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Discussions

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Faculty Spotlight: Dr. Jessica Fox

Faculty Spotlight

An interview with

Dr. Fox

by Viral Mistry and Lauren Spizman

Dr. Jessica Fox is an Assistant Professor in the Department of Biology who specializes in neuroscience. In this interview, she discusses her research into the sensory organs of fruit flies, the role these organs play in flight coordinations, and the nature of data collection in general. Finally, she expounds on her personal motivation toward entomology and how research could pave a similarly formative path for prospective scientists.

Q: Can you start by telling me what work you do here on campus as a researcher?

A: I'm a neuroscientist. The Biology Department has a bunch of neuroscientists, and all of us work on invertebrates. In our lab we're studying how flies take information from the environment and use it to move around. We focus mostly on flight and mechanoreceptors, but a lot of our work lately has been studying how flies use multiple modes of sensory systems to collect information from their environment and figure out where to go from that.

Q: I also saw a lot of your research involves fly halteres. Would you mind going into that and also explaining what fly halteres are?

A: Fly halteres are funny little sensory organs, and somehow I have become one of the world's experts on them; there's not that many haltere researchers out there, which is surprising given how important halteres are for flies. Halteres are mechanosensory organs; they're reduced hind wings. Most insects have four wings, two in the front, two in the back.

Flies actually have their second set of wings condensed into little club-shaped structures,

"In our lab we're studying how flies take information from the environment and use it to move around."

Photo Provided by Dr. Jessica Fox

"Fly halteres are funny little sensory organs, and somehow I have become one of the world's experts on them."

and those are the halteres. They don't generate lift, they just contribute to sensation. The job of the halteres is to detect body rotations, so the halteres flap up and down while flies fly. At the base of the halteres, there are sensory cells, and when those are deformed by various forces, they send information to the nervous system. If you cut the halteres off of a fly, they can't fly.

Q: Are halteres specific to flies or a particular species of flies?

A: All flies have halteres! There are different orders of insects and they're all named for their wings. The big four insect orders are the following: Coleoptera, which means "sheath" wings and includes beetles; Hymenoptera which means "membranous" wings, and includes bees, ants and wasps; Lepidoptera, which means "scaly" wing, and includes butterflies and moths; Diptera, which means two-wings includes flies.

All flies have halteres such as mosquitoes. Basically if you have halteres, you're a fly; if you don't have them, you're probably not a fly, though there are a couple of flies that have lost their halteres over the course of evolution and don't have anything, but none of those flies can fly.

Q: How did you get into this area of insect research?
A: I've always been interested in insects and biology, and the college I went to offered an entomology major in addition to the biology major. I liked taking the insect-based classes, so I majored in entomology as an undergrad. I didn't know exactly what I wanted to do, but I got interested in insect behavior, how animals experience the world, and how they use that information. I started doing research in an insect behavior lab, then decided to get my PhD in neurobiology. Entomology is where you see all this research on insects, but I'm also interested in neuroscience. I work on the nervous systems of bugs, and I've always been interested in flight control. All the research I've done has been on flight control, and my PhD work was about halteres.

While in my postdoctoral work I had mostly studied vision and not halteres, now that I have my own lab I'm combining those two subjects. I'm trying to understand how the haltere system and the visual system work together to get flies where they need to go.

Q: Can you talk a little bit about the differences between insect behavior and higher-order mammalian behavior?
A: It's really similar. It doesn't always look that similar, but if you look at the retina of a human and the retina of an insect they are basically the same. The cells have different names and are shaped differently, but they're wired the same way. For example, we've studied for a while how humans control their gaze. We can move our eyes around inside our heads, and figure out what we want to look at and where our heads are pointing. We do that using our vestibular system combined with visual information.

Flies do the same thing, but their eyes are basically fixed to their heads, so they're easier to study. When studying flies, you only have to look where their head is pointing, which is where they're looking. It's even easier with the halteres because the haltere is outside the fly. So instead of having to do surgery in their brain, we can do these manipulations super easily.

For example, I can have an undergrad come in, cut the halteres off of ten flies in one afternoon, observe their behavior, and collect data about fly behavior without halteres. In contrast, if we were doing this in a mouse, I'd have to fill out some forms, I'd have to have the student be specially trained, actually do the surgery, let the mouse recover, and we'd have one mouse finished after a couple weeks.

We always try to look at like what can this give us for humans, but a lot of our work is not for inspiration to cure human diseases. Although that's interesting to us too, we're mainly looking for inspiration on how to make things fly. Flies have had two hundred million years to figure out how to fly, and they're quite good at it. If we can make a machine that flies like a fly does--that would be amazing. Thus, a lot of our work is funded by the Air Force. We're interested in flies not just because flies can be a good model for humans, but also because flies are really cool and they are able to do things that we or our flying machines can't.

Q: How would you say your research and the work you do affects your teaching style and the classes you teach?
A: I teach Sensory Biology because I'm interested in sensory systems. What I think is nice about working with insects is that the amount of training required to do interesting experiments is not that high. Some of our experiments do take a lot of training; for example, my grad students do electrophysiology experiments, which involve cutting open flies and recording the activity of individual neurons in their nervous system. It takes practice and skill to place an electrode into a tiny nerve cell and record data from it. On the other hand, most of the work undergrads do involves gluing flies to sticks and putting them in flight arenas to have them do experiments for us. We can show them

different kinds of visual stimuli and record their responses.

If you're interested in getting more involved in this research, you can design your own experiments and write a little bit of code to change the stimulus, allowing you to ask a new question about how flies are experiencing the world. I've had a lot of undergrads do really well in my lab. In fact, we just got a paper accepted last week and the 2nd and 3rd authors are both undergrads. I think it's easier for undergrads to work here than in a mouse lab or a primate lab because you're allowed to do more here. It's just easier to get your hands on the experiments in a fly lab.

The question of sensory biology is how do we take information in and process it. I like teaching my sensory biology class because I can talk about halteres, which are a specific type of mechanoreceptor. It's nice to back up a little bit to a big picture question, as I do when I'm teaching about how the visual and olfactory systems work together.

Q: What advice would you give to an undergraduate student interested in research?

A: Get involved as soon as you can! I think getting involved in research early is the best thing to do. I have seniors come to me and say they want to do their capstone project in my lab and it's just not enough time for them to produce something interesting by the end of their senior year.

"...getting involved in research early is the best thing to do."

My students who have been on the paper that was accepted last week started when they were freshmen. They both came and went during their time here, but still had plenty of time to do this project. If you don't find a lab that's doing what you want to do, keep looking. If you don't find the first lab that accepts you to be interesting, you can switch.

I think undergrad research is one of the big strengths we have at CWRU. We don't require all of our students to do it, but if you don't do it at CWRU, you're missing out on one of the things that makes us different from other universities. For a school this size, we have a ton of labs that you could work in, not just in the biology department but also in the School of Medicine or the Cleveland Clinic.

I always encourage my advisees to do research, and I try to get them to do it as soon as possible. It's a good way to make friends who are not all undergrads. If you're an undergrad and join my lab, I have two grad students and a post-doc. These connections can be ones you make for life. It's good to meet people who are a different age and at a different career stage. They can counsel you on potential career paths beyond graduation.

This interview has been edited for length and clarity with the consent of Dr. Fox.

A Selection of Dr. Fox's Work

Mureli, S and Fox, JL. (2015). Haltere mechanosensory influence on tethered flight behavior in *Drosophila*. Journal of Experimental Biology 218, 2528-2537. doi: 10.1242/jeb.121863

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Daniel, TL, Dieudonne, A, Fox, JL, Myhrvold, CA, Sane, SP, and Wark, B. (2008). Inertial guidance systems in insects: from the neurobiology to the structural mechanics of biological gyroscopes. Navigation 55 (4): 235-240.