Stanford

Stephen A. Baccus

Professor of Neurobiology

Bio

ACADEMIC APPOINTMENTS

- Professor, Neurobiology
- Member, Bio-X
- Member, Wu Tsai Human Performance Alliance
- Member, Wu Tsai Neurosciences Institute

HONORS AND AWARDS

- Terman Fellow, Stanford University (2004-2007)
- Pew Scholar, Pew Charitable Trusts (2005-2009)
- Vision Research Grant, Karl Kirchgessner Foundation (2005)
- Sloan Fellow, Alfred P. Sloan Foundation (2007-2009)
- McKnight Scholar Award, McKnight Endowment Fund (2007-2010)
- Vision Research Grant, E. Matilda Ziegler Foundation for the Blind (2010-2013)

LINKS

- Lab website: https://baccuslab.stanford.edu

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

We study how the circuitry of the retina translates the visual scene into electrical impulses in the optic nerve. Visual perception is initiated by the molecules, cells and synapses of the retina, acting together to process and compress visual information into a sequence of spikes in a population of nerve fibers. One of the largest gaps in neuroscience lies in the explaining of systems-level processes like visual processing in terms of cellular-level mechanisms. This problem is tractable in the retina because of its experimental accessibility, and the substantial amount already known about basic retinal cell types and functions.

Our goal is to extract general principles of computation in neural circuits, and to explain specific retinal visual processes such as adaptation to contrast and image statistics, and the detection of moving objects. To do this, we use a versatile set of experimental and theoretical techniques. While projecting visual scenes from a video monitor onto the isolated retina, an extracellular multielectrode array is used to record a substantial fraction of the output of a small patch of retina. Simultaneously, we record intracellularly from retinal interneurons in order to monitor and perturb single cells as the circuit

operates. To measure the activity of both populations of interneurons and output neurons, we record visual responses optically using two-photon imaging while simultaneously recording with a multielectrode array. Finally, all of this data is assembled and interpreted in the context of mathematical models to predict and explain the output of the retinal
circuit.

An additional focus of the lab is to develop approaches to stimulate the nervous system using focused ultrasound. Recent studies have shown that ultrasound can activate the retina with high spatial and temporal precision. This technology holds promise as a noninvasive tool to study the brain and treat diseases of the nervous system both in the retina and elsewhere in the brain.

Teaching

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Minseung Choi, Bella Hofflich

Postdoctoral Faculty Sponsor

David Au

Doctoral Dissertation Advisor (AC)

Vivek Chundru, Youssef Faragalla, Shenghua Liu, Kyrstyn Ong, Javier Weddington

GRADUATE AND FELLOWSHIP PROGRAM AFFILIATIONS

- Neurosciences (Phd Program)

Publications

PUBLICATIONS

- **Interpreting the retinal neural code for natural scenes: From computations to neurons.** *Neuron*
  Maheswaranathan, N., McIntosh, L. T., Tanaka, H., Grant, S., Kastner, D. B., Melander, J. B., Nayebi, A., Brezovec, L. E., Wang, J. H., Ganguli, S., Baccus, S. A.
  2023

- **Information Geometry of the Retinal Representation Manifold**
  Ding, X., Lee, D., Melander, J. B., Sivulka, G., Ganguli, S., Baccus, S. A.
  edited by Oh, A., Neumann, T., Globerson, A., Saenko, K., Hardt, M., Levine, S.
  NEURAL INFORMATION PROCESSING SYSTEMS (NIPS).2023

- **HyenaDNA: Long-Range Genomic Sequence Modeling at Single Nucleotide Resolution**
  Nguyen, E., Poli, M., Faizi, M., Thomas, A. W., Sykes, C., Wornow, M., Patel, A., Rabideau, C., Massaroli, S., Bengio, Y., Ermon, S., Baccus, S. A., Re, et al
  edited by Oh, A., Neumann, T., Globerson, A., Saenko, K., Hardt, M., Levine, S.
  NEURAL INFORMATION PROCESSING SYSTEMS (NIPS).2023

- **Synchronous inhibitory pathways create both efficiency and diversity in the retina.** *Proceedings of the National Academy of Sciences of the United States of America*
  Manu, M., McIntosh, L. T., Kastner, D. B., Naecker, B. N., Baccus, S. A.
  1800; 119 (4)

- **How inhibitory neurons increase information transmission under threshold modulation.** *Cell reports*
  Hsu, W. M., Kastner, D. B., Baccus, S. A., Sharpee, T. O.
  2021; 35 (8): 109158

- **A mechanistically interpretable model of the retinal neural code for natural scenes with multiscale adaptive dynamics.** *Conference record. Asilomar Conference on Signals, Systems & Computers*
  Ding, X., Lee, D., Grant, S., Stein, H., McIntosh, L., Maheswaranathan, N., Baccus, S.
  2021; 2021: 287-291
- **From deep learning to mechanistic understanding in neuroscience: the structure of retinal prediction.** *Advances in neural information processing systems*
  Tanaka, H., Nayebi, A., Maheswaranathan, N., McIntosh, L., Baccus, S. A., Ganguli, S.
  2019; 32: 8537-8547
- **Adaptation of Inhibition Mediates Retinal Sensitization.** *Current biology : CB*
  Kastner, D. B., Ozuysal, Y., Panagiotakos, G., Baccus, S. A.
  2019
- **Radiation force as a physical mechanism for ultrasonic neurostimulation of the ex vivo retina.** *The Journal of neuroscience : the official journal of the Society for Neuroscience*
  Menz, M. D., Ye, P. n., Firouzi, K. n., Nikoozadeh, A. n., Butts Pauly, K. n., Khuri-Yakub, P. n., Baccus, S. A.
  2019
- **From deep learning to mechanistic understanding in neuroscience: the structure of retinal prediction**
  Tanaka, H., Nayebi, A., Maheswaranathan, N., McIntosh, L., Baccus, S. A., Ganguli, S.
  edited by Wallach, H., Larochelle, H., Beygelzimer, A., d'Alche-Buc, F., Fox, E., Garnett, R.
  NEURAL INFORMATION PROCESSING SYSTEMS (NIPS).2019
- **Adaptive feature detection from differential processing in parallel retinal pathways.** *PLoS computational biology*
  Ozuysal, Y., Kastner, D. B., Baccus, S. A.
  2018; 14 (11): e1006560
- **Inferring hidden structure in multilayered neural circuits.** *PLoS computational biology*
  Maheswaranathan, N., Kastner, D. B., Baccus, S. A., Ganguli, S.
  2018; 14 (8): e1006291
- **Inferring hidden structure in multilayered neural circuits** *PLOS COMPUTATIONAL BIOLOGY*
  Maheswaranathan, N., Kastner, D. B., Baccus, S. A., Ganguli, S.
  2018; 14 (8)
- **Ultrasound Elicits Behavioral Responses through Mechanical Effects on Neurons and Ion Channels in a Simple Nervous System** *JOURNAL OF NEUROSCIENCE*
  Kubanek, J., Shukla, P., Das, A., Baccus, S. A., Goodman, M. B.
  2018; 38 (12): 3081–91
- **Optimal Information Transmission by Overlapping Retinal Cell Mosaics.** *Proceedings of the ... Conference on Information Sciences and Systems. Conference on Information Sciences and Systems*
  Zhang, Y., Kastner, D. B., Baccus, S. A., Sharpee, T. O.
  2018; 2018
- **A Communication-Theoretic Formulation of a Continuous Linear-Nonlinear Model of Retinal Ganglion Cells**
  Sorooshyari, S. K., Baccus, S. A., IEEE
  IEEE.2018
- **Optimal Information Transmission by Overlapping Retinal Cell Mosaics**
  Zhang, Y., Kastner, D. B., Baccus, S. A., Sharpee, T. O., IEEE
  IEEE.2018
- **Deep Learning Models of the Retinal Response to Natural Scenes.** *Advances in neural information processing systems*
  McIntosh, L. T., Maheswaranathan, N. n., Nayebi, A. n., Ganguli, S. n., Baccus, S. A.
  2016; 29: 1369–77
- **Synchronized amplification of local information transmission by peripheral retinal input** *ELIFE*
  Jadzinsky, P. D., Baccus, S. A.

2015; 4

- **Critical and maximally informative encoding between neural populations in the retina.** *Proceedings of the National Academy of Sciences of the United States of America*
  Kastner, D. B., Baccus, S. A., Sharpee, T. O.
  2015; 112 (8): 2533-2538
- **Building Blocks of Temporal Filters in Retinal Synapses** *PLOS BIOLOGY*
  Suh, B., Baccus, S. A.
  2014; 12 (10)
- **Building blocks of temporal filters in retinal synapses.** *PLoS biology*
  Suh, B., Baccus, S. A.
  2014; 12 (10)
- **Insights from the retina into the diverse and general computations of adaptation, detection, and prediction** *CURRENT OPINION IN NEUROBIOLOGY*
  Kastner, D. B., Baccus, S. A.
  2014; 25: 63-69
- **Spatial segregation of adaptation and predictive sensitization in retinal ganglion cells.** *Neuron*
  Kastner, D. B., Baccus, S. A.
  2013; 79 (3): 541-554
- **Transformation of visual signals by inhibitory interneurons in retinal circuits.** *Annual review of neuroscience*
  Jadzinsky, P. D., Baccus, S. A.
  2013; 36: 403-428
- **Precise Neural Stimulation in the Retina Using Focused Ultrasound** *JOURNAL OF NEUROSCIENCE*
  Menz, M. D., Oralkan, O., Khuri-Yakub, P. T., Baccus, S. A.
  2013; 33 (10): 4550-?
- **Linking the Computational Structure of Variance Adaptation to Biophysical Mechanisms** *NEURON*
  Ozuysal, Y., Baccus, S. A.
  2012; 73 (5): 1002-1015
- **Disinhibitory gating of retinal output by transmission from an amacrine cell** *PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA*
  Manu, M., Baccus, S. A.
  2011; 108 (45): 18447-18452
- **Coordinated dynamic encoding in the retina using opposing forms of plasticity** *NATURE NEUROSCIENCE*
  Kastner, D. B., Baccus, S. A.
  2011; 14 (10): 1317-U135
- **Architecture and activity-mediated refinement of axonal projections from a mosaic of genetically identified retinal ganglion cells** *NEURON*
  Huberman, A. D., Manu, M., Koch, S. M., Susman, M. W., Lutz, A. B., Ullian, E. M., Baccus, S. A., Barres, B. A.
  2008; 59 (3): 425-438
- **A retinal circuit that computes object motion** *JOURNAL OF NEUROSCIENCE*
  Baccus, S. A., Oelveczky, B. P., Manu, M., Meister, M.
  2008; 28 (27): 6807-6817
- **Retinal adaptation to object motion** *NEURON*
  Oelveczky, B. P., Baccus, S. A., Meister, M.
  2007; 56 (4): 689-700
- **Image processing for a high-resolution optoelectronic retinal prosthesis** *IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING*
  Asher, A., Segal, W. A., Baccus, S. A., Yaroslavsky, L. P., Palanker, D. V.
  2007; 54 (6): 993-1004

- **Timing and computation in inner retinal circuitry** *ANNUAL REVIEW OF PHYSIOLOGY*
  Baccus, S. A.
  2007; 69: 271-290

- **From a whisper to a roar: Adaptation to the mean and variance of naturalistic sounds** *NEURON*
  Baccus, S. A.
  2006; 51 (6): 682-684

- **Dynamic predictive coding by the retina** *NATURE*
  Hosoya, T., Baccus, S. A., Meister, M.
  2005; 436 (7047): 71-77

- **Design of a high-resolution optoelectronic retinal prosthesis.** *Journal of neural engineering*
  Palanker, D., Vankov, A., Huie, P., Baccus, S.
  2005; 2 (1): S105-20

- **Design of a high-resolution optoelectronic retinal prosthesis** *JOURNAL OF NEURAL ENGINEERING*
  Palanker, D., Vankov, A., Huie, P., Baccus, S.
  2005; 2 (1): S105-S120

- **Towards high-resolution optoelectronic retinal prosthesis** *15th Conference on Ophthalmic Technologies*
  Palanker, D., Huie, P., Vankov, A., Asher, A., Baccus, S.
  SPIE-INT SOC OPTICAL ENGINEERING.2005: 223–233

- **Retina versus cortex: Contrast adaptation in parallel visual pathways** *NEURON*
  Baccus, S. A., Meister, M.
  2004; 42 (1): 5-7

- **Segregation of object and background motion in the retina** *NATURE*
  Olveczky, B. P., Baccus, S. A., Meister, M.
  2003; 423 (6938): 401-408

- **Fast and slow contrast adaptation in retinal circuitry** *NEURON*
  Baccus, S. A., Meister, M.
  2002; 36 (5): 909-919