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The Horseshoe Crab— A Reminder of Delaware's Past

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There is an old cliché that says "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 cliché—the horseshoe crab.

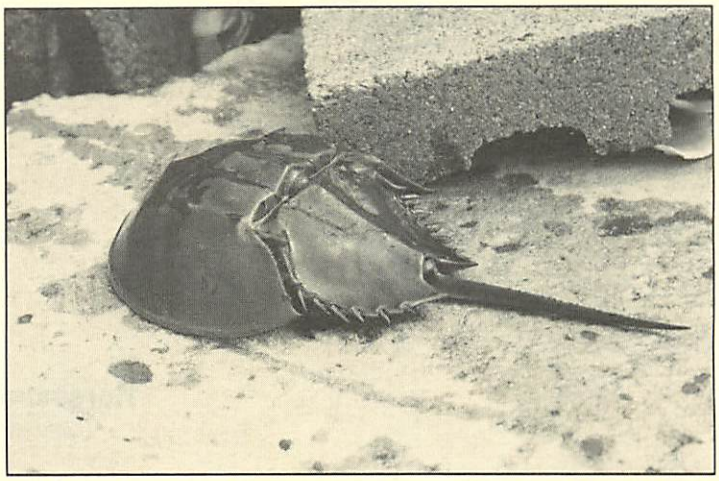
Once, many millions of years ago, there were many members of the horseshoe crab group or Xiphosura, meaning sword-tailed animals. In fact, they were the dominant critters long before the dinosaurs arrived. Horseshoe crabs and their relatives the sea scorpions once numbered in the hundreds of species, but only four species of horseshoe crabs exist today. Three species are found in the Far East, from Japan through Vietnam, and one is found along the Atlantic coast, from Nova Scotia south to the Yucatán in Central America. What accounts for this distribution? Scientists believe that the continental drift played a major role in distributing the horseshoe crab. As the continents drifted apart, we were left with one species on our East Coast.

What Is a Horseshoe Crab?

Well, it's a member of the arthropod phylum, which includes insects, spiders and scorpions, and crabs, but it isn't a crab. Crabs have two pairs of antennae and a pair of mandibles, or jaws. Horseshoe crabs lack all three. And unlike crabs, which have one pair of claws, horseshoe crabs have five pairs of claws. The first pair of claws are the chelicerae; the second pair, in the male, are the pedipalps (see diagram); and the remaining pairs of claws are found on the horseshoe crab's walking legs. Similar structures are also found on spiders and scorpions.

If you compare the legs of a true crab with the legs of a horseshoe crab, you'll find another significant difference. Most edible crabs, classified as decapod crustaceans, have 10 legs (five pairs), including the claws. Horseshoe crabs have 14 legs (seven pairs) under their helmet-like shell, or carapace (prosoma). Therefore, while its hard shell and numerous appendages with claws may remind us of a crab, the horseshoe crab is not a crab at all. Instead, its closest relatives are spiders and scorpions.

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

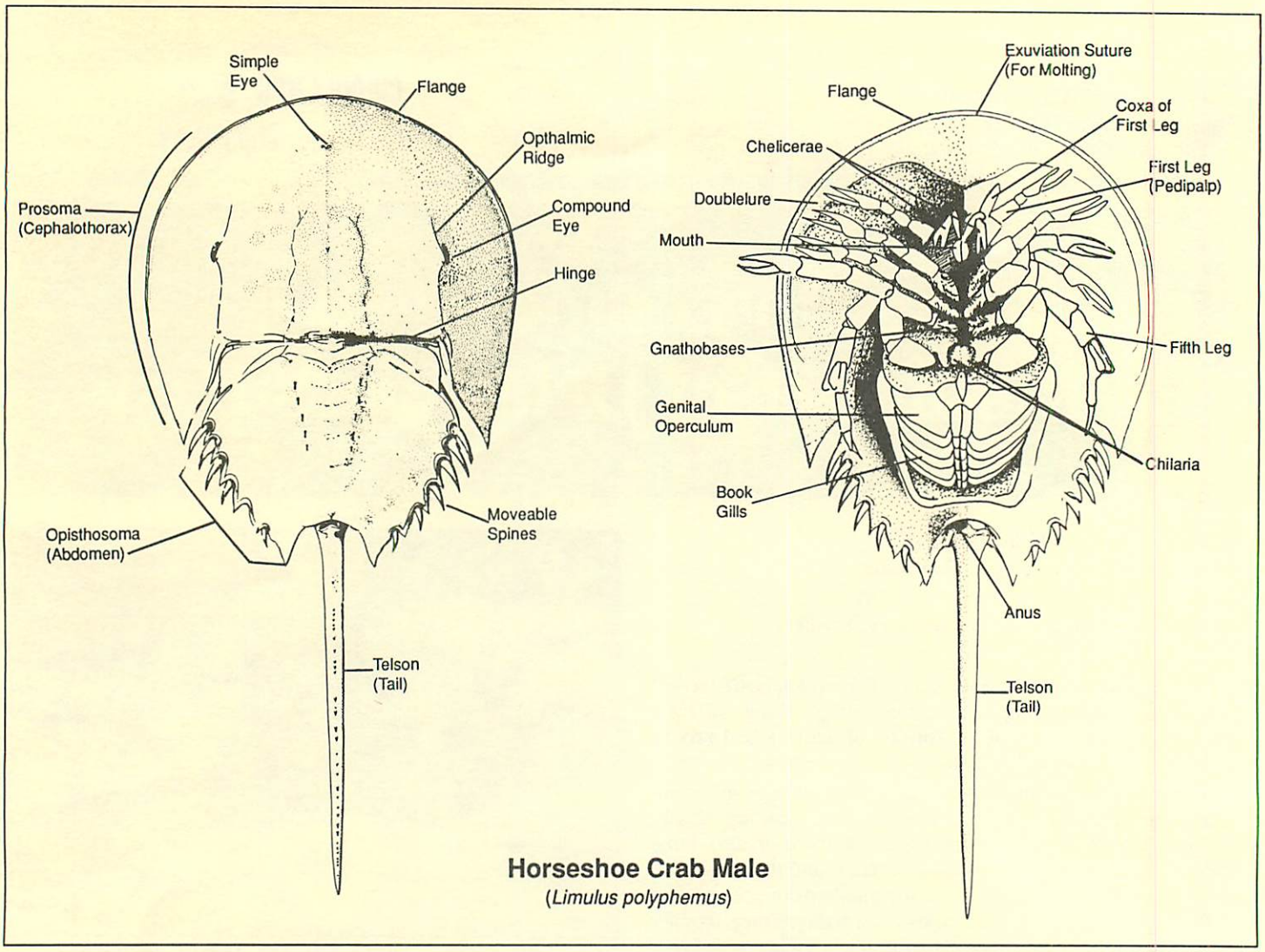


The horseshoe crab is a familiar sight along the Delaware Bay. Although it may look menacing, the horseshoe crab is harmless.

Life History and Biology

Horseshoe crabs are animals of temperate seas, and the Delaware Bay is the center of the population along the Atlantic coast. During the cold months, the crabs 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 the peak of mating activity occurs during the latter part of May and is coordinated with the evening spring tides. At that time, literally millions of horseshoe crabs can be found on Delaware Bay beaches.

First the males arrive, followed by the females a week or two later. Females average 30% larger than males. The females are larger because they produce relatively large eggs (1.5 mm, or one-sixteenth inch) and one female may lay anywhere from a few thousand to 20,000 or more eggs at a time. To attract a mate,



Horseshoe Crab Male

(*Limulus polyphemus*)

the female releases a pheromone, a natural chemical substance that serves as a sexual stimulant, into the water. The male patrols the nearshore waters and uses the claspers located on the end of his first pair of legs (pedipalps) to hook onto the abdomen of the female as she heads toward the beach. She then leads him to the edge of the water, scoops out a crude nest, and deposits her eggs, which he fertilizes as she drags him over them. The newly laid eggs are lime-green and opaque. In a few days, they double in size and the outer layer peels away, leaving the eggs 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 the spring tide—the higher-than-normal tide that occurs around the times of new and full moon, and the neap tide—the lower-than-normal tide that occurs at the first and third quarters of the moon.

After hatching, the juvenile horseshoe crabs dig their way out of the sand. Unlike many familiar marine invertebrates such as crabs, shrimp, or starfish, which must pass through several stages before they look like their adult counterparts, horseshoe crabs begin life as miniature adults. Approximately 3 mm (one-eighth inch) across, they have all the tools they need to survive except for a fully functional digestive system. For about a week, they swim about, absorbing their yolk sac as their digestive system matures. Then they begin looking for tiny clams and worms to eat.

To find prey, the horseshoe crab pushes its way along the bay bottom, digging a little furrow like a farmer plowing the ground. As he does so, his chelicerae act like feelers, determining the presence of prey. When the crab feels or smells a worm or clam, one of the claws picks it up and pushes it up to the gnathobases, the heavy, spiny appendages 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 with which to chew its food, it must bring all of its legs together and use the gnathobases to crush the worm or clam. Bits of dead food get hung up on the gnathobases. Then the chelicerae, which are in front of the mouth, and the chilaria, which are behind the mouth, act like hands, pushing the food into the crab's mouth.

Feasting primarily on worms, clams, and dead fish, young horseshoe crabs will continue to molt and grow for the next nine to ten years until they finally reach maturity. Young horseshoe crabs molt often, but as they reach sexual maturity, molting occurs 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.

While most of the time horseshoe crabs can be found crawling on the bay bottom, occasionally you may see them swimming

near the surface. They turn over (upside down) and swim by moving their legs and gills back and forth in a progressive wave from front to back. Juveniles (hatchlings) are actually quite good at swimming, but adults are really only about one step beyond plankton, which are at the mercy of the currents. Horseshoe crabs "hibernate" much like the blue crab over winter in that they move offshore, seeking muddy areas to relax in until the following April when the cycle begins again.

How long can horseshoe crabs live? No one really knows. Some scientists have speculated that 30 years is a possibility. A few horseshoe crabs have been kept in aquarium habitats for 15 years. Obviously, a critter that does not begin breeding until age nine or older (in comparison, blue crabs reach sexual maturity at approximately 18 months) should have a lifespan that enables it to reproduce for a number of years.

The Shorebird Connection

While horseshoe crabs and shorebirds have been coming to Delaware Bay beaches for millions of years, it has only been in the last decade that ornithologists have discovered that many species of migratory shorebirds coordinate their spring migration with the arrival of 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. And feed they do, often doubling or tripling their weight in a few short weeks on the shores of the Delaware Bay. In fact, more birds migrate through the Delaware Bay than anywhere in the lower 48 states. And while the other three species of horseshoe crabs all have toxic eggs—at least to humans—our horseshoe crab's eggs do not appear to be toxic.

Commensal/Parasite Relationships

A horseshoe crab is virtually a walking hotel, with any number of creatures living on its shell. These hitchhikers range from microscopic bacteria to easily visible critters. For example, it's not uncommon for one horseshoe crab to have barnacles, blue mussels, slipper shells, bryozoans, sponges, and flatworms attached to its shell. And these are the animals you can see without a microscope; there are countless others that you cannot see.

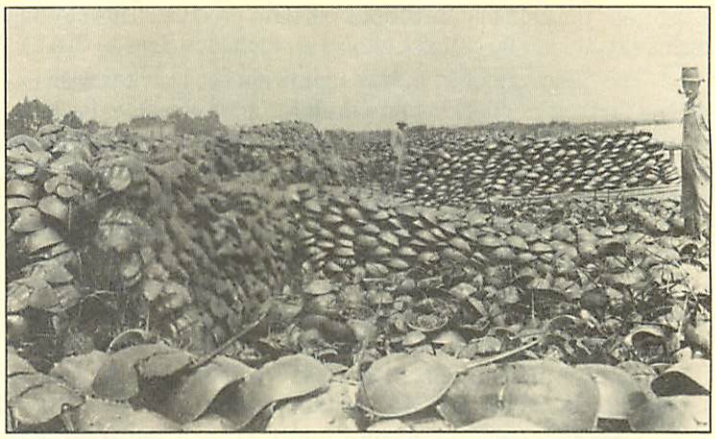
While most of these hitchhikers have little or no effect on the day-to-day life of the horseshoe crab, one of them—bacteria—may ultimately lead to its death. For example, although the horseshoe crab's chitin suit of armor is almost indestructible, the wear and tear of living can leave it with injuries—a cut or scratch—that will allow bacteria to gain a foothold. Gradually these bacteria will "eat" through the shell and expose the horseshoe crab to other microbes, which will be fatal.

Similarly, the horseshoe crab hosts a flatworm which glides around its ventral, or bottom, surface feeding on the scraps of food that the horseshoe crab may miss in its haphazard method of feeding. The flatworm cements its eggs to the gills of the horseshoe crab. This cement appears to weaken or abrade the chitinous gills, again allowing bacteria to invade, spelling the eventual death of the horseshoe crab.

Historical Uses and Economics

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, the flesh of our local species was eaten by the Indians. The Indians ate the chunk of meat in the abdomen (opisthosoma) that is used to move the horseshoe crab's tail.

In addition, the Indians used the horseshoe crab's shell, the carapace, to bail water from their dug-out canoes, and they used its tail for a spear tip. The Indians also passed to us the knowledge that the horseshoe crab was an excellent fertilizer, for it is rich in nitrogen. 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.



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)

Other uses of the horseshoe crab included feed for chickens and hogs, and bait for eels. The use for chicken and hog 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, where it has helped us make great strides in eye research, surgical suture and wound dressing development, and detection of bacteria in drugs.

The horseshoe crab (*Limulus polyphemus*) may be 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 some aspect of the horseshoe crab's physiology. For example, much of what we know about how our eyes function began over 50 years ago with research 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 still is an ideal laboratory animal for eye research.

Other researchers are studying the horseshoe crab's chitin 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, medical researchers have known that chitin-coated suture material enhanced healing time by 35-50%. But it wasn't until recently that researchers with the University of Delaware Sea Grant College Program developed a method to spin pure chitin filaments for suturing. A Japanese firm has 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 burn treatments.

Perhaps the greatest 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 *Limulus* contained a clotting agent that would attach to bacterial toxins, the

dangerous poisons that infectious bacteria produce. This clotting agent would later be called Limulus Amoebocyte Lysate (LAL).

The discovery of LAL was significant because it was an excellent method of checking any drug for gram-negative bacteria, which are particularly difficult to detect. Gram-negative bacteria are a group of bacteria that contain a number of human pathogens, such as spinal meningitis. Thus, LAL was particularly important to the pharmaceutical industry since gram-negative bacteria contamination had been a source of concern and previous drug tests required injecting a group of rabbits with products and waiting to see if the animals developed a fever. Today, Limulus Amoebocyte Lysate is the standard test for the industry. No drugs leave a pharmaceutical company without an LAL test as required by the Food and Drug Administration.

Several companies manufacture LAL and sell it all over the world. One of the companies, Marine Biologicals, Inc., operates near Cape May, New Jersey, where it has access to huge numbers of horseshoe crabs in the Delaware Bay. Large females 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 amoebocytes, a type of blood cell, from the liquid, or plasma. The amoebocytes are then freeze-dried and processed for pharmaceutical uses. The horseshoe crab is held for a period of at least 24 hours after bleeding and is then returned to the Delaware Bay. Although researchers believe that the crabs are not harmed by the bleeding process, they continue to monitor their methods to guard their "golden goose."

What Does the Future Hold?

Too often we learn the value of something too late. In the case of the horseshoe crab, we know its value now, and as a result, many people are concerned about future horseshoe crab populations. An experience that we should learn from is that 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, thus rendering them unsuitable for the nests of the horseshoe crab. Today, in Japan, the sight of a single pair of mating horseshoe crabs is somewhat rare. Fortunately, that is not true here.

The value of the horseshoe crab is easily measured economically, yet environmentally, the picture is much larger when we consider the millions of migrating shorebirds and all the other critters—fishes, turtles, the entire estuarine food chain—that depend on the horseshoe crab's eggs as a food source. And as research continues, we may find additional uses for the horseshoe crab's blood to further medical science, perhaps in detecting other human diseases.

Scientists currently estimate the horseshoe crab population at a minimum of 2-4 million, 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 largest population. Currently, the population is stable and possibly slowly increasing. Researchers have also shown that while pollution does stress the horseshoe crab, the unique arthropod is more tolerant of pollution than many other species. Perhaps, as some have said, two creatures could survive a nuclear war—the common cockroach and, yes, the horseshoe crab.

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