Math Aspects of Neurophysiology

J Rinzel, Fall 2016
Wednesday, 2:30pm-4:20 pm, WWH 1314.

MATH-GA 2863 Advanced Topics in Math Physiology (Courant Inst)
NEURL-GA 3042 Special Topics in Neural Science (CNS)
BIOL-GA 2855 Special Topics in Math Physiology (Biology)

Contact info: rinzeljm@gmail.com
Office: Rm 919 in Courant, Rm 753 in CNS; phone: x83308

1. (sept 7-14) Overview and some “toy models” (integrate & fire) [1]
2. (sept 14) Membrane biophysics [2]
   a. Electrodiffusion theory for ion fluxes: resting potential; flux through open channels
   b. Channel gating; deterministic and stochastic treatments
3. Excitability and action potentials (APs) [4-6]
   a. (sept 21) The Hodgkin-Huxley model
      i. development of the model, I-V rel'ns
      ii. phase plane treatment of V-m, and V-n/h reductions
      iii. repetitive firing, Hopf bifurcation
   (sept 28) TBD
   b. (oct 5) The Morris-Lecar model
      i. phase plane analysis of AP, single and multiple steady states
      ii. repetitive firing: Type I (saddle-node), II (Hopf)
      iii. bistability of various types
   c. (oct 5) Functional diversity of currents
   d. (oct 12) Other firing dynamics
      i. onset firing: Type III, input slope detector
      ii. adaptation; post-inhibitory rebound
      iii. bursting w/ fast/slow geometric analysis
      iv. Optional: stochastic firing; phase-locking
4. Cable equation, axonal propagation [7-9]
   a. Optional: numerical methods.
   b. (oct 19) Traveling AP and AP trains; sing perturb’n treatment; dispersion relation; kinematics
   c. (oct 26) Stimulus-response properties & numerical methods
d. (nov 2) Effects of inhomogeneities; propagation in myelinated axon

5. Dendritic signaling [10-11]
   a. (nov 9) Rall’s model: equivalent cylinder approximation; estimating passive neuronal parameters; compartmental treatment
   b. (nov 16) Signal attenuation in branching trees
   c. (nov 16) Active properties in dendrites
   (nov 23) Thanksgiving break
   d. (nov 30) Reduced models with few compartments; segregated currents
   e. (nov 30) Coincidence detection with dendrites; dendritic spines

6. Synaptic transmission and dynamics [12-13]
   a. (dec 7) Models for postsynaptic conductance dynamics
   b. (dec 7) Presynaptic considerations: calcium domains, pool depletion
   c. (dec 14) Facilitation, depression, plasticity (LTP, STDP, NMDA)
   d. (dec 14) Optional: Effects on cell interactions - synchronization or not.

Some references (on reserve in Courant Library)

Available on course web site (NYU Classes)

https://www.math.nyu.edu/faculty/peskin/neuronotes/index.html

What’s expected:

- Homework: 4 or so assignments (~ 40% of grade)
- Modeling project: written and oral presentation (~ 40%)
  o Your model or from literature; your question.
  o Report: 5-7 pgs. Intro, Methods, Results, Conclusions; figs & captions.
  o Oral presentation at end of term
  o Abstract due Nov 29
- Other: participation etc (~20%)