The secrets of the lowly ground beetle could lead to better tissue engineering

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Jake Socha, assistant professor of engineering science and mechanics at Virginia Tech, is leading a study of insects to determine if their internal fluid flows may provide engineers and scientists with new ideas for how to build better artificial tissues and organs, and for the design of new medically implantable microdevices. The National Science Foundation calls this work part of the Emerging Frontiers in Research and Innovation. Credit: Virginia Tech Photo

The first engineering study of the internal fluid flows of insects, creatures that have evolved efficiently over millions of years, may provide engineers and scientists with new ideas for how to build better artificial tissues and organs, and for the design of new medically implantable microdevices.

Insects are about to be analyzed in a new way by a host of Virginia Tech engineering faculty. They will be using some fancy state-of-the-art equipment, such as a kilometer-long synchrotron x-ray light source, which might be enough to scare any bug. And first up will be beetles, grasshoppers and silk moths because they have some endearing characteristics.

The results could be a deeper understanding of how to manage insects, with the potential to lead to advances in agricultural, commercial and residential pest control. In addition, this first engineering study of the internal fluid flows of insects, creatures that have evolved efficiently over millions of years, may provide engineers and scientists with new ideas for how to build better artificial tissues and organs, and for the design of new medically implantable microdevices.

The National Science Foundation calls this work part of the Emerging Frontiers in Research and Innovation. NSF has agreed to support this effort, spearheaded by Jake Socha, assistant professor of engineering science and mechanics (ESM) at Virginia Tech, for the next four years with a $2 million award.

Virginia Tech's Institute for Critical Technology and Applied Science (ICTAS) has also agreed to support this research as a "Grand Challenge" project for the next three years with an award of $298,466.

Working with Socha is Jon Harrison, a professor at Arizona State University's School of Life Sciences, and three additional investigators from Virginia Tech: Raffaella DeVita and Anne Staples, assistant professors of ESM, and Rafael Davalos, assistant professor of biomedical engineering. ESM's Ishwar Puri, Shane Ross, and Mark Stremler, as well as electrical engineer Masoud Agah and mechanical engineer Pavlos Vlachlos, all of Virginia Tech, round out the team of investigators.

Engineers like to talk about the mechanics and dynamics of flow, and they have studied this field for decades. But Socha and his team want to apply their knowledge of how insects manage fluid flows at the microscopic level for bioengineering purposes. And to do so, they envision harnessing "the agility, dynamic range, low power requirements, self-contained nature, and efficiency of the flows on specific insects' respiratory and circulatory systems to revolutionize the design of microfluidic systems," the team explained.

Insects are often considered to be the most successful group of living species in Earth's history. Unlike mammals, insects breathe by transporting oxygen directly to tissues without the help of a circulatory system. "Their complex air-filled tracheal network delivers oxygen from the environment directly to the tissues, and conversely transports carbon dioxide from the tissues directly to the environment," Socha said.

In previous research, Socha and colleagues opened a new window into the inner workings of insects by using synchrotron x-ray imaging to enable the direct visualization of internal microstructures in living animals. According to Socha, "a key finding was a new form of convective respiration termed 'rhythmic tracheal compression' in which parts of the animal's tracheal system collapse and reinflate on the order of 10 to 20 times per minute."

Although scientists do not yet know exactly why some insects use this respiration process, it could be that "compressions function to target airflow to specific internal tissues, such as the heads of legs, and to keep oxygen partial pressures high for sudden fast movements like escape or for the regulation of acids and bases within their bodies," Socha said.

This knowledge is leading the team of researchers to ask if the pumping of the insect tracheal system can serve as a bio-inspiration for novel engineered systems such as implantable microdevices and for tissue engineering.

Similarly, the insects' circulatory system is profoundly different from mammals. The insect system consists of a simple tube, the dorsal vessel that runs the length of the body, and pushes the insect's blood into the open body cavity. By contrast, the flow of fluid in mammals occurs in a closed system of tubes, produced by pressure pulsations from the heart.

"Insects pump blood through the heart toward the head, and in some species, reverse the flow toward the abdomen. In this open system, once the blood exits the heart or aorta, it courses around tissues and organs to every part of the insect's body, including the tips of the legs, and somehow returns to the heart," Socha said.

Socha explained why they selected three specific insects to study. They chose the ground beetle since it exhibits rhythmic tracheal compression, the grasshopper because its heart is large and therefore relatively easy to image, and the larvae, pupae, and adults of the silk worm moth. The latter are particularly interesting to the researchers because the larvae and pupae appear to deliver gases primarily by diffusion, whereas the adults have air sacs and exhibit abdominal pumping and convective ventilation.

The researchers also have an educational component as part of the NSF grant. Socha has already appeared on the National Geographic and History channels for his work with flying snakes and insects, and National Geographic has expressed interest in this new endeavor. Socha and his colleagues will also work with primary and secondary school teachers in under-resourced classrooms to develop novel replacement lessons that integrate biology and engineering.

Prior to entering graduate school, Socha joined the national Teach for America program and worked as a high school teacher in Centerville, Louisiana. As the only science teacher in a small rural school at the time, he taught all of the middle and high school's science courses.

Source: Virginia Tech (news : web)

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