Gut microbes help hibernating ground squirrels emerge strong and healthy in spring

January 28 2022, by Hannah V. Carey, Matthew Regan

When not hibernating, ground squirrels need to feast to store energy. Credit: Robert Streiffer, CC BY

Ground squirrels spend the end of summer gorging on food, preparing for hibernation. They need to store a lot of energy as fat, which becomes their primary fuel source underground in their hibernation burrows all winter long.

While hibernating, ground squirrels enter a state called torpor. Their metabolism drops to as low as just 1% of summer levels and their body temperature can plummet to close to freezing. Torpor greatly reduces how much energy the animal needs to stay alive until springtime.

That long fast comes with a downside: no new input of protein, which is crucial to maintain the body's tissues and organs. This is a particular problem for muscles. In people, long periods of inactivity, like prolonged bed rest, lead to muscle wasting. But muscle wasting is minimal in hibernating animals. Despite as much as six to nine months of inactivity and no protein intake, they preserve muscle mass and performance remarkably well—a very handy adaptation that helps ensure a successful breeding season come spring.

How do hibernators pull this off? It's been a real head-scratcher for hibernation biologists for decades. Our research team tackled this question by investigating how hibernating animals might be getting a major assist from the microbes that live in their guts.

A nitrogen-recycling system

We knew from previous research that a hibernator's gastrointestinal system undergoes dramatic changes in its structure and function from summer feeding to winter fasting. And it's not only the animals who are fasting all winter long—their gut microbes are, too. Along with our microbiology collaborators, we figured out that winter fasting changes the gut microbiome quite a bit.

And then we wondered … could gut microbes play a functional role in the process of hibernation itself? Could certain bacteria help keep muscle and other tissues working when the mostly immobile animals aren't eating?

Biologists had previously identified a clever trick in ruminant animals, such as cattle, that helps them survive times when protein intake in the diet is low or protein needs are especially high, such as during pregnancy. A process called urea nitrogen salvage allows the animal to recoup nitrogen—a critical ingredient for building protein—that would otherwise be excreted in urine as the waste product urea. Instead, the urea's nitrogen is retained in the body and used to make amino acids, the building blocks of proteins.

The 13-lined ground squirrel shows minimal signs of muscle wasting, even after hibernating for up to six months. Credit: Robert Streiffer, CC BY

This salvage operation depends on the chemical breakdown of urea molecules to release their nitrogen. But here's the kicker: Chemical breakdown of urea requires urease, an enzyme that animals do not produce. So how does a cow, for instance, get that nitrogen out of urea?

It turns out certain microbes that are normal residents of animals' guts can do just that. They make the urease enzyme and use it to chemically split urea molecules, freeing up the nitrogen, which becomes part of ammonia molecules. Microbes then absorb ammonia and use it to make new protein for themselves.

Peculiarities of the ruminant digestive system allow those animals to benefit greatly from this process. But for other animals—like hibernators and us—it was less clear whether and how the urea nitrogen could make its way into the animals' bodies to support protein synthesis.

This was our challenge as scientists: Could we demonstrate urea nitrogen recycling in hibernators and show that it is particularly helpful to them the longer they fast?

Our experimental game plan

Using the 13-lined ground squirrel, we designed experiments to investigate key steps in urea nitrogen salvage.

First, we injected into the squirrel's bloodstream urea molecules in which the two nitrogen atoms were replaced by a heavier form of nitrogen that naturally occurs only in tiny amounts in the body.

We were able to follow these heavier nitrogen atoms as the injected urea moved from the blood into the gut, then as microbial urease broke down the urea into its component parts, and finally into the squirrels' tissue metabolites and proteins. Wherever we saw higher levels of the heavier form of nitrogen, we knew that urea was the source of the nitrogen, and therefore gut microbes had to be responsible for getting the urea nitrogen back into the animals' bodies.

To confirm that the microbes were doing the nitrogen recycling, we compared squirrels that had normal gut microbiomes to squirrels that didn't. We treated some animals with antibiotics to reduce gut microbes at three times of the year: summer; early winter, when they were one month into fasting and hibernation; and late winter, whwithen they were four months into fasting and hibernation.

In squirrels with normal microbiomes, we saw evidence of urea nitrogen salvage at each step of the process that we tested. But squirrels with depleted microbiomes displayed minimal urea nitrogen salvage. Our observations confirmed that this process was indeed dependent on the gut microbes' ability to break down urea and liberate its nitrogen in the hibernators' guts. Hibernators' liver and muscle tissue incorporated the most urea nitrogen during late winter—that is, the longer they'd been hibernating and without food.

We also found that the ground squirrels contribute to this remarkable symbiosis. During hibernation, their gut cells increase production of proteins called urea transporters. These molecules are lodged in intestinal cell membranes and shepherd urea from the blood into the gut where the microbes that contain urease are found. This assist means that what little urea the animal makes during hibernation has an easier route to the gut.

Finally, we found that it wasn't just squirrels who benefited from this process. The microbes too were using the urea nitrogen to build their own proteins, showing that urea nitrogen salvage provides both parties with this important molecular building block during the long winter fast.

Could this kind of symbiosis help humans?

This example of hibernator-microbe symbiosis has potential clinical applications. For example, undernourishment, which affects millions of people globally, leads to a progressive decline in muscle mass and compromises health. Sarcopenia, which is muscle wasting that is a natural part of aging, impairs mobility and makes people more susceptible to injury. A detailed understanding of how the hibernator nitrogen salvage system is most effective when the risk of tissue loss and muscle wasting is greatest could lead to new therapeutics to help people in similar situations.

Another potential application is in human spaceflight, during which crew members experience high rates of muscle atrophy because of a microgravity-induced suppression of muscle protein synthesis. Even the extensive exercise regime that astronauts undertake to offset this is insufficient. A microbiome-based countermeasure that facilitates muscle protein synthesis similar to the process we have observed in hibernators may be worth investigating.

These applications, though theoretically possible, are a long way from delivery. But studies in the 1990s demonstrated that humans are capable of recycling small amounts of urea nitrogen with the help of their gut microbes. So the necessary machinery is in place—it just needs to be optimized.

This article is republished from The Conversation under a Creative Commons license. Read the original article.

Provided by The Conversation

Citation: Gut microbes help hibernating ground squirrels emerge strong and healthy in spring (2022, January 28) retrieved 25 April 2024 from https://phys.org/news/2022-01-gut-microbes-hibernating-ground-squirrels.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.