexico, and Texas, where it's more commonly known as the javelina.

The term *collared* refers to the band of light fur that this species of peccary has at the base of its neck, extending around its throat and over its shoulders. The name *javelina* was given to the species by Spanish colonizers—the same people who first released feral pigs on this continent. It may be derived from the Spanish word for spear, *jabalina*, presumably for the animal's pointed teeth. Some argue that it's rooted in the Spanish word for wild pig, *jabali*, suggesting that the Spaniards themselves mistakenly identified peccaries as pigs. It's an easy thing to do.



Collared Peccary (Javelina)

Dicotyles tajacu

LEAST CONCERN



White-Lipped Peccary

Tayassu pecari

LEAST CONCERN



Chacoan Peccary

Catagonus wagneri

LEAST CONCERN

There are no native pigs, wild or domesticated, in the Americas. They're all classified as either feral or nonnative animals—unlike peccaries, which are native wildlife that have existed here for millions of years.

Javelinas versus Pigs

Size is one of the more noticeable distinctions. Javelinas are medium-sized animals, standing 20 to 24 inches tall at the shoulder and about 3 to 4 feet long. They weigh around 40 to 60 pounds. Wild boars can reach a more imposing 200 pounds, and domesticated pigs can get even larger. Also, male and female javelinas are generally the same size and look the same, while pig species are sexually dimorphic, with males larger than females.

Javelinas have somewhat shaggy, gray-brown fur with lighter-colored, or grizzled, tips. Wild boars and most feral pigs have similar coloration, although they generally don't have grizzled fur. Pink farm pigs that have gone feral revert to a wild, shaggy, brown form within a few generations, although they sometimes still show more varied appearances, including paler coloration, less shaggy fur, and even spotting.

Javelinas have small ears and short tails that are mostly hidden by their fur. In contrast, domesticated pigs and their descendants have larger, more prominent ears and longer, clearly visible curly tails.

Both javelinas and pigs have feet with four toes and walk on just two of them, leaving a “cloven hoof” track. The structure of their feet is different, however. On their back feet, javelinas only have three toes, not four. The third is little more than a dewclaw—a vestigial toe located higher up on the leg that rarely shows up in tracks.

Their dentition differs as well. Javelinas have 38 teeth, while pigs have 44. Both have elongated canine teeth—sometimes called tusks. But these canine teeth in a javelina are straighter and dagger-like, while in feral pigs and boars, they're curved and often grow large enough that they are visible outside the mouth in true tusk form.

Internally, javelinas and pigs have some distinct differences as well, notably in their digestive tracts. Pigs have a simple, monogastric digestive system—meaning they have one major stomach compartment and rely primarily on enzymes to break down foodstuffs for digestion. Most other ungulates are ruminants—meaning they have multiple stomach chambers and rely on microbes to ferment and extract nutrients from the plants they eat, especially cellulose, which is otherwise indigestible. Javelinas have a complex digestive tract with multiple chambers that also utilize microbes to aid in the processing of their food. Pigs also have gallbladders, while javelinas do not.

Javelinas have a scent gland on their backs above their tail through which they emit a strong, musky scent to mark territory, communicate with other javelinas, and deter predators. They also have sweat glands; pigs lack both scent and sweat glands.

One reliable difference between the coat of a feral pig or boar and that of a javelina is the javelina's collar of light fur around its neck.

Reproductive and Behavioral Differences

Both pigs and javelinas can reproduce year-round. Pigs, however, reach sexual maturity more quickly than javelinas, sometimes as early as 6 to 10 months old, and can produce litters of six or more young.

In contrast, javelina females don't typically reproduce until after they reach a full year and sometimes not until they're 2. They give birth to between one and four young, although, typically, they have twins. In the desert Southwest of the US, javelina females typically give birth in the summer rainy season after a gestation of 142 to 148 days. Javelina young are precocial, meaning they're completely mobile shortly after birth, and run with the herd rather than stay in a nest. The reproductive differences between javelinas and pigs are especially important because they mean that javelinas don't reproduce anywhere near as quickly as pigs.

Both javelinas and pigs are social animals that live in family groups or herds. Pigs form herds made up of females and young with as little as a dozen animals but can reach much greater numbers. Mature male pigs are generally solitary, joining the herds only for mating. Javelinas tend to form smaller herds, often with fewer than 10 individuals but sometimes with up to 50, made up of both males and females of all ages. One javelina male is dominant and ensures that the others do not mate with the females.



A pig herd is called a sounder, and a javelina herd is known as a squadron.

Javelina Habitat and Diet

Javelinas have such a wide range because they're adaptable and able to survive in a diversity of habitat types, including deserts, shrublands, both tropical and subtropical grasslands, dry broadleaf forests, savannas, flooded grasslands, and more. They can thrive if there is dense, scrubby ground cover and if the winter weather isn't extreme.

They are technically considered omnivores, eating a mix of plant and animal foods. They don't deliberately hunt for prey but feed opportunistically on small animals they encounter while foraging, including insects and other invertebrates, lizards, snakes, frogs, rodents, eggs, and carrion. But plant foods make up the greatest portion of their diet and include mesquite beans, fruits, berries, seeds, roots, tubers, bulbs, palm nuts, acorns, grasses, and other herbaceous green vegetation, along with agave, yucca, and various cactus species.

One of their favorite foods—and a primary one in the desert Southwest—is prickly pear cactus. The tough and spiny foods aren't a problem for javelinas, which have equally tough mouths with molars that can easily grind down the plant fibers and spines. The liquid-filled pads of cactus and other succulent plants also supply javelinas with much of their water needs, although they do also need water to drink.

Javelinas play an important role in the ecosystem, distributing and fertilizing the seeds of fruit they eat, helping to keep populations of small animals such as rodents in check, and serving as prey for other animals.

Javelina Defense Tactics

Javelina predators include mountain lions, coyotes, bobcats, and jaguars. But they are no easy meal. They don't have particularly good eyesight, but they do have a strong sense of smell, which they use not only for foraging and staying with their squadron but also to detect danger. When cornered or threatened, they can aggressively attack and do severe damage with their sharp tusks.

For such stocky creatures, javelinas can move at quite a clip, reaching speeds of around 35 miles an hour.

Counterattacking a predator, though, is a javelina's last line of defense. They would much rather avoid being seen in the first place, and their fur offers excellent camouflage against the scrubby vegetation and desert landscape. When they

rest, javelinas readily use caves, rock crevices, and other holes in the ground, including old mine shafts, both to escape the heat and to avoid predators.

Living socially is also a line of defense against predators. Ten noses and pairs of eyes detect potential danger better than one set. And a bunch of javelinas scattering can confuse or intimidate a predator.

Javelina mothers can be fiercely protective of their young and will attack predators and bite with their formidable canine teeth. Strangely, though, females also sometimes flee from a threat and leave their young behind. Unfortunately, this behavior is a contributing factor to the high mortality rate of young javelinas. On average, those that survive to adulthood typically live to about 10 years old in the wild but up to 20 in captivity.

Coexisting with Javelinas

People and javelinas have been coexisting for millennia. Javelinas were a food source for ancient indigenous Americans and remain so for many people in South and Central America today. In the US, they are classified as a game species, and populations are managed by state wildlife agencies for sustainable harvest and healthy herds.

In agricultural areas, javelinas can sometimes become pests when they feed on crops, although they do far less harm than feral pigs. The same is true in home gardens, though fencing is effective for keeping them out. Another

good tactic is to not grow exotic plants that attract them and instead create a natural landscape with native desert plants, which javelinas do eat but can also find outside of your garden.

Javelinas are often active after dark or at dawn and dusk, partly to avoid encounters with people. In suburban areas, where they aren't actively hunted and are used to human presence, javelinas often just ignore people when they do cross paths with them. This can give people a false sense of security around them. Sometimes, people are tempted to try to interact with, touch, or feed javelinas, but that is always a bad idea. Approaching any wild animal can cause it to defensively attack, and feeding wildlife can be harmful to the animal by altering its natural diet. It can also create a dangerous situation when the javelinas become habituated and associate humans with food, losing their natural fear of us.

Javelinas are a valuable, ancient native species that we can live alongside safely if we just remember that they're wild animals and respect them as such by giving them their space. Fortunately, javelinas are doing well and have been classified as a species of least concern. As long as we keep the distinction between them and pigs in mind, their future looks secure.

Pet dogs are particularly vulnerable to interactions with javelinas. It's important for people to keep their dogs leashed and under control whenever they're out in nature.

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9

Opossum: A Kangaroo Cousin in Your Backyard

Some people dismiss opossums as useless pests and think of them as “giant rats” because they have naked tails like rats and are found so widely. But opossums aren’t even closely related to rodents, and they actually help keep populations of rodents and other pests in check. Opossums are much more closely related to kangaroos—which should give you a hint of just how interesting their evolutionary history is. This lecture explores the Virginia opossum, *Didelphis virginiana*, the only opossum found north of Mexico.

Evolution of Marsupials

Virginia opossums are medium-sized mammals, growing to around 2 feet in length including the tail and weighing anywhere from 5 to more than 10 pounds when mature, with males slightly larger than females. They have pointed snouts with a pink nose, rounded black ears with white tips, and long, naked tails that are black at the base and pale pink and scaly along their length.

Otherwise, this opossum species is covered in shaggy fur that ranges from nearly white to silvery gray to almost black. Opossum faces are mostly white, and sometimes there are faint black markings that extend from the back of the head down the forehead, almost like a widow's peak. Their legs have black fur, but their feet are naked and pink like the tail and have five digits.

Like the kangaroo, the Virginia opossum is a marsupial. Marsupials are mammals that give birth to very underdeveloped young. Once born, these tiny young must crawl to their mother's pouch on her lower abdomen and attach themselves to a nipple, where they feed and continue their development.

Today, people often associate marsupials with Australia because kangaroos and koalas are the most familiar ones. But marsupials first evolved in North America more than 65 million years ago, toward the end of the reign of dinosaurs. The earliest of them were much more like today's Virginia opossum than like kangaroos.

Those early marsupials expanded their range south into South America, disappearing from North America entirely for millions of years when the two continents separated. From South America, marsupials made their way across Antarctica to Australia, which at that time were still connected and much warmer. As the Australian continent separated, marsupials there proliferated and evolved into the kangaroos, koalas, wombats, and other modern marsupial species.

It was around 3 million years ago that North and South America reconnected, allowing the Virginia opossum to expand back north. Today, there are more than 100 opossum species, with most of them found in South America.



Virginia Opossum

Didelphis virginiana
LEAST CONCERN

Opossum or Possum?

The possum and opossum are not the same thing. Though related—they're both mammals and both marsupials—they're separated by evolutionary history and belong to different taxonomic families. Opossums belong to the Didelphidae family and are found in North and South America, while possums belong to the Phalangeridae family and are found in Australia, New Guinea, and other islands of the Australasian region.



Nevertheless, the English common names possum and opossum come from the same source. How the two different groups of marsupials came to be known by those names is a confusing tale of colonialism and Eurocentrism.

To the Algonquian-speaking Powhatan people who lived in what is now Virginia, the North American species was known as *aposoum*. When the English colonizers attempted to pronounce and spell the native word, it morphed into the word *opossum*.

In the mid-1700s, when English colonizers first reached Australia, they—not incorrectly—observed that some of the marsupials there seemed similar to those they were already familiar with from the Americas, so they called them by the same name: opossum.

Later, though, it was determined that the two groups of marsupials were in fact different, even though distantly related. The *o* was therefore dropped from the name of the Australasian group, and they became known simply as possums.

To further confuse things, many people in the United States have adopted the habit of abbreviating *opossum* to just *possum* because it's easier to say. But the correct name for the North American animal is opossum. Regardless of what common name you call an animal, the most precise name is the two-part Latin name that's used universally—in the case of the Virginia opossum, *Didelphis virginiana*.

If you prefer the term *possum* and you're writing about the Virginia opossum, put an apostrophe at the beginning of its name to indicate the missing *o*—*'possum*—something you shouldn't do when writing about the Australasian possums.

Range Expansion

Prior to European colonization, the Virginia opossum was found from Central America north throughout Mexico and the southeastern quarter of the United States from eastern parts of Texas north to eastern Iowa, east through the Midwest along the southern tip of the Great Lakes, through Pennsylvania and New Jersey, then south to the tip of Florida. Its natural habitat is woodlands, stream valleys, and wetlands.

In the last century, however, the species has begun to expand northward and westward. Today, it can be found in the upper Great Lakes states and throughout New England, and it has even crossed the border into Canada. It's also pushed west and can now be found in parts of New Mexico, Arizona, Colorado, Wyoming, and South Dakota.

This expansion is partly due to the tremendous adaptability of the species. Virginia opossums will eat just about anything, including green vegetation, fruit, nuts, insects, slugs, rodents, frogs, snakes, young birds, and eggs. They aren't picky about living quarters either, taking up residence in almost any sheltered place—including your shed or attic.

There are also fewer checks on the opossum population than there used to be. Humans have eliminated larger predators like red wolves and cougars in the East, and even predatory species that remain there normally don't venture into places with denser human populations, offering opossums areas of relative refuge. Humans have also introduced opossums to places outside their historic natural range that they'd be unlikely to reach on their own.

The one exception is the coyote, which has filled in the niche left empty when red wolves were eradicated by humans. Now, coyotes are found everywhere that opossums are in the United States.

Climate change is also a factor. As average global temperatures rise, opossums are able to occupy northern latitudes that previously would have been out of bounds for them—including cities, which tend to be warmer than the surrounding countryside thanks to the urban heat island effect.

Ecological Importance

Depending on where they live, opossums are a food source for larger mammalian predators, including bobcats, mountain lions, coyotes, wolves, foxes, and bears. Large birds of prey, such as great horned owls, hawks, and eagles, also prey on opossums. Large native snakes could potentially take young opossums, and in the South, alligators eat opossums that venture near the water. In Florida, the nonnative Burmese python is also a predator, and populations of medium-sized mammals like the opossum have plummeted in some areas where these snakes have become established.

Ecologically, Virginia opossums also help keep populations of the animals they eat in check. In addition, feeding on fruit such as pawpaws and persimmons benefits these fruit-bearing trees, as opossums disperse and fertilize the seeds when they defecate. Some South American opossum species also pollinate plants when they visit flowers to feed on nectar, as do possums in Australasia. Opossums' consumption of carrion helps prevent the spread of pathogens and disease.



The Virginia opossum is resistant to distemper and rabies and therefore doesn't contribute to the spread of these diseases the way some other animals do.

However, since opossums sometimes den in spaces inhabited by humans, it's important to note that their feces can carry pathogens that can make people sick if handled directly. Opossum droppings can also carry a protozoan that can cause equine protozoal myeloencephalitis. If you find opossum droppings—or any wildlife droppings for that matter—call a professional animal control company to clean the area and install exclusion devices.

Adaptations and Behaviors

Virginia opossums are skillful grabbers and climbers. For one, they have an opposable digit on their back feet, much like primates. This “thumb” helps opossums hold firmly onto tree branches. They also have prehensile tails to help them navigate easily from limb to limb. No other native mammal in North America has a prehensile tail.



Opossums are crepuscular, meaning they’re usually most active around dusk and dawn. Though they don’t have particularly good eyesight, opossums have good hearing and a good sense of smell, and their sensitive whiskers help them navigate their environment in the dark. They’re also equipped with 50 teeth in their long mouths—more than any other mammal in North America.

The undercoat of the opossum is biofluorescent, meaning it glows pink under ultraviolet light—beyond the range of human vision. More research is needed, but this trait might provide a camouflaging benefit that helps opossums avoid detection by predators that do see in the ultraviolet range.

They have also evolved the ability to deter predators by faking death. This involuntary bodily reaction to danger is where the phrase “playing possum” comes from—referring to the tactic of faking surrender to survive a dangerous or uncomfortable situation.

Life Cycle

Males attract mates by making a clicking sound and through pheromones that trigger ovulation in the females. Mother and young also communicate with clicking sounds. Otherwise, opossums are largely solitary and silent animals.

Virginia opossums give birth to their young after a very short gestation period, just 11 to 13 days. With so little time to develop, newborns have no fur, no back legs, and eyes that are shut. They resemble pink kidney beans and are about the same size as one. They navigate by scent to their mother’s pouch, where they nurse and continue developing.

On average, opossums have around 8 or 9 young in a litter but can have as many as 20. Females have only 13 nipples—arrayed in a circle of 12, with the 13th one in the middle—so if more than 13 young are born, not all will survive.

The young—called joeys, just like the young of other marsupials—nurse for around 3 months. Their eyes open somewhere between 50 and 70 days after birth. When they grow too big to fit in the pouch, they’ll cling to their



mother's back. It's a vulnerable time for the whole lot because it's hard for a female laden with babies to escape from predators. When they're just 4 to 5 months old, the babies strike out on their own.

Most opossums don't make it past their first year, falling prey to predators or getting hit by cars. Even if they do survive, opossums only live for around 2 to 3 years. Fortunately, they can produce 2 or even 3 litters a year. That, combined with their willingness to eat just about anything and den just about anywhere, has kept their population numbers healthy.

The Virginia opossum doesn't always get the love and appreciation it deserves, but its surprising skills and impressive adaptability certainly deserve respect. It will likely be around for a long time to come!

SIGNS OF AN OPOSSUM

- ❑ They have five digits on each foot, and their short claws typically leave marks at the tips of the digits.
- ❑ Their back feet are larger than the front and have opposable thumbs—which gives their back tracks the appearance of a tiny human hand.
- ❑ The front foot appears before the back.
- ❑ Their scat looks similar to dog droppings and is usually deposited in long, solid pieces that often break in the middle. It's typically dark in color and smelly when fresh.

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10

Secrets of the Leatherback Sea Turtle

Much of the life of a leatherback sea turtle is a mystery, taking place out in the open ocean and often deep below its surface. But what is known about these massive and strange-looking creatures is awe-inspiring, which makes it all the more distressing to know that, like so many other species, they're now endangered—rapidly disappearing from this planet because of human activity. But there are steps that can be taken now to save them from extinction if people make it a priority. This lecture explores some of the things that make the leatherback sea turtle so amazing and worth saving.



The massive leatherback sea turtle can grow to be more than 6 feet in length and weigh more than a ton. Their front flippers can each be up to 6 feet long as well—the longest of all the sea turtle species.



Leatherback Sea Turtle

Dermochelys coriacea

ENDANGERED

Evolution of Turtles

The first turtles emerged around 260 million years ago. Unlike today's turtle species, many early turtles had teeth rather than toothless beaks. They also didn't have shells like modern turtles do—but they had precursors to them! The lower shell structure first evolved to provide early terrestrial turtles with more stability and leverage for burrowing. The upper shell evolved in later species. The protection from predators that the shell offered was a side benefit.

And no, turtles can't crawl out of their shells, which are part of their skeleton. The upper shell is called the carapace, and the lower shell is the plastron. In most species, the shell is made up of the same bones that form the spine and rib cage in other animals. These bones are fused together in turtles and covered in plate-like exterior scales.

The first sea turtle ancestors evolved around 230 million years ago from those terrestrial turtles. The first true sea turtles didn't emerge, though, until around 110 million years ago, during the Cretaceous period. Today, there are seven living sea turtle species, but the leatherback is the only member of its taxonomic family, which explains why leatherbacks are very different from the other sea turtle species—they come from a different lineage.

Unique Features and Capabilities

Leatherbacks are pelagic, meaning they live in the open ocean. They have the widest global distribution of any living reptile species, and their range extends into waters that are colder than those of any other sea turtle species. In North America, leatherbacks range as far north as the numbing waters of the North Pacific up to Alaska and into the North Atlantic off Canada's coast. They can even be found north of the Arctic Circle.

Leatherbacks have been documented at 4,000 feet deep and can hold their breath for an hour and a half.

While leatherbacks aren't warm-blooded, or endothermic, in the traditional sense, they're not quite cold-blooded, or ectothermic, either. They can maintain a body temperature of around 79° Fahrenheit despite conditions around them, something no other living reptiles can do.

How do they do it? Rather than generating heat metabolically via internal core body functions, leatherbacks generate it mechanically through the constant pumping of the muscles that power their massive flippers. In colder water, they increase the stroke rate of their flippers to generate more heat; in warmer waters, they reduce it to stay cool.

Unlike true endotherms, which send warm blood from the core to the limbs via arteries and transfer cooled blood from the limbs back to the core via veins, leatherbacks do the opposite. They generate heat in their limbs and send it to the core. This allows their limbs to stay warmer than their core, which is good since they essentially never stop swimming. If the leatherback's flippers got cold and went numb and stiff, the animal could drown. They also have adaptations to retain the heat that they generate, including a thick layer of fat that surrounds their head and core.

Their ability to generate and retain heat is part of what enables them to dive to phenomenal depths in the ocean. Their unique shells, which are covered in thick, rubbery skin, are also an important factor in this ability to dive. If their shells were hard, like those of other sea turtle species, they would crack under the enormous pressure down there. The leatherback's softer, more flexible shell allows it to tolerate that pressure, opening up habitat other seas turtles can't access.

Nesting Populations and Behaviors

When they're ready to lay eggs, leatherback females haul out onto beaches and dig nests in the sand. Nesting activity happens year-round, depending on where in the world it occurs—but always during the warm months, which occur at opposite times of year in the Northern and Southern Hemispheres.

The nesting population found in North America's Atlantic waters belongs to the Northwest Atlantic subpopulation. These leatherbacks forage in cold northern waters but nest on beaches from North Carolina southward to Florida as well as along the Gulf Coast, throughout the Caribbean region, and northern South America. In the US, most nests are found on the East Coast and southern tip of Florida, the Virgin Islands, and Puerto Rico, and eggs are laid there between March and July. Other Atlantic leatherback subpopulations nest in other parts of South America and across the ocean in Africa.

The nesting population in North America's Pacific waters belongs to the East Pacific subpopulation. These leatherbacks forage further south and primarily nest on beaches in Mexico and Costa Rica and, to a lesser degree, in Panama and Nicaragua, typically between September and March. Most of the leatherbacks in the Pacific belong to the West Pacific subpopulation, however, and nest on the other side of the ocean in Indonesia, Papua New Guinea, and the Solomon Islands.

Leatherback sea turtles can travel an astonishing 10,000 miles each year between foraging areas at sea and their nesting beaches. They use geomagnetic orientation to navigate these migration routes and are capable of orientation in complete darkness.

Courtship and mating take place in the water. Females may mate with several males during this time. A few weeks after mating, typically at night during a high tide, the huge female leatherback will haul herself onto a beach and crawl past the high tide mark.

The female leatherback will create multiple sand mounds to make it harder for predators to pinpoint the exact location of the egg chamber. Leatherbacks are the only sea turtles that camouflage their nests this way.

She will use her flippers to dig a wide, shallow depression around her body. At the bottom of this, she'll use her back flippers to excavate an egg chamber a few feet deep, where she'll deposit anywhere from 50 to 150 or more eggs. She'll bury them in sand and then set about erasing the nesting depression by throwing sand with her front flippers.

Once the nest is hidden, the female will begin the arduous journey back to the water. She might repeat this process 10 or more times during one nesting season. While male leatherbacks mate every year, females only do so every 2 to 5 years because of the enormous amount of energy it requires.

Life Cycle

Eggs hatch in about 8 to 10 weeks, usually at night. For sea turtles, warmer nest temperatures produce females, while cooler temperatures produce males. Leatherback hatchlings measure around 2 to 3 inches in length and have scales and sometimes claws on their flippers, but those disappear as the animals grow.

After hatching beneath the sand, the babies must dig their way to the surface. When they emerge, they're instinctually drawn to the lighter sky above the ocean and head in that direction toward the safety of the water.

Many hatchlings fall prey to predators on their journey from the nest to the sea. Those that reach the water swim straight out to sea for several days and follow the currents. Like all sea turtle species, not much is known about young leatherbacks after this point—except that juveniles tend to stick to warmer tropical waters. It's thought that they seek out places with major upswells rich in food that can fuel their rapid growth.



If there's too much artificial lighting along the shoreline, leatherback hatchlings can become disoriented and crawl away from rather than toward the ocean—in which case they won't survive.

Leatherbacks reach sexual maturity at anywhere from 9 to 25 years of age. They begin migrating into cold water feeding grounds only when they reach adult sizes that allow them to tolerate the cold. The average life span of leatherbacks is unknown, but it's estimated that they can live anywhere between 30 and 50 years or more.

Prey and Predators

While leatherbacks do occasionally feed on fish, cephalopods, and seaweed, they favor jellyfish and similarly soft-bodied marine invertebrates such as salps. They need to eat many such creatures to meet their daily caloric needs.

And they have special adaptations designed to handle their light, squishy prey. They've got cusps at the tip of their upper jaw that give their beak a W-shaped appearance. These function a bit like stabbing teeth to grab onto soft prey. And they have mouths and throats filled with backward-pointing spines perfectly adapted to capturing and swallowing their gelatinous prey and forcing it down into their stomachs.

Adult leatherbacks have few predators. Large shark species—tiger sharks, in particular—are a threat and often take bites out of the flippers or even the shells of leatherbacks. Orcas sometimes prey on leatherbacks as well. But turtles are not helpless. They've been documented aggressively defending themselves against sharks. Their dark coloration provides camouflage when seen from above in the dark ocean waters, and their lighter undersides make them harder to spot against the ocean surface if approached from below. Their massive front flippers can also propel them at speeds of 22 miles per hour if threatened.

On land, however, they have no defenses. Female leatherbacks have been killed by jaguars on Central and South American nesting beaches, though this is very rare.

Threats to Leatherbacks

Like all sea turtle species, leatherbacks are rapidly disappearing, with an estimated 40% population decline globally in recent years. In some parts of the world, their eggs and even the adult turtles are harvested as a food source and for the oil derived from the turtle's fat. Even though the turtles are protected in most places, illegal harvests continue.

Many leatherbacks die as bycatch of the fisheries industry, especially by longline swordfish and tuna fisheries as well as shrimp trawling and gillnet fishing. They are also killed or injured by boat strikes along highly developed coastlines, especially along the East Coast. Coastal development also contributes to another threat—loss of nesting habitat.

Plastic ingestion is also a major problem. Leatherbacks can easily mistake clear plastic for their jellyfish prey. They also ingest fishing line, balloons, plastic bags, floating tar or oil, and more. If they don't poison or choke the animal, these materials fill the gut and prevent the turtle from getting enough nutrition from natural foods to survive.

Looming over it all is climate change. The increase in extreme storms is causing major beach erosion, which can result in a 40% to 60% annual loss of nests. Also, as the planet warms, sand temperatures rise, which can cause turtle eggs to perish or produce an excess of females.

Leatherbacks are listed and protected as endangered by the US Fish and Wildlife Service under the Endangered Species Act as well as by international treaties. If humans continue conservation efforts and commit to addressing climate change in real ways, this ancient and unique sea turtle will continue to traverse the world's oceans for millions of years to come.

SIGNS OF A LEATHERBACK SEA TURTLE

- Look for the spray when they surface from underwater to breathe.
- Go to the beach early in the morning during nesting season and look for turtle tracks in the sand. They make distinctive parallel “butterfly strokes” with their front flippers, and their tracks are large—up to 7 feet wide!



- Look for tail marks in the tracks. These appear as a single continuous centerline down the middle of the track where the tail drags, with noticeable tail-point marks.
- Look for nests. They are large mounds in the sand, often surrounded by the other, diversionary mounds.

Never approach or pursue a leatherback or disturb their nests. This stresses the animal and can interrupt or alter its natural behavior or even harm it.

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11

What to Do If You Meet a Black Bear

Bears are fascinating, intelligent, and resourceful creatures. This lecture focuses mostly on the American black bear, *Ursus americanus*, which is found across many parts of North America and is the bear that you're most likely to encounter. In recent decades, the species has been making a comeback in some places where it had once disappeared. That's great news from a conservation perspective—but humans need to do a little bit of work to welcome these original inhabitants of the land back to their historic range. Knowing how to behave is important for both you and the bear—and so is knowing whether the bear you've met is a black bear or some other kind of bear.

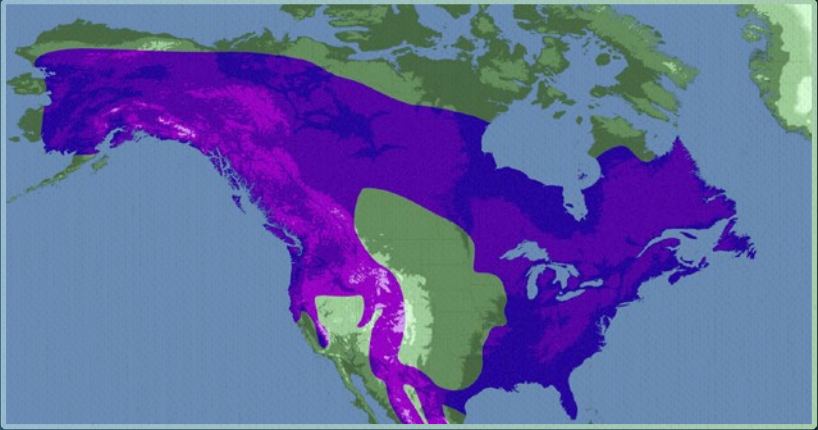


American Black Bear

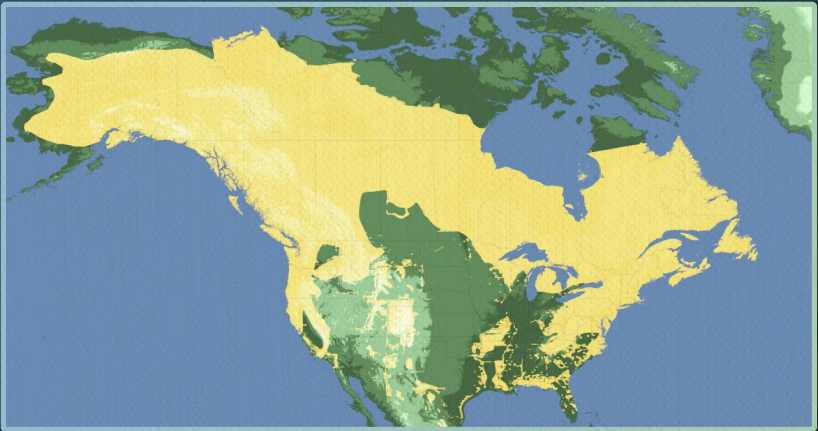
Ursus americanus

LEAST CONCERN

HISTORIC RANGE



MODERN RANGE



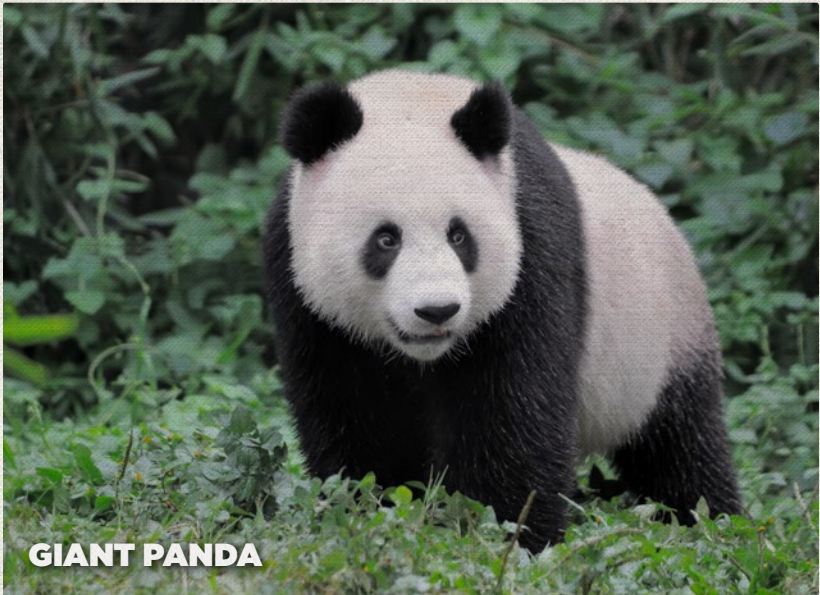
Taxonomy

Bears are mammals that belong to the taxonomic order Carnivora and the family Ursidae. The ancient ancestors of bears looked similar to modern raccoons, in both size and shape. And in fact, bears do share a common ancestor with raccoons. Modern bears are most closely related to the branch of mammalian carnivores known as the Mustelidae superfamily, which includes the different families comprised of the weasels, otters, badgers, wolverines, skunks, red pandas, and raccoons. They are also closely related to the pinnipeds, a group that includes seals, sea lions, and walruses.

There are eight bear species living today around the globe: polar bears, brown bears (grizzlies are one type of brown bear), giant pandas, sun bears, sloth bears, spectacled bears, Asiatic black bears, and American black bears. Though there are considerable differences in size and appearance among these species, they all have stout bodies with four stocky legs; long snouts; small, rounded ears; thick fur that's often shaggy; flat paws with five nonretractile claws; and short tails. Many black bears are indeed black, but coloration can vary from reddish brown and light brown to almost blonde and from silvery blue to slate gray—there are even black bears with white fur!



**KERMODE BEAR
(SUBSPECIES OF AMERICAN BLACK BEAR)**



On average, black bears stand around 3 feet tall at the shoulder while on all fours. Their length from nose to tail is about 6 feet. They are sexually dimorphic, with males larger than females. A large male black bear can exceed 600 pounds in weight, while females seldom exceed 200 pounds.

Though both black and brown bears are found in North America and often share habitat, American black bears are more closely related to Asiatic black bears. The ancestral black bear to both the modern Asiatic and American species crossed from Asia to North America almost 5 million years ago via land bridges that are no longer present. Modern brown bears evolved in Asia as well but crossed into North America much more recently—during the last ice age, around 13,000 years ago.

Range and Diet

Historically, black bears were found wherever forests or brushy habitat grew over most of North America from Canada south into northern Mexico, from wooded wetlands at sea level to mountain forests at high elevation. Today, they're still found across most of Canada and some parts of northern Mexico. In the United States, they're found in parts of the Pacific Northwest, California, the Rocky Mountains, the Great Lakes, the Northeast south along the Appalachians, and scattered pockets throughout the Southeast and Florida. In comparison, brown bears are currently found only in a few northwestern US states and Canadian provinces and in Alaska.

Black bears also live in and around suburbs, even near large urban areas like New York City. In wilder habitats, their home ranges can be up to 300 square miles, but in more urban habitats, they may stay within just a few square miles. Males have much larger ranges than females.



Although part of the order Carnivora, black bears are omnivores and eat a wide range of food—fruits, berries, grasses, foliage, roots, insects, small animals, fish, and carrion. They also readily take advantage of anthropogenic food sources, such as garbage, pet food, and bird seed.

What they eat varies by the season. Carrion is eaten year-round when they find it. They eat increasing amounts of food in summertime in preparation for winter, consuming as many as 8,000 calories a day. As fall approaches, bears enter a period called hyperphagia, during which they can consume up to 20,000 calories a day as they build the base of body fat that they'll need for the cold months ahead. Black bears typically don't eat anything or even drink water in the winter. Instead, they survive by entering a long dormant period, during which they live off their accumulated fat reserves.

Hibernation

You might have heard that bears hibernate. The truth is a bit more complicated. Hibernation is an adaptation to seasonal changes or other environmental conditions that limit the food or other resources an animal needs to survive. By the strictest definition, hibernation means the animal enters a state where its metabolism, heart rate, and body temperature drop drastically, and it remains motionless and inactive for long periods of time—sometimes many months.

Black bears do slow down in the fall and enter underground dens, caves, hollowed-out logs, and cavities high up in the trees to live off their fat stores. Their body temperature, however, doesn't lower significantly like it does in deep hibernating species such as rodents or bats. Black bears also rouse and move about within their dens—and sometimes leave them—throughout the winter. Female black bears even give birth while in the winter den.

So, bears enter a torpor and go dormant, but that doesn't meet the technical requirements for hibernation. Still, most biologists today use a broader definition of the word *hibernation* to include what bears do.

Reproduction and Life Cycle

Black bears mate in the summer months, and pregnancy lasts around 7 months. Cubs are typically born between January and February. Average litter size is one to three cubs. Newborn bears are tiny and helpless, but they nurse and grow quickly. By the time the family leaves the den in March or April, the cubs weigh around 5 pounds. By their first birthday, they can weigh 80 pounds.

The cubs stay with their mother through their first year and den with her for another winter. They'll strike out on their own the following spring or summer. This reproductive cycle means that black bear females produce litters every other year.

Black bear cubs are at risk from wolves, mountain lions, and brown bears where their ranges overlap. But one of the biggest threats is other black bears. Male bears will instinctually kill and eat cubs if they can, which will make the mother bear available for mating again sooner. An estimated 50% of cub deaths are attributed to cannibalization by other black bears.

Only around half of black bear cubs born live past their first summer. Those that do, however, go on to live an average of 20 to 25 years.



Adaptations for Survival

Black bears have an exceptional sense of smell that they use to find food. In fact, bears as a group are thought to have one of the best senses of smell in the entire animal kingdom. Most experts agree that black bears can detect odors from at least a few miles away. They also have good eyesight, despite their relatively small eyes.

Black bears are very strong and highly dexterous, capable of opening screw-top jars and manipulating door latches. They use their claws as defensive and predatory weapons and as digging tools to access food.

They also use their claws for climbing. This is a key survival strategy for young black bears, but adults climb as well. Adult brown bears, in comparison, cannot easily climb trees due to their size and different claw structure.

It has been hypothesized that brown bears are more defensively aggressive than black bears because brown bears cannot easily climb trees. Because black bears can climb trees, they've evolved a strong response to flee from threats, whereas brown bears have evolved more of a fight response.

What to Do during an Attack

If a brown bear attacks, it's typically doing it to neutralize a perceived threat. Fighting back will only reinforce that you pose a threat and cause the bear to attack even harder. Your best chance of surviving is to play dead and cover your head and neck. If a brown bear feels you are no longer a threat, often it will leave you alone.

Since black bears typically flee from humans, they probably won't approach you unless they're unusually curious, have lost their fear of humans due to previous experiences, or are desperately hungry. In such situations, the best

thing to do is to yell, clap, and hold your jacket up over your head to appear larger and intimidate the animal. If the bear does attack, fighting back is your best chance of survival. That's because unlike brown bear attacks, which are typically defensive, black bear attacks are likely to be predatory in nature. If you play dead during a black bear attack, you'll likely end up dead in reality.

Running or climbing a tree isn't advised; black bears can run 30 miles per hour and easily climb trees. Aggressively hit the bear in the face, poke its eyes, and use bear spray to stop the attack.

Female black bears with cubs will defensively charge to threaten humans away but don't typically attack if fleeing is an option. There is no record of anyone being killed by a mother black bear defending her cubs. Brown bear mothers, on the other hand, are more likely to aggressively defend their cubs.

Most people in North America, however, don't live near brown bears, and the likelihood of a black bear attack is extremely low. Black bears attack fewer than one person per year in North America.

Your best strategies for avoiding dangerous encounters with black bears are preparation and prevention. Do your research and know if bears live in the area where you'll be hiking or camping. If they do, carry bear spray and know how to use it. Periodically make noise or tie a bell to your backpack to alert bears to your presence so that you don't surprise them, especially in areas of dense vegetation. Keep your dog leashed; half of black bear attacks involve unleashed dogs, which trigger the defensive aggression the bear would have if facing wolves.

While we should always be cautious around wild animals, spotting a black bear is something special. Thanks to their adaptability, the continent has some 300,000 black bears as of the writing of this course, and the species is categorized as "least concern." That's something to be celebrated.

If a brown bear attacks, play dead and cover your head and neck. If a black bear attacks, fight back.

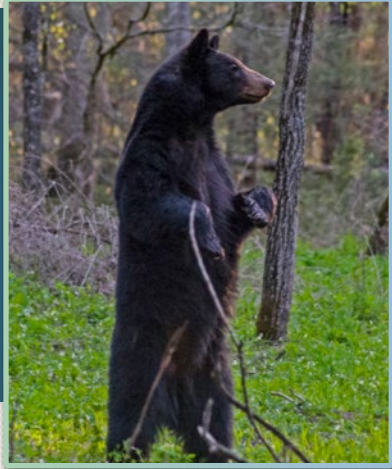
BROWN BEARS VERSUS BLACK BEARS

BROWN BEARS



- generally much larger than black bears
- prominent hump on their shoulder
- downward-sloping rump
- smaller ears in relation to the size of their head
- longer front claws
- curved or “dished” profile of the head

BLACK BEARS



- generally smaller than brown bears
- no shoulder hump
- rounded rump
- larger ears in relation to the size of their head
- shorter claws
- straight profile of the head

SIGNS OF A BLACK BEAR

TRACKS

- Foot length ranges between 5.5 and 9 inches.
- They have five toes on each foot. The inner toe does not always leave a track.
- Front tracks are wider and shorter than rear tracks. Bears often travel in an over-step walk, with their rear foot falling in front of where the front foot fell. This can sometimes look like a double track.
- Tracks are much smaller than those of brown bears, and claw marks are more deeply depressed and closer to the toe pads.
- Toes are closer to the foot pad, and the bottom of the outer toe aligns with the top of the inner toe.



SCAT

- Depending on what the bear ate, it can be cigar-shaped or loose and may contain scraps of fur, bone, and scales.
- Typically, it does not smell bad and might smell like fermented fruit.
- In summer and fall, it often contains bright berries and leaves and may be stained red or purple.





TERRITORY MARKINGS ON TREES

- Claw marks are usually long and shallow scratches in the bark.
- Incisor bites are deep enough that pieces of bark and wood are sometimes pulled out.
- Bites leave nearly horizontal marks that look like a dot and a dash where the upper and lower canine teeth came together.
- Hair may be caught in the bark or wood 2 to 5 feet up the tree, and bites can be as high as 5.5 to 6.5 feet.
- Stomp-walking tracks may be near marked trees. This is a form of scent-marking where the bear stomps, twists, and slides each footstep, which makes the tracks easier to spot.

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12

The Horseshoe Crab's Many Gifts

If you've ever visited the beaches along the US Eastern Seaboard or the Gulf Coast in the spring or summer, you've likely encountered the strange-looking creature that is the subject of this final lecture. The horseshoe crab might be the oldest unchanged animal species on our planet. It looks like it could be from another galaxy, but it plays a crucial role in our marine and coastal ecosystems. And many of us owe our health or even our lives to it without even knowing it.

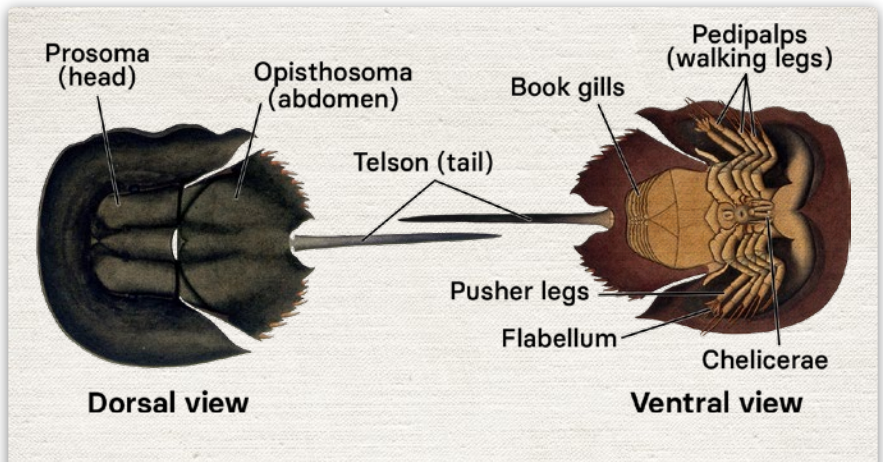
Taxonomy and Anatomy

Despite their name, horseshoe crabs are not crabs at all. They're hard-shelled marine arthropods with segmented legs like true crabs, but they're more closely related to spiders and scorpions, which are arachnids. Still, they aren't arachnids either. Horseshoe crabs and arachnids belong to a larger group called the chelicerates—the only arthropods that lack antennae. Horseshoe crabs are the only living members of the order Xiphosura, from the Greek word meaning “sword tail,” which is a fitting name given their long, spike-like tails.

Globally, there are four horseshoe crab species. The mangrove, southern, and tri-spine horseshoe crabs are found in the Indian and Pacific Oceans along the coast of Southeast Asia. Only the Atlantic horseshoe crab is found in North American waters. Its scientific name is *Limulus polyphemus*.

Horseshoe crabs can grow anywhere from 14 to 19 inches in length from the front of their shells to the tip of their tails, so they're rather large for invertebrates. Females are significantly larger than males.

A horseshoe crab's body is divided into three sections. The forward section is the biggest and is called the prosoma. This is the horseshoe-shaped part of the shell that is often referred to as the “head” and gives these animals their common name. Underneath the prosoma shell are the brain, heart, mouth, digestive tract, nervous system, and glands of the animal.



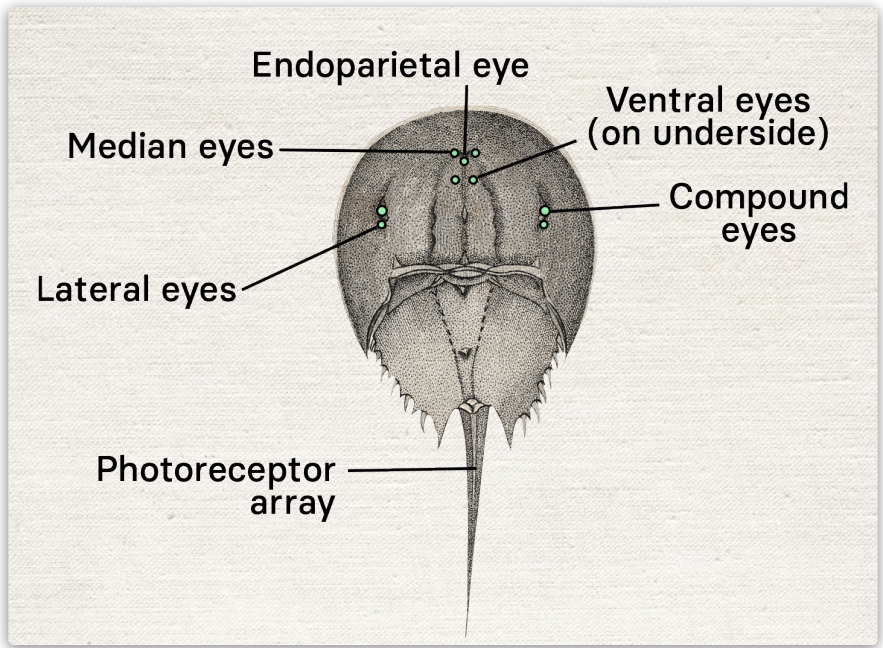
Also under this part of the shell are six pairs of appendages. The first pair, called chelicerae, have claws and are used for feeding. The next four pairs are the walking legs, called pedipalps, each of which also has a claw on the end. The sixth pair is called the pusher legs, which the animal uses to move forward. These legs also have a sensory appendage at their base called a flabellum that the horseshoe crab uses to determine water quality.

Behind the prosoma, the center segment is the opisthosoma, or abdomen. It is also covered with a hard shell. Under it are muscles used for movement, the respiratory and reproductive organs, and protective spines along the sides, which the animal can move.

Horseshoe crabs breathe through structures called book gills—a series of flaps that look like the pages of an open book. There are five sets of them. As the animal pumps water over the book gills, oxygen is absorbed. Pumping water through them can also help young horseshoe crabs propel themselves forward in the ocean. Even though they breathe through gills, horseshoe crabs can survive up to 4 days out of water.

The last body segment is the telson, or tail, which horseshoe crabs use to steer while swimming and to flip themselves over if they get turned on their backs. However, they can't always manage that on dry land, and if they're unable, they'll likely perish.

Contrary to popular belief, the telson isn't venomous, and horseshoe crabs don't use it as a defensive structure. Horseshoe crabs might look scary, but they're no danger to humans. They don't even bite.



Horseshoe crabs have nine eyes. The largest are two compound eyes on the top of the prosoma; they aid in finding mates during spawning. Behind those is a smaller pair of noncompound eyes, and toward the front of the prosoma, there are three more. Underneath the prosoma is still another set of eyes that allows the animal to see what's underneath it. They also have multiple light receptors on their telson that help them follow the daily light and dark cycle—an array that's sometimes counted as a 10th eye.

Horseshoe crabs can regrow lost limbs.



Atlantic Horseshoe Crab

Limulus polyphemus

DECLINING



Evolution and Resilience

Based on fossil evidence, the first horseshoe crabs evolved at least 445 million years ago during the Paleozoic Era, some 200 million years before the age of the dinosaurs. And horseshoe crabs have shown very little physiological change over evolutionary time. This has earned them the title living fossils.

Since horseshoe crabs first appeared on this planet, life here has undergone five major extinction events—all of which these resilient creatures survived. They've made it through the ecological destabilization caused by major volcanic eruptions, atmospheric change, global warming and cooling events, and acidification and loss of oxygen in the ocean.

How did they do it? One important factor is their blood. In humans and most other animals, hemoglobin carries oxygen. In horseshoe crabs, its hemocyanin that carries oxygen instead. Hemocyanin can do this work even in anoxic conditions—that is, when there's little oxygen around—but hemoglobin can't. During periods when large amounts of carbon dioxide were released from volcanoes or asteroid strikes, global temperatures rose and caused widespread loss of oxygen in marine environments. That spelled doom for many species, but because of hemocyanin, horseshoe crabs survived.

Habitat and Reproduction

The Atlantic horseshoe crab inhabits shallow coastal waters that have soft, sandy, or muddy bottoms up to 35 miles offshore as well as brackish waters near land. It ranges along the coastal shelf from Maine to Florida on the Atlantic coast and along the Florida, Alabama, Mississippi, and Louisiana coasts in the Gulf of Mexico. There is also a population across the Gulf along the coast of the Yucatán Peninsula at the southern end of Mexico.

Their annual spawning events happen during the late spring and early summer. They prefer to spawn at night and during the full and new phases of the moon because that's when the tides are the highest. High tide allows for quicker and safer movement between ocean and land and reduces the chance an adult will become stranded when reproducing.

Males arrive along the shore first and wait for females. Potential mates choose each other using pheromones and possibly visual cues as well. Males grasp the females' shells while they are still in the water. Sometimes, several males will attend to one female, and they will all head for the beach together.

Once on the beach, the female will dig a nest in the sand and lay around 4,000 eggs, which the male or males then fertilize. Females can create four or five such nests in a night and will return with successive tides on subsequent nights to continue laying.



Large females can lay up to around 80,000 eggs in a spawning season.

After about 2 weeks, the eggs hatch, and the tiny larvae, which look like miniatures of the adults minus a tail, crawl into the ocean. There, they'll rapidly grow and molt their exoskeleton about six times during their first year. After 3 to 4 years, growth slows and they molt only once a year. They reach breeding age at around 10 years and are thought to live as many as 40 years.

HOW TO OBSERVE A HORSESHOE CRAB DURING SPAWNING SEASON

- ❑ Look for them on the beach in the early morning.
- ❑ Look for distinctive tracks in the sand: two solid lines made by the outer edges of their shells, with interior dotted lines made by their clawed legs as they move along the sand.
- ❑ Look for their nests, which are shallow and typically covered by sand—but don't disturb them.
- ❑ Look for loose eggs near a nest that has been raided. Eggs are soft-shelled and resemble peas in size and texture. They are typically gray, white, green, or blue.



Diet and Ecological Importance

Horseshoe crabs are omnivores, a trait that helps them survive. They eat a wide variety of marine invertebrates as well as algae. They'll also readily feed on dead fish and other organisms that fall to the sea floor.

They don't have jaws or even teeth, so horseshoe crabs crush their food with their legs and pass small bits into their mouth with their claws. Because of this, they prefer thin-shelled prey that are relatively easy to crush and consume. Like birds, horseshoe crabs also have a gizzard that helps grind up their food before it enters the stomach.

Some sea turtles and shark species prey on horseshoe crabs. Along the coast, they can fall prey to alligators. Terrestrial predators, including foxes and birds, sometimes feed on horseshoe crabs that have gotten stuck upside down in the surf during spawning. But it's the horseshoe crab eggs that are most important as a food source for other species ecologically, specifically for shorebirds.



The red knot, a migratory shorebird, is dependent on horseshoe crab eggs laid along Delaware Bay beaches during their spring migration. As horseshoe crab populations have dropped in recent years, red knot populations have followed. The bird is now listed as threatened and is rapidly disappearing.

Indigenous people relied on horseshoe crabs as a source of food, tools, and fertilizer. In the 19th and first half of the 20th centuries, their utility as a crop fertilizer became more widely exploited commercially. This practice ended in the 1960s as chemical fertilizers became readily available. But in the late 20th century, the emerging eel and whelk fisheries industry began to harvest horseshoe crabs as bait. This large-scale consumptive use has drastically reduced the horseshoe crab population.

Biomedical Importance

One critically important way that humans rely on horseshoe crabs is in biomedical research. The animal's special blood contains a type of blood cell called an amoebocyte, which helps protect the horseshoe crab against pathogens. When the amoebocytes detect something dangerous in the animal's bloodstream, they form a clot around it, containing the pathogen and preventing it from spreading.

In the 1970s, scientists began using horseshoe crab blood to test the safety of biomedical products. Amoebocytes are extracted from the blood and used to create a compound called *Limulus amoebocyte lysate*. This compound is used to detect and quantify bacterial endotoxins in injectable drugs, medical devices, and vaccines. If clotting occurs, it means the product is contaminated and not safe to administer to people.

If you've ever benefited from an injected drug, a medical device, or a vaccine—including the COVID-19 vaccine—you've got horseshoe crabs to thank!

Horseshoe crab blood is drawn from live horseshoe crabs. Although some animals do die from the process, the goal is to return them safely to the wild. Typically, they are released within 24 hours, and their blood volume returns to normal within a week.

HOW TO HELP A HORSESHOE CRAB OVERTURNED ON A BEACH

- ❑ Have no fear: It won't bite or sting you.
- ❑ Pick it up with both hands by its prosoma—the horseshoe-shaped part of the shell toward the front of the animal.
- ❑ Don't hold it at the joint between its front and back shells where your finger might get pinched if the animal struggles.
- ❑ Turn it right side up and place it back in the water.



Conclusion

Despite their long existence, the future of horseshoe crabs remains uncertain. Today, they are internationally listed as a vulnerable species. They face habitat loss due to coastal development. They are being overharvested for fishing bait. And to a lesser degree, they are threatened by the same blood harvesting that is so vital in biomedicine—although research is underway to develop a synthetic substitute.

As you've seen throughout this course, all species are part of an ecosystem, and what happens to one always affects others. In combination, major impacts on multiple species can have wider consequences.

Another extinction event is now underway on our planet. This time, the primary driver is human activity. Species have always come and gone, but it's been estimated that the current rate of species extinction is somewhere between 1,000 and 10,000 times higher than normal. It threatens to destabilize entire planetary ecological functions, imperiling not just the natural world but human life itself.

But we're not helpless. The fate of the horseshoe crab, like that of many other species discussed in the course, is dependent on the choices humans make. If we take action and do our part in caring for the wildlife around us, we can turn the declines around and accomplish amazing things.

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