Stressed-out tadpoles grow larger tails to escape predators

March 5 2013

A wood frog tadpole with a normal-size tail. Photo by Michael Benard.

When people or animals are thrust into threatening situations such as combat or attack by a predator, stress hormones are released to help prepare the organism to defend itself or to rapidly escape from danger—the so-called fight-or-flight response.

Now University of Michigan researchers have demonstrated for the first

time that stress hormones are also responsible for altering the body shape of developing animals, in this case the humble tadpole, so they are better equipped to survive predator attacks.

Through a series of experiments conducted at field sites and in the laboratory, U-M researchers demonstrated that prolonged exposure to a stress hormone enabled tadpoles to increase the size of their tails, which improved their ability to avoid lethal predator attacks.

"This is the first clear demonstration that a stress hormone produced by the animal can actually cause a morphological change, a change in body shape, that improves their survival in the presence of lethal predators. It's a survival response," said Robert Denver, a professor of molecular, cellular and developmental biology and of ecology and evolutionary biology.

The team's surprising findings are detailed in a paper to be published online March 5 in the journal *Proceedings of the Royal Society B*. First author of the paper is Jessica Middlemis Maher, a former U-M doctoral student, now at Michigan State University, who conducted the work for her dissertation.

Scientists have long known that environmental changes can prompt animals and plants to alter their morphology and physiology, as well as the timing of developmental events. For example, tadpoles can accelerate metamorphosis into frogs in response to a drying pond, a high density of predators or a lack of food.

A wood frog tadpole with a normal-size tail.

The term "phenotypic plasticity" is used to describe modifications by animals and plants in response to a changing environment.

"There's been a lot of interest in phenotypic plasticity among developmental biologists and evolutionary ecologists for more than 70 years, but there's been relatively little focus on the mechanisms by which the environmental signal is translated into a functional response," Denver said.

"We've known, for example, that tadpoles can change their body shape in response to predation risk. But until now, nobody knew the basic physiological mechanisms mediating that response. That's what's novel about this study."

The study involved wood frog tadpoles and the stress hormone

corticosterone, which is similar to the human stress hormone cortisol. Tadpoles were collected from ponds at U-M's E.S. George Reserve in Pinckney, Mich., northwest of Ann Arbor.

Some of the tadpoles were reared in tanks at the reserve. Dragonfly larvae, which are known predators of tadpoles, were placed in small cages inside the tanks and were fed live tadpoles. When under attack, tadpoles release chemical signals called pheromones that travel through the water to alert other tadpoles to the presence of predators. The researchers found that tadpoles repeatedly exposed to the alarm pheromone over several days showed elevated whole-body levels of corticosterone.

In the laboratory, other tadpoles were exposed either to the alarm pheromone, to corticosterone or to a chemical that blocks the synthesis of the stress hormone. Over the course of several days, tadpoles treated with either the pheromone or the stress hormone developed deeper tails and shorter trunks than control animals, while tadpoles treated with the pheromone and the hormone inhibitor had shallower tails and longer trunks than those exposed to the pheromone alone.

"A key finding was showing that you could eliminate the effect of the alarm pheromone on tadpole body shape by blocking the production of the stress hormone," Denver said. "If you block production of the animal's hormone and it inhibits the change in tail size, then that's a powerful argument that the production of corticosterone is physiologically important for the morphological change."

In another experiment, tadpole tails were placed in a petri dish containing corticosterone. Over the course of several days the tails grew larger, suggesting that the hormone was acting directly on the tail to make it grow.

"The action of the stress hormone on the tail to cause it to grow was unexpected because in adult vertebrates, including humans, prolonged exposure to stress hormones typically inhibits the growth of tissues," Denver said. "In humans, chronic stress causes muscle wasting."

In another set of experiments, normal-tailed tadpoles and large-tailed tadpoles produced by exposure to corticosterone or alarm pheromone were placed in tanks containing uncaged dragonfly larvae, which were allowed to attack the tadpoles. The large-tailed tadpoles had a higher survival rate than their smaller-tailed neighbors.

The third author of the Proceedings of the Royal Society B paper is Earl Werner, director of the E.S. George Reserve and a professor in the U-M Department of Ecology and Evolutionary Biology.

Provided by University of Michigan