Humidity increases odour perception in terrestrial hermit crabs

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Adult Coenobita clypeatus hermit crab using a discarded snail shell for protection: Both pairs of antennae are clearly visible. Olfactory receptors are located on the inner pair of antennae, which are bent upwards. The crabs' sense of smell is still underdeveloped in comparison to insect olfaction. © MPI for Chemical Ecology/ Krl'ng

(Phys.org) -- Max Planck scientists have found out that the olfactory system in hermit crabs is still underdeveloped in comparison to that of vinegar flies. While flies have a very sensitive sense of smell and are able to identify various odour molecules in the air, crabs recognize only a few odours, such as the smell of organic acids, amines, aldehydes, or seawater. Humidity significantly enhanced electrical signals induced in their antennal neurons as well as the corresponding behavioural responses to the odorants. The olfactory sense of vinegar flies, on the

other hand, was not influenced by the level of air moisture at all. Exploring the molecular biology of olfaction in land crabs and flies thus allows insights into the evolution of the olfactory sense during the transition from life in water to life on land.

Crabs and flies are arthropods. Like many other life forms, they made a transition from water to land life in ancient times. The ancestors of the family of terrestrial hermit crabs (Coenobitidae) probably took this step about 20 million years ago. Today, hermit crabs live their entire lives on land, except for the larval stage. Odour signals are important cues for the crabs' search for food. In order to detect odour molecules outside the water on land, the sensory organs of arthropods had to adapt to the new, terrestrial environment. How did sensory perception evolve during the transition from sea to land?

"The land hermit crab Coenobita clypeatus is an ideal study object to answer this question," says Bill Hansson, director of the Department of Evolutionary Neuroethology at the Max Planck Institute for Chemical Ecology in Jena, Germany. The animals live in humid regions close to the sea and regularly visit water sources. Females release the larvae into the sea, where they grow into young crabs. These young crabs look for empty snail shells and live on land. They eat fruits and plants. This way of life suggests that the olfactory sense in crabs is still at an early stage of development.

In a series of experiments, Anna-Sara Krång, who worked on an EU-funded Marie Curie Project, tested 140 odour substances with different chemical properties, such as acids, aldehydes, amines, alcohols, esters, aromatic compounds, and ethers. She measured the excitation in the neurons of the crabs' antennae in response to single substances. The results were so-called "electroantennograms" (EAGs) which measured tiny voltage changes across the cell membranes in the microvolt range.

A striking feature of the subsequently performed bioassays was that the crabs' behavioural responses to odorants were more obvious and much faster at a significantly increased humidity, assumingly due to an enhanced electrical excitability of their antennal neurons. The EAG showed in fact a reaction at the neurons which was three to ten times stronger if active odours were applied at a higher humidity. In contrast, antennal neurons of vinegar flies did not show any differences and responded evenly and independently of the degree of humidity.

The analysis of the experiments revealed that hermit crabs responded primarily to water-soluble polar odorants, such as acids, aldehydes and amines, because their effect may be easily enhanced in humid air. These results suggest that crabs have so-called ionotropic receptors in their antennal neurons. Such receptors were found in other crustaceans, such as water fleas (Daphnia pulex) or lobsters (Homarus americanus). In the water flea genome, no genetic information was actually found for so-called olfactory receptors, which are responsible for the highly sensitive olfactory system in insects, such as vinegar flies. Although the receptor genes which are present in the hermit crab genome have not been elucidated yet, the scientists assume that olfaction in crabs is mediated by the original, evolutionarily older ionotropic receptors.

It is generally believed that the ancestors of many insect species made the transition from the seas to the continents during much earlier geological eras and that insects have adapted their olfactory system to life on land very well. Terrestrial crustaceans, on the other hand, may be able to use their sense of smell on land thanks to a basic molecular "equipment", but their olfaction is still quite underdeveloped in comparison to insects. Therefore hermit crabs usually stay near the coast: not only because of the short way back to the sea where they reproduce, but also because of their limited sense of smell which does not allow them to orient themselves without any problems in the dry air of the heartlands.

More information: Anna-Sara Krång, Markus Knaden, Kathrin Steck, Bill S. Hansson, Transition from sea to land: olfactory function and constraints in the terrestrial hermit crab Coenobita clypeatus, *Proceedings of the Royal Society B*, June 6, 2012, online first. Doi: 10.1098/rspb.2012.0596