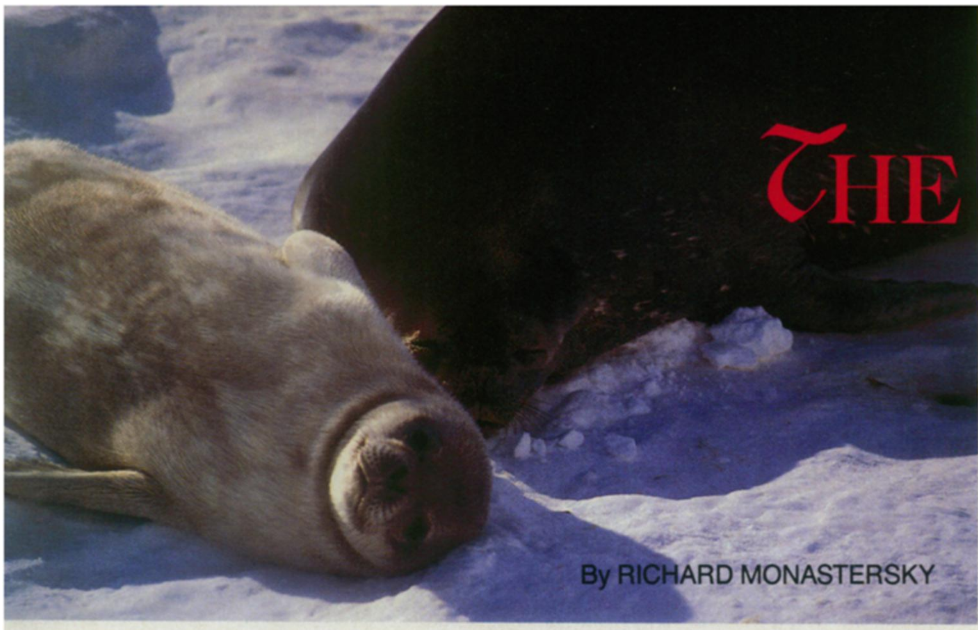

Monastersky

The Cold Facts of Life

By RICHARD MONASTERSKY

Tracking the species that thrive in the harsh Antarctic

It's nap time on the ice, and a few hundred Weddell seals are snoozing in the bright summer sun. Walking among these slumbering lumps of flesh, biologist J. Ward Testa treads close enough to rouse a mother and her pup, a 3-week-old that could pass for a large, furry football, save for its whiskers and flippers. The youngster follows Testa with a wide-eyed stare, while its mother regards the human interloper with a lazy gaze registering little concern.

Testa paces on across the ice, searching for a particular pup wearing what looks like a watch around one of its hind flippers. After checking a few newborns, Testa finally locates the animal resting with its mother beneath an icy cliff. His assistant distracts the 400-kilogram adult with a red flag as Testa removes the Velcro band from the ankle of the pup, which registers its displeasure with a bawling moan. Stepping back, Testa checks the instrument he has just recovered, which contains three days' worth of information on the diving habits of the young animal.

Testa and his colleagues from the University of Alaska in Fairbanks spent several months on this frozen patch of McMurdo Sound, tagging seals and recording their underwater forays in order to learn how Weddell juveniles develop their remarkable diving ability. Resting on land, Weddell seals look like giant sausages and act about as lively. But underwater, they can swim to crushing depths of more than 740 meters and last more than an hour on a single breath.

Relaxing in a research hut erected on the 2-meter-thick ice, Testa says that seals of the extreme south are easier to study than those closer to his home in Alaska. "It would be almost impossible to get this kind of data on northern species. It is almost impossible to see the same animal year after year up there. And in the north, you can't capture seals because they are good at getting away," he says. Unlike Antarctic seals, which face no natural predators while resting on the ice, Arctic seals must remain wary out of the water because polar bears present a constant threat.

Accessibility is only one of the drawing cards that brought Testa and other biologists to the extreme southern latitudes during the most recent field season of the U.S. Antarctic Program, which ended in February. Whether they study seals, penguins, or lichens, these researchers say they work in virtually uncharted intellectual territory, where the basic facts of life are only now coming to light.

Testa's research, for example, will reveal for the first time how seal pups venture out into the world during their early development. Even though the Alaskan biologist returned to his Fairbanks office in December, he keeps tabs on seven of the youngsters through satellite-linked monitors attached to their fur. The transmitters send back summaries of how deep the seals dive and where they travel. Some of the pups have already wandered hundreds of kilometers from their birthplace, roving farther than most of the adults, Testa says.

While Testa tagged seals and tracked their dives this field season, Warren M. Zapol and his crew used an even more sophisticated technique to study how seal bodies respond to the rigors of life underwater.

Zapol brings special skills to his Antarctic work. Most of the year, he can be found in surgery or in the wards of Massachusetts General Hospital in Boston, where he practices anesthesiology and specializes in treating people with respiratory ailments. To learn more about the body's use of oxygen, he has pursued a side career investigating the adaptations that allow seals to dive for so long without developing the problems that people encounter when they stop breathing.

Zapol and his colleagues captured five adult seals and fitted each with a credit-card-sized device implanted into a back muscle used in swimming. The instrument, called a spectrophotometer, emits two colors of light from half-watt lasers and measures the amount of light reflected back toward the device by blood and tissue. Because the color of oxygen-rich blood differs from that of blood lacking oxygen, the spectrophotometer provides a record of how quickly oxygen concentrations drop as the animals remain submerged. Wires from the implanted device run into a small data-storing computer glued to the seal's fur.

To perform their experiment, Zapol's group had to ensure that they could find the seals to retrieve the spectrophotometer measurements between dives. Normally, seals might not return to the same spot, so the researchers released their subjects in a hole the team drilled through the ice many kilometers from the nearest natural opening. When a seal surfaced at the hole for a rest and some air, one team member downloaded the spectrophotometer data through a fiber-optic cable attached to the computer. Another researcher collected a blood sample for measuring hormone concentrations and other factors. A third measured the size of the seal's spleen by passing an ultrasonic probe over the animal's body.

Although the researchers have not finished analyzing the results from their recent trip, they did record a standout dive lasting 93 minutes — much longer than the dives measured in the past. "I think we clocked a record," Zapol says.

Even more important than that breathtaking statistic, the experiment will offer insight into how muscles work during dives, something never before studied in seals outside the confines of a laboratory. The results show that seals use a complex means of keeping oxygen concentrations from dropping at a dangerous rate during dives. "We're finding a deeper level of control of blood oxygen levels than we had ever imagined," Zapol says.

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After removing a monitor from a newborn Weddell seal, J. Ward Testa (right) and Amal Ajmi move away from the pup and its mother. A 10-centimeter-thick layer of blubber keeps the mother warm.

A few dozen kilometers from Zapol's seal hole, the vast sheet of sea ice breaks into odd-shaped floes that drift north toward the Ross Sea. Here, 30 Emperor penguins mingle idly in the sun, taking a break from an afternoon of diving for fish. At the sight of humans, the nearest penguins drop onto their portly bellies and row with their wings, a maneuver that sends them sliding across the snow like toboggans. When they realize that no pursuer has followed, the birds stop and spin around. A quick push-up sets them back on their feet, and they survey the herd of bipeds dressed in red nylon coats. As if to get a better view, the stout penguins stretch skyward, revealing necks so impossibly long that one wonders where they were just moments before.

Of all the animals that inhabit the Antarctic, the Emperor stands out as the hardiest. Other birds escape the piercing winter winds by heading north, but the Emperor stays behind, breeding on the exposed ice surface. After laying an egg, the famished female heads off to hunt in the relatively warm water. The male endures the dark months on his own, incubating the egg out on the ice through blizzards and temperatures that can drop below −50°C.

For 60 days, each stalwart male stands with an egg balanced on his feet, keeping it off the ice. During the worst days, when furious gales suck away body heat, the males huddle in tight scrums for warmth. They can fast for up to four months, including the incubation and the courting period beforehand. By the time the chicks hatch, the males have lost up to half of their body weight.

Whereas other penguins breed during the summer months, the immense size of the Emperors requires them to get an early start. By incubating the eggs in winter, the 1-meter-tall, 30-kilogram birds ensure that their chicks will emerge near the beginning of spring, giving the young the maximum number of days possible to put on weight before the next winter descends.

Last November, a team led by Gerald L. Kooyman of the Scripps Institution of Oceanography in La Jolla, Calif., camped out by a colony of 20,000 Emperors in an attempt to learn basic facts about how the adults collect food for their quickly growing young. Kooyman wanted to discover just how far adult Emperors commute in search of springtime fodder. To track the birds, the researchers captured several adult penguins and glued satellite-linked radio transmitters to their feathers. The birds also carried depth-recording devices similar to the ones worn by Testa's seal pups.

Although Kooyman had some hunches about where the birds would go, scientists had scant information on penguin foraging prior to this experiment. "We didn't know anything when we started. This is the first of this kind of study on any aquatic bird," Kooyman says.

For a first study, it started off with a bang. When Kooyman initially tried the tracking technique two years ago, he discovered that the birds did not stick close to the colony as expected. Instead, they traveled hundreds of kilometers, usually swimming, to capture fish, which they regurgitated once they returned to their chicks. One record setter completed a 1,454-kilometer-long loop in 29 days – a trek equivalent to shuttling from Washington, D.C., to Detroit and back. Kooyman and his co-workers presented their early findings in the Nov. 26, 1992 NATURE.

Although scientists know little about other Antarctic penguins, Kooyman surmises that these smaller birds, such as the Adélie, stick close to home while collecting food because their tiny chicks require feedings every day or two. The husky Emperor chicks can wait much longer – perhaps a week – between meals, enabling their parents to range farther.

Kooyman's work shows that the Emperor's habitat extends over an enormous area. Not only do these birds trek hundreds of kilometers from the colonies, but they also capture fish at various levels within the water, from near the surface to near the seafloor, almost 500 meters underwater.

From what he has learned so far, Kooyman thinks Emperors could serve as a natural barometer to gauge the health of the Antarctic ecosystem. They rove far and hunt at various levels in the ocean, but they return to their chicks and mates, making it easy for scientists to study them and census their populations.

"There's a means of keeping track of them at a level we cannot do with most other marine vertebrates. If we can define their distribution and the types of food they feed on, we can use them as an [ecological] indicator," Kooyman says.

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Unlike other penguins, which fashion nests on land, Emperors incubate their eggs by balancing them on their feet while standing on the sea ice. Some Emperors never set foot on land.

Although ice blankets 98 percent of Antarctica, a few spots remain uncovered, providing a rare peek at the exposed skin of the southern continent. Called "dry valleys," these oases of rock formed when the Transantarctic Mountains rose up millions of years ago, blocking the path of the glaciers that had flowed through and carved great chasms.

From a lookout high above one of the valleys, the landscape below seems incapable of sustaining life. The parched stones have been sculpted by fierce winds that occasionally drop off the polar plateau and scream down the valley with hurricane strength, evaporating what paltry snow falls from the sky. The air holds so little moisture that this environment is as dry as many hot deserts, and its temperatures rarely rise above freezing.

Yet a few hardy organisms eke out a living here, in ways that have caught scientists by surprise. E. Imre Friedmann, a biologist with Florida State University in Tallahassee, studies one of the more unusual Antarctic residents, a type of lichen that escapes the severe conditions by hiding inside porous orange sandstone.

"Outside, on the surface, life is impossible because it is so cold and so dry that no organism would survive. But there is a refuge in the rock, where there is more water and higher temperatures," Friedmann explains.

Found in many other deserts around the world, such organisms are called cryptoendoliths, which means "hidden in rock." Cryptoendoliths are the only known forms of life on the cliffs and terraces more than 1,000 meters above the dry-valley floors. The lichen – a symbiotic partnership of algae and fungi – lives a few millimeters below the surface of the rock, forming tricolor stripes of black, white, and green that look like an organic version of some national flag. Some rocks also contain low numbers of cyanobacteria, or blue-green algae.

The dry-valley lichens prefer north-facing rocks, which soak up enough of the strong polar sunlight to reach temperatures 15°C higher than those of the surrounding air. Even in subfreezing weather, the warmed rocks can melt small patches of snow that have eluded the sponge-like winds. This snowmelt provides the only source of moisture for the cryptoendoliths. Pores within the rock hold the water for a week or two after the snow has disappeared, even while the outside humidity remains desert dry.

While the sandstone makes a relatively cozy home for the lichens, they still face a tough life by most standards. Between the warm sunlight and the icy winds, these organisms endure wild temperature changes that can bounce from freezing to thawing and back several times an hour on the worst days.

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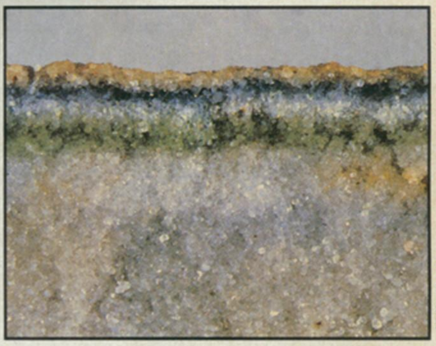

Friedmann

***A** view across Wright Valley, a dry valley, shows a glacier flowing off the polar plateau. At the upper elevations of the dry valleys, lichens survive only by hiding under the surface of sandstone rock. When split open (below), a rock shows the black, white, and green stripes of lichen. Nematodes and other microscopic invertebrates colonize the soils on the valley floor.*

Since the mid-1970s, when he discovered the Antarctic cryptoendoliths, Friedmann has sought to understand how these organisms survive in such an extreme world. Like other photosynthetic organisms, algae in the lichen harness energy from the sun to convert carbon dioxide and water into useful molecules. But life at this latitude comes at a high cost. In the January-February MICROBIAL ECOLOGY, Friedmann and his colleagues report that the lichen uses up more than 99.9 percent of its photosynthetic products simply to keep alive, with only 0.025 percent going toward reproduction and building cells. In contrast, a typical plant has roughly 10 percent left over for functions other than basic survival.

"The cryptoendolithic organisms are living at the edge of the environment. They barely produce enough to survive," Friedmann says.

Such hardship may bestow one advantage, though. Several lines of evidence suggest the lichens remain alive for thousands of years – placing them among the longest-lived organisms known. Because they spend so much of their lives frozen, these Methuselahs of the microscopic world operate at a pace that befits the realm of geology more than that of biology. Friedmann and other biologists are now trying to pin down the actual life span of the lichen cells and what role the organism plays in Antarctic ecology.

Down on the floor of the dry valley, a different sort of hidden ecosystem thrives. When biologist Diana W. Freckman of the University of California, Riverside, first visited this area three years ago, she expected to find scant life in the desiccated soils far from the lakes and ephemeral rivers where other researchers had discovered numerous organisms. But even in the driest dirt, Freckman found surprising numbers of microscopic roundworms, called nematodes, that subsist on bacteria and yeast in the soils.

"There is actually a little food chain down there," Freckman says with a voice that registers astonishment even several years after her discovery. "How can life exist there? It's almost life without water when you really think about it."

As a nematologist who studies this class of animals all over the world, Freckman says the harsh dry-valley environment offers a unique research opportunity because the ecosystem there is so simple. With no higher plants or animals to complicate the picture, biologists have a better chance of untangling the web of life and learning its rules.

"That's wonderful," Freckman says. "It's an outdoor laboratory. If you reduce the complexity of the system, all of a sudden you can see what the factors are that make it tick and you can start applying that knowledge to a more complex system. That's the basic reason I'm there. It's a very simple system and I can't find another one like that." □