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INSIDE JEB

Turtle hearts can cope with having low oxygen

A red-eared slider. Photo credit: Amanda Bundgaard.

Living trapped under the ice in a pond all winter doesn't sound like much fun, especially for an animal that normally breathes air. However, several turtle species in North America do just that. While these animals may have drawn the short straw when it comes to the habitat they reside in, they have also developed some remarkable adaptations which allow them to survive in such a difficult environment. One such adaptation is their ability to tolerate having very low or no oxygen and then suddenly having normal levels of oxygen again. In humans, this type of event happens in the short term when someone suffers a heart attack or stroke, generally resulting in the mitochondria of cells producing reactive oxygen species, chemicals such as hydrogen peroxide and superoxide, which damage or even kill cells. However, the turtles don't seem to incur any damage from this process, which led Amanda Bundgaard and Angela Fago of Aarhus University, Denmark, to delve into the mechanisms by which red-eared sliders (*Trachemys scripta elegans*) solve the problem of dealing with these harmful chemicals.

Working with researchers from the University of Cambridge, UK, and the University of Manchester, UK, Bundgaard and Fago placed the shelled reptiles in water that had no oxygen dissolved in it and measured the amount of reactive oxygen species after 3 h underwater followed by 1 h on land. Surprisingly, the turtles' hearts didn't have higher levels of these damaging chemicals after being resupplied with normal amounts of oxygen than they did when they were starved of oxygen under the water. Even more surprisingly, the sliders had even lower levels of reactive oxygen species than turtles that never experienced the absence of oxygen. Bundgaard and the team then set about discovering how these remarkable reptiles were able to keep their production of reactive oxygen species to a minimum.

From previous research in mammals, the researchers knew that the build-up of succinate (a chemical involved in the Krebs cycle) and depleting energy sources (ATP and ADP) are important factors in generating reactive oxygen species such as superoxide. The amount of succinate in the heart cells nearly doubled in the turtles that experienced extremely low oxygen levels. However, mammals that experience heart attack- or stroke-like events have increases in succinate levels that are 10 times higher than normal, suggesting that the turtles are doing something to keep their succinate levels lower. During this time, the turtles were also able to maintain relatively normal levels of ADP while experiencing low oxygen levels, suggesting that they are able to make energy efficiently without oxygen. Keeping succinate levels low is not the only way that an animal can deal with these chemicals, they can also produce large quantities of antioxidants. However, when the team measured how much superoxide and hydrogen peroxide turtles' hearts could remove, the levels were comparable to those of mice and iguanas, neither of which experience prolonged periods without oxygen.

Although the team is quick to point out that surviving without oxygen is very different from having a stroke, as blood is still flowing while the turtles are underwater, these turtles' remarkable ability to keep their generation of reactive oxygen species in check seems to be what is driving their ability to not accumulate damage to their tissues after their winter-long hibernation under the ice. While the sliders may have drawn the short straw in terms of their habitat, they have certainly come up with some remarkable adaptations to make the best of their situation.

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