Real Seals Wear Helmets

by Robert Evans

The northern elephant seal can dive deeper and longer than a sperm whale, stay submerged for up to two hours, and reach depths of more than a mile. Doctors may be able to use the new knowledge of the seal's unusual physiology to develop treatments for heart attacks and strokes in humans.

The young elephant seal, all three hundred pounds of him, lies quietly in a sewer pipe, which has been cut in half lengthwise and closed at the ends to contain the animal. In the room where a huge machine with a tubular chamber waits, humming softly, a plexiglass helmet, resembling the headgear a human diver might wear, is placed over the animal's head. Moments later, water begins to pour into the interior of the helmet until it is filled completely. The elephant seal makes no protest at having to hold its breath, but simply closes its eyes as its temporary bed moves slowly into the tube in the center of a standard hospital MRI imaging system. Moments later, a technician turns the machine on, and the scientists standing nearby heard the rapid pounding and continuous buzzing of the magnet at its heart. The seal lies still, as though in sleep.

Standing nearby is Burney LeBoeuf, professor of biology at UC Santa Cruz, where he has been studying elephant seals for more than twenty-five years. He knows that they are among the deepest and longest divers of all mammals, able to stay submerged for two hours and reach depths of a mile or more. Biologists, physiologists and physicians would like to understand how these seals do that, how their body continues to function while they are holding their breath for hours.

By tricking an elephant seal into believing it is diving, Peter Hochachka and Sheila Thornton of the Zoology Department of the University of British Columbia in Vancouver are learning how the seal is able to survive such long periods underwater. During the dive, the seal's blood flows only to vital organs, and essential oxygen is stored in the spleen. When the animal surfaces, blood flows to all organs, which are not damaged by the shutting down and opening up of blood flow. An understanding of why the organs can survive all those changes may someday help heart-attack and stroke victims survive, and may give surgeons a way to protect soldier before surgery for battlefield injuries.

Burney LeBoeuf has been studying the diving of these animals since 1983. Until that time, all that was known about them came from studies on land, and it was not until Gerry Kooyman of Scripps built the first recorder that could be attached to a seal that biologists learned how long and how deep the animal dived. "Until then," Le Boeuf explained, "we didn't know anything about where they made a living." Information from the recorders told them that the elephant seal dives around the clock, staying down for more than 20 minutes and remaining on the surface for only three. The animal does this for periods of two-and-a-half months when it is out at sea, travelling from the California coast to the Aleutian islands in the northern Pacific. The females do it for ten months out of the year, which means that more than 90 percent of their time is spent underwater, at depths of up to a mile or more.

Sitting in his office as he describes what he knows about elephant seals and their diving, Burney LeBoeuf begins to acquire a barely perceptible smile. His eyes flick back and forth among various pictures of his seals: two bulls fighting for the right to mate; a helpless pup staring at the camera through its large brown eyes; a prostrate female suckling her young. "Do you know that the animal spends most of the year with its lungs collapsed?" he asks casually, throwing the question into the conversation, though not expecting an answer. "It breathes out on the way down, and by about 100 feet, its lungs are collapsed."

How the seal can do that is what Sheila Thornton wants to know. In order to study the blood circulation of the animal, she and her colleagues capture a healthy young elephant seal, condition it to wearing a watertight helmet and then pop the 300-pound animal into a magnetic resonance imaging (MRI) scanner and watch where the blood flows within the seal. The MRI scanner is capable of making detailed pictures of soft tissue within the body of the seal, which holds its breath as though it were descending into the depths of the ocean.

Thornton has made images of the seal's circulation after the animal has been tricked by the flooded helmet. "They have the ability to shift their blood flow. They can stop blood flow to areas of the body that may not require it during the dive and preferentially send it to the brain and heart, which are hypoxia-sensitive tissues," she said. "We know that blood flow to the kidneys is basically shut down during the dive." But the critical event occurs when blood flow is restored when the animal comes to the surface again. In humans the re-establishment of blood-flow-reperfusion it is called- causes severe damage to organs. Thornton would like to know what protects the seal's organs, for then physicians might be able to use that knowledge to protect human beings in crisis. Please see the dive image.

Another part of her research deals with what happens to oxygen in the muscles and blood as the seal descends. They get oxygen from their spleen, where it is stored as the lungs collapse on the way down, and since the seal has two-and-a-half times as much blood per body weight as we humans do, it will always beat us in a breath-holding contest.

"Large seals are the champion divers of all marine mammals," says Hochachka in. "We don't think there's a limit to their dives. We've measured them to a depth of a mile and a duration of two hours, so we know that they can probably do more than that." Hochachka is intrigued by the seal's ability to deal with hypoxia-the state of being without oxygen, a condition that in most humans produces death within minutes. Knowing how elephant seals manage oxygen could help doctors in their treatment of patients when they have suffered some trauma that temporarily puts parts of the body into hypoxia.

One of his colleagues in the research effort, Dr. Warren Zapol, is chief of anesthesia at Massachusetts general hospital. "The greatest dream in human biology, in medicine really, is to dream of ways to shut down the metabolism when we can't supply the oxygen and take away waste products," he says. "Most critically, this would occur in acute heart attacks, acute strokes and on the battelefield, when about 25 percent of killed-in-actions bleed out acutely within five minutes. If you knew how to shut down metabolism, much as the seal can do, you could preserve the brain and the heart, the two most sensitive organs from injury." He explains that although they didn't know it, surgeons were using in the operating room one method of slowing down metabolism that recently we have learned the seal was doing: cooling. Burney LeBoeuf likens it to a heating unit: "If you turn the furnace down, you use less fuel."

"Seals are masters of the rational distribution of blood flow during critical periods when oxygen must be stored and utilized and metered out in a very orderly fashion," Zapol says. Since the animal's lungs are collapsed, oxygen is stored in its spleen, ready for use in any organ that needs it. The life-giving gas is attached to red blood cells and is then delivered around the body in liquid form, just as it is when the animal is breathing, except that there is no more oxygen being supplied from the lungs.

Already there is a product on the marklet that imitates the way that seals manage their oxygen when submerged. One company is marketing a fluid that carries oxygen in the same way, and it has been used to fill the lungs of newly-born premature infants to protect those delicate tissues from injury during the dangerous early days of the infant's life. "That is in a way, mimicking the seal's delivery of large quantities of oxygen," Zapol says.

In the MRI room, the machine has stopped buzzing and banging. The elongate trough that holds the seal slowly emerges from the long, narrow tube in the center of the instrument. A technician drains and then removes the plexiglass helmet from the young elephant seal, now awake and blinking. "They are wonderful animals to work with. They don't seem to stress as other organisms do," says Sheila Thornton. In a few days, the elephant seal will be back on the beach where he came from (see natural history), while the biologists and physicians pore over the data from the experiments, trying to figure out for the benefit of humans what nature has given to the seal. Warren Zapol exults: "The seal is one of the world's greatest submarines. It sets off on a dive for 60 to 90 minutes and carries all the supplies it needs, just as a submarine might do for 90 days."