Final Exam

Final Examination:
Students are not required to take the final examination unless they have failed to submit more than three of the regular Monday Writing Assignments.

Required assignments are:
- W3: Neuroethology’s Roots
- W10 Simple Circuits
- W14 Echolocation
- W22 Linear Systems, spatial vision, barn owl hearing
- W29 Wikipedia project outline
- W31 JAR, Efish, birdwong, and escape
- W39 Corollary discharge, Spike Timing Dependent Plasticity
- W52 Spatial Navigation and Sensory Guidance

The final examination will be administered by appointment any time during the day on Monday, December 12, 2011 from 9 AM until 4:30 PM. Students may pick up their exam packet in 111 Seeley Mudd Hall starting at 9 AM. Each student will have 2 1/2 hours to complete their exam. This will be a closed book examination. Coverage will include the entire semester’s material, but will emphasize the last half of the semester.

WIKI Neuroethology

Move your wikipedia project to the WIKIPEDIA site
Print out final project page and turn in to Saundra Anderson, 111 Mudd Hall, by Friday 12/9 4PM

Deadline for final posting on WIKIPEDIA site:
Friday 12/9 4 PM

Send email to cdh8@cornell.edu when done; include the URL of your site.

Physiological Models of Action Potentials

Original Hodgkin-Huxley Model from 1952.

$g_{\text{ion}}$ is the symbol for the delayed rectifier conductance (K)
m, h, and h are variables that vary between 0 to 1 to describe the variable conductances

Threshold Effect

Stimulus duration:

Stimulus current:

Anodal Break

Repetitive Firing: integrate and fire
H-H model results

Different Firing Patterns for Different Cells

Addition of A current can change spiking threshold, AP duration, Adaptation, Repetitive Firing

H-H model results
Cable Theory

The axon is an elongated cylinder made up of resistive membrane surrounded by saline solution on the outside and on the inside. Each differential length dx of cable has the following components:

- Internal resistance, \( r_i \) determined by the resistivity of the solution, by the cross-sectional area, and by the length of the element, dx.
- External resistance, \( r_e \)
- Membrane capacitance determined by the capacitance of membrane multiplied by surface area of the segment.
- Membrane resistance, \( r_m \) determined by the surface area of the membrane and by the resistivity of the membrane.

Contributions from Cable Theory

Calculation of the membrane voltage as a function of distance away from a current source. A current step is applied at \( x = 0 \); \( T=\infty \) is the final value in response to a sustained current pulse.

From cable theory: response as a function of time. Membrane voltage in response to a current pulse step at \( x = 0 \); Different distances from the source.

H-H model results

Histological Approach to Neural Nets

McCulloch and Pitts (1943) develop a ‘calculus’ of neuron logic (a math theory).
- Model neurons have 2 states: 0 or 1.
- L separate inputs to each output cell.
- Each input is weighted (\( -1 < w < +1 \)) (excitation or inhibition)

\[
y = \theta \left( \sum w_i x_i - S \right)
\]

\( S \) is the threshold.
\( \theta(x) = 1 \) for \( x > 0 \)
\( \theta(x) = 0 \) for \( x < 0 \)
with appropriate connections, possible to get all possible logical connections (AND, OR, NOR, etc).

McCulloch and Pitts, 1943

A ‘Neural Net’

A neural network is an interconnected assembly of simple processing units, which function more or less like neurons. The processing ability of the network is dependent on the strength or ‘weights’ of the interconnections between elements. Weights are adjusted according to rules of learning.
Hebb (1949)

The Hebbian synapse (weight of synaptic strength) changes, with correlation.

In the McCulloch & Pitts calculus,

\[ \Delta w_i = \varepsilon \cdot y(x) \cdot x_i \]

change in weight rate of change

Perceptron Theory

Frank Rosenblatt (1958-1960’s) Cornell Prof, NBB

Similar to McCulloch and Pitts, except weights were allowed to change

‘Supervised learning’

‘Teaching’ permits perceptual classification.

\[ S_j = \sum_{i} w_{ji} \cdot x_i \]

weight of connection

if \( S_j > 0 \), then \( x_j = 1 \)

if \( S_j < 0 \), then \( x_j = 0 \)

Learning Rule

The perceptron learns from examples.

Similar to nervous system, which learns to recognize a stimulus.

Example: learn to classify handwritten letters.

Give examples of letters, provide answers.

Net is presented with an input pattern.

Output is compared with desired output. The desired output is the desired classification scheme.

Weights are then adjusted according to the error.

Learning Rules

1) the network is presented with an input pattern (on left).
2) the network calculates an output, \( x_j \) (not shown)
3) the output is compared to the desired output (i.e. the classification scheme), \( t_j \) (on right)
4) the weights are then adjusted to compute a new output.

\[ w_{ji} \text{ new} = w_{ji} \text{ old} + C(t_j - x_j) \]

\( C \) is the learning rate.

(this is example of one type of back-propagating learning rule)

Back Propagation

Setup: three or more layers of processing units.

Weights adjustable in all layers.

Thresholds: varying degrees of sharpness of sigmoid functions.

Teaching: If network gives wrong answer, adjust the weights in the direction that minimizes the error.

Application of the method:

net works that produce sound in response to text
Handwriting recognition
Speech to text

Bio Robotics

Robots designed based upon animal models
Hexapod robots: based on insect body plan.
Leg movement and coordination based on CPGs of insects that walk.
Forward versus reverse walking
Swimming Robots

http://www.neurotechnology.neu.edu/welcome.html

http://www.neurotechnology.neu.edu/newChevronUndulator.html

http://www.neurotechnology.neu.edu/latmaneuvering.html

Insect Flight

http://www.scholarpedia.org/w/images/9/9f/Biorobotics_3_1.jpg


Summary

NEUROETHOLOGY

"Neuroethologists take a comparative and evolutionary approach to the study of the nervous system. They ask, how do neural circuits work? How are they adaptive to animal behavior? How do brains of animals compare and how did they come about through the process of evolution? What is the hope and interest in the study of a large diversity of animals, compared to a specialized look at just a few mammalian species? Can we hope to understand how animals with specialized behaviors have specialized nervous systems? What is the sensory world of a real animal and how does it vary from species to species? These and other questions will derive this introductory survey of neuroethology including: exotic senses; amazing motor programs; surprising integration."

Learning Objectives

After taking this course, students should be able to:

• Demonstrate mastery of core principles in the field of neuroscience using specific examples drawn from the comparative literature on natural behaviors of animals.

• Demonstrate knowledge of original papers in neuroscience by making use of bibliographic searches and tools; reading and analyzing original articles; and by making written summaries of key points of original research. Students will demonstrate competence in making oral presentations of neuroscience research.

• Demonstrate through speech and writing both the power and usefulness of the comparative method in neuroscience by making reference to specific examples from anatomy, physiology, and behavior.

• Explain in terms of neuronal circuits how some well-studied behaviors are controlled by a particular pattern of neuronal and synaptic connections of neurons with specific cellular properties.

• Cite and explain examples of neural circuits have undergone changes during evolution.