# BIO244 - FINAL PROJECT

The goal of this project is to engage you on more concrete problems where physics can help solve biological problems. Below, we provide you with a list of scientific articles that use physics to understand new aspects of living systems. Some are important landmark papers whose results we may have seen in class, some others are more recent, but all are exciting. Your goal in this mini-project will be to re-analyze and rewrite this papers in “simpler” physical terms.

**Project rules**

- The project writeup is due before June 29, 2020. We encourage you to choose your paper by May 26 so we are still able to help you.
- You can work in teams of 2 but not more.
- There is no length requirement.

**Assessment**

The project will be evaluated on how well you grasped the scientific concepts and models, but also on creativity and initiative. If you bring you analysis further than the simple instructions below, you may earn bonus points. The project will count towards 30% of your final grade, the bonus points can add up to an extra 10%.

**Instructions**

- Read all abstracts and pick a paper that interests and excites you. If you feel strongly about another topic, feel free to find a paper you’d like to work on that is not on this list and check with Alex if the paper is appropriate for the project.
- Read carefully the paper you selected.
- Write a summary of the paper by focusing on the scientific question, hypothesis, experiments/theory that test the hypothesis and the conclusions of the paper. Also stress on the physical aspects of the work. To do this, use a framework that is as close as possible to the one we used in class. For example, use analogies with springs, beams, surfaces, electrical components or leverage your knowledge of fluid mechanics, statistics or statistical physics. Importantly, describe in detail the physical model used in the papers. You **must** include your own schematics/drawings (hand drawn is ok). Also provide and a derivation of the model when relevant.
- The article contains data that allows testing of the physical model. Use the online tool WebPlotDigitizer to generate a dataset from graphs in the paper figures. Re-plot this data in your favorite data analysis software (Matlab, Python, R or anything else). Re-analyze this data to support the conclusions made in the paper. This can be done using a fit (exponential for example), counting events, measuring slopes, etc… The graphs you generated must be included in the writeup, and your code must be provided as additional information.
- Use a typical format for a journal article: Introduction (should be brief) - Results (has most of the data and model)- Discussion (brief as well). However, don’t quote or just reword the paper, really explain it in your own words as you reanalyze it. It doesn’t have to be long, it just needs to make sense.
- Think critically about the paper. Tell us about what are the shortcomings, what the authors may have missed.
- Bonus example 1: The course has focused on developing physical models for simplified living systems. These models can be used to describe a single entity such as one cytoskeletal filament or one neuron, but usually they must be expanded to understand

emergent behaviors, such as a cytoskeletal network or a brain. Writing down analytical models for these is a daunting task, so one can turn towards simulations to generate insights into their biological behavior. We here suggest that you integrate simulation in your analysis. There are many simulations tools already available out there, for example for action potential propagation (Neuron) and cytoskeletal network modeling (CytoSIM). But you can also write your own for even more bonus points.

- Bonus example 2: Think creatively about the paper and the physical model. For example, tell us about what the physical model implies and describe additional experiments that could further test the predictions.

# List of papers by topic

**[redacted]**

Stretching dna
JF Marko, ED Siggia
Macromolecules 28 (26), 8759-8770
https://pubs.acs.org/doi/pdf/10.1021/ma00130a008

Force and Velocity Measured for Single Molecules of RNA Polymerase
By Michelle D. Wang, Mark J. Schnitzer, Hong Yin, Robert Landick, Jeff Gelles, Steven M. ,
Science 30 Oct 1998 : 902-907

3-Dimensional Organization and Dynamics of the Microsporidian Polar Tube Invasion Machinery
Pattana Jaroenlak, Michael Cammer, Alina Davydov, Joseph Sall, Mahrukh Usmani, Feng-Xia Liang, Damian C. Ekiert, Gira Bhabha
doi: https://doi.org/10.1101/2020.04.03.024240

**[redacted]**

Traction Dynamics of Filopodia on Compliant Substrates
CLARENCE E. CHAN, DAVID J. ODDE
SCIENCE 2008

**Biological membranes:**

Martins, A.F., Bennett, N.C., Clavel, S. et al.
Locally-curved geometry generates bending cracks in the African elephant skin.
Nat Commun 9, 3865 (2018).
https://doi.org/10.1038/s41467-018-06257-3

W. Rawicz, K.C. Olbrich, T. McIntosh, D. Needham, E. Evans,
Effect of Chain Length and Unsaturation on Elasticity of Lipid Bilayers,
Biophysical Journal, 2000,
[redacted]
(http://www.sciencedirect.com/science/article/pii/S0006349500762953)

Dynamics of a Volvox Embryo Turning Itself Inside Out,
Stephanie Höhn, Aurelia R. Honerkamp-Smith, Pierre A. Haas, Philipp Khuc Trong, and Raymond E. Goldstein,
Phys. Rev. Lett. 114, 178101 – Published 27 April 2015


**Molecular motors:**


[redacted] Block, S. Single kinesin molecules studied with a molecular force clamp. Nature 400, 184–189 (1999). https://doi.org/10.1038/22146

[redacted] 6–390 (1997). https://doi.org/10.1038/41111

~~Ahmet Yildiz, Michio Tomishige, Arne Gennerich, Ronald D. Vale,
Intramolecular Strain Coordinates Kinesin Stepping Behavior along Microtubules,
Cell, 2008,
https://doi.org/10.1016/j.cell.2008.07.018.
(http://www.sciencedirect.com/science/article/pii/S0092867408009367)~~

~~Block, S., Blair, D. & Berg, H. Compliance of bacterial flagella measured with optical tweezers. Nature 338, [illegible] (1989).
https://doi.org/10.1038/338514a0~~

Nathan L. Hendel, Matthew Thomson, Wallace F. Marshall,
Diffusion as a Ruler: Modeling Kinesin Diffusion as a Length Sensor for Intraflagellar Transport,
Biophysical Journal, 2018,
https://doi.org/10.1016/j.bpj.2017.11.3784.
(http://www.sciencedirect.com/science/article/pii/S0006349517350464)

~~[illegible], Nathan L. Hendel, Wallace F. Marshall, Hongmin Qin,
Speed and Diffusion of Kinesin-2 Are Competing Limiting Factors in Flagellar Length-Control Model,
Biophysical Journal, 2020,
https://doi.org/10.1016/j.bpj.2020.03.034.
(http://www.sciencedirect.com/science/article/pii/S0006349520303362)~~


[redacted]


Piezo's membrane footprint and its contribution to mechanosensitivity
Christoph A Haselwandter , Roderick MacKinnon
eLife 2018;7:e41968 DOI: 10.7554/eLife.41968

Structure-based membrane dome mechanism for Piezo mechanosensitivity
Yusong R Guo, Roderick MacKinnon
eLife 2017;6:e33660 DOI: 10.7554/eLife.33660

Lin, Y., Guo, Y.R., Miyagi, A. et al.
Force-induced conformational changes in PIEZO1.
Nature 573, 230–234 (2019).

https://doi.org/10.1038/s41586-019-1499-2

Caterina, M., Schumacher, M., Tominaga, M. et al.
The capsaicin receptor: a heat-activated ion channel in the pain pathway.
Nature 389, 816–824 (1997). https://doi.org/10.1038/39807

Makoto Tominaga, Michael J Caterina, Annika B Malmberg, Tobias A Rosen, Heather Gilbert, Kate Skinner, Brigitte E Raumann, Allan I Basbaum, David Julius,
The Cloned Capsaicin Receptor Integrates Multiple Pain-Producing Stimuli,
Neuron, 1998,
https://doi.org/10.1016/S0896-6273(00)80564-4.
(http://www.sciencedirect.com/science/article/pii/S0896627300805644)

Current Clamp and Modeling Studies of Low-Threshold Calcium Spikes in Cells of the Cat's Lateral Geniculate Nucleus
X. J. Zhan, C. L. Cox, J. Rinzel, and S. Murray Sherman
Journal of Neurophysiology 1999 81:5, 2360-2373

[redacted]

HODGKIN AL, HUXLEY AF.
A quantitative description of membrane current and its application to conduction and excitation in nerve. J Physiol. 1952;117(4):500-544.
doi:10.1113/jphysiol.1952.sp004764

[redacted]

Impulse responses in bacterial chemotaxis
Steven M.Block, Jeffrey E.Segall, Howard C.Berg

Chlamydomonas Swims with Two "Gears" in a Eukaryotic Version of Run-and-Tumble Locomotion
Marco Polin, Idan Tuval, Knut Drescher, J. P. Gollub, Raymond E. Goldstein
Science 24 Jul 2009:
Vol. 325, Issue 5939, pp. 487-490
DOI: 10.1126/science.1172667

Antiphase Synchronization in a Flagellar-Dominance Mutant of Chlamydomonas, Kyriacos C. Leptos, Kirsty Y. Wan, Marco Polin, Idan Tuval, Adriana I. Pesci, and Raymond E. Goldstein, Phys. Rev. Lett. 111, 158101 – Published 8 October 2013

[redacted]

Julian Lewis,
Autoinhibition with Transcriptional Delay: A Simple Mechanism for the Zebrafish Somitogenesis Oscillator,
Current Biology, 2003,
https://doi.org/10.1016/S0960-9822(03)00534-7.

Digit patterning is controlled by a Bmp-Sox9-Wnt Turing network modulated by morphogen gradients
J. Raspopovic, L. Marcon, L. Russo, J. Sharpe
Science 01 Aug 2014:
Vol. 345, Issue 6196, pp. 566-570
DOI: 10.1126/science.1252960

Diffusion and scaling during early embryonic pattern formation
Thomas Gregor, William Bialek, Rob R. de Ruyter van Steveninck, David W. Tank, Eric F. Wieschaus
Proceedings of the National Academy of Sciences Dec
2005, 102 (51) 18403-18407; DOI: 10.1073/pnas.0509483102

Apoptosis propagates through the cytoplasm as trigger waves
By Xianrui Cheng, James E. Ferrell Jr.
Science 10 Aug 2018 : 607-612

Spontaneous emergence of cell-like organization in Xenopus egg extracts
By Xianrui Cheng, James E. Ferrell Jr.
Science 01 Nov 2019 : 631-637