Nature Reviews Neuroscience | Published online 29 Jun 2017; doi:10.1038/nrn.2017.82

SENSORY SYSTEMS

Tasting the water

Although how the brain senses internal water balance has been well studied, how water in the external environment is sensed is less well understood. Here, Zocchi and colleagues determine that the mammalian taste system is crucial for the detection of water in the external environment.

The process of taste sensation involves contact of saliva on the tongue to tastants, which are detected by taste receptor cells (TRCs) that in turn activate taste nerves. Different subpopulations of TRCs encode different taste qualities (such as sour or sweet). In this study, disruption of activity of each of these subpopulations revealed that only acid-sensing TRCs (which express polycystic kidney disease 2-like 1 protein (PKD2L1)) seemed to play a part in water detection: disruption of synaptic transmission by expression of tetanus toxin (TeNT) selectively in these TRCs (Pkd2l1TeNT) abolished the response of taste nerves to water.

In vivo extracellular recordings revealed that, whereas application of water to TRCs evoked strong action potentials in taste nerves, saliva had no effect. Saliva consists of water, ions and enzymes, and the triggering of action potentials by water application suggested that prior exposure to certain ions in saliva could be required for this response. Indeed, when bicarbonate ions (but not other ions) were removed from saliva, the response of taste nerves to subsequently applied water was abolished.

PKD2L1-positive TRCs express carbonic anhydrase 4 (CA4) on their extracellular membrane that reversibly catalyses the conversion of carbon dioxide (CO_2) and water into bicarbonate and protons. The authors hypothesized that the washing away of bicarbonate-containing saliva by water could drive a local increase in production of bicarbonate and protons, and that the latter would activate acid-sensing TRCs and trigger activation of taste nerves. Indeed, taste nerves in mice lacking CA4 or in wild-type mice whose oral cavity was treated with CA4 inhibitors showed substantially attenuated responses to water, whereas responses to other tastes were unaffected. Together, these observations support the notion that CA4-mediated local pH change is involved in water responses.
To investigate whether this response to water was involved in water detection, the authors generated mice that expressed channelrhodopsin-2 (ChR2) in PKD2L1-expressing TRCs (Pkd2l1ChR2). In a behavioural model in which attempts to drink from an empty feeding bottle initiated photoactivation of Pkd2l1ChR2 TRCs, water-deprived Pkd2l1ChR2 mice demonstrated strong drinking-like behaviour towards light, suggesting that acid-sensing TRCs mediate external water detection.

Because of their sensitivity to acids, PKD2L1-expressing TRCs were originally identified as candidate sensors of sour taste, which is generally associated with aversive taste like that of lemon. The authors finally tested if TRCs are indeed involved in sour-induced aversion. Interestingly, silencing these TRCs in Pkd2l1TeNT mice did not affect sour-induced aversion, and photostimulation of the same population in Pkd2l1ChR2 mice failed to induce aversion. These findings indicate that acid-sensing TRCs are not essential for sour-induced aversion but are involved in the detection of water in the external environment via a local pH change, which can trigger drinking response in thirsty animals.

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ORIGINAL ARTICLE Zocchi, D., Wennemuth, G. & Oka, Y. The cellular mechanism for water detection in the mammalian taste system. *Nat. Neurosci.* http://dx.doi.org/10.1038/nn.4575 (2017)