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Simulating Physiological and Morphological Properties of Neurons with SNNAP (Simulator for Neural Networks and Action Potentials)

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Introduction

Computer simulations are useful tools for teaching neurophysiological principles as well as for research. To make the tools of computational neuroscience more widely available, we previously developed a Simulator for Neural Networks and Action Potentials (SNNAP). With SNNAP, all aspects of developing and running simulations are mediated via a user-friendly, graphical interface and no programing skills are necessary.

SNNAP was designed as a tool for rapidly developing and simulating realistic models of single neurons and small neural networks. The electrical properties of individual neurons are described with Hodgkin-Huxley type ionic currents. The connections among neurons can be electrical, modulatory or chemical, and they can express many forms of plasticity. SNNAP also includes descriptions of intracellular second messengers and ions, which, in turn, can modulate ionic conductances or synaptic transmission. SNNAP also can simulate current flow in multicompartmental models of neurons.

The specific details of the first version of SNNAP were described in Ziv et al. (*J. Neurophysiol.*, 71: 294-308, 1994). This poster describes a new version (JAVA Ver. 5.1d) of SNNAP, which is now available.

What Are Some Features SNNAP Ver. 5.1d?

- SNNAP can simulate networks of up to 100 cells and 300 electrical, chemical and modulatory synaptic connections.
- Descriptions for the synthesis of second messengers include serial interactions as well as converging and diverging interactions (Fig. 2). For example, both a modulatory transmitter and the levels of intracellular Ca^{2+} can regulate the synthesis of cAMP.
- Descriptions for chemical synaptic connections can include a voltage-dependent component. For example, a model for a synaptic connection can include an NMDA-like conductance.
- Chemical synaptic connections can include descriptions for a pool of transmitter that is regulated by depletion and mobilization and modulated by intracellular ions and second messengers.
- To simulate multicompartmental cells more accurately, SNNAP incorporates tools that allow users to develop models based on morphological parameters, such as the diameter of a cell body or the width and length of a neuronal process (Fig. 5).
- SNNAP includes a batch mode of operation, which allows the user to assign any series of values to any given parameter or combination of parameters. A new batch editor was developed for the most recent version of SNNAP to facilitate the exploration of parameter space.
- For flexible virtual experiments, cells can be injected with currents that have either steplike or user-defined waveforms.
- SNNAP runs in the JAVA environment, and thus can run on virtually any computer or operating system.

Fig. 1. The User Interface Simplifies Developing and Running Simulations

All aspects of developing and running a simulation are mediated via a graphical user interface. For example, to select an equation to describe an ion conductance, the user (**1**) selects Edit Formula from the main control panel; (**2**) selects the type of equation (voltage-dependent conductance; VDG); (**3**) 'pops-up' the list of equations; and (**4**) chooses an equation from the available selection. After an equation has been selected, the values for the necessary parameters are entered by pressing the appropriate button and typing the value into a pop-up box (not shown).

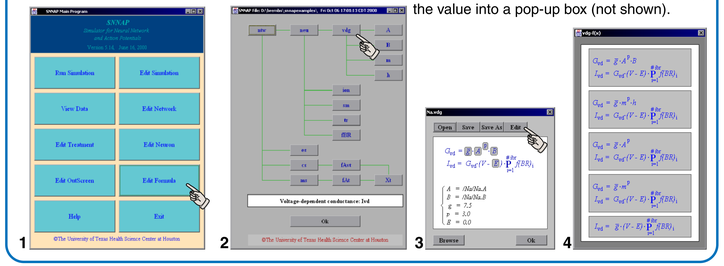
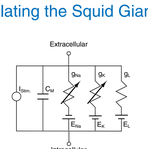
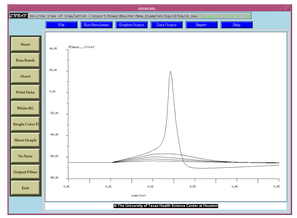


Fig. 2. Simulating Cells With Diverse Biophysical Properties

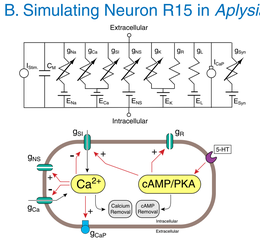
SNNAP allows users to develop models by selecting from a wide array of equations (e.g., Fig. 1). This versatility enables one to simulate the diverse and unique properties of cells. For example, a model of the squid giant axon (**A**) is relatively simple when compared to the of ionic conductances and intracellular processes that are necessary to simulate the bursting R15 cell of *Aplysia* (**B**).

A. Simulating the Squid Giant Axon





B. Simulating Neuron R15 in *Aplysia*



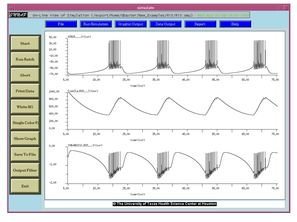
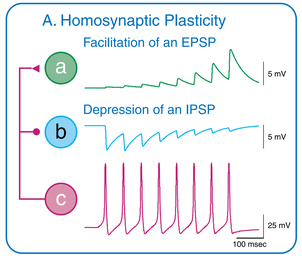


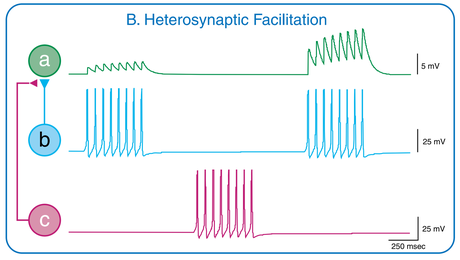
Fig. 3. Simulating Synaptic Connections And Plasticity

Various types of synaptic connections and plasticity can be modeled. For example, homosynaptic facilitation or depression (**A**) can be simulated. By including a second messenger system, heterosynaptic plasticity (**B**) can be simulated. Synaptic connections can have multiple components (**C**), and synaptic connections can induce conductance decreases (**D**). SNNAP can also simulate voltage-dependent synaptic connections much like NMDA-mediated synaptic transmission (not shown).

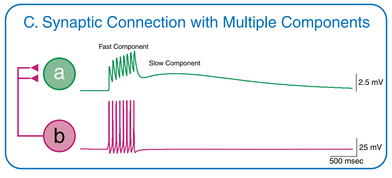
A. Homosynaptic Plasticity



B. Heterosynaptic Facilitation



C. Synaptic Connection with Multiple Components



D. Decreased Conductance Synaptic Connection

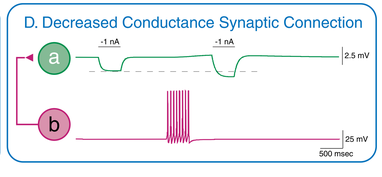
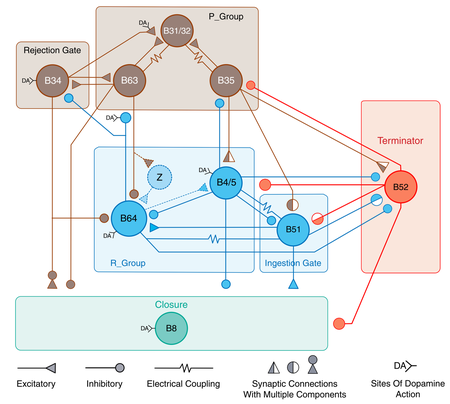


Fig. 4. Simulating A Relatively Complex Neural Circuit

The central pattern generator (CPG) in the buccal ganglia of *Aplysia* provides an example of a relatively complex neural network that has been simulated using SNNAP (**A**). The cells had diverse properties. For example, cells B31/32, B51 and B64 manifest plateau potentials, cells B35 and B52 manifest rebound excitation, and cells B4/5 and B8 fire tonically during sustained depolarization. In addition, many of the synaptic connections had more than one component (e.g., both fast and slow components or a combination of inhibitory and excitatory effects), some synaptic connections induced conductance decreases in the postsynaptic cells, and most of the synaptic connections expressed some type of homosynaptic plasticity. All of these features could be simulated by SNNAP. To simulate 20 sec of activity in this circuit (**B**), required ~2 min using a 800 MHz Pentium based computer (the time step for the integration was 45 microsec) .

A. Schematic Diagram Of A CPG In The Buccal Ganglia Of *Aplysia*



B. Simulated Response Of The CPG

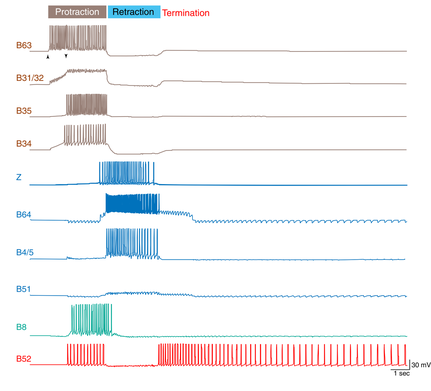
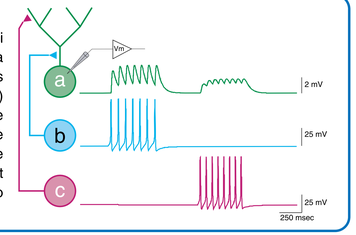


Fig. 5. Simulating A Multicompartmental Cell

SNNAP can model the spread of current in a multi compartmental cell. The postsynaptic cell was modeled as a branching cell with several compartments. The properties of the two presynaptic inputs were identical but one input (c) was further away from the soma than the other (b). The voltage of the postsynaptic cell (a) was monitored in the soma compartment and the two presynaptic cells were stimulated. The EPSPs from the more distal synaptic input (c) were attenuated and had slower kinetics (see also Abstract 759.3).



How Do I Get SNNAP?

It's simple. SNNAP is available free of charge. Just visit the SNNAP web site and download the files.

http://snnap.uth.tmc.edu

If you can't download SNNAP from the web, then we can send you a copy via E-mail or surface mail.

Instructions for installing SNNAP are included in README files and in the manual.

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