

## **BIO 338 “From Synapse to Circuit: Selforganisation of the Brain”**

Exploration of basic neural and synaptic mechanisms and the operation of representative brain circuits, using both theoretical approaches and experimental evidence. Particular attention will be given to Hebb’s Rule (“cells that fire together, wire together”), its cellular basis, its consequences for circuit selforganisation, and its limits. The course is aimed at anyone with curiosity about the brain, who is willing to tackle a range of reading, including original research papers. A solid background in a mathematical, physical or biological science is desirable, though the course will be largely selfcontained.

The course is NOT a general introduction to neuroscience. Although we will consider some specific parts of the brain, the focus will be on general concepts, particularly on how “high level” properties of the brain (such as “mind”) emerge from the interaction of vast numbers of “low level” units such as neurons, synapses and molecules.

Please note that we will use some basic mathematics (statistics, exponential function, a bit of calculus, simple linear algebra). All concepts will be illustrated graphically, but if you are mathphobic please consider carefully before taking the course.

### **Instructor**

**Professor Paul Adams, Room 574, Life sciences Building. Email: [padams@notes.sunysb.edu](mailto:padams@notes.sunysb.edu). Phone 26938. You are encouraged to submit questions about any aspect of the course by email. You must include a subject line which mentions “BIO 338”, otherwise your emails may not be read. My office hours (in Room 574) will be posted on BlackBoard. If possible notify me if you plan to visit my office, and when.**

**BlackBoard You should regularly consult the BlackBoard listing for this course.**

The web address (URL) is: <http://blackboard.stonybrook.edu>

You can access class information on-line at: <http://blackboard.sunysb.edu> If you used Blackboard during the 2003-2004 Academic Year and/or Summer 2004, your login information (Username and Password) has not changed. If you have never used Stony Brook’s Blackboard system, your initial password is your SOLAR ID# and your username is the same as your Stony Brook (sparky) username, which is generally your first initial and the first 7 letters of your last name. For help or more information see:

<http://www.sinc.sunysb.edu/helpdesk/docs/blackboard/bbstudent.php> For problems logging in, go to the helpdesk in the Main Library SINC Site or the Union SINC Site, you can also call: 631-632-9602 or e-mail: [helpme@ic.sunysb.edu](mailto:helpme@ic.sunysb.edu)

**Grading.** Your grade will be based on 2 term papers. The second paper will carry the same weight as the first. If you do not submit your papers on time, you risk lowering your grade. If you are late submitting your first paper, you will not receive an advisory grade, and may be otherwise penalized. If you are unavoidably delayed in submitting either term paper, you must send Paul Adams an email stating the firm date for submission. For the first paper, your topic should be chosen from the list to be provided (and posted on

BlackBoard). For the second paper, you must submit your own proposed topic for approval, with a paragraph summarizing your plan, by email to Paul Adams by Nov 22. You are welcome to come to my office to discuss your proposed paper. Please note that you may be personally interviewed to check that you understand your own term paper! Also, your grade will reflect the extent to which your paper evinces thorough understanding of the material covered in the lectures. A term paper which does not relate to the lecture material but is otherwise excellent will not receive a top grade.

## **Lectures**

**(Mon, Wed, 3.50- 5.10 Room 030 Life Sciences Building Basement)**

**Please note that the following listing is subject to revision as the course advances.**

- Aug 29 Introduction to the Course. Neurons and Synapses.
- Aug 31 Selforganisation in simple physical systems: ferromagnetism
- Sept 7 Self Organisation of Matter. Polynucleotide replication.
- Sept 12. Eigen's molecular evolution theory.
- Sept 14 Membranes, receptors, channels
- Sept 19 Membrane Potential.
- Sept 21 Passive Properties of Neurons. Cable Theory
- Sept 26 The Action Potential
- Sept 28 The Hodgkin Huxley Theory of the action potential
- Oct 10 Solving the HH Equations
- Oct 12 Other Voltage dependent channels
- Oct 17 A well-understood synapse: The neuromuscular junction
- Oct 19 Transmitter release statistics, quantal analysis
- Oct 24 Statistics of ion channels ; **First Term Paper due**
- Oct 26 The nicotinic acetylcholine receptor
- Oct 31 Channel block.

Nov 2 Central excitatory synapses

Nov 7 Inhibition and Neuromodulation

Nov 9 Olfaction

Nov 14 Simple Neural Networks and Linear Algebra

Nov 16 The Linear Associator as a neural network model of memory

Nov 21 Hebb Synapses and Long Term Potentiation

Nov 23 Hopfield Networks and the Hippocampus **Topic Submission Deadline**

Nov 28 Principal Component Analysis

Nov 30 Information Theory and the Brain.

Dec 5 Retina and Thalamus

Dec 7. Neocortex

Dec 12 Models of the origin of language. **Final Paper Due**

### **Text and Readings**

There is no prescribed textbook for the course. However, it is strongly recommended that students purchase and use one of the following standard textbooks of neuroscience:

"Neuroscience: Exploring the Brain", by Bear, Connors and Paradiso; (HSC, Melville) (Probably the best, and cheapest choice; relaxed style; however the other books present much the same material with different emphases and illustrations).

"Principles of Neuroscience" by Kandel, Schartz and Jessell; Comprehensive.

"From Neuron to Brain". Nicholls, Martin, Wallace, Fuchs. Sinauer (excellent for illustrations of important experiments and detailed references to original papers).

"Fundamental Neuroscience" Squire, Bloom etc. Academic Press. A doorstopper but the discussion of some topics is very complete.

"Neuroscience" Purves, Augustine etc. Sinauer. Very good, and comes with a neuroanatomy CD.

In addition, the following texts will be found useful; they have been placed on reserve in the HSC or Melville Libraries.

"Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems", by Dayan and Abbott; HSC; Melville (Tough going for nonmathematicians)

"An Introduction to Neural Networks", by Anderson. HSC; Melville. Included a primer on linear algebra)

Johnston and Wu, Foundations of Neurophysiology (Bradford) HSC, Melville. Engineering influenced accounts of basic neuron electrical properties.

Shepherd, Synaptic Organisation of the Brain (Oxford) HSC (Good descriptions of individual systems (hippocampus, olfaction, thalamus, neocortex)

Levitan and Kaczmarek, The Neuron : Cell and Molecular Biology. Oxford. A basic guide to neurons, with a more biochemical flavor.

Mountcastle: Perceptual Neuroscience: The Cerebral Cortex. Harvard

More Advanced Texts with material relevant to this course.

Modeling Brain Function: The world of attractor neural networks. Amit. Cambridge.

Spikes: Exploring the Neural Code. Rieke et al. Bradford.

Introduction to the theory of Neural Computation. Hertz, Krogh, Palmer. Addison-Wesley

Ionic Channels of Excitable Membranes. Hille. Sinauer

Biophysics of Computation: Information processing in single neurons. Koch. Oxford.

Steps toward Life. Eigen. OUP

Lighter Reading:

Here are several books written for the "intelligent layman" which are stimulating and interesting:

The Astonishing Hypothesis. Frances Crick. The discoverer of the double helix, one of the most penetrating minds in modern biology, argues that the mind is just the interaction of neurons.

Synaptic Self : Joseph Ledoux. An expert on neural basis of emotion looks at learning and the brain

On Intelligence: Jeff Hawkins. An entrepreneur (inventor of the Palm Pilot) enthuses about the neural basis of intelligence.

The Quest for Consciousness: Christoph Koch. A theoretical neuroscientist writes breezily about experimental work on awareness.