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FOCUS

PROJECT

Comparative Evolutionary Analysis of the Organization and Function of the Neural System of the Octopus and the Implications in Relation to the Octopus' Unique Body Plan and Behavior@

Below I describe several of the ideas that I intend to examine

- The neuromuscular system of the octopus arm is distinctly different from those of vertebrates and arthropods. What functional advantages does this unique neuromuscular system achieve for the function and control of flexible versus skeletal appendages?

- Many of the octopus' flexible arm movements involve "waves" as a basic pattern. Is this type of control used to simplify motor control by reducing the degrees of freedom? Or do these wave-like patterns of motion bring other benefits?

- The octopus uses a unique motor control space, the reconfiguration space, in which it dynamically shapes its arm structure. What do such new dimensions of control contribute to soft versus rigid appendages?

- The central and peripheral neural system in the octopus has a special organization, where commands for movement generation are embedded in the peripheral nervous system of the arm. What is gained by this division of control between peripheral and higher motor centers?

- For many years I have been studying mechanisms of short- and long-term synaptic plasticity in both simple and advanced invertebrates, like the octopus, and also in mammals. Summarizing and meta-analyzing the findings of my and other groups may advance our understanding of the evolution and function of complex brain systems.

Recommended Reading

Gutfreund, Y., T. Flash, G. Fiorito, and B. Hochner. 1998. "Patterns of arm muscle activation involved in octopus reaching movements." J. Neurosci. 18, 15: 5976-5987.

Sumbre, G., G. Fiorito, T. Flash, and B. Hochner. 2006. "Octopuses use a human-like strategy to control precise point-to-point arm movements." Current Biology 16: 767-772.

Shomrat, T., I. Zarrella, G. Fiorito, and B. Hochner. 2008. "The octopus vertical lobe modulates short-term learning rate and uses LTP to acquire long-term memory." Current Biology 18: 337-342.

COLLOQUIUM, 11.05.2010

Cephalopods may reveal how complex brains function

My scientific goal is to understand how the nervous system controls complex behaviors, and I approach this by studying the modern cephalopods (octopus cuttlefish and squid). These molluscs are considered the most advanced of the invertebrates. We were originally interested in the highly efficient cephalopod motor system. The octopus provides an outstanding example of efficient and versatile use of its eight long, flexible appendages and, therefore, beside the scientific interest in unraveling the principles of motor control, we also hope to gain inspiration for a new type of flexible robotics. That is, this study follows the popular approach of using biological systems as inspiration for artificial systems and may help solve the very complex engineering task of generation and control of movements in flexible appendages with unlimited degrees of freedom or unlimited maneuverability. In our research, we are searching for principles of motor control that evolved in the octopus to cope with this difficult task. (In comparison, our articulated arm has "only" 7 degrees of freedom.) I shall explain some of the ingenious control solutions used by the octopus for simplifying the control of its arm motion in goal-directed movements like reaching and fetching.

During the motor control study we were fascinated by the cognitive abilities of the octopus and became interested in what in their nervous system makes them at least as intelligent as lower vertebrates. We believe that studying the brains of modern cephalopods can contribute a new evolutionary perspective to the most challenging question in science - 'how does the brain work?' The octopus nervous system contains around half a billion neurons, comparable to the brain of a dog and dramatically more than the 20,000 neurons in the sea hare Aplysia, one of the best studied molluscs. The cephalopods brain is much more simply organized than vertebrate brains. Thus, using these simpler brains to study complex functions like learning and memory, at which the octopus and cuttlefish excel, may reveal universal principles underlying these functions. Studying this subject in molluscs is of special interest, as Eric Kandel and colleagues have deciphered the basic neural processes underlying simple forms of learning and memory in Aplysia (Kandel received the Nobel Prize for Medicine in 2000). Comparing the octopus and Aplysia will reveal whether the mechanisms in the more primitive mollusks are conserved in the advanced cephalopod brains or whether new processes, more like those of vertebrates, have evolved independently and convergently in these intelligent invertebrates. I will describe some of the findings that have emerged from this research approach and show how adaptive brain organization can be.

PUBLICATIONS FROM THE FELLOW LIBRARY

Hochner, Binyamin (Cambridge, Mass.,2012)

An embodied view of Octopus neurobiology

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1045333360

Hochner, Binyamin (2010)

Serotonin is a facilitatory neuromodulator of synaptic transmission and "reinforces" long-term potentiation induction in the vertical lobe of octopus vulgaris

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=757527124

Hochner, Binyamin (2009)

Nonsomatotopic organization of the higher motor centers in octopus

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=757526721

Hochner, Binyamin (2008)

The octopus vertical lobe modulates short-term learning rate and uses LTP to acquire long-term memory

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=757526861

Hochner, Binyamin (2005)

Motor primitives in vertebrates and invertebrates

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=757526519

Hochner, Binyamin (2005)

Motor control of flexible octopus arms

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=757526233

Hochner, Binyamin (2001)

Control of octopus arm extension by a peripheral motor program

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=757526047