AT THE ZOO

The Nau

BY KATIE VENIT

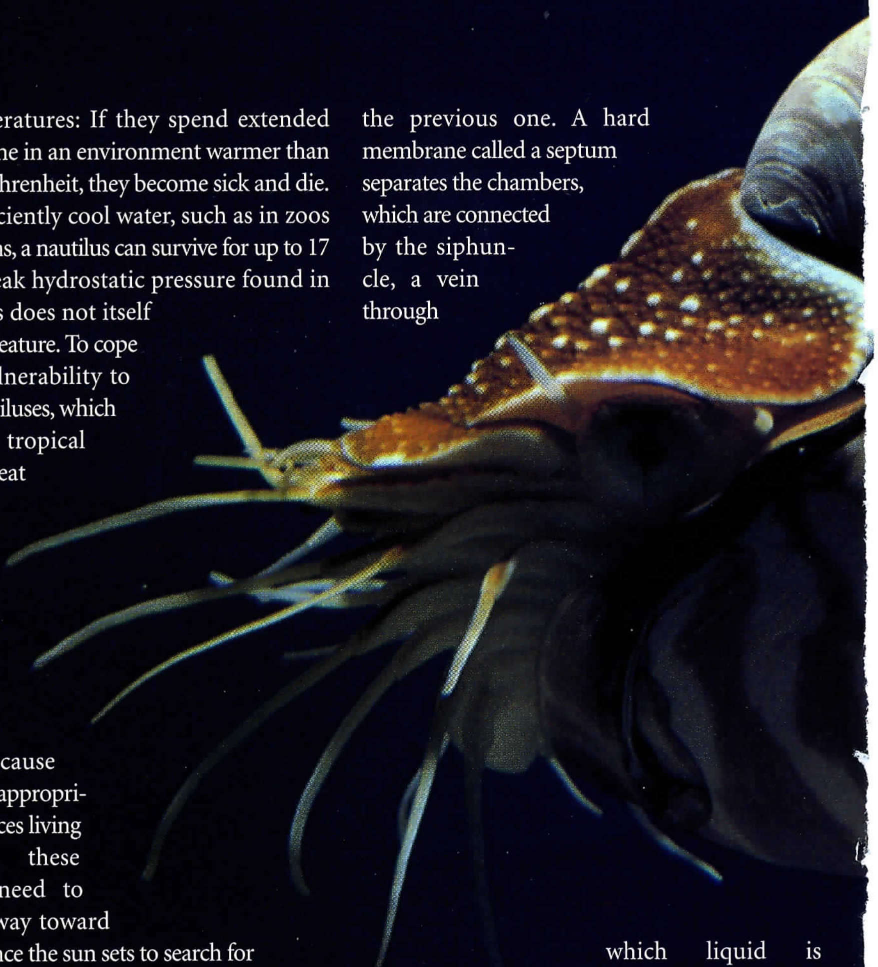
As the fading Fijian sun retreats from the tropics, promising a bit of relief from the oppressive heat, a strange animal stirs in the depths of the ocean. This small sailor anxiously waits in its sandy bed as the ominous yellow orb dies away. Quickly, the animal jets closer to the surface, traversing almost a thousand feet in a couple of hours. By the time it reaches its feeding grounds in the coral, the water in these shallower depths has cooled. The migrant feeds ravenously on the discarded exoskeletons of spiny lobsters and other crustaceans. Eventually, it senses the reemergence of the sunlight, bringing another day of heat. The lone nautilus abandons its feast and sinks back down to the depths to sleep in the sand through the day.

At the peak of their Paleozoic reign 650 million years ago, 3,000 nautilus species shared the sea with the prodigies of that era, the trilobites, as well as the ammonoids, other shelled invertebrates that usurped the ocean from the nautiluses and nearly pushed them into extinction. The nautiluses had the last laugh, however, as the ammonoids and trilobites died out by the end of the Cretaceous period. Today, six species of nautilus—including one with a layer of fur lining the bottom of its shell—survive in pockets of tropical waters in the western Pacific and Indian oceans.

The nightly journey of nautiluses has puzzled scientists for centuries. How can these creatures survive at depths of up to 1,800 feet and then rise to waters as shallow as 300 feet every night? This rapid pressure change would cause other aquatic life either to implode from the hydrostatic pressure in the deep water or to explode from internal pressure in shallow water.

The reason for this journey seems easy enough to identify. Nautiluses are extremely sensitive to warm temperatures: If they spend extended periods of time in an environment warmer than 80 degrees Fahrenheit, they become sick and die. Kept in sufficiently cool water, such as in zoos and aquariums, a nautilus can survive for up to 17 years; the weak hydrostatic pressure found in surface tanks does not itself imperil the creature. To cope with this vulnerability to warmth, nautiluses, which live only in tropical climates, retreat to the cool ocean depths during the day while hiding from predators. However, because there are few appropriate food sources living that deep, these scavengers need to make their way toward the surface once the sun sets to search for sustenance.

How a nautilus manages this feat is a more complicated question, whose solution centers on the creature's shell. Nautilus, cuttlefish, squid, and octopus are cephalopods, considered the most intelligent members of the Mollusk family and of all invertebrates. Unlike their cousins, the nautiluses are the only cephalopods with an external shell—basically a tube that has evolved into a spiral. This spiral is divided into a few dozen chambers, and each chamber leading out from the middle of the spiral is younger and larger than the previous one. A hard membrane called a septum separates the chambers, which are connected by the siphuncle, a vein through



which liquid is removed or added to the chambers.

The soft parts of a nautilus—the head, tentacles, and internal organs—rest in the last and youngest chamber, and they can be retracted into the septum and covered by two large and tough hoods if a nautilus feels threatened. The tiny creatures, which grow four to ten inches long, have between 70 and 90 tentacles, depending on the species and

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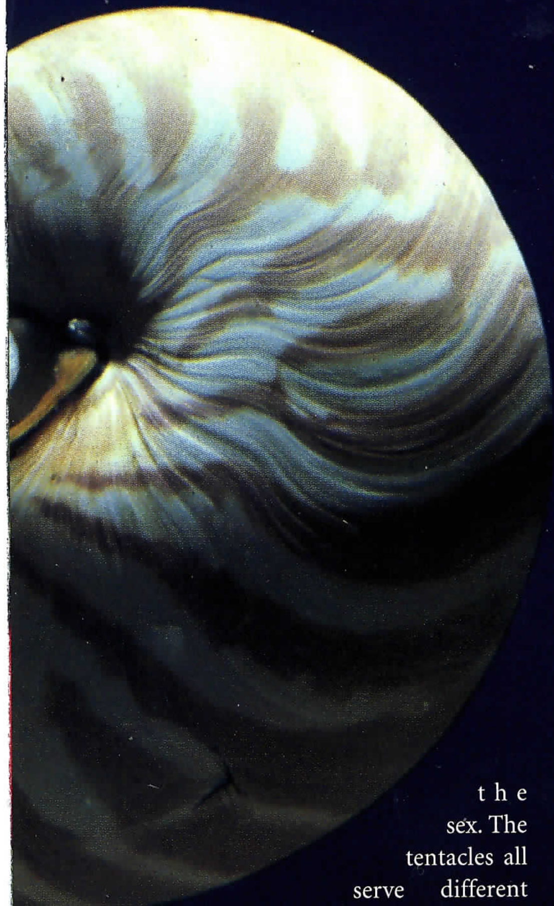


the sex. The tentacles all serve different functions, ranging from catching and holding food to clinging to oceanic objects. Nautiluses also have propulsion organs called hydropónones, protruding forward from between the mass of tentacles. Early scientists dismissed this mechanism as too weak to be responsible for the depth-change mystery and turned instead to the animals' chambered shell for an explanation.

Think back to Archimedes' Principle: An object will float in the water if its mass is less than the mass of the water it displaces. It is easiest to understand how this concept works by thinking of a submarine. When the submarine floats stationary under the water, it has neutral buoyancy. It is essentially weightless, having the same density as the water around it. When the vessel dives, it takes on liquid, increasing its mass but not its volume, thus making it heavier than the surrounding water. It now has negative buoyancy and will maintain this negative buoyancy until it sinks to the denser water below. When the sub surfaces, the process is reversed.

Although it seems feasible that nautiluses—after which Jules Verne's famous fictional submarine was named—would use this same passive mode of locomotion, they cannot. It would take weeks for a nautilus to adjust its density enough to travel the distance that it does in only two hours. Contrary to earlier theory, the hydroponone itself is responsible for the daily migration, using a process of jet propulsion. Water is sucked in and then shot out, and the nautilus goes in whatever direction it wants.

Steady at one atmosphere, the gas pressure in a nautilus's chambers has been found insufficient to bolster shell integrity at great depths. What then keeps its body from yielding to the vast change in pressure? Although early scientists dismissed this possibility, it turns out that the shell's structure itself is strong enough to withstand depths of up to 2,000 feet without the aid of additional internal gas pressure.

Nautiluses do use their internal chambers as fish use their swim bladders: to maintain neutral buoyancy. As a nautilus grows, it gradually drains liquid out of previously formed chambers to compensate for the added mass of the expanding shell and retain neutral buoyancy. For a full-grown nautilus, occasional minor adjustments to the amount of liquid in its chambers are made to compensate for large meals or chips in its shell.

A nautilus tends to establish neutral buoyancy for its average depth, which is usually around 900 feet in the ocean. Nautiluses rarely spend much time at this depth, but maintaining this average level allows greater flexibility in depth change. If a nautilus adjusted its buoyancy so it could rest at the bottom without having to cling to the sand, it would have an extremely difficult time propelling itself all the way to its feeding grounds. The opposite is true if it maintained neutral buoyancy at the surface. Its hydroponone and clinging tentacles are enough to move a nautilus around when it is not neutrally buoyant, as long as it does not wander too far out of range. When a nautilus's depth range changes suddenly, as when it is placed in an aquarium tank, it senses the pressure difference and over time adjusts accordingly to float comfortably in this new environment.

The Smithsonian's National Zoo currently houses seven chambered nautiluses (*Nautilus pompilius*) in the Invertebrate House inside two tanks kept at 63 to 64 degrees Fahrenheit. Although these nocturnal creatures tend to be fairly inactive during Zoo hours, they usually perk up when served a gourmet dinner of frozen shrimp, squid, crab claws, or fish smelt. Yet even when they are slumbering, merely catching a glimpse of these beautiful and otherwise elusive marvels of adaptive engineering is a treat not many are able to experience. Z

Editor's note: The Invertebrate Exhibit will be closed for renovation during a period of three to fours months in the early part of 2001. The building should reopen by May.

Chambered nautilus at the National Zoo.

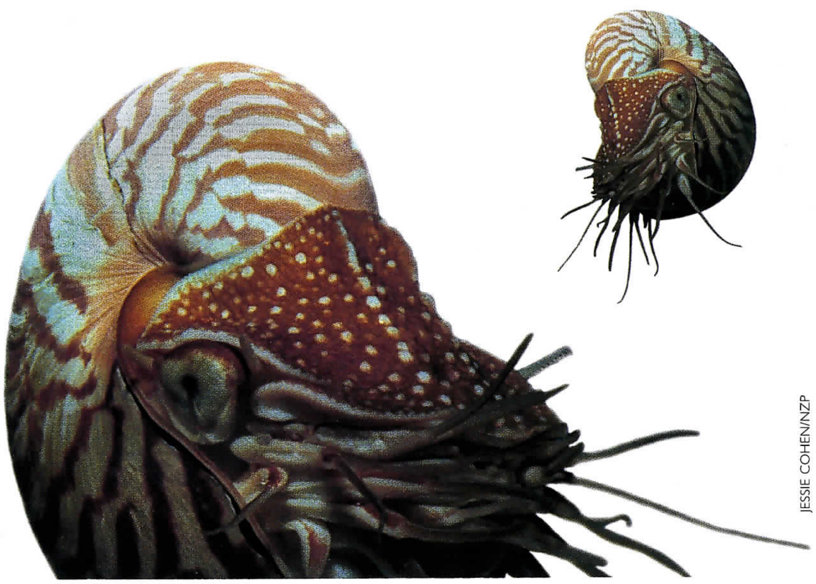
JESSIE COHEN/NZP

WHAT'S IN A NAME?

When the Western world saw its first chambered nautilus (*Nautilus pompilius*), it quickly became intrigued with the strange creature. People imagined that the animal had a membrane that served as a sort of underwater sail. By the time this myth was disproved, it was too late. The name, *nautilus*—from the Latin and Greek words for "sailor"—stuck to these living fossils. Quite a few things have been named after the ancient mariners since then. One is the paper nautilus, a small Mediterranean octopus. In contrast with the chambered nautilus, the paper nautilus has a smaller and thinner protective shell with no air chambers, which the animal can leave behind when it wishes. To distinguish between this octopus and its shelled cousins, the paper nautilus is now properly called *Argonauta.*

Outside the zoological world, Jules Verne immortalized nautiluses in literary tradition when he named Captain Nemo's vessel *Nautilus* in *20,000 Leagues Under the Sea.* The U.S. Navy followed suit, using the same name for its first nuclear-powered submarine. For fitness-conscious Americans, perhaps the most familiar thing named after the tough invertebrates is the Nautilus brand of exercise equipment, which reminds the user of the strength of these remarkable creatures' shells in withstanding 2,000 feet of water pressure. Although they cannot venture down 20,000 leagues, nautiluses can still dive far deeper than most fish or humans dare go.

—*Alex Hawes and Katie Venit*



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