Passive forces help this stick insect bend its legs after a leap.

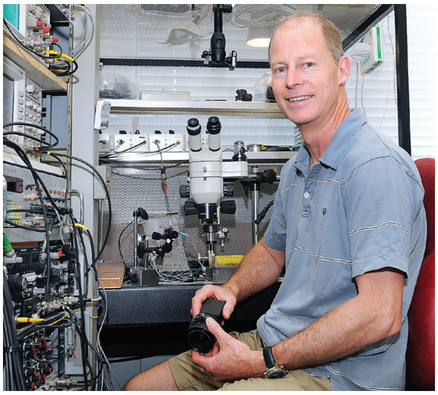
RE-FLEX FORWARD

Insect joints raise ideas for robotics

GRASSHOPPERS FLEX THEIR MUSCLES TO SPRING AHEAD, BUT THEY CAN ALSO MOVE their limbs without using any muscles at all. Instead, they use passive joint forces, according to researchers at the University of Leicester. Passive forces, which are asserted when muscles are extended, are efficient for creating movements because they work predictably and instantaneously. Understanding how insects move is important to more than just biologists: roboticists could use such passive forces in robotic control systems.

Tom Matheson, a reader in neurobiology at the university, and Jan M. Ache, a master's degree student from the University of Cologne who worked in Matheson's lab, wondered how insects control their limbs so well with a nervous system that contains only a few hundred thousand nerve cells. There are 86 billion cells in the human brain.

Inside their hard exoskeletons, insects have muscles that work in opposing, or antagonistic, pairs to move. When one muscle produces movement, it works against a passive antagonist that counteracts its action.



Lead researcher Tom Matheson

During movements, non-contracting muscles generate passive forces. To measure those forces, Ache and Matheson severed the nerve supply of grasshoppers' limbs, leaving the insects unable to contract their muscles. Then, they removed muscles and tendons to examine their passive contributions to certain behaviors, such as scratching.

"We took this to the extreme and removed both of the muscles and all associated connective tissues at the knee joint, and again measured movements following manually imposed deflections of the tibia," Matheson said. "Once these spring-like structures are loaded, passive joint forces are produced which move the joint back towards its resting position."

The grasshoppers' muscles not only work against opposing muscles, but also against passive, springy structures existing within the joints themselves.

"We had assumed the passive forces would be generated in the muscles," Matheson said. "Our new work confirms the general prediction of our modeling, but demonstrates a rather surprising source for some of the passive forces—the joints themselves."

Ache and Matheson tested a few insects in the biological order *Orthoptera*—grasshoppers, locusts, and stick insects. They believe their limbs behave this way to transfer energy from weaker to stronger muscles. The passive joint forces do not help to generate the insects' rapid kicking or jumping movements, which are tibial extensions, but they may decelerate the tibia at the end of a kick.

"The passive joint forces come into play any time the tibia moves into a range where they are effective, regardless of whether the tibia has got there through an active muscle contraction or through the effects of some external force," Matheson said. "In the locust hind leg, when the tibia is extended by an active extensor contraction, it re-flexes as a result of the passive joint forces. If we instead extend the tibia by hand, it re-flexes in the same way."

Axel Schneider, head of the Biomechatronics Group at the University of Bielefeld, said Matheson's research raises questions about the interplay between control and construction in robotics.

"Do agonistic and antagonistic drive systems like muscles have to be symmetric? Is low friction really always the best choice when it comes to joint construction? Rethinking these principles will lead us to new solutions in the design space for future robotic devices," Schneider said. **ME**

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