Podcast Interview: David Hu

PNAS: I’m Sandeep Ravindran, and welcome back to Science Sessions. Insect-sized flying robots could have numerous applications, such as surveillance or search-and-rescue operations. To figure out ways to design such robots to be able to fly even in challenging weather conditions, Georgia Tech mechanical engineering and biology professor David Hu looks at how real flying insects manage to successfully navigate difficult outdoor environments. In a recent PNAS paper, Hu described how mosquitoes survive collisions with raindrops that are about 50 times heavier than them. Hu spoke to us over the phone about his research and how he got interested in this topic.

Hu: No one really had asked the question of how animals deal with rain, in particular flying animals. And it’s of interest these days because there are a lot of new abilities to build robots and flying devices that are about the size of insects. There’s interest by the military and all sorts of agencies, in building a robo-fly, something that can fly like an insect. For these things to really work, it’s important that they deal with nature’s complex conditions outdoors, and that can include wind gusts and rain. That’s what we set out to look at.

PNAS: Why did you decide to study mosquitoes rather than some other flying insect?

Hu: The primary reason is because they’re the easiest to hit with a raindrop. They only fly a meter per second or something like that, whereas raindrops will fall at around 10 meters per second, so the mosquitoes are really easiest to work with. They’re also involved in all sorts of disease transmission, like malaria, so there’s a lot of interest in understanding how mosquitoes are affected by weather patterns and things like that. The more we can understand about what the limitations of these kinds of insects are, the closer we’ll be able to find ways to restrict their access to certain places.

PNAS: Hu describes how he captured the collisions between raindrops and mosquitoes on video.

Hu: The first experiment we tried had a bucket of mosquitoes, and then we tried to drop raindrops from the third storey of our building, and you can imagine it’s impossible to aim these things. So eventually we shrunk down, basically if you imagine you have a very tall container, full of mosquitoes, a hundred mosquitoes flapping, it increases the chances of being struck by a drop. And we film with a special camera. It’s a high-speed camera that can film about 5000 frames per second. And that’s necessary because they flap their wings about 500 times a second.

PNAS: What did you find?

Hu: The most surprising thing we found is that no mosquitoes died. And this is surprising because the raindrops are about 50 times heavier than a mosquito, so that’s the equivalent of us being hit by a Volkswagen Beetle, imagine just cars falling out of the sky. They basically had two primary ways to survive these drops. The most important one is that they’re really lightweight, and it changes the physics of impact. For example,
if you have a balloon, and you try to punch it with your fist, it’s really hard to pop. And part of the reason is because by Newton’s law, the balloon only resists a force proportional to its weight, so this balloon sort of sticks to your fist, and you can’t really apply a large force to it. And that’s what happens with mosquitoes when they’re hit by the drops. Because they’re so much lighter, they don’t slow the drop down at all, and they only get the equivalent of a feather’s weight of force, like a feather’s just stroking them. The second reason is that when they get hit by the drop, they’re able to separate from the drop before they hit the ground. So that’s also very important, because if they stick to the drop too long, they’ll both head to the ground at a very high speed. And they do that by virtue of them being very hydrophobic. They have a lot of hairs on their body, and that makes them very slippery to the drop. And also their long spindly legs catch the air, and basically get flung off the drop. So by these two mechanisms, they reduce the impact force and they escape the drop before hitting the ground, they basically continue flying, and the fly as if it’s not even raining. This also tells us that as micro-flying air vehicles get smaller, surprisingly they get more robust to impact.

**PNAS:** Hu says there are a few situations where rain might actually kill a mosquito.

**Hu:** They’ll stick to the drop for about 5 to 20 body lengths. So if they’re flying very low, they could basically be pinned between the drop and the ground. And that’s exactly how you want to kill a mosquito. For example, if a mosquito’s around your head, you try swatting it with your hand, no matter how hard you hit it, you’re not going to kill it, you’re just going to sort of bounce it around. But if you see one on the table, you might be able to just [slapping sound] smack it. That’s what the drop can do. It turns out if it gets thrown into the ground, a lot of what kills them also is that they get stuck to puddles and things like that, and they can no longer fly.

**PNAS:** Hu is currently studying the effects of other natural conditions on mosquito flight.

**Hu:** There’s still a lot of questions to ask about how mosquitoes survive these sort of challenging outdoor conditions. The next thing we’re looking at is how they survive fog, similar to the kind that’s made by insecticides. One of the surprising things we find is that when the fog is dense enough, they can’t fly at all, they just fall out of the sky. It’s very surprising that there’s certain things like raindrops that they have no problem with, even though the raindrops are 50 times heavier than the mosquitoes. And there are these tiny little drops of fog, that it turns out they do have problems with. By sort of probing with these different kinds of scenarios, I think we can get a bigger and more cohesive picture of insect flight.

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