Syllabus: Systems Neuroscience and Theoretical Neuroscience

# Times

Session: Academic year 2018-19; October 2 - December 14

Lectures: Tuesday and Friday 11:00 – 13:00 (five min break)

Tutorials: Term 1: Friday 9:00 – 11:00

Term 2: Thursday 11:00 – 13:00

# Contacts

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## Programme Coordinator

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## Teaching Assistants

(second year students – individual roles)

# Course Description

The course on systems and theoretical neuroscience is co-taught by SWC and GCNU faculty. Modules are in two week blocks. The first week in the module, both SWC and GCNU students attend one introductory lecture on theoretical context and one on biological context. The second week of each module, students in the SWC programme delve deeper into systems neuroscience with two additional lectures, while GCNU students focus on theoretical material.

# Learning Goals and Learning Outcomes

After the course, students will have an understanding of current topics in systems neurobiology, as well as familiarity with basic theoretical neuroscience concepts.

# Readings, Materials, and Resources

Each lecturer will provide a list of important topics for the lecture and suggested reading before the lecture, as well as problem sets after the lecture. The latter will be worked through during tutorials led by the teaching assistants.

# Course Policies and Expectations

Students are expected to attend all lectures, and come well prepared by looking at the important topics and the suggested reading. Slides and audio for missed lectures can be provided upon request. Students are required to attend the teaching-assistant led tutorials, and try to solve the problem sets beforehand.

# Learning Toolbox

# Learning Resources

# Course Schedule

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| --- | --- | --- | --- |
| Lecture | Lecturer | Title | Overview |
| 1 | Maneesh | Sensation, Perception and Inference | Sensation, perception, priors and inference; generative models; unsupervised learning; contrastive divergence |
| 2 | Maneesh | Coding, Point Processes, and Optimality I | Describing spike trains; neural coding; variability, point processes, Poisson processes, variance, ISI distribution |
| 3 | Maneesh | Coding, Point Processes, and Optimality II | Information theory; how much information does a response carry about a stimulus; uncertainty; entropy; decorrelation in retina |
| 4 | GCNU | Population Coding (and more Optimality) I | Rate coding; tuning curves; continuous estimation; Cramér-Rao bound, Fisher Info, multiple |
| 5 | GCNU | Population Coding (and more Optimality) II | Optimal tuning properties; robustness to noise |
| 6 | Tom MF | Vision |  |
| 7 | Maneesh | Representation and Computation with Uncertainty |  |
| 8 | Nick Lesica | Audition |  |
| 9 | Adam | Control Problems |  |
| 10 | John | Hippocampus |  |
| 11 | Andy | Cortical and sub-cortical movement and posture control |  |
| 12 | Tiago | Why sense and move? |  |
| 13 | Yoh | Innate behavior and animal learning |  |
| 14 | GCNU | Learning/RL | Marrian conditioning, simple learning, Rescorla-Wagner classical conditioning model, Pearce-Hall error learning, contect, extinction, Kalman filter, temporal difference learning and dopamine, predicition error, immediate reinforcement, stochastic policy, direct actor, Tolmanian forward model |
| 15 | Marcus | Basal Ganglia |  |
| 16 | Adam | Intelligent systems/discussion |  |
|  |  | Winter break |  |
| 1 | Peter L | Biophysics 1 | Cable Equation, response of a dendrite to steadily injected current, response of a dendrite to time-dependent injected current |
| 2 | Peter L | Biophysics 2 | modeling branch points, modeling axons |
| 3 | Peter L | Biophysics 3 | Linear algebra, Fourier transforms, ordinary differential equations, linear ODEs, non-linear ODEs |
| 4 | Peter L | Biophysics 4 | Bifurcation theory, stochastic differential equations, central limit theorem, Taylor expansions, intergrals, distributions, delta function, Lagrange multipliers |
| 5 | Tom O | Recording Electrical Signals in Neurons | Electrophysiological and optical (Ca++ and voltage indicators) methods |
| 6 | Troy | Synaptic Transmission | Quantal theory, release probability, post-synaptic receptors, coincidence detection, plasticity |
| 7 | Tiago | Synaptic Integration in Single Neurons | Input-output functions, spatial and temporal integration, time constant, voltage attenuation in cables, compartmental modeling, active properties in dendrites |
| 8 | Yoh | Genes and Behaviour | Discussion: how are genes and molecules relevant to understanding behaviours? Reductionism |
| 9 | Peter L | Attractor Networks |  |
| 10 | Peter L | Feedforward networks/recurrent rate networks |  |
| 11 | Andy | Viral methods for interrogating neural circuits | AAV and rabies virus, genome structure, life cycle, virus production, size constraint, targeting to specific cell types (promotor, Cre/Lox, tropism) |
| 12 | Tom O | Cerebellar Learning | Cerebellum connectivity, behavior and cerebellar learning, circuit hypotheses, theoretical models, cellular mechanisms |
| 13 | Tom MF | Connectivity mapping |  |
| 14 | Marcus | Neuromodulation | Connectome state dependence, differential information flow, Neuromodulatory systems (5HT, Ach, NE, DA |
| 15 | Maneesh | Hebbian Learning 1 |  |
| 16 | Maneesh | Hebbian Learning 2 |  |
| 17 | Peter L | Balanced Networks 1 |  |
| 18 | Peter L | Balanced Networks 2 |  |
| 19 | Peter L | Balanced Networks 3 |  |

https://teachingcommons.stanford.edu/resources/course-preparation-resources/creating-syllabus