Research on mechanisms of the neural system based on chemical senses: From reception to feeding behavior

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Summary of Research

Molecular and Cellular Mechanisms in the Neuro-Information Systems of the Living Organisms, with a Special Focus on Chemical Senses

Human beings have a natural ability to discern various tastes and smells called gustation and olfaction, respectively, but these abilities are not limited to highly evolved mammals. They are found in most animals, ranging from primates to reptiles or insects. Since gustation and olfaction are fundamental sensations directly linked to feeding, they are believed to be main functions of the neuronal systems from the very start of the evolutionary process. Nevertheless, only recently we have begun to understand how information on these common or basic sensations is generated and processed in the brain.

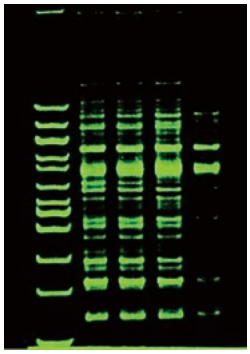
At our laboratory, through studies of the chemosensory nervous systems, we investigate the operational mechanisms of not only the olfactory and gustatory neurons but also the brain and the neuro-information system.

Olfaction in Vertebrate

Professor Nakamura's major interest during his undergraduate years was visual perception. His subsequent research after he realized that methods used in the vision research could be applied to the study on olfactory perception leaded to clarification of the mechanisms by which olfactory cells (olfactory receptor neurons) are electrically excited in response to stimuli with odorants.

His research showed that when olfactory cells are exposed to odorant molecules and become electrically excited, cAMP produced in the cells by the sequential activations of the receptors (proteins that receive the odorant molecules) and the enzymes carries out the signal as a second messenger.

Since then, his laboratory has concentrated on the studies of the olfactory and the related neurons. During these studies, Professor Nakamura realized the importance of genetic engineering to carry forward the study of the neural pathways. His laboratory is founded on his resolve to create an interdisciplinary laboratory integrating electrophysiology, bio-imaging, and molecular biology.

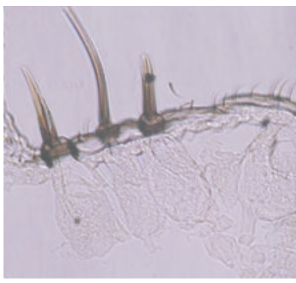


Electrophoresis

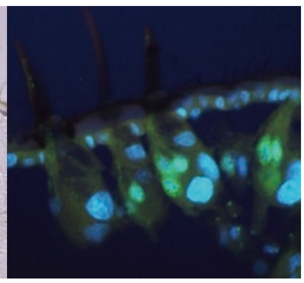
Gustation in Invertebrates

As a next step in his research, Professor Nakamura is applying techniques established in the olfaction studies to studies of the gustatory neurons in insects.

The mechanism of gustatory reception is quite similar to that of olfactory reception. When insect gustatory cells receive sugar molecules, for example, the cells themselves generate impulses, and transmit the information directly to the brain. Today, we can trace path ways from the receptor cells to the entrance of the brain. However, as many things including the mechanisms for activating taste cells are not fully understood, the insect gustatory system is still one of the major subjects.



Fluorescence microscope image of same sensory hair



Bright field microscope image of insect sensory hair

Keywords

Molecular biology; electrophysiology; calcium imaging; patch clamp technique; chemosensory perception (gustation, olfaction); feeding behavior; vertebrates (mammals, amphibians); insects

Affiliations	Zoological Society of Japan; Physiological Society of Japan; Japanese Society for Comparative Physiology and Biochemistry; Japanese Association for the Study of Taste and Smell; Society for Neuroscience (USA)
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Odor Response in Newts

A current joint study focuses on odor response in newts. As in many other animals, odorant-binding proteins are secreted in the mucus at the receptor site in the nose of the newt. These proteins exhibit a unique reaction to odor. Although this protein is not a receptor for olfactory cells, it can bind some odorants. Studies are underway to develop a method to apply this protein to odor sensors.

The lab's resident Japanese fire-bellied newt

The Molecular aspects of Memory and Learning on the Brain in Flies

One unique and current study is to examine the molecular aspects of memory and learning on fly brains. Normally, flies love sugared water. However, by experiencing sugared water together with odor of limonene (an essential oil with lemon flavor), flies are conditioned to avoid the sugared water alone. By the comparison between the conditioned and the control flies, we found that 20 genes were newly expressed in the brains by the conditioning. This result suggests that new proteins were synthesized and functioned in the brains by the conditioning. Of the 20 genes identified, 10 genes show new and unique sequences and the functions of proteins coded by these genes are unknown. Currently, members in the laboratory are trying to elucidate what these genes are.

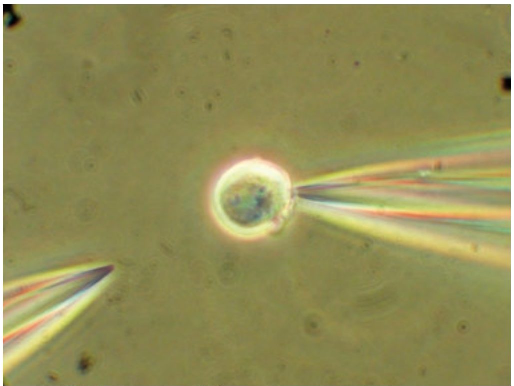
Experiment using flies

Advantages

An Electrophysiological Study Involving Applying the Patch Clamp Technique on Nanometer-Level Subjects

For the considerable number of years our laboratory has concentrated on cellular studies based on an electrophysiological approach, our patch clamp technique has reached an impressive level.

The patch clamp technique is an experimental technique used to examine the properties of ion channels and other structures by observing the electrical characteristics of the cell membranes, such as membrane potential and conductivity. In a patch clamp experiment on the olfactory cells, we begin by isolating the cells. We then move a glass electrode towards a moving cilium (measuring approx. 200 nanometers in diameter) under a microscope until it contacts the cell membrane of the cilium. The small membrane patch sticked to the electrode tip is cut out to form the inside-out configuration. The channel activity in this membrane patch induced by applying signal transducing molecules to the intracellular side of the membrane can be observed electrically. This ability to use the patch-clamp technique to nanometer-level subjects is among our laboratory's strengths.



Patch clamp experiment (top) and electro-olfactogram recording experiment (bottom)

A Solid Combination of Electrophysiology and Molecular Biology for Studies of the Neuro-Information System

Another advantage we offer is that our approach is based on a solid combination of electrophysiology and molecular biology to explore neurons. We believe that studies of the neuronal mechanisms in the smell and taste based on the physical and material foundations using electrophysiology and molecular biology would lead to the thorough understanding of the sensory phenomena.

Another key strength is that experiments on a wide range of animals, from vertebrates to insects are possible. We can perform experiments and validations to determine whether the results of experiments on the “micro brains” of insects can be applied to vertebrates, as well as experiments on the specific animals.

Future Prospects

Applying Our Research Results in Various Areas

Much remains to be resolved in the domains of our current research, and we will pursue the study of the neural system. We have learned that there are similar mechanisms functioning in the visual and olfactory perceptions, as well as in the vertebrates and insects.

Thus, a successful approach established for one type of perception or for a certain species will be applied to a wide range of researches in a vast frontier of new challenges. In addition to tackling the mystery of unresolved mechanisms, we are interested in finding ways to apply our results to other fields of study.

For example, the results of our studies on taste and smell may contribute to developing dieting programs or countermeasures to lifestyle disorders. Our results may also find applications in agriculture. Analyzing the taste and odor perception of pest insects and identifying odorants or tastants that repel them may lead to the development of a new pest control method without the use of pesticides.