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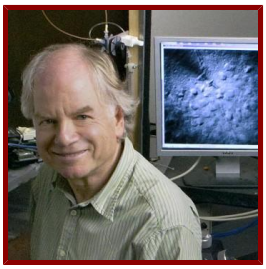

Shaul Hestrin, PhD

Professor of Comparative Medicine

CONTACT INFORMATION

- **Alternate Contact**

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Bio

ACADEMIC APPOINTMENTS

- Professor, Comparative Medicine
- Member, Bio-X
- Member, Wu Tsai Neurosciences Institute

LINKS

- Hestrin Lab: https://web.stanford.edu/~shestrin/

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

Cellular activity in neocortical circuits and behavior

The main interest of my lab is to understand how the properties of neocortical neurons, the circuits they form and the inputs they receive give rise to neuronal activity and behavior. Our approach includes behavioral studies, two-photon calcium imaging, in vivo whole cell recording in behaving animals and optogenetic methods to modulate activity of cortical neurons.

The neocortex represents about 80% of the human brain and is associated with wide range of functions including sensory perception, motor movement, memory and higher aspects of cognition. In the neocortex a major synaptic input originates from local cortical neurons. In addition, thalamic inputs, together with distant corticortical inputs and neuromodulator inputs play critical role. How these diverse inputs combine at the cellular and circuit level to generate neuronal activity and behavior is the focus of our studies.

We have developed methods to define cell types using genetics and other means. In vitro approach allowed us to characterize the wiring pattern of microcircuits and the synaptic properties of specific connections. To investigate how neuronal properties and interactions generate neuronal activity under physiological conditions we study cortical neurons in vivo in behaving mice. By combining whole cell recordings, calcium imaging

and optogenetics we study the subthreshold activity and circuit activity that drive spike generation in cortical neurons. Importantly, by studying and manipulating neuronal responses as well as behavioral performance we can investigate the relation between neuronal activity and animal perception.

Teaching

COURSES

2026-27

- One Health Journal Club: COMPMED 200 (Win, Spr)

2025-26

- One Health Journal Club: COMPMED 200 (Win, Spr)

2024-25

- Cellular/Molecular Neuroscience Laboratory: NEPR 288 (Sum)
- One Health Journal Club: COMPMED 200 (Aut, Win)

2023-24

- Cellullar/Molecular Neuroscience Laboratory: NEPR 288 (Sum)
- One Health Journal Club: COMPMED 200 (Aut, Win)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Youssef Faragalla, Kyrus Mama, Javier Weddington

GRADUATE AND FELLOWSHIP PROGRAM AFFILIATIONS

- Neurosciences (PhD Program)

Publications

PUBLICATIONS

- **Motivation and Engagement during Visually Guided Behavior.** *Cell reports*
  Ortiz, A. V., Aziz, D., Hestrin, S.
  2020; 33 (3): 108272
- **Correlation of Synaptic Inputs in the Visual Cortex of Awake, Behaving Mice.** *Neuron*
  Arroyo, S., Bennett, C., Hestrin, S.
  2018
- **Feature-Specific Organization of Feedback Pathways in Mouse Visual Cortex** *CURRENT BIOLOGY*
  Huh, C. Y. L., Peach, J. P., Bennett, C., Vega, R. M., Hestrin, S.
  2018; 28 (1): 114-+
- **Layer 6 corticothalamic neurons activate a cortical output layer, layer 5a.** *journal of neuroscience*
  Kim, J., Matney, C. J., Blankenship, A., Hestrin, S., Brown, S. P.
  2014; 34 (29): 9656-9664
- **Controlling brain states.** *Neuron*
  Bennett, C., Arroyo, S., Hestrin, S.
  2014; 83 (2): 260-261
- **Nicotinic modulation of cortical circuits** *FRONTIERS IN NEURAL CIRCUITS*
  Arroyo, S., Bennett, C., Hestrin, S.
  2014; 8

- **Nicotinic modulation of cortical circuits.** *Frontiers in neural circuits*
  Arroyo, S., Bennett, C., Hestrin, S.
  2014; 8: 30-?
- **Subthreshold mechanisms underlying state-dependent modulation of visual responses.** *Neuron*
  Bennett, C., Arroyo, S., Hestrin, S.
  2013; 80 (2): 350-357
- **New insights into the classification and nomenclature of cortical GABAergic interneurons** *NATURE REVIEWS NEUROSCIENCE*
  DeFelipe, J., Lopez-Cruz, P. L., Benavides-Piccione, R., Bielza, C., Larranaga, P., Anderson, S., Burkhalter, A., Cauli, B., Fairen, A., Feldmeyer, D., Fishell, G., Fitzpatrick, D., Freund, et al
  2013; 14 (3): 202-216
- **Mechanisms Generating Dual-Component Nicotinic EPSCs in Cortical Interneurons** *JOURNAL OF NEUROSCIENCE*
  Bennett, C., Arroyo, S., Berns, D., Hestrin, S.
  2012; 32 (48): 17287-17296
- **Prolonged Disynaptic Inhibition in the Cortex Mediated by Slow, Non-alpha 7 Nicotinic Excitation of a Specific Subset of Cortical Interneurons** *JOURNAL OF NEUROSCIENCE*
  Arroyo, S., Bennett, C., Aziz, D., Brown, S. P., Hestrin, S.
  2012; 32 (11): 3859-3864
- **Neuroscience. The strength of electrical synapses.** *Science*
  Hestrin, S.
  2011; 334 (6054): 315-316
- **Noradrenaline Enhances Signal-to-Noise Ratio of Inhibitory Inputs in the Dorsal Cochlear Nucleus** *NEURON*
  Hestrin, S.
  2011; 71 (2): 197-198
- **Synaptogenesis of Electrical and GABAergic Synapses of Fast-Spiking Inhibitory Neurons in the Neocortex** *JOURNAL OF NEUROSCIENCE*
  Pangratz-Fuehrer, S., Hestrin, S.
  2011; 31 (30): 10767-10775
- **Cell-type identity: a key to unlocking the function of neocortical circuits** *CURRENT OPINION IN NEUROBIOLOGY*
  Brown, S. P., Hestrin, S.
  2009; 19 (4): 415-421
- **Intracortical circuits of pyramidal neurons reflect their long-range axonal targets** *NATURE*
  Brown, S. P., Hestrin, S.
  2009; 457 (7233): 1133-U89
- **Cannabinoid sensitivity and synaptic properties of 2 GABAergic networks in the neocortex** *CEREBRAL CORTEX*
  Galarreta, M., Erdelyi, F., Szabo, G., Hestrin, S.
  2008; 18 (10): 2296-2305
- **Petilla terminology: nomenclature of features of GABAergic interneurons of the cerebral cortex** *NATURE REVIEWS NEUROSCIENCE*
  Ascoli, G. A., Alonso-Nanclares, L., Anderson, S. A., Barrionuevo, G., Benavides-Piccione, R., Burkhalter, A., Buzsaki, G., Cauli, B., DeFelipe, J., Fairen, A., Feldmeyer, D., Fishell, G., Fregnac, et al
  2008; 9 (7): 557-568
- **D-1-like dopamine receptor activation modulates GABAergic inhibition but not electrical coupling between neocortical fast-spiking interneurons** *JOURNAL OF NEUROSCIENCE*
  Towers, S. K., Hestrin, S.
  2008; 28 (10): 2633-2641
- **Background synaptic conductance and precision of EPSP-spike coupling at pyramidal cells** *JOURNAL OF NEUROPHYSIOLOGY*
  Zsiros, V., Hestrin, S.
  2005; 93 (6): 3248-3256

- **Synchronous versus asynchronous transmitter release: a tale of two types of inhibitory neurons.** *Nature Neuroscience*
  Hestrin, S., Galarreta, M
  2005; 8 (10): 1283-1284
- **Electrical synapses define networks of neocortical GABAergic neurons** *Trends in Neurosciences*
  Hestrin, S., Galarreta, M.
  2005; 28: 304-309
- **Electrical coupling among irregular-spiking GABAergic interneurons expressing cannabinoid receptors** *JOURNAL OF NEUROSCIENCE*
  Galarreta, M., Erdelyi, F., Szabo, G., Hestrin, S.
  2004; 24 (44): 9770-9778
- **Synaptic interactions of late-spiking neocortical neurons in layer 1** *JOURNAL OF NEUROSCIENCE*
  Chu, Z. G., Galarreta, M., Hestrin, S.
  2003; 23 (1): 96-102
- **Electrical and chemical synapses among parvalbumin fast-spiking GABAergic interneurons in adult mouse neocortex** *PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA*
  Galarreta, M., Hestrin, S.
  2002; 99 (19): 12438-12443
- **Spike transmission and synchrony detection in networks of GABAergic interneurons** *SCIENCE*
  Galarreta, M., Hestrin, S.
  2001; 292 (5525): 2295-2299
- **Electrical synapses between GABA-releasing interneurons** *NATURE REVIEWS NEUROSCIENCE*
  Galarreta, M., Hestrin, S.
  2001; 2 (6): 425-433
- **Enhanced neurotransmitter release at glutamatergic synapses on oxytocin neurones during lactation in the rat** *JOURNAL OF PHYSIOLOGY-LONDON*
  Stern, J. E., Hestrin, S., Armstrong, W. E.
  2000; 526 (1): 109-114
- **Burst firing induces a rebound of synaptic strength at unitary neocortical synapses** *JOURNAL OF NEUROPHYSIOLOGY*
  Galarreta, M., Hestrin, S.
  2000; 83 (1): 621-624
- **A network of fast-spiking cells in the neocortex connected by electrical synapses** *NATURE*
  Galarreta, M., Hestrin, S.
  1999; 402 (6757): 72-75
- **Differences in the properties of ionotropic glutamate synaptic currents in oxytocin and vasopressin neuroendocrine neurons** *JOURNAL OF NEUROSCIENCE*
  Stern, J. E., Galarreta, M., Foehring, R. C., Hestrin, S., Armstrong, W. E.
  1999; 19 (9): 3367-3375
- **Frequency-dependent synaptic depression and the balance of excitation and inhibition in the neocortex** *NATURE NEUROSCIENCE*
  Galarreta, M., Hestrin, S.
  1998; 1 (7): 587-594
- **Developmental regulation of basket/stellate cell->Purkinje cell synapses in the cerebellum** *JOURNAL OF NEUROSCIENCE*
  Pouzat, C., Hestrin, S.
  1997; 17 (23): 9104-9112
- **Properties of GABA(A) receptors underlying inhibitory synaptic currents in neocortical pyramidal neurons** *JOURNAL OF NEUROSCIENCE*
  Galarreta, M., Hestrin, S.
  1997; 17 (19): 7220-7227
- **Subunit composition, kinetic, and permeation properties of AMPA receptors in single neocortical nonpyramidal cells** *JOURNAL OF NEUROSCIENCE*

Angulo, M. C., Lambolez, B., Audinat, E., Hestrin, S., Rossier, J.
1997; 17 (17): 6685-6696

- **Molecular and physiological diversity of cortical nonpyramidal cells** *JOURNAL OF NEUROSCIENCE*
  Cauli, B., Audinat, E., Lambolez, B., Angulo, M. C., Ropert, N., Tsuzuki, K., Hestrin, S., Rossier, J.
  1997; 17 (10): 3894-3906
- **Morphology and physiology of cortical neurons in layer I** *JOURNAL OF NEUROSCIENCE*
  Hestrin, S., Armstrong, W. E.
  1996; 16 (17): 5290-5300
- **Correlation between kinetics and RNA splicing of alpha-amino-3-hydroxy-5-methylisoxazole-4-propionic acid receptors in neocortical neurons** *PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA*
  Lambolez, B., Ropert, N., Perrais, D., Rossier, J., Hestrin, S.
  1996; 93 (5): 1797-1802
- **Diversity of glutamate receptors in neocortical neurons: Implications for synaptic plasticity** *Jacques Monod Conference on Synaptic Plasticity and Cellular Mechanisms of Memory*
  Audinat, E., Lambolez, B., Cauli, B., Ropert, N., Perrais, D., Hestrin, S., Rossier, J.
  EDITIONS SCIENTIFIQUES MEDICALES ELSEVIER.1996: 331–32
- **DIFFERENT GLUTAMATE-RECEPTOR CHANNELS MEDIATE FAST EXCITATORY SYNAPTIC CURRENTS IN INHIBITORY AND EXCITATORY CORTICAL-NEURONS** *NEURON*
  Hestrin, S.
  1993; 11 (6): 1083-1091
- **ACTIVATION AND DESENSITIZATION OF GLUTAMATE-ACTIVATED CHANNELS MEDIATING FAST EXCITATORY SYNAPTIC CURRENTS IN THE VISUAL-CORTEX** *NEURON*
  Hestrin, S.
  1992; 9 (5): 991-999
- **DEVELOPMENTAL REGULATION OF NMDA RECEPTOR-MEDIATED SYNAPTIC CURRENTS AT A CENTRAL SYNAPSE** *NATURE*
  Hestrin, S.
  1992; 357 (6380): 686-689
- **PROPERTIES OF EXCITATORY POSTSYNAPTIC CURRENTS RECORDED INVITRO FROM RAT HIPPOCAMPAL INTERNEURONS** *JOURNAL OF PHYSIOLOGY-LONDON*
  Sah, P., Hestrin, S., Nicoll, R. A.
  1990; 430: 605-616
- **MECHANISMS GENERATING THE TIME COURSE OF DUAL COMPONENT EXCITATORY SYNAPTIC CURRENTS RECORDED IN HIPPOCAMPAL SLICES** *NEURON*
  Hestrin, S., Sah, P., Nicoll, R. A.
  1990; 5 (3): 247-253
- **EXCITATORY SYNAPTIC CURRENTS IN PURKINJE-CELLS** *PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES*
  Perkel, D. J., Hestrin, S., Sah, P., Nicoll, R. A.
  1990; 241 (1301): 116-121
- **ACTIVATION KINETICS OF RETINAL CONES AND RODS - RESPONSE TO INTENSE FLASHES OF LIGHT** *JOURNAL OF NEUROSCIENCE*
  Hestrin, S., Korenbrot, J. I.
  1990; 10 (6): 1967-1973
- **ANALYSIS OF EXCITATORY SYNAPTIC ACTION IN PYRAMIDAL CELLS USING WHOLE-CELL RECORDING FROM RAT HIPPOCAMPAL SLICES** *JOURNAL OF PHYSIOLOGY-LONDON*
  Hestrin, S., Nicoll, R. A., Perkel, D. J., Sah, P.
  1990; 422: 203-225
- **PHYSIOLOGICAL-PROPERTIES OF EXCITATORY SYNAPTIC TRANSMISSION IN THE CENTRAL-NERVOUS-SYSTEM** *COLD SPRING HARBOR SYMPOSIA ON QUANTITATIVE BIOLOGY*
  Hestrin, S., Perkel, D. J., Sah, P., Manabe, T., Renner, P., Nicoll, R. A.

1990; 55: 87-93

- **TONIC ACTIVATION OF NMDA RECEPTORS BY AMBIENT GLUTAMATE ENHANCES EXCITABILITY OF NEURONS** *SCIENCE*
  Sah, P., Hestrin, S., Nicoll, R. A.
  1989; 246 (4931): 815-818
- **VOLTAGE-ACTIVATED POTASSIUM CHANNELS IN THE PLASMA-MEMBRANE OF ROD OUTER SEGMENTS - A POSSIBLE EFFECT OF ENZYMATIC CELL-DISSOCIATION** *JOURNAL OF NEUROSCIENCE*
  Hestrin, S., Korenbrot, J. I.
  1987; 7 (10): 3072-3080
- **EFFECTS OF CYCLIC-GMP ON THE KINETICS OF THE PHOTOCURRENT IN RODS AND IN DETACHED ROD OUTER SEGMENTS** *JOURNAL OF GENERAL PHYSIOLOGY*
  Hestrin, S., Korenbrot, J. I.
  1987; 90 (4): 527-551
- **THE PROPERTIES AND FUNCTION OF INWARD RECTIFICATION IN ROD PHOTORECEPTORS OF THE TIGER SALAMANDER** *JOURNAL OF PHYSIOLOGY-LONDON*
  Hestrin, S.
  1987; 390: 319-333
- **KINETICS OF ACTIVATION OF ACETYLCHOLINE-RECEPTORS IN A MOUSE MUSCLE-CELL LINE UNDER A RANGE OF ACETYLCHOLINE CONCENTRATIONS** *BIOPHYSICAL JOURNAL*
  Hestrin, S., Korenbrot, J. I., Maricq, A. V.
  1987; 51 (3): 449-455
- **THE EFFECTS OF A MYASTHENIC SERUM ON THE ACETYLCHOLINE-RECEPTORS OF C2 MYOTUBES .2. FUNCTIONAL INACTIVATION OF THE RECEPTOR** *JOURNAL OF NEUROSCIENCE*
  Maricq, A. V., Gu, Y., Hestrin, S., Hall, Z.
  1985; 5 (7): 1917-1924
- **ACTIVATION OF ACETYLCHOLINE-RECEPTORS CAUSES THE PARTITION OF HYDROPHOBIC CATIONS INTO POSTSYNAPTIC MEMBRANE-VESICLES** *NATURE*
  Davis, C. G., Hestrin, S., LANDAHL, H., Gordon, A. S., Diamond, I., Korenbrot, J. I.
  1983; 302 (5908): 525-528
- **THE INTERACTION OF POTASSIUM WITH THE ACTIVATION OF ANOMALOUS RECTIFICATION IN FROG-MUSCLE MEMBRANE** *JOURNAL OF PHYSIOLOGY-LONDON*
  Hestrin, S.
  1981; 317 (AUG): 497-508