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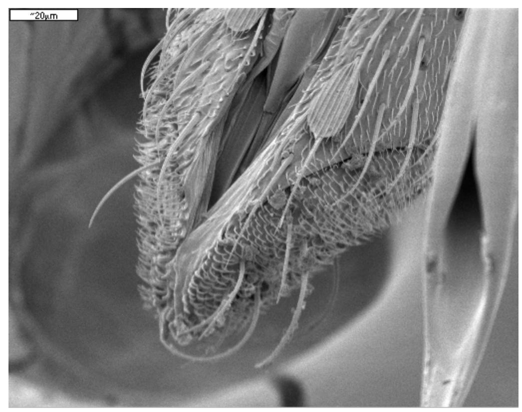
Mimicking Mosquitoes: NC State Researchers Devising Painless Blood-Drawing Method

FOR IMMEDIATE RELEASE

Diabetics may soon have the mosquito to thank for alleviating some of their pain.



A scanning electron microscope image shows the machinery behind a mosquito's blood-sucking prowess: the proboscis (left) and the tip of the fascicle (right).

Researchers at North Carolina State University are collaborating to study, then mechanically mimic, the blood-sucking prowess of mosquitoes. Their ultimate goal is to design a "synthetic mosquito" capable of drawing blood painlessly – an especially attractive idea for the millions of diabetics worldwide who must draw blood several times a day for glucose monitoring. Development of a painless blood collection method could also lessen the trauma for newborns that require monitoring of a variety of different constituents, such as bilirubin levels that signal jaundice.

Dr. M.K. Ramasubramanian, associate professor of mechanical and aerospace engineering and the project's principal investigator, has joined forces with Dr. Jay Tu, professor of mechanical and aerospace engineering, who specializes in manufacturing processes, and Dr. Charles Apperson, professor of entomology, who provides biological expertise, to form what Ramasubramanian called a "perfect combination" of researchers. The project recently was approved for funding by the National Science Foundation.

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The primary objective of the project is to study the specific mechanics of drawing blood by a mosquito. This requires the study of the material and structural characterization of the parts of mosquito anatomy used to accomplish the task – specifically, the proboscis and fascicle. The proboscis acts as a sheath for the fascicle, the actual tube that punctures the skin like a hypodermic needle. After a mosquito lands and locates a place to feed, she – only females bite – lowers her head to the skin's surface, allowing the fascicle to enter the tissue while the proboscis folds to the side.

Studying a slow-motion video of mosquitoes feeding on a student's thumb, Ramasubramanian noted another detail: "See the shaking it does? The mosquito is not just striking like a shot at the doctor's office; it's gently wiggling the fascicle to insert it into the skin. Pretty sophisticated behavior, actually."

Wiggling dynamics – does the fascicle move in a circular motion or just back and forth – might be important to the process, he said. Also, how does the mosquito get the force to drive the fascicle through the skin's surface? By modeling the behavior of the fascicle, a graduate student, Vinay Swaminathan, has discovered that the mosquito is using what is called a nonconservative follower force application strategy by tilting the head to prevent bucking and to apply large forces in the process. In addition, the lateral and longitudinal vibration helps stabilize the fascicle like that of the Indian rope trick. With these sophisticated features, the mosquito is able to generate as much as 10 times the force required to statically buckle the fascicle.

It is well known that the fascicle bends once it is inside the tissue, almost at a right angle, yet it maintains a hollow tube approximately 30 micrometers in diameter that allows the blood to travel through to the mosquito's abdomen. Reproducing this flexibility and small size – a micrometer is one thousandth of a millimeter – while maintaining structural integrity during the insertion process and flow is a critical part of the project. Bending is necessary for easier access to capillaries, but if the tube pinches to less than 5 micrometers, red blood cells could get stuck inside.

"The material that makes up the fascicle is amazing," Ramasubramanian said as he pointed to a super close-up image captured with a scanning electron microscope and transmission electron microscope. "It's like an intricately woven and coated fabric that has both strength and flexibility – a classic composite structure." While other scientists have devised ultrafine hypodermic needles out of silicon, those needles broke easily.

Atomic force microscopy will help determine force deflection characteristics of the fascicle, or how much bending it can take without breaking. Microtensile tests will allow the determination of the properties of the fascicle structure as a composite. Graduate student Rob Gannnon is working on developing the microtensile stage for biological tissue testing. This information will in turn determine the type of material they can use, whether steel, titanium or something else entirely. "We will have to study novel materials, then translate all our research findings into engineering specifications in order to assemble a viable device," Ramasubramanian said. "But there are a host of manufacturing issues to understand first."

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That's where his colleague's expertise comes in, he said. "Tu will be looking at questions like how do we actually take a 40-micrometer-diameter wire and drill a 30-micrometer hole through it – can we use lasers to do it? And how do you assemble a device suitable for mass production?"

And what about the itching? Dr. Ramasubramanian cites Dr. Apperson, who is providing the mosquitoes and is instrumental in helping set up the system of videotaping the mosquito feeding. Mosquitoes inject an anti-coagulant through their saliva into the host's skin when they feed. This keeps the blood from solidifying during draw, but it also causes the allergic reaction in skin that results in swelling and itching. The anti-coagulant would not be necessary for a synthetic mosquito. Still, production of such a novel blood-drawing device and subsequent development of a glucose monitor interface present a sticky challenge. Ramasubramanian knows that the process will be complicated but says the possibilities are endless.

The researchers could, he suggested, design something that fits on the back of a watch. A real mosquito gets 2.5 microliters of blood in one draw, which is sufficient to test for glucose levels – currently available home-use tests already rely on blood from a single finger prick. One synthetic mosquito could keep an almost constant check on a diabetic's glucose levels – automatically and painlessly. Taking the concept one step further, the system could be reversed to inject insulin or other therapeutic agents back into the body when necessary. Such a device could potentially be available in the next five to 10 years, Ramasubramanian said.

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