Topics in Computational Neuroscience 2017: Networks Tuning

# Course description

## We know that brains consist of multiple functional regions that each host multiple neural networks, which in turn are built of anything from dozens to millions of neural cells. To understand how brains work we need, among other things, to know how individual neurons within each of these networks are connected (at least statistically speaking), and how their properties are tuned to make the network function as it should. In this seminar course you will read and present primary papers that use imaging, electrophysiology, advanced statistical analysis, and modeling to study how neural networks are tuned and shaped in various biological systems. For the final assignment you will have a choice between a mini-project on data analysis and a short review paper. The course is recommended for upper college students with neuroscience or/and computational background

## Ways of communication

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E-mail is the main way of out-of-class communication for this course. Make sure to check your mail regularly. Under normal circumstances all assignments (lab reports, grant proposals) should be uploaded to Moodle. There is no textbook associated with this course.

**Office hours:** Wed 1-2:30, Fri 11-12:30.

# Goals of the course

By the end of this course you will:

1. Have a good idea about the spirit of data-rich research in modern network neuroscience
2. Have experience in working your way through reasonably math-heavy neuro papers
3. Learn the principles of data analysis for calcium imaging
4. Learn some fancy statistical methods (or at least learn to interpret their results)

In other words:

* If you are on a neuroscience track, you will know what math to learn, and hopefully will be less afraid of it
* If you are a on a computational track, you'll become somewhat familiar neuroscience, and will be more prepared to enter this field in the future (if necessary)

# Weekly plan of topics

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| **N** | **Dates** | **Reading** |
| 1 | Feb 2 | Intro. Learn / refresh what these words mean, and how they work: neuron, synapse, axon, action potential, ion channel, Na and K voltage-gated channels, inhibition, glutamate and GABA. Read about Ca imaging, learn how it works, and how signals look like. |
| 2 | 9 | *Snowstorm happened* |
| 3 | 16 | Carroll, M. S., J. C. Viemari, et al. (2013). "Patterns of inspiratory phase-dependent activity in the in vitro respiratory network." Journal of Neurophysiology **109**(2): 285-295. |
| 4 | 23 | Lütcke, H., Gerhard, F., Zenke, F., Gerstner, W., & Helmchen, F. (2015). Inference of neuronal network spike dynamics and topology from calcium imaging data. *Neural Circuits Revealed*. |
| 5 | Mar 2 | *same paper, part 2* |
| 6 | 9 | Gourevitch, B. and J. J. Eggermont (2007). "Evaluating information transfer between auditory cortical neurons." Journal of Neurophysiology **97**(3): 2533-2543. |
| 7 | 16 | Stetter, O., Battaglia, D., Soriano, J., & Geisel, T. (2012). Model-free reconstruction of excitatory neuronal connectivity from calcium imaging signals. *PLoS Comput Biol*, *8*(8), e1002653. |
|  | 23 | *Spring Recess* |
| 8 | 30 | Gerhard, F., Kispersky, T., Gutierrez, G. J., Marder, E., Kramer, M., & Eden, U. (2013). Successful reconstruction of a physiological circuit with known connectivity from spiking activity alone. *PLoS Comput Biol*, *9*(7), e1003138. |
| 9 | Apr 6 | O'Leary, T., Williams, A. H., Caplan, J. S., & Marder, E. (2013). Correlations in ion channel expression emerge from homeostatic tuning rules. *Proceedings of the National Academy of Sciences*, *110*(28), E2645-E2654. |
| 10 | 13 | tbc. Potentially: Elstrott, J., Clancy, K. B., Jafri, H., Akimenko, I., & Feldman, D. E. (2014). Cellular mechanisms for response heterogeneity among L2/3 pyramidal cells in whisker somatosensory cortex. *Journal of neurophysiology*, *112*(2), 233-248. |
| 11 | 20 | tbc. Potentially: Clopath, C., Büsing, L., Vasilaki, E., & Gerstner, W. (2010). Connectivity reflects coding: a model of voltage-based STDP with homeostasis. *Nature neuroscience*, *13*(3), 344-352. |
| 12 | 27 | tbc. Candidate: Butz, M., Steenbuck, I. D., & van Ooyen, A. (2014). Homeostatic structural plasticity increases the efficiency of small-world networks. Frontiers in synaptic neuroscience, 6, 7. |
| 13 | May 4 | Final assignment presentations (tbc) |
| 14 | 11 | Final assignment presentations (for sure) |
| 15 | 18 | *Completion week* |

### Other interesting, related papers

O’Leary, T., Williams, A. H., Franci, A., & Marder, E. (2014). Cell types, network homeostasis, and pathological compensation from a biologically plausible ion channel expression model. *Neuron*, *82*(4), 809-821.

Aljadeff, J., Lansdell, B. J., Fairhall, A. L., & Kleinfeld, D. (2016). Analysis of neuronal spike trains, deconstructed. *Neuron*, *91*(2), 221-259.

Linderman, S. W., & Gershman, S. J. (2017). Using computational theory to constrain statistical models of neural data. *bioRxiv*, 104737.

Zenke, F., Hennequin, G., & Gerstner, W. (2013). Synaptic plasticity in neural networks needs homeostasis with a fast rate detector. *PLoS Comput Biol*, *9*(11), e1003330.

# Grading

Composition of the final grade:

* 40%: Class attendance and participation, including figure presentations, questions, answers, discussions, peer-reviews and other in-class assignments
* 30%: Reading reflections
* 30%: Final assignment, including its presentation

## Reading reflections

Each week we have reading materials assigned, and you will need to submit a reading reflection online (on Moodle). The reading reflection will normally consist of one question, requiring a short response. The questions will vary from week to week. This assignment is always 2 points max (1 point for being on time, and 1 point for a good meaningful response).

## Paper discussions and class participation

We'll discuss a paper every week, in most cases going figure by figure, and paragraph by paragraph. Be prepared to lead a small portion of this discussion (say, a figure or a panel in a figure), offer good follow-up questions, or provide answers.

## Final assignment

You can choose between two types of final assignments: computational project and mini-review.

### Computational project

You will be given a dataset with Ca imaging signals recorded from real cells in real brains, at different developmental stages, and in response to different sensory stimuli. You goal will be to do something interesting about it: ask a meaningful question and try to answer it; visualize it in a novel way; try a new method to approach these signals etc. More information about the dataset, and the dataset itself, will be provided as the course going on.

### Mini-review

Alternatively, you can write a mini-review of some recent research related to the topics discussed in class. Requirements:

* Should compare at least 2 recent (post-2010) primary papers that share something (topic, method, structure, question), but also disagree about something, contribute to each other's findings, or make our understanding of this topic / question / method more nuanced.
* At least one of these papers should be immediately relevant to the topics we discussed (ideally, should also cite one of the papers we discussed). So pretty much it should be either about Ca imaging analysis, or about diversity of multidimensional tuning in neural networks.
* At least 10 references overall (reviews included).
* Not more than 1500 words in total (about 3 pages)

# Other important points

## Missed and late work

Most homework assignments can be handed in within two weeks after the due date, with a penalty on the grade. There are no make-up assignments for participation-like grades, but two worst grades will be dropped. No assignments are accepted after the last day of completion week.

## Academic integrity and plagiarism

You need to do your own work and write your own assignments (tests, homework, exams, essays, lab reports). You should also be ready to defend your work verbally, in person, if needed.

On all other aspects of the course, unless explicitly stated otherwise, collaboration and team work are strongly encouraged. You may seek inspiration by talking to your peers before writing your texts. It is great if you show your work to other students and listen to their feedback. It is very advisable that you work together on lab reports. But the writing itself should be done by you. Borrowing texts from other people or from the internet without acknowledgement is unacceptable, and will result in bad things happening.

## Snow policy

Classes during heavy weather are tied to the activity of the Bard shuttle. If the shuttle is cancelled, the classes are also cancelled (because presumably if a big metal bus is afraid to go outside, we little humans should also stay at home). If shuttle service is restored, and if it happens at least an hour before class, the class is typically held. If there is a risk of shuttle cancellation, make sure to keep an eye on e-mail updates.

## Syllabus mutation policy

Instructor may improve the syllabus during the semester, to make the course even more amazing (for example, we may have to move some topics around). In case of any adjustments, you'll be informed of them in advance.