Chilling Out

How Warm-Blooded Animals Survive Southeast Winters

by Bob Armstrong and Marge Hermans
from Southeast Alaska's Natural World

On a cold night in February, on a mountainside in Southeast Alaska, the snow is six feet deep. The wind is blowing, and the temperature is about 10°F.

In a hollow beneath the roots of a huge old Sitka spruce, a female black bear lies with two newborn cubs. Pink and hairless, with their eyes still squeezed shut, the tiny newborns are snuggled against their mother's warm belly. She is curled around them, holding them against her with the furry warmth of her front and hind legs.

For the next several months the cubs will live in the shelter of the den, squirming over their mother's body and greedily drinking her rich, fatty milk.

The sow will barely waken. She will not eat, sleep, or relieve herself. Her body temperature has dropped four to five degrees (Fahrenheit) below normal, and her heart may beat only 10 or 12 times a minute. Unless disturbed, she will stay this way until early May. Then she will gradually awaken, and the cubs—with thick coats of fur and weighing about five pounds each—will follow her out of the den into the forest that will be their summer home.

Above the bears' den, where not even the scrawniest trees survive, snow covers the boulders at the foot of an old avalanche chute. Beneath them a female marmot and her young of the previous summer are curled within the shelter of her snug

Chickadees survive all winter long in Southeast Alaska partly because they can spend nighttime in a state of torpor. They can rest, chilled below their normal body temperatures, then recover to forage during daylight.

underground burrow. All are still, except when they occasionally turn to stretch or shift position.

The marmots' body temperatures have dropped drastically below normal, and their hearts are beating only four to five times a minute.

Down at the foot of the mountain, a 200-year-old forest stretches toward the icy shore. Inside the gray skeleton of an ancient hemlock tree seven chickadees huddle together in a small cavity. They have found a nest hole carved into the tree's rotten heartwood the previous summer by red-breasted sapsuckers.

The chickadees are resting at body temperatures about 18°F below normal. They will stay in the cavity all night until daylight wakes them to forage for the seeds, spiders, and insect larvae that will carry them through the chilling cold of one more winter day.

Hypothermia, or lowering of the body's core temperature, is a deadly threat to nearly all warm-blooded animals, including humans.

But the bear, the marmot, and the chickadees are surviving precisely because their bodies are in that condition. Chilled below their normal body temperatures, they have slowed down or stopped their physical activity and virtually all their bodily functions.

Each animal, in its own way, is conserving energy and cutting back its food requirements as a way to survive the cold and food shortages of winter. How the animals manage to do this—through carefully regulated processes known as hibernation, deep sleep, and short-term torpor (nearly total mental and physical inactivity)—is one of the marvels of nature.

We are only beginning to understand how these processes work and what remarkable implications these animals' use of regulated hypothermia may have for human beings.

The True Hibernators

Two animals in Southeast Alaska are considered "true hibernators"—hoary marmots, found throughout mainland Southeast, and arctic ground squirrels, found in the coastal mountains north of Skagway.

Each winter these small mammals hole up in sheltered places for as long as six to eight months. Though they may wake occasionally, they primarily sleep. Their body temperatures decline drastically; heartbeat, blood pressure, and oxygen consumption decrease; and much of the time the animals appear to be comatose or even dead. Yet, when spring approaches, something changes. The animals wake up and resume their normal activities.

How do they do it?

Both marmots and ground squirrels eat voraciously in late summer and early fall, often doubling their normal weight. Much of the increase takes the form of fat, which provides twice as much energy as carbohydrate. This gives the animals enough built-in energy to function at a reduced level as they sleep away the winter.

Marmots and ground squirrels also take shelter from the weather in underground burrows—another way to save energy and

Hoary marmots spend the winter hibernating in underground burrows, emerging in the spring to feed on succulent vegetation.

protect themselves during the months they will be mostly inactive.

When marmots enter their burrows for the winter, they plug the entrance to their sleeping chamber with dirt, vegetation, and feces. This blocks out predators such as wolves and prevents the loss of heat, like closing and weatherstripping the door to your house in winter. Layers of earth and snow over the burrow provide insulation from wind and cold, so ambient temperatures in the burrows nearly always stay at least a few degrees above freezing, regardless of the temperatures outside.

Once inside their burrows, the true hibernators allow their bodies to drop into regulated hypothermia gradually, decreasing their activity over several days.

Arctic ground squirrels go into deeper hibernation than any other animal, and much research has been done on them, particularly in northern Alaska.

Researchers at the University of Alaska Fairbanks found the body temperatures of hibernating arctic ground squirrels could drop from a normal 98°F to as low as 34 or 35°F. This is remarkable since the hearts of non-hibernating mammals will not beat at all at temperatures below about 50 to 70°F.

The squirrels' heartbeats also slowed from a normal 350 beats a minute to an extraordinary two to four beats a minute. That would decrease blood flow to the brain by an estimated 80 or 90 percent—a decrease that in nonhibernating mammals would damage or destroy crucial nerve cells within minutes.

Scientists think hibernators get away with this because their metabolic rate also drops, sometimes as much as 98 to 99 percent, and cellular processes slow down significantly.

Blood flow to the extremities slows in hibernating animals as well, but certain parts of the nervous system continue to regulate the animals' metabolism as temperatures drop. That includes parts that perceive changes in the environment, so if the environment gets too cold, the animals will wake up or increase their metabolism to warm up (something that humans suffering from hypothermia cannot do).

Arctic ground squirrels are considered "true hibernators." During hibernation their body temperatures may drop to 34 degrees F. and their metabolic rate may drop as much as 99 percent.

Marmots are believed to wake occasionally during the winter, but they rouse slowly, perhaps taking as long as two hours to regain normal body temperature. Arctic ground squirrels wake for a day or so every three weeks or less. Waking seems to be essential so the animals can remove accumulated wastes that would otherwise poison their bodies.

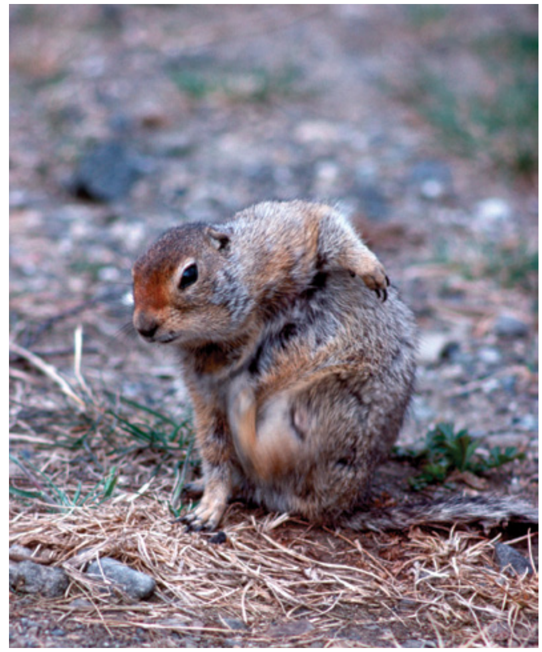
The Bears' "Long Sleep"

Human beings in northern climates have long been aware that brown and black bears hibernate for the winter. Like marmots and arctic ground squirrels, bears lay on heavy layers of fat each late summer and fall. They spend the winter in dens, sheltered from wind, rain, and cold.

But the bears' "long sleep" is different from that of the true hibernators. The bears' body temperatures do not drop as drastically. Their metabolism does not slow as much. And unlike true hibernators, bears can wake from their "sleep" and become active almost immediately.

In 1998 Brian Barnes and Oivind Toien, biologists at the University of Alaska Fairbanks Institute of Arctic Biology, studied two black bears that hibernated on the university campus. The three-year-old female bear and a yearling male, captured as problem bears at Elmendorf Air Force Base near Anchorage, were put in a padded box where they were monitored for heartbeat, shivering, breathing, and brain wave patterns.

The scientists found the bears' body temperatures dropped below their normal level of 99°F but never below about 85°F. Other studies have found bears' metabolic rate drops to only about 50 percent of the normal level.



These changes are not as extreme as those undergone by true hibernators, but they are enough to save considerable energy through the winter. It is believed bears do not "sleep" as deeply because it would take too long for such large animals to cool down and warm up again.

Bears do not urinate or defecate for the whole time they are asleep in their dens. This has especially intrigued scientists who wonder how the animals can survive for six to eight months without excreting harmful bodily wastes.

Studies have found that urea is produced in the liver, released into the blood, and excreted in saliva, which the animals swallow. When urea reaches the intestine, bacteria convert it back into bicarbonate and ammonia. Other bacteria convert the ammonia into protein. The ammonia is completely recycled. The bears' bodily wastes are degraded and reabsorbed.

The Short-Term Torpor of Chickadees

Chickadees, one of a number of songbird species that overwinter in Alaska, use regulated hypothermia in yet a different way. Unlike marmots, ground squirrels, and bears, they cannot store up enough fat to carry them through weeks or months of hibernation. So instead they forage during the day, then save energy by allowing their body temperatures to drop during the night.

When roosting chickadees turn down their internal thermostats, their normal body temperature may drop from about 108°F to 90°F. Peter Marchand, author of the fascinating book *Life in the Cold,* explains that chickadees do this by controlling shivering.

Like most birds, chickadees shiver a lot in winter, using that muscle movement to warm themselves up. But, Marchand writes, chickadees do even more:

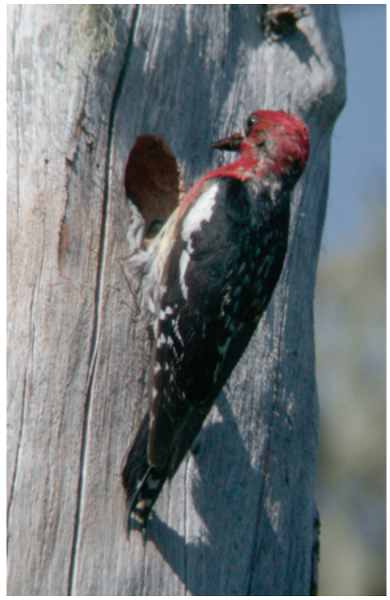
> *By controlling shivering through shorter and less frequent shivering outbreaks, body temperature gradually drops until a particular depth of hypothermia (varying seasonally) is reached. Shivering is then resumed with regular bursts, maintaining a closely regulated hypothermia.*

On a cold winter night the bird thus saves 20 percent of the energy normally required to maintain body temperature.

Chickadees do put on an amazing amount of extra fat in winter, according to Pierre Deviche and Susan Sharbaugh, two researchers at the University of Alaska Fairbanks.

The biologists found that in winter the birds seemed to eat as much as they could during the day. In fact, they gained the equivalent of 10 percent of their body weight in fat, then burned virtually all of it up during the night.

Imagine a person who weighed 150 pounds eating enough to gain 15 pounds in a day, then burning it off during the night and waking up weighing 150 again in the morning. "It's a huge physiological feat," Sharbaugh said.



Nest holes excavated by red-breasted sapsuckers in summer make perfect shelters for small resident birds such as chickadees and brown creepers in winter.

Like marmots and ground squirrels, chickadees seek out places where they can shelter and hide from predators during their torpor.

When he was on Admiralty Island studying forest habitat near Hawk Inlet, Alaska biologist Jeff Hughes watched chickadees and other small birds piling into cavities in large old trees and snags at the end of the day. Hughes wrote in an article for *Natural History* magazine:

> *Since nights may be sixteen hours long, and the birds typically roost from before sunset to sunrise, chickadees, creepers, and hairy woodpeckers essentially spend most of the winter in these tree holes. A single hole often contains more than one bird and may be crowded with roostmates of a few different species.*

Hughes found the temperature inside an occupied cavity can be six to 11°F higher than the temperature outdoors, even in weather below freezing. Combined with a daytime buildup of fat and nighttime regulated hypothermia, these shelters must help birds save tremendous amounts of energy during winter.

Anna's hummingbirds are rare in Southeast Alaska. They are more often seen at sugar water feeders in the fall.

Bob's Recollections

Eagle's Torpor

An Anna's hummingbird showed up at my Juneau home one cold day in October. I lured him inside because the flowers were gone and the sugar water in the outside feeder was in danger of freezing. I kept him alive with a mixture of Similac, sugar, fish food flakes, and water.

I was to keep him for about a month, then someone from the Alaska Raptor Center in Sitka was going to take him to a hummingbird rehabilitation facility in San Diego. I named him Eagle.

Eagle seemed content having the run of my dining room. He would go into torpor at dusk and awaken at daybreak. Indoor lights did not alter this pattern.

During torpor he appeared oblivious to any activity around him. I could move about, rattle dishes, or talk, and he would remain perfectly still on his perch. He appeared stiff, with his neck pulled down, his eyes closed, and his bill pointing up in the air.

When it was time for Eagle to be carried south, I captured him in the middle of the night while he was still in torpor. His body seemed lifeless; he did not move or open his eyes. However, the whole time I held him he uttered a pitiful squeaking sound.

Hummingbirds have the highest metabolic rate and the greatest metabolic range of any vertebrate. The ability to go into torpor helps them to conserve energy and may be critical to their survival.

In general, they are capable of lowering their body temperature to that of the surrounding air during torpor. This is quite a feat since their daytime activity temperature is about 104° F.

As the birds wake from torpor, their temperature increases about 2° F per minute. This means that a torpid hummingbird in Southeast would require about 27 minutes to fully awaken from an overnight temperature of 50° F to its normal operating temperature of 104° F.