Experiential Learning in Neurophysiology for Undergraduate Biomedical Engineering Students

John DiCecco, Shelley Silva, John Coughlin, Timothy Swaby, Jiang Wu, MS, Ying Sun, PhD, Kiyoaki Kuwasawa, PhD, and Robert Hill, PhD
Department of Electrical and Computer Engineering, Department of Biological Sciences, University of Rhode Island, Kingston, RI 02881-0805 USA; Okayama University of Science, Japan

***Abstract*— The undergraduate engineering curriculum generally consists of a significant amount of theory and mathematics that are deemed necessary to solve problems in the real world. For biomedical engineering undergraduates this often results in limited hands-on experiences with live tissue samples and biological experimental techniques. In the Biomedical Engineering Program at the University of Rhode Island, this issue is addressed to some extent by implementing an experiential electrophysiology laboratory. The two-semester project course exposes the students to laboratory skills in dissection, instrumentation and physiological measurements. The focus of the projects is: 1) recording of action potentials in cerebral ganglia of the pond snail (*Lymnaea stagnalis)*, 2) measuring of contractile forces and action potentials in odontophore protractor muscles of the American channeled whelk (*Busycon canaliculatum)* by use of a sucrose gap apparatus. This laboratory has proven to be an effective way to provide undergraduate biomedical engineering students with invaluable experiences in neurophysiology.**

***Index Terms*— Biomedical Engineering, electrophysiology, microelectrode, neurophysiology, sucrose gap.**

I. Introduction

BIOMEDICAL engineering education may come from within a traditional engineering curriculum. This is the case at the Electrical Engineering Department of the University of Rhode Island. The program focuses on electrical engineering as it pertains to biomedical applications. A need exists to integrate the traditional engineering training with the intricacies of biological systems. Engineers are better prepared to solve problems when they have a first-hand understanding of what the problem is and its cause. For medical education during the last decade, the pedagogical style has also shifted from factual teaching towards contextual, or problem-based, learning [1]. To this end, we have developed a laboratory course to address these issues and give the biomedical engineering students the insight and research skills necessary to understand and help solve biological and physiological problems.

The course is taught jointly by a biomedical engineering professor and a biology professor. This interdisciplinary approach makes the course beneficial to the engineering students. The students are presented the opportunity to apply electrical engineering skills to physiological systems.

Manuscript received January 29, 2004. This work was supported as a cooperative between the College of Engineering and the College of Arts and Sciences.

John DiCecco is a senior biomedical and electrical engineering major at the University of Rhode Island, Kingston, RI 02881 USA (phone: 401-284-1266; e-mail: diceccoj@ ele.uri.edu).

Shelley Silva is a senior biomedical and electrical engineering major at the University of Rhode Island, Kingston, RI 02881 USA

John Coughlin is a senior biomedical and electrical engineering major at the University of Rhode Island, Kingston, RI 02881 USA

Timothy Swaby is a senior biomedical and electrical engineering major at the University of Rhode Island, Kingston, RI 02881 USA

Jiang Wu is a biomedical and electrical engineering Ph.D. candidate at the University of Rhode Island, Kingston, RI 02881 USA

Dr. Ying Sun is a professor of biomedical and electrical engineering at the University of Rhode Island, Kingston, RI 02881 USA

Dr. Kiyoaki Kuwasawa is a professor of neurobiology at the Okayama University of Science, Japan

Dr. Robert Hill is a research professor of biology and biological sciences at the University of Rhode Island, Kingston, RI 02881 USA

II. Experiments

A. Action Potential Recording Using Microelectrode Methodology

In 1952, Hodgkin and Huxley published a series of four papers describing the inward and outward currents of Na^+ and K^+ through the cell membrane [2]. These papers were the result of years of experimentation with the squid giant axon and the voltage clamp. In order to measure the influx of sodium ions and the outward flow of potassium ions, the membrane potential must be held fixed, or clamped, at a certain value. Therefore, any change in current, i.e. the flow of ions, which underlies an action potential, can be detected.

The neurophysiologic experiment conducted at our self-constructed lab at the University of Rhode Island involves the cerebral ganglia of the pond snail, *Lymnaea stagnalis*. Although the ganglia are very small, on the order of 200 to 400µm, the individual neurons are comparatively large. In fact, they are large enough to record the action potential with a pulled glass pipette microelectrode. However, removing the ganglia intact requires terrific skill and a lot of

practice since the ganglia are completely obstructed, positioned inferior to the buccal muscle. Once the buccal muscle is moved, the ganglia are exposed and the process of meticulously separating the ganglia from the axons, only 10-100µm in length, begins [3]. The enzyme, pronase, is used to further expose the neurons inside the ganglia and allow for direct contact with the microelectrode. A Faraday cage surrounds the entire microelectrode recording to shield the experiment from the 60Hz noise generated by the ambient light and recording equipment. The voltage clamp (Axon Instruments Gene Clamp 500) is used to amplify the signal of the neuron, while the digital Oscilloscope (Tektonix TDS 3012B) and chart recorder (AstroMed Dash IV) perform the detection and recording of the action potential, respectively.

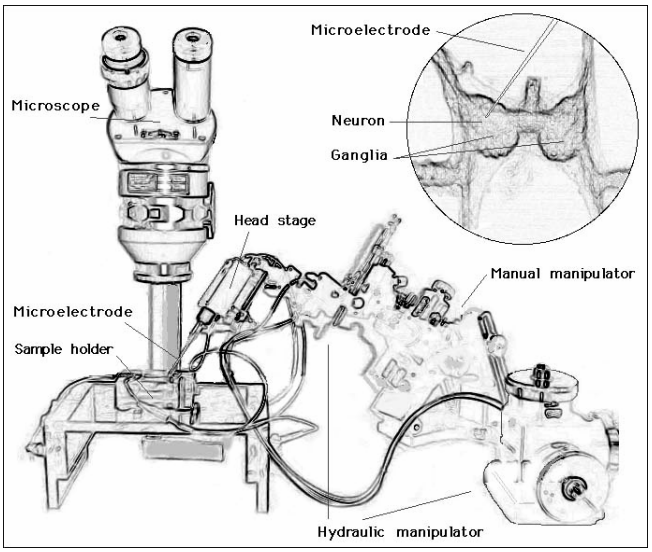

Figure 1. Microelectrode setup for neuron action potential recording. Inset shows the ganglia of *Lymnaea stagnalis.* (Mag. 500X)

B. Membrane Potential and Contractility Measurements Using Double Sucrose Gap Methodology

The American channeled whelk, *Busycon canaliculatum*, has a proboscis that varies from 4 to 8 cm in length. The muscles that control the radula, the teeth-like eating mechanism, are the odontophore protractors and retractors. The protractors are primarily used for re-positioning, while the retractors perform the power stroke in the scraping movement of eating. As such, the protractors are singular and smaller in nature, and this make threading through the double rubber membrane of the sucrose gap set up easier (See figure 2).

Preparation of the tissue sample begins with breaking the shell of the *Busycon* to expose the snail body. Beneath the

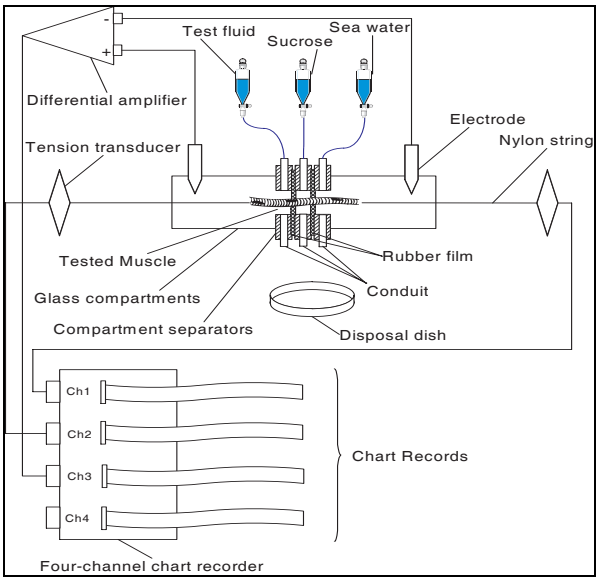

Figure 2. Single sucrose gap experiment setup

mantle and slightly lateral to the midline, the proboscis is located. This tube-like structure, covered by a protective sheath, is then separated from the body by removing it at the base. Once the proboscis is removed, careful dissection of the protective sheath reveals the musculature associated with the movements of the radula and the odontophore cartilage. Next, the protractor muscles are removed [4].

Successful recording of contractility from the force transducers (See figure 2) requires proper tension in the attaching filament. It is difficult to chemically isolate each side of the tissue sample via a double sucrose barrier, therefore careful preparation of both the specimen and the solutions is critical. Muscle contraction is achieved by introducing KCl to one side.

III. DISCUSSION

The experiments developed in this neurophysiology course have provided invaluable experimental training for the biomedical engineering students. Despite the specificity of the experiments, they exemplify advanced research in neuroscience and are technically challenging to motivate the students.

[1] Epstein RJ. Learning from the problems of problem-based learning. *BMC Education* 4: 1-7, 2004.

[2] Hodgkin AL, Huxley AF. A quantitative description of membrane current and its application to conduction and excitation in nerve. *J. Physiol 463*: 391–407, 1952.

[3] Walker RJ. Intracellular Microelectrode Recording from the Brain of Helix. In: Experiments in Physiology and Biochemistry, ed. by Kerkut GA. New York: Academic Press, 1968.

[4] Harrington, Lesley et al. Voltage Clamp of Cardiac Muscle in a Double Sucrose Gap. *Biophysical Journal* 13: 626-647, 1973.