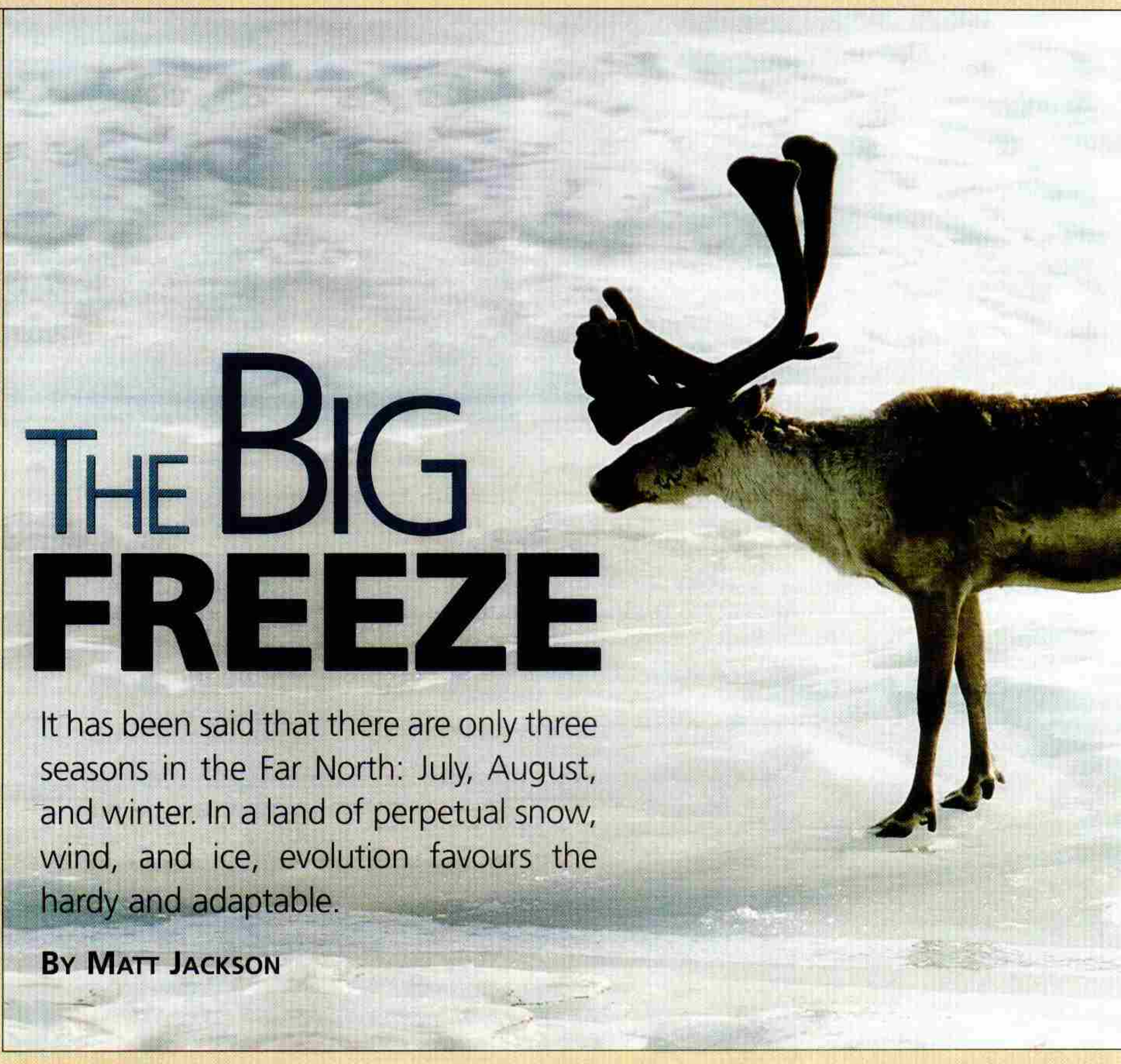


# THE BIG FREEZE

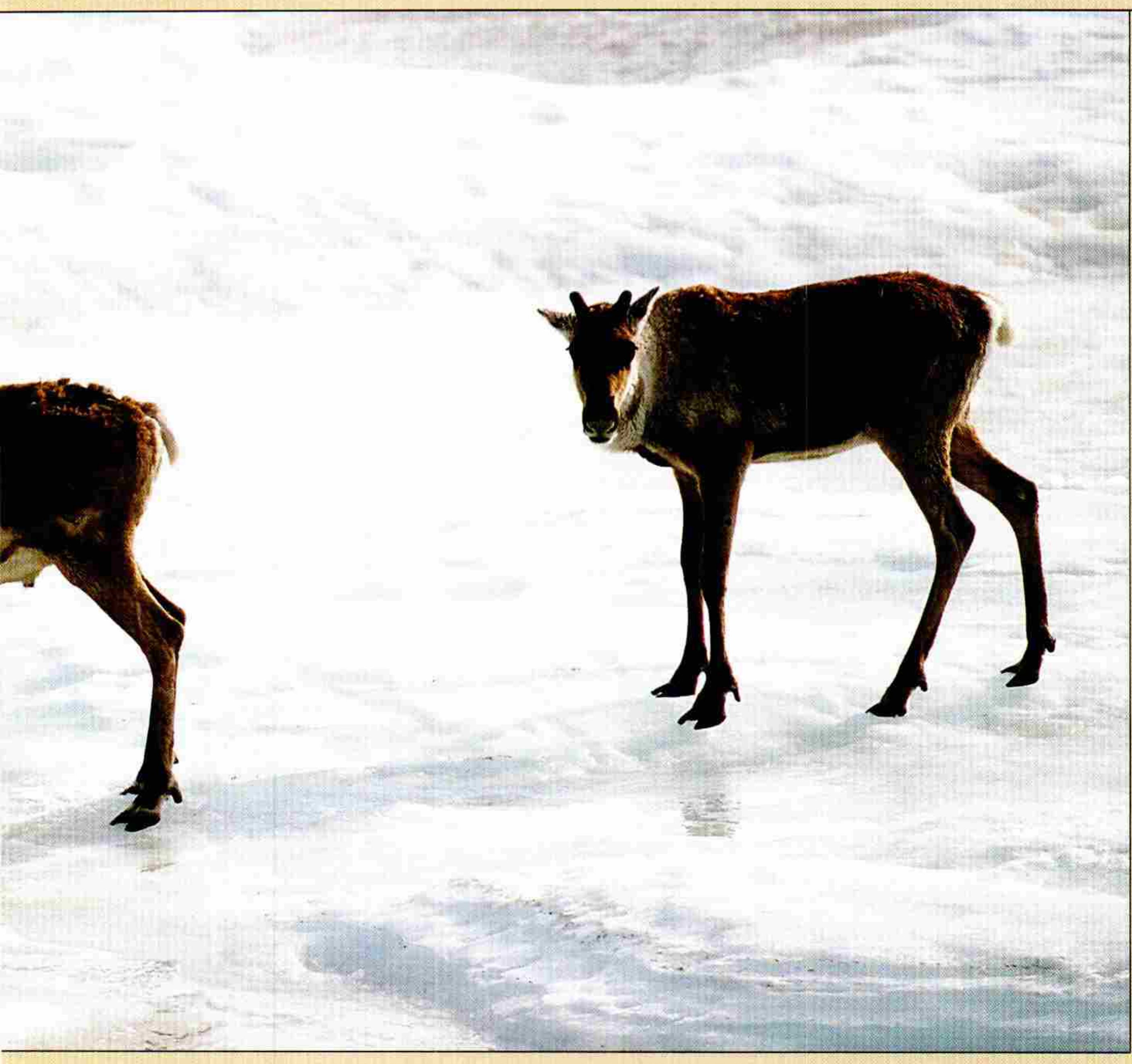
It has been said that there are only three seasons in the Far North: July, August, and winter. In a land of perpetual snow, wind, and ice, evolution favours the hardy and adaptable.

**BY MATT JACKSON**

For the past 1.5 million years, the Porcupine caribou herd has roamed the icy tundra north of the Arctic Circle, a place where winter, as Robert Peary once described it, is "a roaring, hissing, suffocating Niagara of snow, rising hundreds of feet into the air." By living here, they have braved some of the coldest, harshest, bleakest, windiest conditions on earth—and they have not only survived, they have prospered. These animals once lived on Beringia, an ancient plain that was surrounded by massive icefields during the Pleistocene era (2 million to 10,000 years ago). Their adaptability allowed them to outlast mighty herbivores like the mammoth, not to mention a posse of fearsome predators: sabre-toothed tigers, scimitar cats, dire wolves, and a hulking, fleet-footed beast called the short-faced bear.

Beringia was not for the feeble. Covering present-day northern and central Yukon, Alaska, and Siberia, large sections of the plain were repeatedly submerged and exposed by glaciers over tens of thousands of years. According to American zoologist John Winnie Jr., Beringia acted as "a biological filter that only allowed certain individuals and species to pass." Unable to digest nutrient-poor arctic plants or to survive subzero temperatures, mammals living on Beringia competed fiercely for food and space. "These conflicts must have risen to the level of war, and the weapons of this war weren't fangs or claws, but genes," continues Winnie. "Competitors survived by using meagre resources more effectively, by out-foraging rivals, even by simply staying warmer."

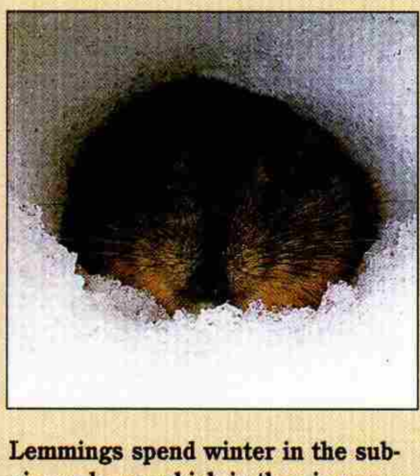
Why evolution favoured barren ground caribou, above, over other species is not entirely certain, but there's no question that these gangly animals are a laundry list of ice-age adaptations. Their circulatory system



prevents rapid loss of heat in the legs by allowing out-flowing blood to transfer heat to in-flowing blood, effectively trapping heat inside the body. Their stomachs produce an enzyme called lichenase, which breaks down compounds in lichens, making the bleakest winter forage digestible. Even caribou fat has evolved: it's a substance that, not unlike antifreeze, remains liquid at temperatures far below zero.

And that's only the beginning. Their winter coat is composed of hollow guard hairs, an advanced insulation system that traps heat between filaments. Their hooves grow longer and sharper during the winter months, acting as miniature snowshoes while also helping them dig forage from under the snow. And unlike other members of the deer family, both males and females grow antlers. The fact that females keep their antlers over the winter months, while males do not, appears to be nature's way of giving pregnant cows a crucial advantage when competing for a limited food supply.

Caribou, of course, are not the only large mammals that have learned to thrive in this environment—they are merely the oldest. In total, some three dozen animal



*Daniel J. Cox, naturalexposures.com (2)*

**Lemmings spend winter in the subnivean layer, which is the air space between the snow and the ground.**

species migrated north after the great ice sheets receded. Only caribou, Dall sheep, lemmings, voles, and tundra shrews are ice-age leftovers from Beringia. Yet bitterly cold temperatures and chronic lack of food still affect arctic animals today, and only species that have developed unique strategies for coping can live in this raw and formidable landscape.

"The fascinating thing about biodiversity," says Larry Wang, a wildlife physiologist from the University of Alberta in Edmonton, "is that even species from the same order use different tactics to survive winter." Lemmings, for example, remain active all winter long, while Arctic ground squirrels, above, slip into a comatose state where breathing may decrease to one small breath every five minutes. Why two such similar species have developed two different tactics for bridging the gap between autumn and spring is hard to say. Squirrels are probably big enough to make hibernating economical, while lemmings find hyperactivity a better technique for stoking the internal fire.

The supercooling technique used by Arctic ground squirrels is most astonishing because their bodies can warm from -1.7 degrees to 37 degrees Celsius in only a few hours. "How can a heart continue to operate under such conditions?" wonders a fascinated Wang. "Being able to recover so quickly is unique."

As Brian Barnes of the University of Alaska discovered, the squirrels sleep in a state of suspended animation for weeks at a time, waking periodically to eat and defecate, then returning into hibernation. What would surely kill other warm-blooded mammals—causing hypothermia or heart failure—is obviously normal for these little rodents. Over eons, they have mastered a biochemical feat that maintains calcium flow from heart cells into the bloodstream and back again. This calcium exchange is critical to the animals' survival because, as the body cools, plummeting temperatures typically impair calcium flow. Yet a ground squirrel's metabolism can somehow control this calcium flow even at the subzero level.

Robert McCaw

**Arctic ground squirrels do not need any antifreeze agents to supercool.**

Remarkably, of all mammals living in the Far North, only ground squirrels, grizzly bears, and denning female polar bears actually hibernate. Others face winter's onslaught head-on, and none seem more diversely adapted than polar bears, below, as comfortable on land as they are on pack ice or even in the water.

It's well known that the bears spend most of their time hunting ringed seals on ice floes, yet their gargantuan paws are also effective paddles that can propel them through water at an astonishing 150 metres per minute. As a result, they are well equipped to withstand prolonged immersion: their limb bones are porous, without marrow, and full of oil; they have a layer of blubber up to 7.5 centimetres thick; and their spongy skin comes equipped with thick, oily guard hairs that are practi-

Mark Augustowich, Spectrum Stock

**With a thick layer of fat, long, protective guard hairs and a dense under layer of fur, polar bears can withstand temperatures of at least -40 degrees Celsius.**

Wayne Lynch

cally waterproof. These are all necessary adaptations, because many polar bears—presumably after getting stranded on drifting pack ice—have been found swimming in places out of sight of land. Their marine adaptations are even useful for gathering underwater food. On occasion, they've been known to dive for kelp or to attack seabirds from below like a massive white submarine with teeth.

While caribou may be the most completely adapted arctic mammals and polar bears the most diverse, muskox, above, probably deserve the grand prize for having the most impressive adaptations. They are the only northern mammals, after all, that seek no shelter during even the most severe arctic blizzards. Instead, bull muskox form a wedge-shaped apex with their heads facing directly into the wind, shielding females and yearlings from gusting snow and ice particles. And there they stand, sometimes for days, indifferent to the snow drifting in around them.

How do they deal with such extreme exposure? Along with stubby legs, tiny ears, and short tails, these animals are blessed with a layer of exceptionally warm wool fibre called qiviut under a skirt of coarse outer guard hairs. The two layers of hair form an impenetrable and essential adaptation that protects muskox calves in the middle of the huddle. The long outer guard hair drapes down to the ground, forming an insulated skirt—the only measure of protection a newly born calf has against gale-force winds ripping across the tundra.

**Faced with slim pickings in winter, muskox can slow down some of their bodily functions—and even reduce the weight of their liver and kidneys by half—to conserve energy.**

Even the smallest animals find ways to take the cold season in stride, relying on hearts that beat several hundred times a minute to keep them warm. Hidden beneath a thick, insulating layer of snow is a veritable critter shopping mall, called the subnivean zone, that is home to charismatic little creatures such as voles, lemmings, and shrews. Even in the dead of winter, these animals scurry about producing brown fat that, when metabolized, generates more heat than simple white fat does. And when other forage is not available, lemmings can digest moss, a plant that most animals find indigestible.

Stalking these small rodents are ermines, or short-tailed weasels, slithering silently through the hidden tunnels engineered by their prey. Lemmings continue to breed all winter long, and if conditions are good, a single female will produce up to a dozen young every month or two. Within 20 days, young females are, themselves, fertile and ready to reproduce. As a result, weasels are necessary to keep the lemming population in check, just as gyrfalcons and snowy owls keep weasel numbers under control. It's thought that because ermines, themselves, are prey, the black splotch at the end of their tail helps focus a raptor's attention on something less vital. This is a superb adaptation for a winter-white animal like the ermine, giving it an opportunity to escape razor-sharp talons unscathed.

In addition to mammals, everything from insects to amphibians has developed strategies for coping with the Arctic's terminally short summer, taking advantage of specialty niches on the evolutionary ladder. All species living north of sixty must adapt, or they won't survive. "If you want to live in the Arctic, you basically have to live through nine months of subzero temperatures," says Ken Storey, a wildlife researcher at Ottawa's Institute of Biochemistry. "But learning to cope with winter allows a species to expand its range, which is one of the classic evolutionary tactics for passing on genes."

For more than 15 years, Storey and his wife, Jan, have been studying

Thomas Kitchin, Tom Stack & Associates

**Ermines, or short-tailed weasels, have chocolate brown coats in the summer that turn snow white come winter.**

the wood frog, a nondescript little amphibian that has done just that. Unlike most frogs, which dive down to the bottom of ponds to hibernate, wood frogs tuck themselves under leaf litter on the ground and freeze. When spring arrives, they simply defrost and hop away. The thing that most puzzled researchers was how a cold-blooded amphibian like the wood frog could become freeze-tolerant. A number of species are freeze-resistant, such as the goldenrod gall moth caterpillar, which can stay fluid at -55 degrees Celsius by producing special blood proteins capable of binding to embryonic ice crystals and halting their formation. But to become freeze-tolerant—a coping mechanism that actually lets ice form inside the body—is an incredibly complex adaptation that only the wood frog and a few other amphibian, reptile, and invertebrate species have been able to achieve.

This is how it works. During the short arctic summer, wood frogs eat voraciously to build up large reserves of glycogen in their liver. As soon as the mercury drops below a certain threshold, the glycogen starts breaking down into glucose and immediately floods the frogs' tiny organs. Ice penetrates throughout the amphibians' cavities and eventually encases the vital organs, but with blood-sugar levels up to 100 times the normal level, the organs can remain ice-free. Blood stops flowing, the heart stops beating, and the frogs cease to breathe. Only their neurological functions continue, although they are barely detectable. When spring arrives and the frogs finally begin to thaw, the number of clotting

Robert McCaw

**Wood frogs freeze from the outside in and thaw from the inside out—first the heartbeat resumes, followed by blood flow, breathing, and muscle activity.**

proteins in the bloodstream rises. This helps to repair any damage that might have been caused by the ice.

There's no doubt that this evolutionary advantage has allowed wood frogs to increase their range substantially across North America—even leapfrogging above the Arctic Circle in places. Because land thaws before water, wood frogs wake up two months before other frog species, and while other amphibians are still snoozing at the bottom of rivers and ponds, wood frogs are eating, mating, and making tadpoles. This presumably means they'll have longer to fatten up before the tribulations of winter start all over again.

Another example of freeze tolerance occurs in the Arctic woolly bear, a plump, fuzzy little caterpillar with orange guard hairs, above. Woolly bears are miniature titans—an excellent example of what evolution can accomplish where there's a need. While most caterpillars develop for one season before metamorphosing, woolly bears have mastered the art of slowing down. On average, these caterpillars live for an astonishing seven years, storing food reserves over the short summer and freezing solid every winter. At the end of their last year, they weave a silk cocoon and, early the next summer, emerge as an Arctic moth. All the energy stored over the previous seven years now goes into finding a mate and breeding before winter arrives.

One of the greatest joys of studying adaptability in arctic wildlife is uncovering improbable little secrets like those of caribou or wood frogs. That any species would remain in a hostile environment like Canada's Far North might at first seem strange, yet for many animals, the Arctic is home, and they could live comfortably nowhere else. Just think of a muskox bull, which would quickly overheat if it lived further south. Or a polar bear that, unlike other bears, feels at home both on land, on ice, and in arctic waters. Polar bears, muskox, caribou: it's nice to know that even under the most unforgiving conditions, life will find a way.

Wayne Lynch

**While most moths live as caterpillars for only two to four weeks, Arctic woolly bears remain in their larval form for an average of seven years.**

## Super Cool Learnings

The wood frog and its cool little buddies may be impressive in their own right, but can we humans learn anything from the ways freeze-resistant and freeze-tolerant creatures adapt to winter weather? John Crowe, who, with Fern Tablin, heads the biostabilization group at the University of California's Davis School of Veterinary Medicine, thinks we can.

Some of Crowe's colleagues recently conducted research on polar fish, trying to unlock the secrets of how special blood proteins act as natural antifreeze. According to Crowe, these proteins allow polar fish to thrive in waters that would freeze most creatures to death in minutes. As supercooling works for the Arctic ground squirrel and glucose for the wood frog's internal organs, these proteins appear to block the growth of ice crystals inside the body before irreversible damage can be done. The scientists have observed that a liquid shell of water surrounds the proteins, even when locked in ice as cold as -60 degrees Celsius. More recently, the Crowe-Tablin group has shown that these proteins stabilize cellular membranes during the chilling process without freezing.

The antifreeze proteins were discovered more than 30 years ago by Robert Feeney, a biochemist at the University of California Davis campus, and have since been shown to preserve human blood platelets in cold storage for up to three weeks. Currently, these platelets are very difficult to warehouse and typically have to be discarded after only a few days.

Antifreeze proteins are also helping University of California scientists understand biomineralization, a process whereby living tissue evolves into crystalline substances such as bone and tooth enamel. Unfortunately, biomineralization also contributes to such conditions as kidney stones and artery blockages, which can lead to heart disease. Can studying polar fish help us learn to prevent these ailments? Scientists hope so. By exploring how ice crystals react with antifreeze proteins, they hope to find solutions to prevent these diseases.