Syllabus for BIOL 485/PHYS 741R: Measuring and Modeling Animal Behavior (Fall 2017)

Course Information:

Meeting Time: MW 2:30pm - 3:45pm
Room: 113 Dental School Building (1462 Clifton Road)
Instructor: Dr. Gordon Berman, Assistant Professor of Biology
Office: 2107 Rollins Research Center
Email: gordon.berman@emory.edu (the best way to contact me).
Please put [Behavior] in the subject line so that I can prioritize class-related emails.
Office Hours: By appointment

Goals:

My aim is to provide a broad survey of the experimental, data analytical, and theoretical techniques in quantitative animal behavior. This will be done through engaging with the primary literature, completion of an end-of-semester project, and (for the graduate student enrollees) approximately bi-weekly computational/analytical assignments. It should be noted that this course is not aimed to be a survey of the specifics and mechanisms of how animals behave – as would be done in a standard introduction to ethology or behavioral neuroscience/genetics course. That's not to say that we won't learn some interesting things about behavior along the way, but instead, our focus will be on understanding the methods that researchers use to quantitatively probe animal behavior, keeping in mind three basic, fundamentally intertwined, questions:

1. What are the best quantities to measure for assessing the underlying behavioral questions?
2. How can these quantities be accurately measured?
3. What type of models can best lead to theoretical understanding of the data?

Themes:

1. **Defining Behavior**
2. **Measuring Behavior**
3. **Latent States and Patterns**
4. **Collective and Social Behavior**
5. **Locomotion and Control**
6. **Behavioral Neuroscience**
7. **Behavioral Genetics**

Course meetings and Quizzes:

After the first three meetings (where I will give an introduction and the lead the first two paper discussions), subsequent classes will be lead by individual students, who will present and discuss papers related to the themes enumerated below. The schedule of papers is listed at the end of this document and students should sign-up for presentation slots online before the second course meeting of the semester via a survey on Canvas. All papers will be posted on the course Canvas site. At least 36 hours prior to every class (excepting the first), I will post a brief quiz/questionnaire onto Canvas about the next papers to be discussed, with questions about previous readings potentially alongside. Answers to these questions **are due on Canvas before noon of the day of every class meeting**. There will also be a box to post any questions and comments or topics about the reading that you would like to discuss, contributions to which will be considered part of your participation grade. Students presenting should send me any notes/slides they used for their paper presentations, as these materials will be used in evaluating the presentations and will be distributed to the class as a resource.

Homework

For graduate enrollees, homework assignments will be due approximately bi-weekly (5 or 6 over the semester). Assignments will be related to the papers we have discussed in class and will consist of computational and analytical exercises. For computational problems, I am agnostic as to the choice of programming language, although I imagine that python, Matlab, Mathematica, and/or C/C++ will prove the most useful. Group work is encouraged, but I ask that all collaborators' names be listed on the final document and that each individual writes their own solutions and code.

Final Project

A final project will also be required of all enrollees, **due before 11:59pm on Friday, December 8th**. This project can take one of three forms: (1) A detailed grant-proposal-like document that outlines a set of specific experiments or models to undertake, (2) A detailed review article describing and synthesizing progress and future directions within a particular field, or (3) A computational, theoretical, or data-analytical project related to the themes of the course. Graduate enrollees are particularly encouraged to choose option (3) and to incorporate their own research, if possible. Additional papers related to the discussed topics in this course will be posted in Canvas for inspiration.

Paragraph-long project proposals will be due by the beginning of class on October 11th and project outlines will be due on November 8th. All projects must be pre-approved by the instructor.

If choosing option (1), the proposal must include sections detailing the necessary scientific background, the overarching goals and significance of the proposed research, a set of proposed experiments/analyses/modeling projects, potential pitfalls and problems, necessary resources, and a projected timeline for the work.

For option (2), the review should encompass a relatively large swath of behavioral research (e.g. "Using perturbations to study sensorimotor learning" or "Methods for unsupervised learning of behavioral dynamics"). The general standard for an 'A' project is that a first year Ph.D. student should be able to read the review and be immediately up to the state of the art in the field you have decided to write about.

For option (3), my expectation for the project is that it will either be an application of an method/model/technique we have discussed to a previously unexamined system or a replication of an existing work, with some extension added-on. This could be adding another term to a model or analyzing a different parameter regime, applying another analysis to the same data set, or a variety of other options. Deeper extensions will be expected of graduate students' projects than will be expected for undergraduates.

One last potential option is for the class to engage in a team project, with the goal of producing an original research output by the end of the semester. This can be discussed as the semester progresses, and all of the same due-dates would apply. All students are responsible for listing their independent contributions to the project.

All projects will be presented during the final two sessions. The presentation will be approximately 15% of the overall project grade. Further details will be provided closer to the first due date.

Evaluation:

Undergraduate Students: 25% paper presentations, 15% quizzes, 45% final project, and 15% course participation.

Graduate Students: 20% paper presentations, 10% quizzes, 30% homework assignments, 30% final project, and 10% course participation.

The participation grade will be assessed through a combination of attendance, participation in discussions, and submitted discussion questions/comments.

Absences:

Because course participation is a significant portion of the grade, attendance will be noted. Please discuss with me if you need to miss a class for whatever reason. **Pre-excused** absences can be made-up through handing in written notes of the papers to be discussed.

Honor code:

The Emory College Honor code applies to all work in this class.

Tentative Schedule

8/23: **Introduction**

8/28: **Defining Behavior: Ethology**

Discussion Papers:

- Tinbergen, N. On aims and methods of ethology. Zeitschrift für Tierpsychologie 20, 410-433 (1963).
- Skinner, B. F. The experimental analysis of operant behavior. Annals of the New York Academy of Sciences 291, 374-385 (1977).

8/30: **Defining Behavior: Quantifying Behavior**

Discussion Papers:

- Leshner, A. & Pfaff, D. W. Quantification of behavior. PNAS 108 Supp 3, 15537-15541 (2011).
- Anderson, D. J. & Perona, P. Toward a Science of Computational Ethology. Neuron 84, 18-31 (2014).

9/6: **Defining Behavior: Behavior and Mechanisms**

Discussion Papers:

- Krakauer, J. W. et al. Neuroscience Needs Behavior: Correcting a Reductionist Bias. Neuron 93, 480-490 (2017).
- Chiel, H. J. & Beer, R. D. The brain has a body: adaptive behavior emerges from interactions of nervous system, body and environment. Trends Neurosci 20, 553-557 (1997).

9/11: **Measuring Behavior: Image Analysis**

Discussion Papers:

- Dell, A. I. et al. Automated image-based tracking and its application in ecology. Trends in Ecology & Evolution 29, 417-428 (2014).
- Straw, A. D., et al, Multi-camera real-time three-dimensional tracking of multiple flying animals. Journal of the Royal Society, Interface 8, 395-409 (2011).

9/13: **Measuring Behavior: Center of Mass Tracking**

Discussion Papers:

- Dankert, H. et al. Automated monitoring and analysis of social behavior in Drosophila. Nat Methods 6, 297-303 (2009).
- Prez-Escudero, A. et al. idTracker: tracking individuals in a group by automatic identification of unmarked animals. Nat Methods 11, 743-748 (2014).

9/18: **Measuring Behavior: Limb Tracking**

Discussion Papers:

- Mendes, C. S. et al. Quantification of gait parameters in freely walking wild type and sensory deprived Drosophila melanogaster. eLife 2, e00231 (2013).
- Machado, A. S. et al. A quantitative framework for whole-body coordination reveals specific deficits in freely walking ataxic mice. eLife 4, e07892 (2015).

9/20: **Measuring Behavior: Supervised Analysis**

Discussion Papers:
- Kabra, M., et al. JAABA: interactive machine learning for automatic annotation of animal behavior. Nat Methods 10, 64-67 (2013).
- de Chaumont, F. et al. Computerized video analysis of social interactions in mice. Nat Methods 9, 410-417 (2012).

9/25: **Measuring Behavior: Unsupervised Analysis**

Discussion Papers:
- Stephens, G. J. et al. Dimensionality and dynamics in the behavior of C. elegans. PLoS Comput Biol 4, e1000028 (2008).
- Osborne, L. C. et al. A sensory source for motor variation. Nature 437, 412-416 (2005).

9/27: **Measuring Behavior: Unsupervised Analysis**

Discussion Papers:
- Berman, G. J. et al. Mapping the stereotyped behaviour of freely moving fruit flies. Journal of the Royal Society Interface, 11, 20140672 (2014).
- Wiltschko, A. B. et al. Mapping Sub-Second Structure in Mouse Behavior. Neuron 88, 1121-1135 (2015).

10/2: **Latent States and Patterns: Patterns of behavior**

Discussion Papers:
- Dawkins, R. Hierarchical organisation: A candidate principle for ethology. (1976).

10/4: **Latent States and Patterns: Hierarchical Structure**

Discussion Papers:
- Dawkins, R. & Dawkins, M. Hierarchical Organization and Postural Facilitation - Rules for Grooming in Flies. Animal Behaviour 24, 739-755 (1976).
- Seeds, A. M. et al. A suppression hierarchy among competing motor programs drives sequential grooming in Drosophila. eLife 3, e02951 (2014).

10/11: **Latent States and Patterns: Time Scales & Predictability**

Discussion Papers:
- Heiligenberg, W. Random processes describing the occurrence of behavioural patterns in a cichlid fish. Animal Behaviour 21, 169-182 (1973).
- Stephens, G. J. et al. Emergence of long timescales and stereotyped behaviors in Caenorhabditis elegans. PNAS. 108, 7286-7289 (2011).

10/16: **Locomotion and Control: Legged Locomotion**

Discussion Papers:
- Srinivasan, M. & Ruina, A. Computer optimization of a minimal biped model discovers walking and running. Nature 439, 72-75 (2006).
- Full, R. J. et al. Quantifying dynamic stability and maneuverability in legged locomotion. Integrative and Comparative Biology, 42(1), 149-157 (2002)

10/18: **Locomotion and Control: Flight Maneuvers**

Discussion Papers:
- Card, G. & Dickinson, M. Performance trade-offs in the flight initiation of Drosophila. J Exp Biol 211, 341-353 (2008).
- Ristroph, L. et al. Discovering the flight autostabilizer of fruit flies by inducing aerial stumbles. PNAS. 107, 4820-4824 (2010).

10/23: **Locomotion and Control: Robotic Models**

Discussion Papers:
- Dickinson, M. H. et al. Wing rotation and the aerodynamic basis of insect flight. Science 284, 1954-1960 (1999).
- McInroe, B. et al. Tail use improves soft substrate performance in models of early vertebrate land locomotors. Science 353, 154-158 (2016).

10/25: **Collective and Social Behavior: Flocking**

Discussion Papers:
- Vicsek, T. et al. Novel type of phase transition in a system of self-driven particles. Physical Review Letters 75, 1226-1229 (1995).
- Buhl, J. et al. From disorder to order in marching locusts. Science 312, 1402-1406 (2006).

10/30: **Collective and Social Behavior: Social Interactions**

Discussion Papers:
- Coen, P. et al. Dynamic sensory cues shape song structure in Drosophila. Nature 507, 233-237 (2014).
- Klin, A.et al. Two-year-olds with autism orient to non-social contingencies rather than biological motion. Nature 459, 257-261 (2009).

11/1: **Collective and Social Behavior: Collective Decision Making**

Discussion Papers:
- Couzin, I. D.et al. Effective leadership and decision-making in animal groups on the move. Nature 433, 513-516 (2005).
- Strandburg-Peshkin, A. et al. Shared decision-making drives collective movement in wild baboons. Science 348, 1358-1361 (2015).

11/6: **Behavioral Neuroscience: Adaptation & Control**

Discussion Papers:
- Ahrens, M. B. et al. Brain-wide neuronal dynamics during motor adaptation in zebrafish. Nature 485, 471-477 (2012).
- Sober, S. J. & Brainard, M. S. Vocal learning is constrained by the statistics of sensorimotor experience. PNAS. 109, 21099-21103 (2012).

11/8: **Behavioral Neuroscience: Multi-sensory Integration**

Discussion Papers:
- Gepner, R., et al. Computations underlying Drosophila photo-taxis, odor-taxis, and multi-sensory integration. eLife 4, (2015).
- Zhou, B. et al. Chance, long tails, and inference: a non-Gaussian, Bayesian theory of vocal learning in songbirds. bioRxiv (2017).

11/13: **Behavioral Neuroscience: Reinforcement Learning**

Discussion Papers:
- Schultz, W., Dayan, P. & Montague, P. R. A neural substrate of prediction and reward. Science 275, 1593-1599 (1997).
- Desrochers, T. M. et al. Optimal habits can develop spontaneously through sensitivity to local cost. PNASi. 107, 20512-20517 (2010).

11/15: **Behavioral Neuroscience: Neurons + Behavior**

Discussion Papers:
- Robie, A. A. et al. Mapping the Neural Substrates of Behavior. Cell, 170(2), 393-406 (2017).
- Porto, D. A. et al. Reverse-Correlation Analysis of Mechanosensation Circuit in C. elegans Reveals Temporal and Spatial Encoding, bioRxiv (2017).

11/20: **Behavioral Genetics: Phenotyping**

Discussion Papers:
- Weber, J. N., Peterson, B. K. & Hoekstra, H. E. Discrete genetic modules are responsible for complex burrow evolution in Peromyscus mice. Nature 493, 402-405 (2013).
- Brown, A. E. X. et al. A dictionary of behavioral motifs reveals clusters of genes affecting Caenorhabditis elegans locomotion. PNAS. 110, 791-796 (2013).

11/22: **Project Workshop**

11/27: **Behavioral Genetics: Individuality**

Discussion Papers:
- Ayroles, J. F. et al. Behavioral idiosyncrasy reveals genetic control of phenotypic variability. PNAS 112, 6706-6711 (2015).
- Freund, J. et al. Emergence of Individuality in Genetically Identical Mice. Science 340, 756-759 (2013).

11/29: **Project Presentations**

12/4: **Project Presentations**