Maintaining salt balance helps insects avoid frosty fate: Could assist with pest control

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Drosophila. Credit: Wikipedia

For humans, getting chilly is a problem that can usually be solved with a hat and mitts, but for insects it's not so simple. A study led by a York University Postdoctoral Fellow has found that for some insects, the key to cold weather survival is in keeping their salt balance in check, and that finding could help with controlling pests in the future.

Insects make up more than 75 per cent of all animal species; some are beneficial, such as pollinators, but others are carriers of disease.

"Insects lose the ability to maintain proper salt and water balance in the cold. When they are chilled, sodium and water move from the insect's blood into their gut," said Heath MacMillan, who led the study. "This is bad news for the insect because it concentrates potassium in the hemolympha [blood] where it remains."

In the study published today in the journal *Scientific Reports*, researchers from Canada, Denmark and the United Kingdom suggest that the difference between life and death for an insect in the cold is a matter of keeping potassium levels low in their blood (hemolympha).

Humans generate excess heat and retaining that heat means staying toasty on a cold winter night. Insects, however, have a body temperature that is the same as the air around them (they are ectothermic), meaning that if it is 0°C outside, the insect is 0°C inside, and a hat won't help. Many insects have evolved to be remarkably tolerant to large swings in temperature, but others are quite intolerant and die after only short exposures to the cold.

"Like us, insects always work to keep levels of potassium outside of their cells low, because high levels can completely disrupt nerve signaling and the ability of muscles to contract. If potassium levels get high enough in the cold, they can even cause permanent tissue damage and death," said MacMillan.

MacMillan and his collaborators thought that if insects could maintain water and salt balance in the cold, it might have something to do with the Malpighian tubules. This is because the Malpighian tubules of insects are organs that serve a similar physiological role to mammalian kidneys, which help mammals to maintain salt and water balance by removing

salts and water from the blood as needed.

The team studied the effects of cold exposure on salt and water balance in five species of fruit flies collected from different locations around the globe. "The species of flies from high latitudes, where winters are colder, were much better at maintaining ion and water balance at low temperatures," said MacMillan. This ability to survive in the cold seems to be specifically associated with the Malpighian tubules. "The tubules of the cold tolerant insects helped to keep sodium and potassium at normal levels in the blood during cold exposure, while those of insects that are easily killed by low temperature lost their ability to properly regulate salt balance in the cold".

Johannes Overgaard, an associate professor at Aarhus University who worked on the study, said "This work is significant because it identifies physiological mechanisms in specific organs that can determine whether an insect lives or dies at low temperatures." said. "This is a major step forward in our understanding of insect stress tolerance, and could help us to predict how different insect species will respond to a changing climate".

The study's authors hope that this research will also contribute to the development of new ways of controlling insect pests. "This foundational knowledge is critical," said Professor Shireen Davies of Glasgow University, a co-author on the study. "The Malpighian tubules are regulated by some hormones that are only found in insects, so there is great potential for safely and precisely altering the ability of agricultural pests or insects that transmit disease to regulate salt and water balance under times of stress. By doing so, we may find new and safe ways of controlling how well these species survive winter in temperate and polar climates."

More information: Heath A. MacMillan et al. The capacity to

maintain ion and water homeostasis underlies interspecific variation in Drosophila cold tolerance, *Scientific Reports* (2015). DOI: 10.1038/srep18607