Jonathan B. Sellon

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Research Interests

Biological image and video motion analysis, dynamics of viscoelastic and poroelastic materials, cochlear mechanics, lumped and finite element modeling, and acoustics

Education

Harvard University–Massachusetts Institute of Technology
Program in Health Sciences and Technology (HST), Cambridge, MA

PhD, Biomedical Engineering, September, 2016

- Speech and Hearing Bioscience and Technology Program
- Thesis Topic: *The Functional Role of Tectorial Membrane Poroelasticity in Cochlear Mechanics*
- Advisor: Dennis M. Freeman, PhD

Massachusetts Institute of Technology, Cambridge, MA

SM, Electrical Engineering and Computer Science, February, 2013

- Topic: *Viscosity and porosity contribute to both speed and decay of tectorial membrane traveling waves*
- Advisor: Dennis M. Freeman, PhD

University of Chicago, Chicago, IL

BS, Biological Chemistry, June 2010

- *Departmental Honors*
- *General Honors from the College*
- Advisor: Margaret Gardel, PhD
- Topic: *Cellular Mechanosensation: Correlating Cytoskeletal Protein Expression to Varying Substrate Stiffness*

BA, Chemistry, June 2010

BA, Biological Sciences, June 2010

Minor in Linguistics

Research Positions

Postdoctoral Associate September 2016 to Present
Research Lab for Electronics at MIT
Supervisor: Dennis M. Freeman, PhD
Collaborating Lab: Alan J. Grodzinsky, ScD
Project: Determining the functional role of tectorial membrane poroelasticity in controlling the motions of individual hair cell bundles

Graduate Research Assistant September 2010 to September 2016
Research Lab for Electronics, Micromechanics group,
Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology
Supervisor: Dennis M. Freeman, PhD
Project: Determining the functional role of tectorial membrane poroelasticity in controlling traveling waves in the cochlea

Undergraduate Research Assistant September 2007 to June 2010
Gordon Center for Integrative Science, Cellular Biophysics Lab
University of Chicago
Supervisor: Margaret Gardel, PhD
Project: Correlating cytoskeletal protein expression to adhesive substrate stiffness

Undergraduate Research Assistant June to September 2007
Institute for Theoretical Astrophysics,
University of Heidelberg
Supervisor: Mordecai-Mark Mac Low, PhD
Project: Correlating gravitational stability of galaxies to star formation rates

Internship July 2006 to January 2007
Department of Astrophysics,
American Museum of Natural History
Supervisor: Mordecai-Mark Mac Low, PhD
Project: Modeling of astrophysical characteristics using gas dynamics

Internship July 2005 to September 2005
Laboratory of Sensory Neuroscience,
Rockefeller University
Supervisor: A.J. Hudspeth, PhD, MD

Refereed Journal Publications

1. N. Wadhwa, J.G. Chen, **J.B. Sellon**, D. Wei, M. Rubinstein, R. Ghaffari, D.M. Freeman, O. Buyukozturk, P. Wang, S. Sun, S.H. Kang, K. Bertoldi, F. Durand, and W.T. Freeman. A Motion Microscope for Visualizing and Quantifying Small Motions. E. pub. 2017 Oct 16. ***Proc. Natl. Acad. Sci. USA*** doi: 10.1073/pnas.1703715114.

2. **J. B. Sellon**†, R. Ghaffari, and D. M. Freeman. Geometric requirements for tectorial membrane traveling waves in the presence of cochlear loads. ***Biophys J.*** 2017 Mar 28;112:1059-1062. doi: 10.1016/j.bpj.2017.02.002 PMID: 28237025 †Corresponding author

3. S. Farrahi, R. Ghaffari, **J.B. Sellon**, H.H. Nakajima, and D.M. Freeman. (2016) Tectorial Membrane Traveling Waves Underlie Sharp Auditory Tuning in Humans. ***Biophys J.*** 2016 Sep 6;111(5):921-4. doi: 10.1016/j.bpj.2016.07.038. PMID: 27544000

4. **J. B. Sellon***, S. Farrahi*, R. Ghaffari, and D. M. Freeman. (2015) Longitudinal spread of mechanical excitation through tectorial membrane traveling waves. ***Proc Nat Acad Sci USA***, vol. 112, no. 42, pg. 12968-12973. doi: 10.1073/pnas.1511620112. PMID: 26438861 *equal contribution

5. **J.B. Sellon**, R. Ghaffari, S. Farrahi, G. P. Richardson, and D. M. Freeman. (2014) Porosity controls spread of excitation in tectorial membrane traveling waves. ***Biophys J.*** 2014 Mar 18;106(6):1406-13. doi: 10.1016/j.bpj.2014.02.012. PMID: 24655516
Covered in ***MIT News*** *and* ***WIRED***

6. R. Ghaffari, S.C. Page, S. Farrahi, **J.B. Sellon,** and D.M. Freeman. (2013) Electrokinetic properties of the mammalian tectorial membrane. ***Proc. Natl. Acad. Sci. USA.*** 110:4279-4284. doi: 10.1073/pnas.1214744110. PMID: 23440188

Papers in Preparation

1. **J.B. Sellon**, M. Azadi, H.T. Nia, R. Oftadeh, R. Ghaffari, A.J. Grodzinsky, and D.M. Freeman. Poroelasticity of the Tectorial Membrane at the Nanoscale.

2. **J.B. Sellon**, A. Mansour, R. Ghaffari, and D.M. Freeman. Opposite electrokinetic motions of apical and basal regions of the tectorial membrane.

3. C. E. Lemons, **J. B. Sellon**, D.M. Freeman, and J. Meaud. Examining the Effects of Anisotropy on Longitudinally Propagating Waves on Isolated Tectorial Membranes.

Refereed Conference Proceedings

1. **J.B. Sellon**, R. Ghaffari, and D.M. Freeman. (2018) Effects of Geometry and Cochlear Loads on Tectorial Membrane Traveling Waves. *In Press* Mechanics of Mammalian Hearing. C. Bergevin and S. Puria eds. ***AIP Conf. Proc.***

2. C. E. Lemons, **J. B. Sellon**, D.M. Freeman, and J. Meaud. (2018) Examining the Effects of Anisotropy on Longitudinally Propagating Waves on Isolated Tectorial Membranes. *In Press* Mechanics of Mammalian Hearing. C. Bergevin and S. Puria eds. ***AIP Conf. Proc.***

3. S. Farrahi, R. Ghaffari, **J.B. Sellon**, H.H. Nakajima, and D.M. Freeman. (2018) Cochlear Tuning... of Mice and Men. *In Press* Mechanics of Mammalian Hearing. C. Bergevin and S. Puria eds. ***AIP Conf. Proc.***

4. R. Ghaffari, S.C. Page, S. Farrahi, **J.B. Sellon** and D.M. Freeman. (2015) Electromechanical role of fixed charge in the mammalian tectorial membrane. In Mechanics of Mammalian Hearing: Protein to Perception. D. Karavitaki and D. P. Corey, eds. ***AIP Conf. Proc.*** 1703, 080001; http://dx.doi.org/10.1063/1.4939392

5. S. Farrahi*, **J.B. Sellon***, R. Ghaffari, and D.M. Freeman. (2015) The role of tectorial membrane stiffness and viscosity on traveling waves and resonance. In Mechanics of Mammalian Hearing: Protein to Perception. D. Karavitaki and D. P. Corey, eds. ***AIP Conf. Proc.*** 1703, 080007; http://dx.doi.org/10.1063/1.4939398 *equal contribution

6. **J.B. Sellon**, R. Ghaffari, S. Farrahi and D.M. Freeman. (2015) Tectorial membrane porosity controls spread of excitation and tuning in the cochlea. In Mechanics of Mammalian Hearing: Protein to Perception. D. Karavitaki and D. P. Corey, eds. ***AIP Conf. Proc.*** 1703, 080003; http://dx.doi.org/10.1063/1.4939394

Talks

1. **J.B. Sellon**, R. Ghaffari, S. Farrahi, G.P. Richardson, and D.M. Freeman. Tectorial Membrane Porosity Controls Spread of Excitation and Tuning in the Cochlea. Mechanics of Hearing, Attica, Greece. June 2014.

2. **J.B. Sellon**, R. Ghaffari, S. Farrahi, G.P. Richardson, and D.M. Freeman. Tectorial Membrane Waves Control Spread of Excitation and Tuning in the Cochlea. Mechanical Forces in Development, Cambridge, MA. Nov. 2013.

Conference Abstracts and Posters

1. D. M. Freeman, R. Ghaffari, S. Farrahi, **J.B. Sellon**. Cochlear mechanisms underlying the sharp frequency selectivity of hearing. ***J. Acoust. Soc. Am.*** 141, 3507 (2017); doi: http://dx.doi.org/10.1121/1.4987351

2. **J.B. Sellon**, R. Ghaffari, and D.M. Freeman. Effects of Geometry and Cochlear Loads on Tectorial Membrane Traveling Waves. Mechanics of Hearing, Ontario, Canada, June 2017.

3. C. E. Lemons, **J. B. Sellon**, D.M. Freeman, and J. Meaud. Modeling Longitudinal Propagation of Radial and Longitudinal Motion on Isolated Tectorial Membrane Segments. Association for Research in Otolaryngology Midwinter Meeting, Baltimore, MD, Feb. 2017.

4. **J. B. Sellon**, R. Ghaffari, and D.M. Freeman. Longitudinal Coupling of the Tectorial Membrane Counteracts Viscous Loss in the Subtectorial Gap. Association for Research in Otolaryngology Midwinter Meeting, San Diego, CA, Feb. 2016.

5. S. Farrahi*, **J.B. Sellon***, R. Ghaffari, and D.M. Freeman. The role of tectorial membrane stiffness and viscosity on traveling waves and cochlear tuning. Mechanics of Hearing, Attica, Greece. June 2014.

6. **J. B. Sellon**, S. Farrahi, R. Ghaffari and D. M. Freeman. Two Effects of Viscosity Revealed by Tectorial Membrane Traveling Waves. Association for Research in Otolaryngology Midwinter Meeting, Baltimore, MD, Feb. 2013.

7. S. Farrahi, R. Ghaffari, **J.B. Sellon**, and D.M. Freeman. Decreasing Stiffness Reduces Spread of Excitation via TM Waves. Association for Research in Otolaryngology Midwinter Meeting, Baltimore, MD, Feb. 2013.

8. Y. Beckham, **J. Sellon**, and M. Gardel. Transcriptional Feedback Loops in Regulation of Cellular Adhesion and Tension. American Society for Cell Biology Conference, Dec. 2009.

9. **J. Sellon**, M. Mac Low, Y. Li, and R. S. Klessen. Diagnosis of Gravitational Instability in Models of Star-Forming Galaxies. Massive Star Formation Conference, Heidelberg, Germany, Sept. 2007.

Project Technical Contributions

- A Motion Microscope for Visualizing and Quantifying Small Motions:
  I worked on applying a motion magnification technique to video data of biological tissues. The technique, developed at MIT CSAIL, involves characterizing and amplifying local displacements in a video by examining spatial local phase of motion over time. My technical contribution involved tailoring the technique for amplifying nanoscale motions of biological tissues.
- Geometric requirements for tectorial membrane traveling waves in the presence of cochlear loads:
  I developed both an analytic and lumped element model of the mammalian tectorial membrane, an extracellular matrix of the inner ear, to demonstrate the role that geometry of the tissue has on enabling it to overcome fluid damping in the cochlea. This model demonstrates that the tectorial membrane may have evolved to a particular thickness to enable our fine sensitivity and selectivity of hearing.
- Tectorial Membrane Traveling Waves Underlie Sharp Auditory Tuning in Humans:
  We demonstrated that the spread of excitation of tectorial membrane traveling waves is similar in humans and mice, although the mechanical excitation spans fewer frequencies of the cochlea in humans-suggesting a possible mechanism for sharper cochlear tuning. This project involved developing methods to characterize small motions of biological tissues in large video data sets.
- Longitudinal spread of mechanical excitation through tectorial membrane traveling waves:
  I used chemical manipulations and a lumped element model to demonstrate that shear viscosity damps traveling waves in the cochlea, ultimately sharpening cochlear frequency selectivity. To demonstrate this result I developed high throughput motion analysis techniques for stroboscopic video data and utilized a lumped element model of the inner ear to determine biological tissue material properties.
- Porosity controls spread of excitation in tectorial membrane traveling waves:
  I used a combination of chemical manipulations, mouse models of human deafness, and computational modeling to demonstrate that the nanoscale pores of the mammalian tectorial membrane control its shear viscosity. This project involved developing methods to characterize small motions of biological tissues in large video data sets.
- Improving sub-pixel motion estimation algorithms for stroboscopic video data:
  I mentored two MIT undergraduate computer science students to develop methods for improving sub-pixel motion estimation algorithms and high throughput video data input methods.

Peer Review

Reviewer for *Journal of the Acoustical Society of America*

Awards

- 2016 Martha Gray Prize for Excellence in Research, honorable mention
- 2013 Harvard-MIT HST IDEA^2 Fellowship
- 2012 National Science Foundation Graduate Research Fellowship
- 2010 National Institutes of Health Training Grant in Speech and Hearing Biosciences and Technology (SHBT), Harvard-MIT Division of Health Sciences and Technology
- 2008 National Institutes of Health, Physical and Chemical Biology Interdisciplinary Research Fellowship, University of Chicago, Cellular Biophysics, Summer 2008-2010
- 2007 Lerman-Neubauer Junior Teaching Fellow, University of Chicago
- 2007 National Science Foundation Grant - Research Experience for Undergraduates (REU), American Museum of Natural History and the University of Heidelberg, Germany
- 2006 Intel Science Talent Search, National Finalist

Graduate coursework

MIT – Electrical Engineering and Computer Science
Biomedical Computing, Artificial Intelligence, Acoustics, Speech Communication

Harvard Medical School–MIT Health Sciences and Technology Program and
MIT Brain and Cognitive Sciences
Biomaterials & Tissue Engineering, Sensory-Neural Systems, Molecular Medicine, Neural Coding & Perception of Sound, Language Acquisition, Anatomy, Physiology of the Ear, The Peripheral Auditory System

Harvard Business School
Commercializing Science

University of Chicago
Biological Physics, Computational Geonomics & Bioinformatics, Structure and Function of Membrane Proteins, Chemical Biology, Extracellular Matrices: Chemistry & Biology

Skills and Experience

- Designing experiments to probe material properties of biological tissues (AFM, MEMS devices, chemical manipulations, computational modeling, and microfluidics techniques)
- Developing techniques for high throughput motion analysis of biological video and image data
- Microscopy techniques (stroboscopy, fluorescence microscopy, FRAP)
- Molecular biology techniques (cell culture, PCR, etc.)
- Finite element and analytic modeling of mechanics of biological tissues
- High throughout motion analysis of biological video data (MATLAB, Python, and UNIX shell scripting)
- Experimental design and assay development for probing mechanics of cochlear tissues
- Coordinating international collaborations with academic labs
- Mentorship in computer vision approaches for analyzing biological video data

Teaching Experience

Teaching Assistant — Fall 2016
6.A01 - Mens et Manus (Introduction to EECS)
Department of Electrical Engineering and Computer Science,
Massachusetts Institute of Technology

Teaching Assistant — Spring 2016
6.UAR - Seminar in Undergrad Research
Department of Electrical Engineering and Computer Science,
Massachusetts Institute of Technology

Teaching Assistant — Fall 2009-Spring 2010
BIOS 20200 - Introduction to Biological Chemistry
Division of Biological Sciences,
University of Chicago

Graduate leadership positions

- MIT Graduate Student Council Advising Initiative Chair, 2015-2016
- Harvard-MIT HST Resources for Easing Friction and Stress (REFS) mediator, 2011-2016
- Representative to the HST Graduate Committee, 2013-2014
- Harvard-MIT HST Joint Council President, 2012-2013
- Harvard-MIT HST Joint Council Treasurer, 2011-2012
- Harvard-MIT HST Joint Council Community Service Chair, 2010-2011

References

Dennis M. Freeman
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Dept. of Electrical Engineering and Computer Science — E-mail: freeman@mit.edu
Massachusetts Institute of Technology

Alan J. Grodzinsky
Professor of Biological, Electrical,
and Mechanical Engineering — Phone: 617-253-4969
Dept. of Biological Engineering — E-mail: alg@mit.edu
Massachusetts Institute of Technology

Christopher A. Shera
Professor of Otolaryngology and Physics & Astronomy — Phone: 323-442-2312
Keck School of Medicine — E-mail: christopher.shera@usc.edu
University of Southern California

John J. Guinan, Jr., PhD
Professor of Otolaryngology — Phone: 617-573-4236
Massachusetts Eye and Ear — E-mail: john_guinan@meei.harvard.edu
Harvard Medical School