DOUBLE MAP SUPPLEMENT: IRELAND, MODERN AND HISTORIC

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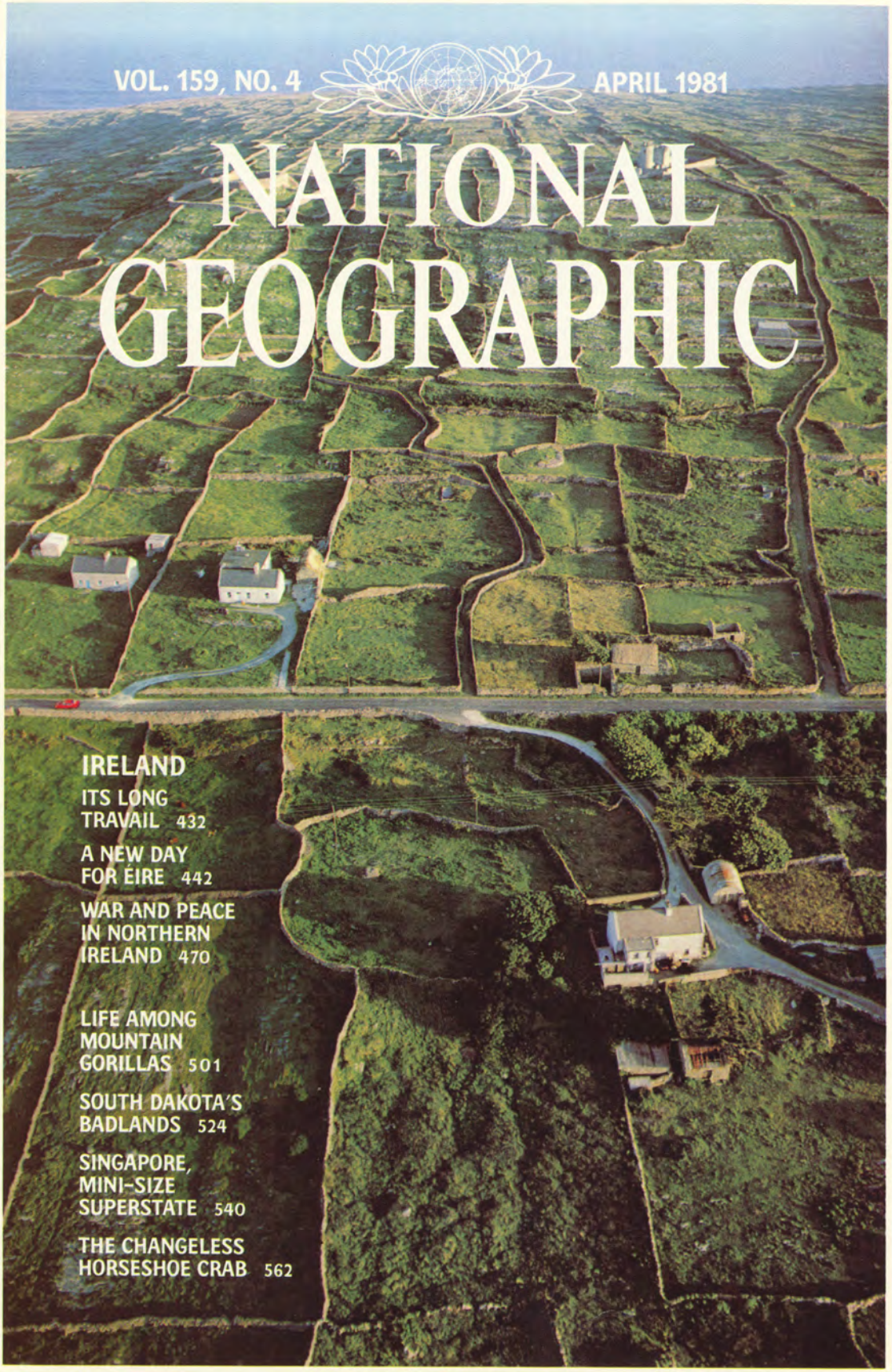


SEE "GORILLA" WEDNESDAY, APRIL 8, ON PBS TV

tidewater farmers still follow the practice.

Once there were many species of horseshoe crabs, but only four survive. Three species range along the shores of Southeast Asia and nearby islands. Their American cousins populate the Atlantic coast intermittently from Maine to Yucatán.

Many commercial fishermen of Chesapeake Bay and other areas, cashing in on the new business of airfreighting live eels to Europe and the Far East, bait their traps with horseshoe crabs. Other watermen view them as pests, accusing them of devouring soft-shell clams and young mussels.

But medical science has found these humble animals to be valuable allies. Researchers from the Johns Hopkins University Medical School made an important discovery in 1964. Working at Woods Hole Marine Biological Laboratory in Massachusetts, they found that horseshoe crab blood clots when exposed to endotoxins, chemical poisons released from some bacteria. Such clotting can be used as an alarm signal when testing substances intended for human internal use.

K. W. BARTHEL; MUSEUM AT THE SOLENHOFER AKTIEN-VEREIN, GERMANY

Death tracks spiral *from a horseshoe crab fossil—some 145 million years old—found in German limestone. From seas that once covered Europe, the animals dispersed to Asia and North America.*

Each year thousands of horseshoe crabs are harvested and hauled alive to pharmaceutical laboratories, where they donate some of their blood to benefit humans.

Crab Extract Tests Medical Safety

Gathering material for a doctoral thesis on horseshoe crabs, I journeyed many hundreds of miles with my husband, Jack, from our Gulf coast home at Panacea, Florida, to the chill waters of Maine.

One stop was in South Carolina, where we visited a field station run by Travenol Laboratories, Inc., makers of such health-care products as kidney dialyzers, transfusion sets, and intravenous solutions. Dr. Fred Pearson, a company executive, told us his firm uses an extract made from crab blood cells in a coagulation test to check for the presence of endotoxins.

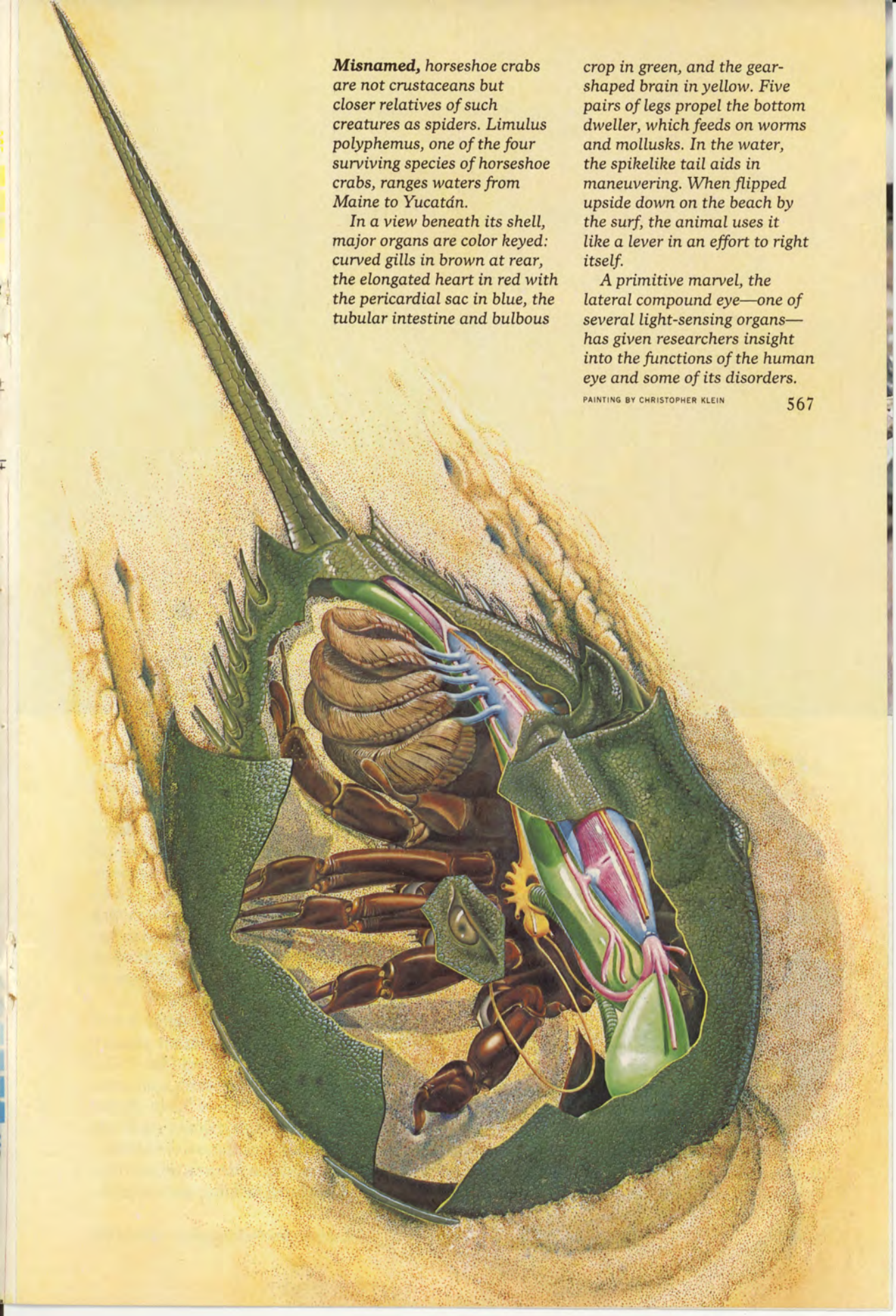
"Anything we manufacture that will be put into the human body must be certified safe before we can sell it," Dr. Pearson said. "This test is also being used experimentally to diagnose meningitis."

Aboard a shrimp trawler in Port Royal Sound on a Travenol collecting trip, we watched the nets bring up dozens of big horseshoe crabs, some weighing ten pounds.

Back on shore, technicians extracted cloudy white blood from the crabs and bottled it. Exposure to air turned the blood a bluish color. The blue comes from hemocyanin, a copper-based molecule that carries oxygen throughout the crab's circulatory system. The crabs were then returned to the sea, apparently unharmed.

In another area of medical research—the human eye, its functions, its failings—horseshoe crabs play an equally important role. Scientists named the American horseshoe crab *Limulus polyphemus* after the one-eyed giant of Greek myth. *Limulus* (meaning "sidelong") actually has nine eyes: one oval lateral eye on each side of its shell, two small ones in the center, and five light-receptive organs beneath its shell.

With this elaborate equipment the crab forms a crude image of its undersea world. Although light may serve to guide movements, the exact role of the visual system



Misnamed, *horseshoe crabs are not crustaceans but closer relatives of such creatures as spiders. Limulus polyphemus, one of the four surviving species of horseshoe crabs, ranges waters from Maine to Yucatán.*

In a view beneath its shell, major organs are color keyed: curved gills in brown at rear, the elongated heart in red with the pericardial sac in blue, the tubular intestine and bulbous crop in green, and the gear-shaped brain in yellow. Five pairs of legs propel the bottom dweller, which feeds on worms and mollusks. In the water, the spikelike tail aids in maneuvering. When flipped upside down on the beach by the surf, the animal uses it like a lever in an effort to right itself.

A primitive marvel, the lateral compound eye—one of several light-sensing organs—has given researchers insight into the functions of the human eye and some of its disorders.

PAINTING BY CHRISTOPHER KLEIN

Peak spring tides *signal mating time as the crabs move in from the depths. Males, which are smaller, restlessly patrol the shallows and give chase as outnumbered females break through the "stag line." With modified claws, the males grasp them and are towed ashore.*

There, chaos ensues. A squadron of suitors vie to fertilize the eggs of a lone female partly buried in their midst on a Florida beach ***(above)****. Some of the eggs, dislodged as she begins to heave upward from the shallow nest, rest atop her shell. Moving with the tide, the crabs spawn repeatedly.*

Predators like laughing gulls ***(above right)*** *gorge on eggs washed free by the surf. But the sand protects thousands more* ***(top)****, most timed to hatch in a few weeks, when another flood tide will help rupture the eggs and carry the young to sea.*

in the animal's behavior remains unknown.

For more than 50 years the lateral eye of the horseshoe crab has been studied. By recording electrical impulses from the crab's optic nerve, Dr. H. Keffer Hartline of Rockefeller University discovered many principles underlying the functioning of all visual systems. For his pioneering work with *Limulus*, he shared a 1967 Nobel prize.

Syracuse University's Dr. Robert Barlow continues the retired Dr. Hartline's work in his mentor's old lab at Woods Hole.

"More is known about the lateral eye of the horseshoe crab than any other sensory system in any animal," he declared. "The simple organization of the crab's eye, compared to a cat or human eye, makes it easy to record and analyze the electrical signals the eye uses to send information to the brain."

Dr. Barlow gave us a demonstration that seemed, in its bizarre fashion, to bridge the

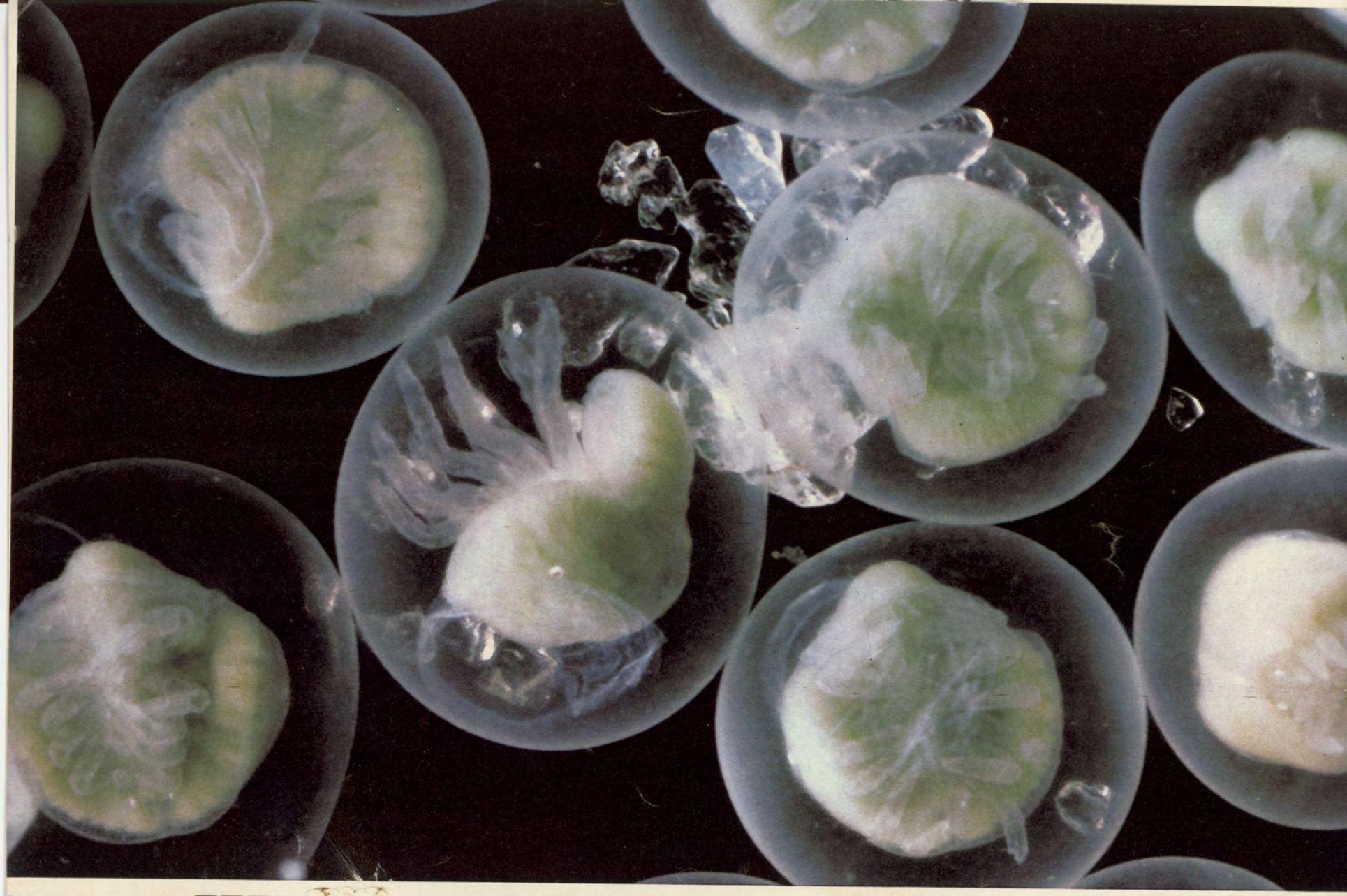
eons from primordial darkness to space-age technology. Fastened to a platform was a live horseshoe crab. Part of its shell had been cut away to expose the white, stringy optic nerve leading from a large, multifaceted eye to the brain. Electrodes connected the crab to a computer, an oscilloscope, and other electronic gear. As Dr. Barlow adjusted controls, the images of nerve impulses flickered across the screen.

"This kind of research with *Limulus,*" said Dr. Barlow, "has provided important insight into how the human eye perceives lines, borders, and contrasts. These patterns of light sensitivity, as recorded in this manner, have also guided our research in such eye diseases as retinitis pigmentosa, which causes tunnel vision and can lead to total blindness."

During the horseshoe crab breeding season we visited Rutgers University's oyster research station north of Cape May, New Jersey, where Delaware Bay meets the Atlantic. "This bay has probably the largest population of horseshoe crabs on the Atlantic coast," marine biologist Dr. Carl Shuster told us as we followed him down the beach. "At Cape Cod and other places to the north, you find them by the thousands, here by the hundreds of thousands."

As far as we could see, the beach teemed with crabs intent on breeding. Flocks of screaming gulls wheeled in the bright June sky, swooping down to seize jellylike crab eggs exposed by the tide. Waves of sandpipers ran before us, joining in the feast.

As ebb tide began, the females thrust themselves out of the sand and dragged their tenaciously attached males back into the surf. They would move only a short distance from shore to wait 12 hours for the next high tide, then reemerge to lay more eggs. Soon



Like crystal balls *a mere three millimeters in diameter, translucent eggs showcase developing crab embryos* ***(left)****. A newly hatched larva, nurtured by retaining part of its egg yolk, shows the nub of a tail* ***(below)****.*

Successive molts pace growth. Often mistaken by beachcombers for the animal itself, the shell splits around the front rim, and the crab, compressed within, walks out and expands about 25 percent ***(bottom)****. Molting slows with age, making this crusty old crab* ***(below)*** *a more permanent home for snails and barnacles.*

the beach was empty except for a few hundred stranded crabs lying on their domed backs, twitching their spidery legs and trying to right themselves with their swordlike tails, or telsons.

In the spring, when the horseshoe crabs head for the beach to spawn, the male clutches the larger, egg-laden female with his fistlike grasping claws. When they reach the water's edge the female digs in to lay her eggs while the waves foam about them.

As many as a dozen males may jostle around the mating pair, each seeking to couple with the female and spread his white sperm as she deposits thousands of tiny gray-green eggs in sticky clusters. Possibly only the first male to reach a female succeeds in fertilizing her eggs.

By spawning and burying her eggs at full and new moons, the times when maximum gravitational pulls cause especially high tides, the female protects her progeny. Some mysterious instinct brings her to the beach at those times, and for two weeks the water will not reach the nests again.

The embryos develop in one of the harshest of all marine environments, their sand-covered nests enabling them to withstand broiling heat and torrential rains. By midsummer on the Florida Gulf coast, almost anywhere we dug along the high-tide line, we found nests filled with half-developed eggs or tailless hatchlings only an eighth of an inch wide.

Not even the most vicious storms can destroy these ancient, persistent creatures. When a fierce summer squall struck the breeding ground near our home, Jack and I rushed down to the beach where pounding waves scoured away the protective sand.

Tank tread *seems to furrow a Florida beach as a horseshoe crab returns to the sea* ***(below)****. Stranded at low tide, it plows a bow wave of sand while digging in to escape the sun's heat* ***(above)****. Virtually inedible, condemned for feeding on clams, ground up for fertilizer, and crushed for eel bait, these living fossils still seem well armored against extinction.*

Thunder crashed as I waded through the surf, struggling to pull a small plankton net.

A giant graybeard of a wave rushed in at eye level, knocked me down, and nearly snatched the net from my hand. Exhausted, I struggled ashore in the driving rain and crouched behind a fallen tree where Jack washed the contents of my net into a bucket.

There in the floating seaweed, swarming like bees, were several thousand hatchlings swimming in dizzying spirals. As we suspected, the surf was full of baby horseshoe crabs riding the waves to freedom.

Release of hatchlings by storm action is the exception. Larval escape from nest to sea normally takes place in relatively calm waters by night, when the moon is full and succeeding high spring tides cover the nests and soak gently into the sand. Crawling and kicking, untold millions of larvae make their way to the surface and are returned to the ocean with the receding waves.

Despite Odds, These Ancients Survive

Feeble swimmers, adult horseshoe crabs walk on the ocean bottom, moving with the tides to and from the beaches. On shore their legs carry them laboriously across the sand. Jack and I checked their movements by affixing numbered plastic tags to their shells. Cooperative beachcombers who found the tagged crabs notified us of time and location. Our data indicate that most Florida crabs never travel more than four miles from their spawning place.

By the time they are adults, horseshoe crabs commonly exceed two feet in length. They have few natural predators. Loggerhead turtles rip through their legs and tear out their flapping gills. Forty crabs were once found in the stomach of a 12-foot tiger shark caught off Sarasota, Florida. Otherwise, man is without a doubt their worst enemy—destroying their habitat, polluting their waters, using them as fertilizer and eel bait, and often just mindlessly crushing the crabs he finds on beaches.

Still, considering its history and its high rate of reproduction, *Limulus polyphemus* will very likely survive, waiting patiently until our bones join those of the woolly mastodons, dinosaurs, and other creatures that once strutted their time upon the earth and then were seen no more. □