# Experiment-based modeling of neurons and networks Spring 2017

## Description

This course focuses on developing models that capture the salient features of neuron and network dynamics. Students will collect data using whole-cell recording, dynamic clamp, and optogenetic stimulation techniques in the *in vitro* slice or culture preparation. Several approaches to modeling the data will be discussed, including spiking (Hodgkin-Huxley, integrate-and-fire neurons and variants), rate, and mean field models. The goal is to choose the simplest model that will account for the intrinsic and statistical properties of individual neurons and networks. Note that there will be three 4-hour labs; to preserve the total hours for the course, the class will not meet in the week following each lab session.

#### Prequisites

Cellular Neural Science (NEURL-GA 2001), 2207) Sensory and Motor Systems (NEURL-GA 2202) Math Tools (NEURL-GA

## Lecturer

Alex Reyes <u>Reyes@cns.nyu.edu</u> Meyer 1058 8-3994

Lecture	Wednesday, 2:00-4:00	Room 807
Lab	Wednesday: 2:00-6:00	Room 1058

## Grading:

Grading will be based on 3 mini-projects (30% each) and on class participation (10%)

# <u>Syllabus</u>

#### 1. (Jan. 25): Overview of course (classroom)

a. Review of Passive/Active properties of neurons

b. Whole-cell recording technique primer

#### 2. (Feb. 1): Intrinsic Properties of neurons (classroom)

a. Survey of neuron types and their firing characteristics b. Biophysically-realistic models vs. simple spiking models <u>Readings:</u>

> Schwindt et al. (1997), J. Physiol. 77:2484 Naud et al. (2008), Biol Cybern. 99:335 Izhikevich, (2004) IEEE Trans 15: 1063 Markram (2004), Nature 3:798

## 3. (Feb. 8): Intrinsic Properties of neurons (lab: 4hrs)

- a. Whole-cell recordings of cortical neurons
- b. Passive properties, Firing rate vs current, responses to noisy input

#### 4. (Feb. 15): Reyes office hours (no class)

a. additional lab time if necessary

## 5. (Feb. 22): Discussion of data /models (classroom)

#### $\rightarrow$ mini-project 1 due

a How well does model fit data?

b. Under what conditions are assumptions valid?

#### 6. (March 1): Synaptic properties I: unitary PSPs (classroom)

a. Basic properties of synaptic potentials, Depression/Facilitation
b. Biophysical vs phenomenological models of synapses
<u>Readings</u>:

Reyes et al. (1998) Nat. Neurosci 1: 279 Tsodyks & Markram (1997), PNAS 94:719 Markram et al. (1998), PNAS 95:5523

## 7. (March 8): Synaptic properties II: barrages (classroom)

a. Statistics of in vivo spiking

b. Modeling synaptic barrages; Spiking vs Rate models

- d. Principles of dynamic clamp
- Reading:

Oviedo & Reyes, (2012) PLoS one 7:e33831 Sharp et al. (1993), J. Neurophys. 69: 992 Churchland et al. (2010); Nat. Neurosci. 13:369

#### 8. (March 15): Spring Recess (no class)

#### 9. (March 22): Measuring synaptic properties (lab: 4 hrs)

- a. Paired recordings to measure unitary synaptic potentials
- b. Dynamic clamp to mimic synaptic barrages

## 10. (March 29): Reyes office hours (no class)

a. additional lab time if necessary

## 11. (April 5): Discussion of data /models (classroom)

## → mini project 2 due

- a. Do phenomenological models capture essential features of synaptic data?
- b. Functional implications of depression/facilitation

#### 12. (April 12): Network Dynamics I: mean field approximation (classroom)

- a. Conditions for achieving balance between excitation and inhibition b. Experimental evidence for balanced regime
  - b. Experimental evidence for balanced regime

Reading

van Vreeswijk & Sompolinksy (1998) Neural Comp 10:1321 Barral & Reyes (2016) Nat. Neurosci

#### 13. (April 19): Network Dynamics iI: modulating correlations (classroom)

a. Factors affecting subthreshold and suprathreshold correlations <u>Reading</u>

Renart et al. (2010) Science 327: 587 Cohen & Kohn (2011); Nat. Neurosci. 14:811

## 14. (April 26): Optogenetic stimulation of culture networks (lab: 4hrs)

a. re-creating in vivo activity with light stimulation of channel rhodopsin expressing neurons

#### 15. (May 3): Reyes office hours (no class)

a. additional lab time if necessary

## 16. (May 10): Discussion of data /models (classroom)

## $\rightarrow$ mini project 3 due

a. Limitations of Mean field approximation of network activity