Can taste neurons detect odorants?

The common view is that taste is devoted to the detection of sapid molecules while olfaction is specialized in the detection of volatile molecules. This distinction holds for humans as well vertebrates, and is taken for granted also for invertebrates like insects. By using *Drosophila melanogaster* as an insect model, we challenged this view by showing that gustatory neurons to sense some volatile molecules but not others, when delivered at high concentration. Such a situation is likely to be encountered when flies are feeding upon a substrate, which contains not only non-volatile molecules like sugars or alkaloids, but also a constant outflow of molecules emanating from the food on which scores of microorganisms like bacteria and yeast are striving.

Initially, we defined 3 objectives to this project: 1) assess if odorants can be detected by taste neurons, 2) evaluate if odorants can modify the detection of tastants, and 3) investigate the transduction mechanisms involved in the detection of odorants by taste neurons. To achieve these aims, we thus proposed to try out different electrophysiology techniques (and develop new techniques if needed) to find out a suitable technique for recording from taste neurons from taste sensilla in response to odorants. For the second aim, we proposed to collaborate with other laboratories having the adequate technical expertise to develop a technique to stimulate taste sensilla with tastants and odorants simultaneously, and for the third aim we proposed to selectively ablate different neurons in a taste sensilla using available genetically modified Drosophila strains, to find out the type of neuron involved in detecting odorants.

Experimental procedures

Currently available techniques to record from gustatory sensilla are mostly adapted to molecules in a water solution. To this mean, people usually cap the tip of a hair with a fine tip glass capillary (10 µm or less), containing a liquid with the tastant and an electrolyte to conduce electrical potential to a low noise amplifier. The tastant molecules diffuse from the inside of the capillary to the dendrites of the gustatory neurons through a nanoscale pore located at the tip of the sensillum. This is one of the morphological characteristics of insect gustatory sensilla that is quite distinct from insect olfactory sensilla, which have a cuticula covered with even more minute nanopores through with odorants captured by the external cuticula diffuse and penetrate into the shaft of the hair.

While volatile molecules are can be solubilized by dissolving them in water using a solvent like ethanol or DMSO, this approach is of limited use because the solvent has a definite negative impact on the lipophilic membranes of the neurons. We obtained good recordings of the electrophysiological activity of the gustatory neurons by inserting a tungsten electrode at the base of a sensillum, which allowed us to stimulate the tip of the sensillum with vapors of volatile odorants. Different odorants like acetic acid, acetone, 1-octanol, 1-octen 3-ol, and isoamyl propionate were tested in the vapor phase by putting the chemical in liquid phase in a capillary, allowing it to evaporate, and then blowing it to the tip of a taste sensilla by flowing pressurized air through the capillary. This technique allowed us to deliver high concentrations of these different chemicals toward taste sensilla of the proboscis, and to demonstrate that some taste sensilla (but not all) are responding to these volatile chemicals. In the sensilla which show a change in the firing rate of the neurons, whereby the neurons are excited or inhibited by the volatile molecules, it was further found that not all neurons responded to these chemicals. This suggests that taste neurons are equipped with membrane receptors sensitive to the chemicals we have tested, and that these receptors

Attempt was made towards uncovering the mechanisms behind detection of odorants in taste sensilla by looking at response of the above mentioned chemicals in mutant Drosophila lines affected in the expression of olfactory/gustatory receptors (IR25a and IR76b mutants). Selective ablation of the sugar sensitive neuron and bitter sensitive neuron was also tried by crossing genetically modified lines (UAS-Gal4 system). Owing to problems either in the Gal4 lines (Gr5a-Gal4 and Gr33a-Gal4) or the UAS-DTI line, ablation of the targeted neurons could not be achieved within the frame of this project.

Insect taste neurons can detect some odorants

Robust electrophysiological responses were obtained from taste sensilla in response to acetic acid, acetone, 1-octanol, 1-octen 3-ol, and isoamyl propionate. This proves that chemicals in the vapor phase can be detected through the taste sensilla showing that the taste system in insects can detect not only sapid molecules in a water solution, but also molecules from the air as well. Behavioral experiments complemented the electrophysiology results. It was found that flies ablated of their olfactory organs (antennae and maxillary palps) avoid acetic acid vapors just like unmanipulated control flies. Mutant flies (poxn) that lack taste sensilla did not avoid acetic acid vapors after ablation of olfactory organs, showing that vapors sensed through the taste sensilla impact the chemo-aversion behavior of flies. It was also found that aversive chemical vapors (acetic acid) impacts the appetitive behavior of flies. Flies will normally extend their proboscis in response to sucrose solution. It was found that the presence of acetic acid vapors inhibited the proboscis extension response in anosmic flies, showing that odorants can modify the detection of tastants by direct action on the peripheral taste receptors.

Potential impact

This is the first time such a comprehensive study has been directed towards evaluating the capabilities of taste neurons to detect volatile molecules. Actually, although scarce observations suggested that taste neurons might respond to volatiles, such responses were considered so far like experimental artefacts rather than having a biological meaning. Our observations indicate that volatiles should have a direct impact on how sapid molecules are detected and that taste neurons are equipped with receptors capable of interacting with such ligands. These observations are thus not only important for understanding how insects detect their chemical world in their natural environment, it also suggests that most studies devoted to understand the physiology of taste neurons have completely neglected these classes of molecules, on the (wrong) assumption that volatiles have no effect on taste.

Interaction between different sensory modalities is usually known to occur at the secondary level of higher information processing centers (brain), but we are showing that it can occur also at the primary level of signal detectors itself. Our work challenges the view that odorants and tastants are detected through different chemosensory systems (olfactory versus gustatory). It opens up new questions regarding the evolution of chemosensory systems and puts forth the need to think whether insects can be considered to have a separate gustatory system or whether it should be considered as a general chemosensory system.