

MEDIA REVIEW

Neurons In Action: Computer Simulations with NeuroLab

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2000 Sinauer

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Neurons in Action was developed by Drs. John W. Moore and Ann E. Stuart. Dr. Moore is a co-author of NEURON, a powerful simulation environment that models neurons based on the equations that describe their behavior. Using NEURON, Moore and Stuart created the seventeen tutorials that make up *Neurons in Action*. These tutorials vary in their level of complexity and can be used to teach neurophysiology to students at the undergraduate through graduate level.

The first tutorial, The Membrane Tutorial, introduces the student to the excitable neuronal membrane. Students initially inject current into a cell with a plain lipid bilayer membrane and observe the subsequent changes in capacitive current and membrane voltage. Students then add, one-by-one, a sodium potassium pump to create a resting potential across the membrane, leak channels, and finally the Hodgkin-Huxley sodium and potassium channels necessary for an action potential. As each component is added, reference is made to the terms for capacitive current, leak current, and sodium and potassium currents in the Hodgkin-Huxley equation. Thus, by the end of the tutorial, the student has gained not only a basic understanding of the components of an excitable membrane but also a basic grasp of the famous equation that describes the action potential.

The tutorials are grouped into three levels. Level 1 includes seven tutorials that explore the ionic mechanisms underlying the resting and action potential, the effects of membrane resistance, capacitance, and axon diameter on passive current flow, and effects of axon diameter and myelination on action potential propagation. These tutorials are excellent for the beginning student in neurophysiology. Most tutorials provide movies of voltage changes along the axon over time. For example in the Partial Demyelination tutorial, students watch an action potential propagate along a myelinated region of an axon and then fail once it reaches the demyelinated region. Several of these tutorials provide insights into clinically important phenomena, information that is often of great interest to students. For example, in the Patch Action Potential Tutorial, students simulate the effects of anesthetics on action potentials. Student test the effects of temperature on the amplitude and duration of action potentials and use this information in the Partial Demyelination Tutorial to explain the effects of an increase in body temperature on action potential propagation in patients with multiple sclerosis.

Level II contains five tutorials that focus on the action potential. Most of these tutorials are accessible to the beginning student with some guidance from the instructor.

The Voltage Clamp Tutorial takes the students through Hodgkin and Huxley's famous experiments while the Threshold Tutorial provides a much better and more thorough explanation of action potential threshold than found in most textbooks. Students can examine the effects of axon geometry, toxins, and drugs on action potential propagation in the Diameter Change and Channel Densities Tutorials.

Level III contains five tutorials that take a sophisticated look at synaptic integration. Reversal potentials are examined in the Postsynaptic Potential Tutorial, a tutorial appropriate for the beginning student. Surprising effects on membrane potential are seen with combinations of IPSPs and EPSPs in the more advanced Postsynaptic Interactions Tutorial.

Most textbooks describe current flow and membrane potential changes only in axons of constant diameter and uniform properties. In contrast, several Level II and III tutorials explore current flow in parts of the cell (i.e. dendrite, soma, and axon) with different geometries. The student learns, for example, that soma and axon geometry dictate where the action potential initiates in the cell.

One great attribute of *Neurons in Action* is that the tutorials provide a historical perspective on groundbreaking experiments and experimenters. Frequent links in the tutorials direct students to the relevant literature as well as provide students with informative and sometimes amusing quotes from such pioneers as Hodgkin, Huxley, and Cole. In addition, information is given on the difference between an ideal, typical, and "out of control" voltage clamp.

The instructor is key to making *Neurons in Action* most effective. *Neurons in Action* can be used "live" during lecture. The Voltage versus Space movies used in many of the tutorials provide dramatic demonstrations of voltage changes down an axon over time.

Neurons in Action mimics laboratory experiments by allowing the user to change one parameter at a time and then observing the result. However, in the lab, the results of each manipulation may take hours to uncover, and the experimenter may have to repeat the exercise numerous times. Thus, much time and thought can be devoted to explanations of a single result. With *Neurons in Action*, the students can observe the effects of several parameter changes in a minute. As a result, the students can suffer from information overload. Thus, *Neurons in Action* may be used most effectively when the instructor gives the students multiple, short assignments.

The tutorials are written in a way that allows the motivated student to teach himself or herself the material

but are not always written in a way easy for an instructor to grade. The questions in a given tutorial may vary in level of difficulty, and, often, answers to questions posed in the tutorials are provided via links. In some cases, therefore, it may be better for the instructor to write his or her own questions that highlight the information that he or she would like to convey.

While working with students on real experiments in the lab, it is easy for the instructor to uncover difficulties or misconceptions that the students have with the material. If, however, the instructor sends the students off to work on simulations on their own, these misconceptions or difficulties may not be uncovered. By assigning and frequently grading short assignments with *Neurons in Action*, the instructor can monitor the student's grasp of the material before moving on to the next level. Alternatively, the instructor can organize virtual labs in which students work on the tutorials in a computer lab in the presence of the instructor.

Neurons in Action can be used extremely effectively in combination with laboratory exercises. For example, students can study stimulation thresholds and refractory periods in real giant fibers of the crayfish and then observe the same phenomena in the Patch Threshold and Patch Refractoriness Tutorials. Information from the two types of exercises reinforces each other and teaches students the advantages and disadvantages of actual electrophysiological recordings versus computer simulations.

In the past, many students have had difficulty installing *Neurons in Action* on their own computers. These difficulties should be eliminated with the latest edition (version 1.5) of the software that will provide "one-click" installation on either PC or Mac computers. I have been able to install the latest PC edition easily on several different computers using Windows 98, 2000, and XP operating systems.

Neurons in Action has its own website (www.neuronsinaction.com) that contains useful information on the software, suggestions for faculty, sample tutorials, and an address for emailing the authors.

In summary, *Neurons in Action* is a powerful and versatile tool for teaching neurophysiology at the undergraduate and graduate level. Tutorials are designed for both the beginning and advanced student. Interactive simulations allow the student to explore the basic mechanisms of action potential initiation and propagation as well as synaptic physiology. The number of virtual experiments that students can perform is practically limitless. Finally, it may surprise and impress the students to realize that this sophisticated simulation software is based upon the equations for the action potential developed by Alan Hodgkin and Andrew Huxley more than fifty years ago.