Using fruit flies to understand how we sense hot and cold

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Drosophila melanogaster

Innately, we pull our hand away when we touch a hot pan on the stove, but little is known about how our brain processes temperature information. Northwestern University scientists now have discovered how a fruit fly's brain represents temperature, mapping it neuron by neuron, which has implications for understanding the much more complex human brain and how it responds to sensory stimuli.

"The brain is a beautiful machine, and one of the new frontiers in biology is to understand how it works," said Marco Gallio, who led the research. "The fruit fly is a fantastic model in which to study how the brain controls behavior, and it can help us understand how sensory circuits work in humans."

Gallio is an assistant professor of neurobiology in Northwestern's Weinberg College of Arts and Sciences.

In a study of *Drosophila melanogaster*, Gallio and his team uncovered a coordinated ensemble of neural responses to temperature in the fly's brain. In imaging the fly brain as it responded to hot or cold environments, the researchers found that multiple neural pathways carry from the antennae different types of information about temperature, and the pathways converge in three key areas in the brain.

Most neurons respond to either hot or cold, but some trade accuracy for speed. These neurons are good at alerting the animal of a sudden temperature change, but they quickly stop responding and leave the job of reporting how hot or cold it is to different neurons.

In a surprise finding, the researchers also learned that a third type of neuron responds to both hot and cold. As both hot and cold temperatures can be quite dangerous to the small fruit fly, this cell type may convey a generic "danger" signal associated with temperature change, the researchers said.

"Humans are more resilient than flies in reacting to temperature change," Gallio said, "but the principles we are finding in the fly brain—the logic and organization—likely are the same in both. Whether human or fly, the sensory systems have to solve the same problems, so they often do it in the same ways."

The work represents the first comprehensive mapping of the brain circuit that processes temperature information in any animal. The study will be published March 4 by the journal *Nature*.

"We decided to focus on temperature as one of the most fundamental sensory modalities," Gallio said. "Much like in the fly antenna, the sensory neurons in our skin respond to either hot or cold temperature. The brain knows what the hand feels by simply keeping track of which cell type is active—what we call a 'labeled line' system."

In their study, Gallio and his colleagues discovered that the fly brain is able to extract a range of information from the activity of hot and cold neurons. Their results also suggest how the fly can use this information to guide attractive or aversive behaviors.

The three types of neurons the researchers identified are:

- Neurons that are very fast at signaling the onset or offset of heating or cooling (fast adapting, "narrowly tuned")
- Neurons that respond more slowly but are much more accurate in reporting absolute temperature (slow adapting, "narrowly tuned")
- Neurons that respond to both hot and cold and are critical to flies avoiding hot and cold environments ("broadly tuned")

The fruit fly is a great model system in which to study the processing of sensory stimuli, Gallio said. The fly has quite complex behaviors coupled with a genetically and anatomically simpler nervous system than ours.

"We know very little about how neurons communicate in our brain to produce our behavior and emotions, so we study innate responses in model systems such as the fruit fly to understand basic brain functions," Gallio said. "Then we can apply these intellectual tools to understand our brain and how it controls behavior."

Gallio's group is one of only a few in the world that is systematically studying temperature sensing in fruit flies. In earlier work, Gallio identified where hot- and cold-sensing neurons are located on the fly's antenna. He next wanted to know where in the brain these signals from the periphery were sent, which led to the study reported in *Nature*.

In the study, the researchers first used a photolabeling strategy to trace the connections that relay peripheral temperature information to the brain. They found the signals largely converge onto three target regions: the Mushroom Body and the Lateral Horn (both well-known centers for sensory processing) and the Posterior Lateral Protocerebrum (now defined as a major site of thermosensory representation).

Next, using in vivo calcium imaging, the researchers identified the thermosensory projection neurons activated by either hot or cold stimuli ("narrowly tuned" neurons) and those that respond to both heating and cooling ("broadly tuned" neurons).

After learning that the neural information took different paths to the brain, Gallio and his team initially were puzzled. "We found there was an elegant answer," Gallio said. "Some neurons respond to only hot, some neurons respond to only cold, and some neurons respond to both hot and cold. They all converge in the brain, where all the messages are orchestrated into a cohesive response."

More information: Temperature representation in the Drosophila brain, DOI: 10.1038/nature14284

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