Researchers get to the 'bottom' of how beetles use their butts to stay hydrated

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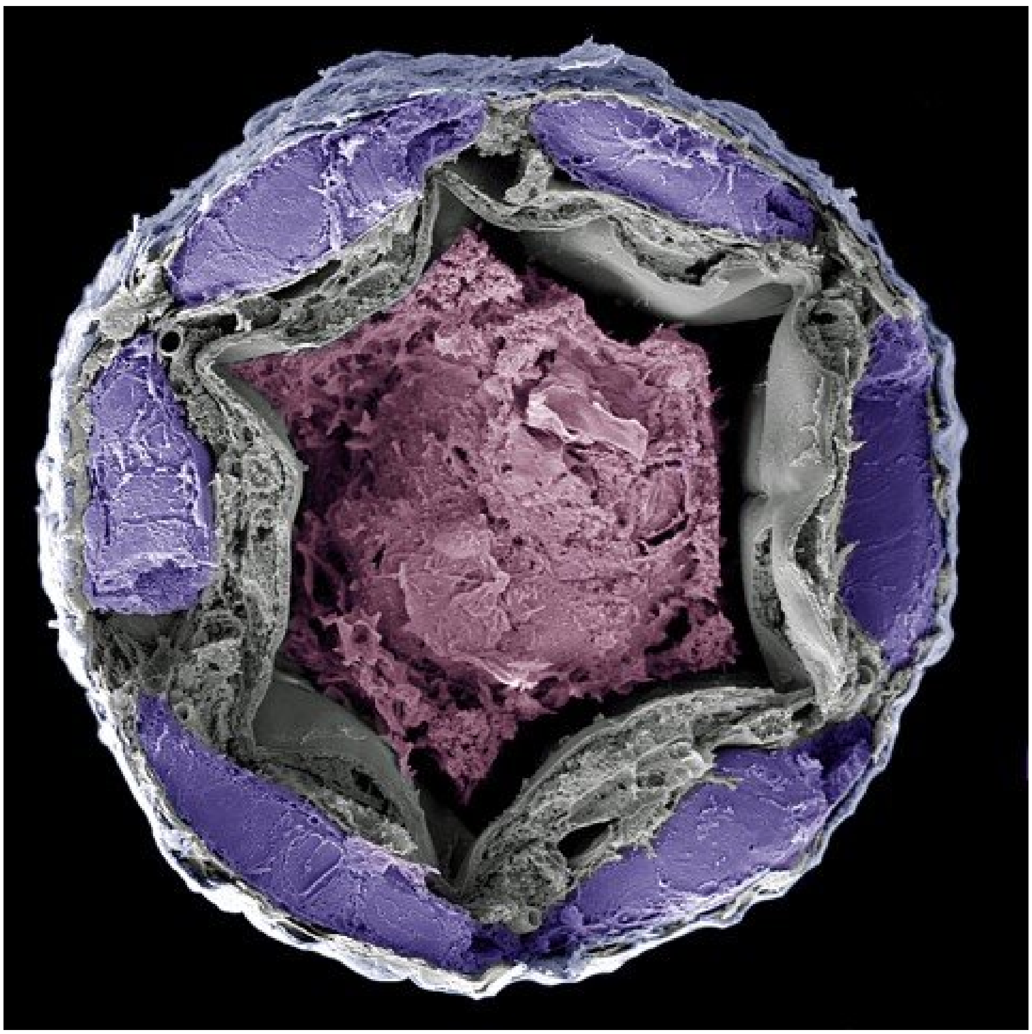


Microscopic cross-section of the beetle's hindgut. The picture shows the dry stool in magenta colors surrounded by the intestine in gray. The malpighian tubule of the beetle is seen in purple. Credit: Kenneth Veland Halberg

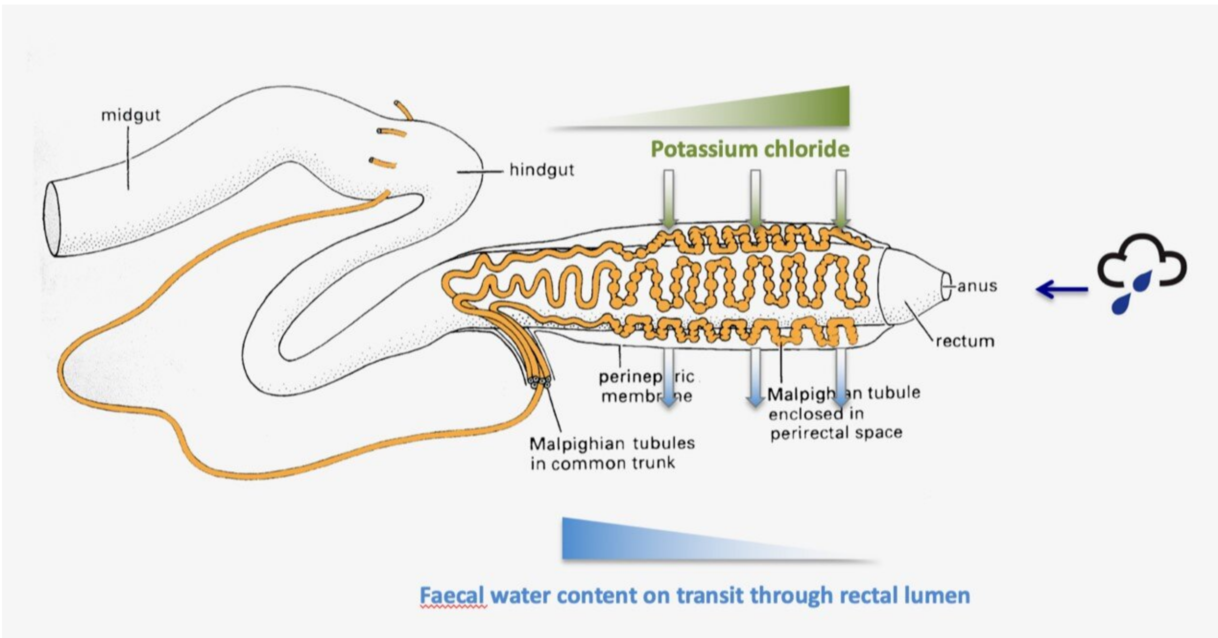
Beetles are champions at surviving in extremely dry environments. In part, this property is due to their ability to suck water from the air with their rear ends. A new collaborative study by researchers from the University of Copenhagen and the University of Edinburgh explains just how. Beyond helping to explain how beetles thrive in environments where few other animals can survive, the knowledge could eventually be used for more targeted and delicate control of global pests such as the grain weevil and red flour beetle.

Insect pests eat their way through thousands of tons of food around the world every year. Food security in developing nations is particularly affected by animal species like the grain weevil and red flour beetle, which have specialized in surviving in extremely dry environments, granaries included, for thousands of years.

In the new study, which is published in *Proceedings of the National Academy of Sciences* , researchers at the University of Copenhagen's Department of Biology investigated the molecular and physiological processes underlying the ability of beetles to survive their entire lives without drinking any liquid water whatsoever. One of the secrets of this characteristic is found in their rear ends.

Indeed, beetles can open their rectums and take up water from moist air and convert it into fluid, which they can then absorb into their bodies. This novel approach to consuming water has been known for more than a century within scientific circles around the world, but never fully clarified until now.

"We have shed new light on the molecular mechanisms that allow beetles to absorb water rectally. Insects are particularly sensitive to changes in their water balance. As such, this knowledge can be used to develop more targeted methods to combat beetle species which destroy our food production, without killing other animals or harming humans and nature," says Associate Professor Kenneth Veland Halberg of the Department of Biology, who led the research.



Model of the beetles inside and how it extracts water from the air. Credit: Kenneth Halberg

Bone dry stool testifies to effective fluid extraction

The researchers studied the internal organs of [red flour beetles] to learn more about their ability to absorb water through the rectum. Red flour beetles are used as so-called model organisms, which means that they are offer tools that make them easy to work with and that their biology is similar to that found in other beetles.

Here, the researchers identified a gene that is expressed sixty times more in the beetle's rectum compared to the rest of the animal, which is higher than any other gene they found. This led them to a unique group of cells known as leptophragmata cells. Upon closer inspection, they could see that these cells play a crucial role when the beetle absorbs water through its rear end.

"Leptophragmata cells are tiny cells situated like windows between the beetle's kidneys and the insect circulatory system, or blood. As the beetle's kidneys encircle its hindgut, the leptophragmata cells function by pumping salts into the kidneys so that they are able to harvest water from moist air through their rectums and from here into their bodies. The gene we have discovered is essential to this process, which is new knowledge for us," explains Kenneth Veland Halberg.

Besides being able to suck water out of the air, beetles are also extremely effective at extracting liquid from food. Even dry grain, which may consist of 1-2 percent water, can contribute to a beetle's fluid balance.

"A beetle can go through an entire life cycle without drinking liquid water. This is because of their modified rectum and closely applied kidneys, which together make a multi-organ system that is highly specialized in extracting water from the food that they eat and from the air around them. In fact, it happens so effectively that the stool samples we have examined were completely dry and without any trace of water," explains Halberg.

Food security in developing nations is particularly affected by animal species like the grain weevil and red flour beetle which have specialized in surviving in extremely dry environments, granaries included, for thousands of years. Credit: Kenneth Halberg

As much as 25 percent global food production is lost

Over the past 500 million years, beetles have successfully spread across the planet. Today, one in five animal species on Earth is a beetle. Unfortunately, beetles are also among the pests that have a devastating impact on our food security. The red flour beetle, grain weevil, confused flour beetle, Colorado potato beetle and other types of beetles make their way into up to 25 percent of the global food supply every year.

We use approximately $100 billion in pesticides worldwide every year to keep insects out of our food. However, traditional pesticides harm other living organisms and destroy the environment.

Therefore, according to Halberg, it is important to develop more specific and "eco-friendly" insecticides that only target insect pests, while bypassing more beneficial insects such as bees. This is where a new and better understanding of beetles' anatomy and physiology could become key.

"Now we understand exactly which genes, cells and molecules are at play in the beetle when it absorbs water in its rectum. This means that we suddenly have a grip on how to disrupt these very efficient processes by—for example—developing insecticides that target this function and in doing so, kill the beetle," says Halberg.

"There is twenty times as much insect biomass on Earth than that of humans. They play key roles in most food webs have a huge impact on virtually all ecosystems and on human health. So, we need to understand them better," concludes the researcher.

More information: Muhammad T. Naseem et al, NHA1 is a cation/proton antiporter essential for the water-conserving functions of the rectal complex in Tribolium castaneum, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2217084120

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