The Crayfish Stretch Receptor Project: A Joint Exercise for Biology Students and Electrical Engineering/Computer Science Students

Robert Olberg, Ph.D.
Biology Department
Union College
Schenectady, NY 12308
Phone: 518 388 6509
olbergr@union.edu

Palma Catravas, Ph.D.
Electrical and Computer Engineering
Union College
Schenectady, NY 12308
Phone: 518 388 6306
catravap@union.edu

Summary of Activity

The idea behind this experimental two-week lab exercise is to allow students in biology and students in electrical and computer engineering to collaborate on a joint project. We will explore the signals generated by a muscle stretch receptor in the crayfish as we vary muscle length sinusoidally. Along the way we will consider the sources and frequency content of both the signal and the noise inherent in electrophysiological recording. We will apply digital signal processing techniques to address the noise problem. And finally, we will quantify the receptor responses at various stimulus frequencies.

Integration of Disciplines

Biology and Electrical/Computer Engineering

Learning Objectives

The biology students will benefit from the experience in dealing with quantitative data and in learning to communicate with students who have a more quantitative background. The engineering students, when presented with the mathematically oriented introduction to digital signal processing, tend to lose sight of the connection between the course material and its practical application. They will benefit by learning to apply their quantitative approaches to real-world scientific applications, which will at times include coming to grip with less-than-perfect data sets. They will increase in their understanding and appreciation of the expertise of their peers in the discipline of biology. We believe that both groups will benefit from the experience of learning to communicate across disciplines, a skill increasingly required in academics and in the workplace.

Target Level

This exercise is designed for college sophomores and juniors.

Tools and Materials

- Crawdad. A CD-ROM Lab Manual for Neurophysiology. Robert A Wyttenbach, Bruce R. Johnson, Ronald R. Hoy. Sinauer Associates, Inc. PO Box 407, Sunderland, MA 01375. publish@sinauer.com; www.sinauer.com. 413-549-4300
- MATLAB
- CHARTDATA

Theory and Background

Precise control of muscle requires feedback information about muscle length. Stretch receptors provide this information In most muscles in both vertebrates and invertebrates. Among the most thoroughly studied of all stretch receptors are those found in the crayfish. Imbedded in small bundles of muscle fibers just under the dorsal cuticle of the crayfish abdomen, these sensory neurons fire action potentials in response to the stretch produced by abdominal flexion. The firing frequency of the crayfish stretch receptors increases as the muscle is lengthened, a nearly linear relationship between firing frequency and muscle length. Because the crayfish stretch receptor is easily accessible and functions for a long time after the abdomen has been excised from the animal, it is ideally suited for neurophysiological investigation.

Stretching a muscle causes action potentials (spikes) in the stretch receptors, which then act on motor neurons to make the muscle contract. In this way, stretch receptors mediate feedback control of muscle length. Perhaps the best studied of all stretch receptors are the muscle receptor organs (MROs) of crustaceans, especially those of the crayfish. There are two types of MROs in crayfish, a slow-adapting (or tonic) receptor called MRO_1, and a fast-adapting (or phasic) receptor called MRO_2. We will probably see the signals of both of these receptors, but we will focus on MRO_1.

Safety Precautions

No hazardous materials are used in this preparation. As always, the saline solution used to keep the dissected crayfish moist must be kept away from the electronics. If glass suction electrodes are used they should be disposed of in a responsible manner, i.e. in a glass disposal container.

Miscellaneous Advice to Instructors

The lab exercise described in "Crawdad" describes a method for quantifying the crayfish MRO response to displacement using a micromanipulator to flex the tail by measured amounts. However, to stretch the MRO in a controlled and reproducible way, we have used pen motors and power amplifiers extracted from various physiological chart recorders, such as Grass Instruments polygraphs. A thread tied to the crayfish telson is tied to a six inch wooden applicator stick mounted on the pen motor, so that up and down movement of the stick is translated into abdominal flexion.

Extensions and Options

There are numerous options for further exploration of this biological system. A simple question to ask students is whether the MRO is a more reliable indicator of stretch

distance or stretch speed (or perhaps even acceleration). This will require students to design appropriate mechanical stimulation regimes. Another question that students can easily address is the effect of temperature on MRO coding of stretch. This is a biologically relevant question, because crayfish are ectotherms, whose body temperature varies widely under natural conditions. Using this same data, the engineering students can examine how temperature affects the frequency spectrum of the MRO spikes, information that can be related back to ion channel kinetics. MRO responses are also modulated by biogenic amines such as serotonin and octopamine. The effect of these amines can easily by studied by adding them to the saline bathing the preparation. Serial dilutions will allow students to generate dose-response curves of the effect of the amines.

References

Crawdad. A CD-ROM Lab Manual for Neurophysiology. Robert A Wyttenbach, Bruce R. Johnson, Ronald R. Hoy. Sinauer Associates, Inc. PO Box 407, Sunderland, MA 01375. HYPERLINK "mailto:publish@sinauer.com" publish@sinauer.com; HYPERLINK "http://www.sinauer.com" www.sinauer.com. 413-549-4300