

SYLLABUS for NEUROBIOLOGY 101

updated Sept. 17, 2007



*Harvard College & Graduate School of Arts & Sciences
Fall Term, 2007-2008*

Monday Sept 17, 2007 - January 23, 2008

GSAS Registration, Sept 12, 2007

FAS Upper Class Registration, Sept 14, 2007

Neurobiology 101. Auditory Neurobiology of Language & Music

Lectures Tues & Thurs, 11:30A - 1:00P

Harvard Yard, Sever Hall, Room 202

1 Section per Wk (90 mins), Time & Place to be announced in class

Faculty

Mark Jude Tramo, MD, PhD

Asst. Professor of Neurology, Harvard Medical School

Steering Committee, Harvard University Mind/Brain/Behavior Interfaculty Initiative

Attending Neurologist, Massachusetts General Hospital

Songwriter, Member, ASCAP

www.BrainMusic.org

Office hours by appointment, The Institute for Music & Brain Science, 175 Cambridge St, Suite 340, Room 382, Boston

Jonathan I. Matsui, PhD

Lecturer on Molecular & Cellular Biology, Harvard University

Neurobiology Concentration Advisor for Harvard College Undergraduates, Harvard Faculty of Arts & Sciences

Office hours by appointment, BioLabs Rm 1082a, Divinity Ave, Cambridge

Teaching Fellow

Caroline Niziolek, MS

PhD Candidate, Harvard-MIT Speech & Hearing Bioscience & Technology Graduate Studies Program

Office hours by appointment, BioLabs Rm 1075, Divinity Ave, Cambridge

Guest Lecturers

Marc D. Hauser, PhD

Co-Director, Harvard University Mind/Brain/Behavior Interfaculty Initiative

Harvard College Professor of Psychology and of Organismic & Evolutionary Biology

Louis D. Braida, PhD

Co-Director, Harvard-M.I.T. Speech & Hearing Biosciences & Technology Graduate Studies Program

Henry Warren Ellis Professor of Electrical Engineering, M.I.T.

Sensory Communication Group, Research Laboratory of Electronics, M.I.T.

Bertrand Delgutte, PhD

Co-Director, Harvard-M.I.T. Speech & Hearing Biosciences & Technology Graduate Studies Program

Senior Research Scientist, Research Laboratory of Electronics, M.I.T.
Eaton-Peabody Laboratory of Auditory Physiology, Dept. of Otolaryngology, Harvard Medical School

Course Description

How does the brain transform air-pressure waves striking our eardrums — or the words you are reading on this page — into the sounds we hear in our heads? What parts of the hearing brain are necessary and sufficient to understand spoken, seen, or imagined words, dance to music, and recognize your mother's voice? When do auditory-perceptual capacities critical to language acquisition develop? What happens to linguistic and musical abilities if congenital or acquired diseases alter their underlying molecular substrates and neural circuitry?

In this 13-week lecture course, current knowledge and conceptual insights from multiple scientific disciplines and the humanities (biology, engineering, computer science, psychology, linguistics, music) are brought to bear on these questions. Lectures and Sections are organized into five topics: 1) *Introduction to Auditory Neurobiology*; 2) *Auditory Communication*; 3) *Signal Processing by the Auditory System*; 4) *Molecular Biology of the Auditory System*; and 5) *Developmental Biology of the Auditory System*. We introduce data from experiments investigating how the brain and ear: 1) transform acoustic signals into auditory percepts; 2) discriminate differences within and across acoustic and semantic categories of auditory percepts (e.g., different words, voices, musical instruments); 3) abstract perceptual constancies despite variations in acoustic features (e.g., your roommate's voice here, there, and everywhere last year); and 4) integrate percept formation with implicit knowledge about language and music gained through years of acculturation. Students will be expected to master topics in systems neurobiology, molecular neurobiology, psychophysics, and other fields of active research in auditory neuroscience. Basic principles taught in multiple undergraduate departments will be connected with concepts about the neurobiology of disease as they relate to deafness, aphasia, dyslexia, and amusia; these connections will provide a basis for introducing contextualized material in molecular pathology, systems pathophysiology, neurology, and neuroimaging that are traditionally reserved for medical school and graduate school education. Emerging treatment, rehabilitation, and education technologies and new ideas for future research in the brave new worlds of neurobionics and genetic engineering will be explored.

Pre-requisites

MCB 80. Neurobiology of Behavior
Secondary School Physics or Engineering
Secondary School Algebra and Trigonometry

Not required: Ability to read or play music

Course Requirements & Grading

Lecture & Section Participation & Homework (25% of grade)

One Mid-Term Examination (30% of grade)

Final Examination (45% of grade)

No make-up Mid-Term Examination will be offered.

If you miss the Mid-Term Examination; 1) you must have a written medical excuse from University Health Services in order to pass the course; and 2) your course grade will be calculated as follows: Lecture & Section = 25%; Final Examination = 75%.

Books & Other Resources - Please see end of document*

WEEK 1

Lecture Series I. Introduction to Auditory Neurobiology

Tuesday, Sept 18

Course Overview

The Hearing Brain

Tramo

No Section in Week 1

Thursday, Sept 20

Pictures of Sound

Tramo

Friday, Sept 21, STUDY CARD DAY

5P today is the deadline for undergraduate and graduate students to complete electronic sectioning in our course; Section time(s) and place(es) will have been discussed in class.

WEEK 2

Lecture Series II. Auditory Communication

Tuesday, Sept 25

Chomsky. Expellarmus!

Phonetics, Phonology, & Prosody in Relation to Grammar & Semiotics in Babble, Interjections, Expletives, Conversation, Prose, Poetry, Song, Music, Film, Puns, & Branding (Whew!)

Tramo

Section #1

Acoustical Measurements: From Sound Level Meters to Oscilloscopes to Garage Band

Thursday, Sept 27

Neurophysiology & Neuroanatomy of Language I

Tramo

WEEK 3

Monday, Oct 1

5P today is the deadline for undergraduates to either drop the course or change the grade from a letter-grade to pass-fail (or vice versa) without paying the Registrar a fee

Tuesday, Oct 2

Neurophysiology & Neuroanatomy of Language II

Tramo

Section #2

Acoustic Phonetics & Psychoacoustics Laboratory Demonstrations

Thursday, Oct 4

Neurophysiology & Neuroanatomy of Language III

Tramo

WEEK 4

Tuesday, Oct 9

Evolution of the Language Faculty

Hauser

Section #3

Human Brain Imaging

Thursday, Oct 11

Neurophysiology & Neuroanatomy of Music I

Tramo

WEEK 5

Monday, Oct 15

5P today is the deadline for undergraduates to either drop the course or change the grade from a letter-grade to pass-fail (or vice versa)

Tuesday, Oct 16

Neurophysiology & Neuroanatomy of Music II

Tramo

Section #4

Electro- & Magneto-encephalography (EEG & MEG): Evoked Potentials & Event Related Potentials (EPs & ERPs)

Thursday, Oct 18

Neurophysiology & Neuroanatomy of Music III

Tramo

WEEK 6

Tuesday, Oct 23

Comparisons Between Language & Music

Tramo

Section #5

Review of Auditory Communication

Lecture Series III: Signal Processing by the Auditory System

Thursday, Oct 25

The Ear and Organ of Corti: Signal Amplification, Filtering, Transduction, and Mechanical Tuning in the Auditory Periphery

Matsui

WEEK 7

Monday, Oct 29

5P today is the deadline for graduate students to register for this course

Tuesday, Oct 30

The Auditory Nerve: Representation of Vocal & Musical Stimulus Features in the Discharge Patterns of Auditory-Nerve Fibers

Delgutte

Section #6

Physiology & Anatomy of the Auditory System

Thursday, Nov 1

Miracle Ear: Curing Deafness via Acoustic-to-Bioelectric Signal Transformation & Direct Electrical Stimulation of the Cochlea Using Implantable, Programmable Devices

Braida

WEEK 8

Tuesday, Nov 6

Auditory Brainstem

Tramo

Section #7

Spike Trains & Neural Coding

Thursday, Nov 8

Auditory Brainstem & Auditory Cortex

Tramo

WEEK 9

Tuesday, Nov 13

Auditory Cortex, Multi-Modal Cortex, & Supra-Modal Cortex

Tramo

Section #8

Review of Signal Processing by the Auditory System

Thursday, Nov 15

Mid-Term Examination: Auditory Communication & Signal Processing by the Auditory System

Saturday, Nov 17
Yale Game, at Yale

WEEK 10

Tuesday, Nov 20
Review of Mid-Term Examination
Tramo

Thursday, Nov 22
Thanksgiving
No Class, No Section

WEEK 11

Lecture Series IV: Developmental Biology of the Auditory System

Tuesday, Nov 27
Development of the Ear & Peripheral Auditory Nervous System
Matsui

Section #9
"The (Neuro)Bionic Woman": Prime Time for Bioengineering the Future

Thursday, Nov 29
Development of the Central Auditory Nervous System
Matsui

WEEK 12

Tuesday, Dec 4
Language Development in Infants & Children
Matsui

Section #10
"Ra" vs. "La", Critical Periods, & Sign Language

Lecture Series V. Molecular Biology of the Auditory System

Thursday, Dec 6
Molecular Pathology & Pathophysiology of Genetic Diseases I
Matsui

WEEK 13

Tuesday, Dec 11
Molecular Pathology & Pathophysiology of Genetic Diseases II

Matsui

Section #11

Congenital Hearing Loss & the Search for Mutations

Thursday, Dec 13

Social Psychology of Developmental Communication Disorders

Matsui

WEEK 14

Tuesday, Dec 18

Review of Molecular & Developmental Biology of the Auditory System

Matsui

No Section in Week 14

Wednesday, Dec 19

First Day of Winter Recess

READING PERIOD

Section #12

Date will have been discussed and announced in class

FINAL EXAM

Date will have been announced in class

Exam Group 13: Mon., Jan 14, 2008

Exam Group 14: Thu., Jan 17, 2008

In selecting courses, students should understand that final exams for two courses that fall within the same Exam Group or Exam Group Set (see below) will be scheduled on the same day. Students who want to avoid having two exams on one day should not enroll in two courses with the same Exam Group or Exam Group Set. All courses assigned to the following Exam Group Sets are scheduled to have their final exams on the same day:

Exam Groups 1, 7, 14

Exam Groups 2, 15, 16

Exam Groups 6, 10

Exam Groups 8, 9, 11, 12, 17, 18

Occasionally, the Registrar may need to assign an Exam Group that does not correspond to the meeting days and times of a course - students are therefore advised that they should not make any travel plans until the official final examination schedule is published.

***REQUIRED BOOK & FREWARE**

1. *Fundamentals of Hearing, 5th Ed*, by William Yost. Academic Press, NY, 2007.

Available at the Harvard Coop. Excellent figures, appendices, and supplements re: topics we cover in acoustics, psychophysics, audiology, and signal processing in the peripheral auditory nervous system. Lecture notes and recommended reading will provide additional information on these topics and most, if not all, of the written material about signal processing in the central auditory system, molecular and cellular neurobiology, systems neurobiology, neurobiology of disease, and

neuroimaging. *At Coop; On Reserve.*

2. <http://www.praat.org>.

Paul Boersma and David Weenink's website has Praat freeware ("praat" is Dutch for "gossip" or "speak") — a digital sound recording, editing, and analysis program. We use Praat in our course demonstrations, and it is in widespread use in speech and hearing research laboratories around the world. Kudos to Pal and David! Mac, IBM, and other platforms are supported. One of the best ways to learn about sound perception is to make sounds and listen how different manipulations affect how what you make hears. Just go to the website and download the freeware to a disk that is available to you; run the program and play with sounds while listening on headphones or good loudspeakers to optimize perception. Relevant to material and exercises covered during *Lecture Series I though III* and in Sections. Have fun with it!

RECOMMENDED BOOKS & CD

• http://www.brainmusic.org/MBB91_Webpage/Neurobio101.html This page on the Institute for Music & Brain Science website contains the Course Syllabus, selected lecture slides and images (in the form of powerpoint presentations), section material, pdf's of relevant literature, other types of files, and more – the sum total of which will exceed the space of our course site on the FAS server. The home page, www.BrainMusic.org, has several links that are likely to be of interest to students in the course.

• *Anatomy and Physiology of Hearing for Audiologists*, William Clark & Kevin Ohlemiller, Thomson Delmar, Clifton Park, NY, 2007. *At Coop and On Reserve.* One way to learn how something works is to find out how it breaks. This book does a good job of teaching health professionals who specialize in the diagnostic evaluation of patients with hearing loss *what went wrong* with the basic biological mechanisms in their patients. So, if you read this book (or at least parts of it), you'll make connections between what you learn about the neurobiology of normal hearing with what you learn about the pathophysiology and pathology of hearing loss. Excellent source for current knowledge about the peripheral auditory system, but not the central auditory system; consequently, won't help you gain insights into neural mechanisms underling percept formation and auditory cognition in language and music.

• *The Central Auditory System*, Gunter Ehret & Raymond Romand (eds), Oxford Press, NY 1996. *At Coop and On Reserve.* This is one of the few auditory central nervous system textbooks that covers the single- and multi-unit physiology of auditory cortex, thalamus, midbrain, and medulla in the kind of detail appropriate for a high-level auditory neurobiology course. However, it is an edited book, so it is not surprising that it lacks a central theme to tie the chapters together, other than the fact they are about microphysiology, microanatomy, and signal processing. That said, the much of the material covered in *Lecture Series III: Signal Processing by the Auditory Nervous System*, will draw from literature covered in this book.

• *Spikes: Exploring the Neural Code*, Fred Rieke, David Warland, Rob deRuyter van Steveninck, William Bialek, M.I.T. Press, 1999. *At Coop and On Reserve.* This book is of special interest for students wishing to explore perceptual-physiological correlates from the perspectives of systems neurobiology, computational neuroscience, biophysics, mathematical modeling, and probability and statistics. Relevant to *Lecture Series III: Signal Processing by the Auditory Nervous System*.

• *Cambridge Encyclopedia of Language*, 2nd Ed, David Crystal, Cambridge Univ Press, 1997. *At Coop and On Reserve.* This large book treats the term "language" in its broadest sense across multiple disciplines. The sections on phonetics, phonology, prosody, evolution, and development are relevant to *Lecture Series II: Auditory Communication* and *Lecture Series IV: Developmental Biology of the Auditory System*. The figures are excellent and the condensed format expedites covering the bare essentials. You will need to go beyond this encyclopedia to get a fuller and more accurate picture of each topic.

• *Harvard Dictionary of Music*, 4th Ed, D. Randle (ed), Harvard Press, Cambridge, MA, 2003. *At Coop and On Reserve.* Although coursework and performance in music is not a *pre*-requisite for this course, you will be required to read *about* the acoustics, phonology, and grammar of popular Western music (e.g., rock, classical) during the course. Entries in music dictionaries (e.g., "harmonic analysis", "triad") can be quite informative,

especially after some basic knowledge has been acquired in lectures and sections. *At Coop & On Reserve*. If you buy the Dictionary at Harvard Coop, Harvard Univ Press, or elsewhere, *please make sure you get the 4th edition*.

- *Co-Planar Stereotaxic Atlas of the Human Brain: 3-Dimensional Proportional System: An Approach to Cerebral Imaging*, Jean Talairach and Pierre Tournoux. *On Reserve*. Neuroanatomy always presents a special challenge – short books with good pictures – and labels – are hard to find. Atlases are very expensive and include way too much material. Students often overestimate how difficult this topic is and how much you need to know for a course like this — partly because we aren't clear about what is important to learn and what isn't. You need to learn the anatomy of the cerebral cortex for *Lecture Series II and III*. When it comes to the cerebral cortex, consider this: there are only two hemispheres; each of which has only four lobes and about two dozen gyri (same Greek root as the sandwich “gyros”). You need to know the names of these lobes and gyri. That's the base knowledge. Then, get some sense of how they relate to other, more indirect or abstract designations (e.g., Brodmann's “area 22”, “Wernicke's area”, “auditory” cortex). There are several books at Cabot Library and the Medical School Library (Countway) that are excellent resources – just use “Human Neuroanatomy” as a Hollis search term. There are also several resources available on the Internet. You don't need to learn about the the spinal cord, spinal nerves, or cranial nerves (except the “auditory nerve”, a.k.a., “cranial nerve VIII”, “vestibulocochlear nerve”) for this course. The Talairach Atlas of the cerebral hemispheres is in widespread use in current neuroimaging research.

- *Colorful Introduction to the Anatomy of the Human Brain, A: A Brain and Psychology Coloring Book*, John P.J. Pinel, Maggie E. Edwards, Boston: Allyn & Bacon, Inc., 1997. *On Reserve*. Interactive learning, the old-fashioned way.

- *Introduction to the Psychology of Hearing, 5th Edition*, Moore B, Cambridge Univ, 2003. *On Reserve*. The most popular “psychology of hearing” book for over two decades, this small paperback is single-authored by one of the world's leading psychoacousticians. It has more psychology and less physiology and anatomy than Yost's book. Although “psychology of hearing” is the title, it's really an introduction to the subdiscipline, psychophysics of hearing, for which it can be used as an abridged reference text; it does not cover the subdiscipline, cognitive psychology of hearing, which our course also covers.

- *Introducing Phonetic Science*, M Ashby & J Maidment, Cambridge U Press, NY, 2005. *On Reserve*. The authors do an excellent job explaining and illustrating some of the key points about phonetics and phonology that are introduced in *Lecture Series II: Auditory Communication*.

- *Dictionary of Linguistics and Phonetics, 5th Ed*, David Crystal, Blackwell, Boston, 2003. *On Reserve*. Precise and sometimes in-depth definitions of terms we introduce in *Lecture Series II: Auditory Communication*.

- *The Audio Dictionary, 2nd Ed*, Glenn White, U Wash, Seattle, WA, 1991. Another resource for clarifying the meaning of recondite terms — in this instance, terms used to describe different types of acoustic signals described in *Lecture Series II and III*. We didn't put this on reserve.

- *Acoustical Society of America Auditory Demonstration CD*. Trying to understand, no less talk about, auditory experiments on pitch, harmony, timbre, etc. is as frustrating as trying to follow circuitous directions involving twists and turns around streets with names you've never heard before — and can't even pronounce! Words just don't do it. It's better to listen to the stimuli used in psychoacoustic experiments. Houtsma and Rossing made this “Best of” compilation CD for that reason. If you hear the stimuli and understand what the experiments were about (concise explanations of each track and related experiments are included), your reading of Yost and related recommended books will be clearer. We will use some of the tracks in *Lecture Series II: Auditory Communication*. The CD is published by the Acoustic Society of America. Send orders for the “ASA Auditory Demonstrations on Compact Disc” to Acoustical Society of America (ASA) Publications, P.O. Box 1020, Sewickley, PA 15143-9998; Tel: 412-741-1979; Fax: 412-741-0609; Email (for inquiries): asapubs@abdintl.com. Price: ASA members \$23; Nonmembers \$31. Postage and handling charges are: U.S. orders - \$6.00 for first title; \$2.00 for each additional title; Prepay by check or money order in U.S. funds drawn on a U.S. bank or by Mastercard, Visa, or American Express credit cards.

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