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The Horseshoe Crab

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We've all heard the old saying, "If it works, don't fix it." That applies to many things, including nature. Along our East Coast, you don't have to look far for one of nature's best proofs of that adage—the horseshoe crab.

Millions of years ago, there were many members of the horseshoe crab group or Xiphosura, meaning sword-tailed animals. In fact, they were among the dominant critters 100 million years before the dinosaurs arrived. Numerous species of horseshoe crabs and their extinct relatives the sea scorpions were once plentiful in all the world's oceans, but only four species of horseshoe crabs exist today. Three species are found in the western Pacific, from Japan to Vietnam, and one is found along the western Atlantic coast, from Maine south to the Yucatán Peninsula. Scientists believe that continental drift played a major role in distributing the horseshoe crab. As the continents drifted apart, we were left with only one species on North American shores.

What Is a Horseshoe Crab?

While its hard shell and numerous appendages with claws may remind us of a crab, the horseshoe crab is not a crab at all. Horseshoe crabs belong to the arthropod phylum along with crabs, insects, and other invertebrates with jointed legs, but their closest relatives are spiders and scorpions. Crabs have two pairs of antennae and a pair of mandibles, or jaws; horseshoe crabs lack all three. And if you compare the legs of a true crab with the legs of a horseshoe crab, you'll find another significant difference. Crabs, classified as decapod crustaceans, have five pairs of legs, including only one pair with claws. Horseshoe crabs have seven pairs of appendages under their helmet-like shells, and five pairs are equipped with claws. Some of these claws have special functions. For example, in adult males, the second pair of claws (called pedipalps) have a boxing-glove shape and are used to grasp onto females during spawning.

It is interesting to note that in the first description of the horseshoe crab in 1588, British naturalist Thomas Hariot called it the "horsefoot" crab. Somehow through time we've corrupted that to "horseshoe." Scientists have named the horseshoe crab *Limulus polyphemus*—*Limulus* meaning a little askew or odd, and *polyphemus* after the giant cyclops of Greek mythology.

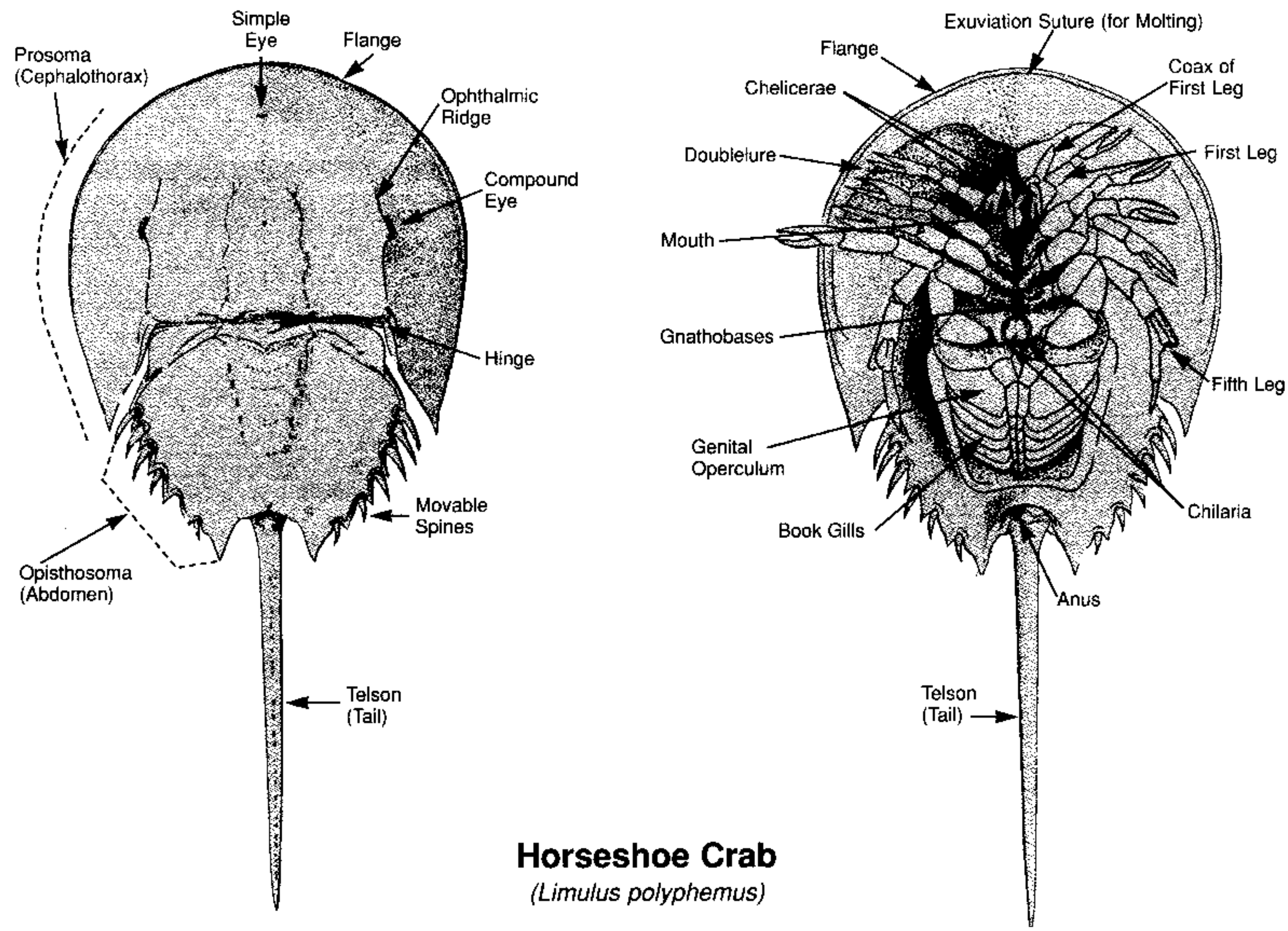
The horseshoe crab is a familiar sight along the Delaware Bay. Although it may look menacing, the horseshoe crab is harmless.

Yet, despite this frightening comparison and its large, spiny body, the horseshoe crab is harmless. Its long, spiked tail is not poisonous, as some may believe. Rather, the crab uses its tail as a lever to flip itself to an upright position when it has been overturned by a wave or a thoughtless human.

Life History and Biology

Horseshoe crabs are animals of the temperate seas, and the Delaware Bay is the center of the population along the Atlantic coast. During the cold months, they lie half-buried in the ocean sediments, but as the day lengthens in the spring, they begin to stir and move toward the beaches, just as they have done for eons. Horseshoe crabs have been observed mating from April through December, but mating activity peaks during the highest tides in late May and early June, at the time of the full or new moon. At that time, a million or more horseshoe crabs appear on Delaware Bay beaches. While they can be observed spawning both during the day and at night, by far the highest numbers spawn at night because of the protection afforded by darkness.

The males arrive first, followed by the females a week or two later. Females average 30% larger than males. To attract a mate, the females release a pheromone, a natural chemical that serves as a sexual stimulant, into the water. Horseshoe crabs also use their relatively good vision to help spot potential mates. Males patrol the nearshore waters and use their pedipalps to hook



Horseshoe Crab
(Limulus polyphemus)

onto the abdomen of a female as she heads toward the beach. She drags him to the water's edge and scoops out a series of five to seven crude nests, depositing several thousand eggs in each nest. Some females have been known to lay up to 90,000 eggs at a time, but the average is more like 20,000. The attached male and other males that gather around the female fertilize the eggs as she lays them. The newly laid eggs are about 1.5 mm, or 1/16 inch, in diameter. At first, the eggs are an opaque, pastel green, but in a few days, they double in size and the outer layer peels away, leaving them transparent.

Ideally, the moisture supplied by the tides and the warmth of the sun allow the eggs to mature and hatch in the two-week period between spring tides (the higher-than-normal tides that occur at the new and full moons). After hatching, the juvenile horseshoe crabs dig their way out of the sand. Unlike many marine invertebrates such as shrimp or starfish, which pass through several stages before they look like their adult counterparts, horseshoe crabs begin life as miniature adults. At approximately 3 mm (1/8 inch) across, they lack only a fully functional digestive system and a movable tail. For about a week, they swim about, absorbing their yolk sac as their digestive systems mature. Juveniles are quite good swimmers. They swim upside down, moving their legs and gills in a progressive wave from front to back. Occasionally, adults swim near the surface in this manner, but they spend most of their time crawling on the bay bottom.

When their digestive systems have developed, the search for food begins. To find prey, horseshoe crabs push their way along the bottom, digging little furrows like a farmer plowing the ground. As they do so, they use their first pair of appendages, the chelicerae, as feelers to determine the presence of prey. When a crab feels or smells a worm, clam, or dead fish, one of the claws picks it up and pushes it toward the gnathobases, the heavy, spiny projections that surround the mouth. (Note that the horseshoe crab has no nose; tiny hairs on the gnathobases act as chemoreceptors, allowing the crab to "smell" prey.) Since the horseshoe crab has no jaws to chew its food, it must bring all of its legs together and use the gnathobases to crush the worm or clam. If bits of food get hung up on the gnathobases, then the chelicerae in front of the mouth and the chilaria behind it act like hands to push the food into the crab's mouth. Horseshoe crabs also have gizzards containing sand and small bits of gravel to help grind up their food.

Horseshoe crabs continue to grow for nine to ten years until they finally reach maturity. Young horseshoe crabs molt often, but as they near sexual maturity, molting slows, probably occurring only once a year. The animals increase in size by 25–30% with each successive molt by pumping in water to expand their new shell, which will harden in 24 hours or so. Males are sexually mature at their sixteenth molt or ninth year. Females need at least 17 molts, or one more than the males, so they usually mature in their tenth year. Unlike crustaceans, such as the blue crab, which back out of their old shells, the horseshoe crab crawls out the front of its shell through a split that develops along the lip or doublelure formed at the junction of the dorsal (top) and ventral (bottom) surfaces.

How long can horseshoe crabs live? No one really knows, but some scientists have speculated that 30 years is a possibility. A few horseshoe crabs have been kept in aquarium habitats for 15 years. Obviously, an organism that does not begin breeding until age nine or older should have a life span that enables it to reproduce for a number of years. (In comparison, the blue crab reaches sexual maturity at approximately 18 months and lives a maximum of four years.)

The Shorebird Connection

More shorebirds migrate through Delaware Bay than anywhere else in the lower 48 states. And while horseshoe crabs and shorebirds have both been coming to Delaware Bay beaches for millennia, only in the last few decades have ornithologists discovered that many species of migratory shorebirds coordinate their spring migration with the arrival of the horseshoe crabs. Hungry shorebirds arrive from wintering at various Central and South American points with but one purpose—feasting on the eggs of the horseshoe crab. They often double or triple their weight in just a few short weeks before continuing to Arctic nesting areas.

Commensal/Parasite Relationships

A horseshoe crab is virtually a walking hotel, with any number of creatures living attached to its shell, from barnacles to blue mussels, slipper shells, bryozoans, sponges, flatworms, and microscopic bacteria and diatoms. While most of these hitchhikers have little or no effect on the day-to-day life of the horseshoe crab, the bacteria can be harmful. The horseshoe crab's armor appears indestructible, but daily wear and tear can leave it with small cuts or scratches that allow bacteria to gain a foothold. Gradually, these bacteria "eat" through the shell, exposing the horseshoe crab to other microbes, which eventually prove fatal. The horseshoe crab also hosts a flatworm that glides around its ventral surface, eating scraps of food that the horseshoe crab misses in its haphazard method of feeding. The worm cements its eggs to the horseshoe crab's gills, weakening or abrading them, and again allowing deadly bacteria to invade.

Historical Uses

Human uses of the horseshoe crab began thousands of years ago with the Indians indigenous to our shores. While the other three species are known to have toxic eggs or flesh caused by dinoflagellates, a type of algae that lives in the surrounding waters, the flesh of our local species was eaten by the Indians. They ate the meat of the abdomen (opisthosoma)— the muscles used to move the crab's tail—and possibly other parts.

In addition, the Indians used the horseshoe crab's shell, the prosoma, to bail water from their dug-out canoes, and they used its tail for a spear tip. The Indians also passed on to the early settlers the knowledge that the horseshoe crab is an excellent fertilizer, for it is rich in nitrogen and releases the nutrient gradually. This information became the base of a strong local fertilizer industry that lasted into the 1950s. Even today, a few farmers till dead horseshoe crabs into their fields.

Other uses of the horseshoe crab have included feed for chickens and hogs, and bait for eels. The use for livestock food is no longer viable, as the crab feed did affect the flavor of the meat. However, horseshoe crabs are still being used as bait for eel pots. "Eeling" is a small industry based on various markets here and in Europe and Japan where eels are a popular food.

Medical Uses

Of all its uses, the horseshoe crab is most important to us in medicine. Thanks to the horseshoe crab, medical science has made great strides in eye research, development of surgical sutures and wound dressings, and detection of bacterial contamination in drugs.

Horseshoe crabs supported a large fertilizer industry on the shores of the Delaware Bay until the 1950s. This photo was taken at Bowers Beach, Delaware, around 1930. (Courtesy of the Delaware State Archives)

Limulus polyphemus is the single most-studied invertebrate animal in the world. Three Nobel Prizes have been awarded to scientists who did some or all of their research on an aspect of the horseshoe crab's physiology. Much of what we know about how our eyes function began over 50 years ago with scientists studying the horseshoe crab's large compound eyes. Because of the size of these eyes, their relatively simple construction, the accessibility of the optic nerve, and the ease of keeping *Limulus* alive in the laboratory, the horseshoe crab is an ideal laboratory animal for eye research.

Other researchers have studied the horseshoe crab's shell. While all arthropods have some chitin, a cellulose-like component, in their shells, *Limulus* chitin is of a very pure type. As a result, scientists have been using *Limulus* chitin in medical research. Since the mid-1950s, researchers have known that chitin-coated suture material enhanced healing time by 35–50%. But it wasn't until the 1970s that researchers with the University of Delaware Sea Grant College Program developed a method to spin pure chitin filaments for suturing. A Japanese firm bought the patent rights and is currently manufacturing suture materials in Japan. The same firm is also making chitin wound dressings for burns, surface wounds, and skin-graft donor sites, which dramatically accelerate healing and reduce pain compared to standard treatments.

Perhaps the most important discovery so far concerning human uses of *Limulus* was made by Frederick Bang in the early 1950s. He discovered that the blue, copper-based blood of the horseshoe crab contained a clotting agent that would attach to the dangerous, fever-inducing toxins produced by many infectious bacteria. This clotting agent would later be called Limulus Amoebocyte Lysate, or LAL.

The discovery of LAL was significant because it yielded an excellent method of checking any drug for gram-negative bacteria, which are particularly difficult to detect. Gram-negative bacteria are a group that cause a number of human diseases, including spinal meningitis. LAL is particularly important to the pharmaceutical industry since gram-negative bacterial contamination had been a source of concern, and previous drug tests required injecting a group of rabbits with drug products and waiting to see if the animals developed a fever. Today, LAL is the standard test for injectable and intravenous drugs, required by the Food and Drug Administration (FDA). It is also used to diagnose diseases like spinal meningitis in patients who are sick.

Several companies manufacture LAL and sell it all over the world. One of the companies, Limuli Laboratories, operates in Dias Creek, New Jersey, where it has access to huge numbers of horseshoe crabs in the Delaware Bay. Large horseshoe crabs are caught, examined for health, and bled using a stainless steel tube that is inserted into the animal's circulatory system. After a specific amount of the horseshoe crab's blood is collected, it is centrifuged to separate the blood cells (amoebocytes) from the liquid plasma. The amoebocytes are then freeze-dried and processed for pharmaceutical uses. The FDA requires that horseshoe crabs be held for at least 24 hours after bleeding before they are returned to the bay. Researchers believe that the crabs are not seriously harmed by the bleeding process. One study indicated that they suffer a 10% higher mortality rate than horseshoe crabs that aren't bled. People in the LAL business carefully monitor their methods to guard their "golden goose."

What Does the Future Hold?

Too often we learn the value of something only after it's gone. In the case of the horseshoe crab, we know its value now, and as a result, many people are concerned about the horseshoe crab's future. We should learn from the experience of the Japanese, whose horseshoe crab species is considered endangered. To accommodate an increasing population as well as increasing industrialization, the Japanese have bulkheaded many of their beaches, rendering them unsuitable for horseshoe crab spawning. Today, in Japan, the population of horseshoe crabs is estimated at about 3,000, and the sight of a single pair of mating horseshoe crabs is rather rare. Fortunately, that is not true here.

The medical value of the horseshoe crab is easily measured economically, yet environmentally, the picture is much bigger when we consider the millions of shorebirds and other critters—fish, turtles, and the entire estuarine food chain—that depend on horseshoe crab eggs as a food source. And we may yet find additional uses for the horseshoe crab's blood, perhaps in detecting or curing other human diseases or as an aid to our immune system. Research on such uses is currently under way.

The horseshoe crab population on the East Coast has rebounded somewhat from the 1950s when the horseshoe crab fertilizer industry came to a halt due to a lack of horseshoe crabs and the invention of synthetic fertilizers. Scientists now estimate the East Coast population at a minimum of 2–4 million individuals, which is probably a conservative figure. About 98% of this population can be found between Cape Hatteras, North Carolina, and Cape May, New Jersey, with the Delaware Bay having the most concentrated population. However, the most recent population studies, in which scientists and volunteers have counted horseshoe crabs on the beaches of Delaware Bay at the peak of the spawning season, suggest a decline in the local population. The cause of this decline is unknown, although weather and other natural factors may play a role. Researchers have shown that the horseshoe crab is more tolerant of pollution than many other species. Perhaps, as some have said, the horseshoe crab and the common cockroach are two creatures that could survive a nuclear war. The question is, can this hardy and unique arthropod survive overharvesting or the gradual encroachment on and deterioration of its spawning grounds?

The Mid-Atlantic states have begun passing laws to protect horseshoe crabs. These laws employ a variety of methods including requiring a license to harvest horseshoe crabs, limiting the number of people allowed to collect them, and/or limiting the number of horseshoe crabs that may be collected. Laws vary from state to state; for up-to-date information on regulations regarding horseshoe crabs, contact your state department of natural resources.

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