

## Mark A. Rutherford, Ph.D.

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### Research Interests

Auditory and vestibular systems, sensory encoding, electrical and chemical signaling across membranes, synaptic physiology, spike generation, molecular anatomy, nano-scale microscopy, electrophysiology,  $\text{Ca}^{2+}$  and voltage imaging, protein function, computational modeling, cochlear implants, structure-function relationships, synaptic development, genetics of hearing and deafness, prevention of hearing loss, drug discovery, lead optimization.

My work as an auditory and vestibular neurobiologist focuses on cellular mechanisms underlying our systems of sound encoding and balance in development, in maturity, and in conditions of inner ear disease. Through a better understanding of what makes hearing and balance happen, we are learning how to protect and restore it. Some current goals of the Rutherford Lab are:

- 1) To identify mechanisms of glutamate excitotoxicity underlying cochlear synapse loss following acoustic trauma.
- 2) To develop therapeutics for prevention of noise-induced synapse loss and hearing loss.
- 3) To clarify the molecular anatomy and plasticity of synapses between mammalian hair cells and nerve fibers, including sex differences.
- 4) To determine physiological mechanisms of synaptic transmission and spike generation that underlie sensory encoding in the ear.
- 5) To better understand the relationships between auditory/vestibular dysfunction and cognitive decline in Alzheimer's Disease.
- 6) To measure ion channel kinetics and topographies to feed multi-compartmental biophysical models of auditory nerve fibers for refinement of cochlear implant performance.

## Positions, Training, Education, Honors

- 2020 Leadership Entrepreneurial Acceleration Program (LEAP) award, Washington University in St. Louis, MO
- 2018 Schacht Lectureship at University of Michigan, Ann Arbor, MI
- 2017 Knowles Lectureship at Northwestern University, Chicago, IL
- 2017 Keynote Speaker at 3rd Chinese Assoc. for Res. in Otolaryngology conference in Nanjing, China
- 2014 Assistant Professor, Dept. of Otolaryngology, Wash. U. in St. Louis
- 2013 Instructor, Dept. of Otolaryngology, Wash. U. in St. Louis
- 2012 Research Scientist, MED-EL project grant, Göttingen, Germany
- 2011 NEURON Summer Course, San Diego, CA
- 2009-2012 Postdoctoral Fellow, Univ. of Göttingen, Germany
- 2009-2012 Alexander von Humboldt Foundation Postdoctoral Research Fellow
- 2005-2009 Postdoctoral Training, University of Oregon
- 2005 The Mouse as an Instrument for Ear Research II, The Jackson Laboratory, Bar Harbor, Maine
- 2000-2005 Ph.D., Biology, University of Oregon
- 2002 Scholarship, Neural Systems and Behavior, Marine Biological Laboratory, Woods Hole, Massachusetts
- 2000-2002 Teacher's Assistant, Neuroscience, University of Oregon
- 1999 Graduation with Honors, University of Missouri
- 1995-1999 National Merit Scholar, University of Missouri
- 1995-1999 B.S., Nutritional Sciences, University of Missouri

## Peer Reviewed Publications

Link to NCBI Bibliography: <https://pubmed.ncbi.nlm.nih.gov/?term=Mark+A+Rutherford+%5BAuth%5D&sort=date>

### Book Chapters:

Rutherford, M.A., Moser, T. "The Ribbon Synapse Between Type I Spiral Ganglion Neurons and Inner Hair Cells." In: Springer Handbook of Auditory Research, Volume 52: The Primary Auditory Neurons of the Mammalian Cochlea. Springer-Verlag New York Eds. Dabdoub, A., Fritzsche, B., Popper, A.N., Fay, R.R. (2016) DOI: 10.1007/978-1-4939-3031-9

Rutherford, M.A., Roberts, W.M. "Afferent Synaptic Mechanisms." In: The Senses: A Comprehensive Reference, Volume: Audition. Elsevier Eds. Basbaum, A., Kaneko, A., Shepherd, G., Westheimer, G. (2007). ISBN: 9780126394825

## Articles:

Hu, N., Rutherford, M.A. and Green, S.H. Protection of cochlear synapses from noise-induced excitotoxic trauma by blockade of Ca<sup>2+</sup>-permeable AMPA receptors. *PNAS* 117 (7): 3828 (2020). PMID: 32015128.

Lingle, C.J., Martinez-Espinosa, P.L., Yang-Hood, A., Boero, L., Payne, S., Persic D., V-Gharffari, B., Xiao, M., Zhou, Y., Xia, X.M., Pyott, S.J., Rutherford, M.A. LRRC52 regulates BK channel function and localization in mouse cochlear inner hair cells. *PNAS* 116 (37): 18397 (2019). PMID: 31451634.

Kyunghee X. Kim, Shelby Payne, Aizhen Yang-Hood, Song-Zhe Li, Bethany Davis, Jason Carlquist, Babak V-Ghaffari, Jay A. Gantz, Dorina Kallogjeri, James A. J. Fitzpatrick, Kevin K. Ohlemiller, Keiko Hirose, and Mark A. Rutherford. Vesicular Glutamatergic Transmission in Noise-induced Loss and Repair of Cochlear Ribbon Synapses. *J Neurosci* 39 (23): 4434 (2019). PMID: 30926748.

Choongheon Lee, John Guinan, Mark Rutherford, Wafaa Kaf, Kaitlyn Kennedy, Craig Buchman, Alec Salt, and Jeffery Lichtenhan. Cochlear compound action potentials from high-level tone bursts originate from wide cochlear regions that are offset toward the most sensitive cochlear region. *J Neurophysiol* 121(3): 1018 (2019). PMID: 30673362.

Lars Becker, Michael E. Schnee, Mamiko Niwa, Willy Sun, Stephan Maxeiner, Sara Talaei, Bechara Kachar, Mark A. Rutherford, Anthony J. Ricci. The presynaptic ribbon maintains vesicle populations at the hair cell afferent fiber synapse. *eLife*, 7, e30241 (2018). PMID: 29328021.

Sebe, J.Y., Cho, S., Sheets, L., Rutherford, M.A., von Gersdorff, H., and Raible, D.W. Ca<sup>2+</sup>-Permeable AMPARs Mediate Glutamatergic Transmission and Excitotoxic Damage at the Hair Cell Ribbon Synapse. *J Neurosci* 37(25): 6162 (2017). PMID: 28539424.

Hirose, K., Rutherford, M.A., and Warchol, M.E. Two cell populations participate in clearance of damaged hair cells from the sensory epithelia of the inner ear. *Hearing Research* 352: 70 (2017). PMID: 28526177.

Ohn, T.L., Rutherford, M.A., Jing, Z., Jung, S., Duque-Afonso, C.J., Hoch, G., Picher, M.M., Scharinger, A., Strenzke, N., and Moser, T. Hair Cells Use Active Zones with Different Voltage Dependence of Ca<sup>2+</sup> Influx to Decompose Sounds into Complementary Neural Codes. *PNAS* 113(32): E4716 (2016) PMID: 27462107.

Kim, K.X., Rutherford, M.A. Maturation of Nav and Kv Channel Topographies in the Auditory Nerve Spike Initiator before and after Developmental Onset of Hearing Function. *J Neurosci* 36(7): 2111 (2016) PMID: 26888923.

Rutherford, M.A. Resolving the Structure of Inner Ear Ribbon Synapses with STED Microscopy. *Synapse* 69(5):242 (2015) PMID: 25682928.

Wong, A.B., Rutherford, M.A., Gabrielaitis, M., Pangršič, T., Göttfert, F., Frank, T., Michanski, F., Hell, S., Wolf, F., Wichman, C., Moser, T. Developmental Refinement of Hair Cell Synapses Tightens the Coupling of Ca<sup>2+</sup> Influx to Exocytosis. *EMBO J* 33(3):247 (2014) PMID: 24442635.

Wong, A.B., Jing, Z., Rutherford, M.A., Frank, T., Strenzke, N., Moser, T. Concurrent Maturation of Inner Hair Cell Synaptic Ca<sup>2+</sup> Influx and Auditory Nerve Spontaneous Activity around Hearing Onset in Mice. *J Neurosci* 33(26):10661 (2013) PMID: 23804089.

Jing, Z., Rutherford, M.A., Takago, H., Frank, T., Fejtova, A., Khimich, D., Moser, T., Strenzke, N. Disruption of the Presynaptic Cytomatrix Protein Bassoon Degrades Ribbon Anchorage, Multi-quantal Release, and Sound Encoding at the Hair Cell Afferent Synapse. *J Neurosci* 33(10):4456 (2013) PMID: 23467361.

von Ameln, S., Wang, G., Boulouiz, R., Rutherford, M.A., Smith, G.M., Li, Y., Pogoda, H.M., Nürnberg, G., Volk, A.E., Stiller, B., Hong, J.S., Goodyear, R.J., Nürnberg, P., Richardson, G.P., Hammerschmidt, M., Moser, T., Wollnik, B., Koehler, C.M., Teitell, M.A., Barakat, A., Kubisch, C. A Mutation in *PNPT1*, Encoding Mitochondrial-RNA-Import Protein PNPase, Causes Hereditary Hearing Loss. *The American Journal of Human Genetics* 91(5):919 (2012) PMID: 23084290.

Rutherford, M.A., Pangršič, T. Molecular Anatomy and Physiology of Exocytosis in Sensory Hair Cells. *Cell Calcium* 52(3-4):327 (2012) PMID: 22682011.

Rutherford, M.A., Chapochnikov, N.M., Moser, T. Spike Encoding of Neurotransmitter Release Timing by Spiral Ganglion Neurons of the Cochlea. *J Neurosci* 32(14):4773 (2012) PMID: 22492033.

Frank, T., Rutherford, M.A., Strenzke, N., Neef, A., Pangršič, T., Khimich, D., Fejtova, A., Gundelfinger, E.D., Liberman, M.C., Harke, B., Bryan, K.E., Lee, A., Egnér, A., Riedel, D., Moser, T. Bassoon and the Synaptic Ribbon Organize Ca<sup>2+</sup> Channels and Vesicles to Add Release Sites and Promote Refilling. *Neuron* 68(4):724 (2010) PMID: 21092861.

Rutherford, M.A., Roberts, W.M. Spikes and Membrane Potential Oscillations in Hair Cells Generate Periodic Afferent Activity in the Frog Sacculus. *J Neurosci* 29(32):10025 (2009) PMID: 19675236.

Roberts, W.M., Rutherford, M.A. Linear and Nonlinear Processing in Hair Cells. *J Exp Bio* 211:1775 (2008) PMID: 18490393.

Rutherford, M.A., Roberts, W.M. Frequency Selectivity of Synaptic Exocytosis in Frog Saccular Hair Cells. *PNAS* 103(8):2898 (2006) PMID: 16473940.

## Grant Support:

### Active

NIH/NIDCD, R01: 1R01DC014712 (Rutherford)  
4/16 – 3/21 \$2,200,000 over 5 years (year one budget \$355,721)  
*Excitation and Excitotoxicity in Type I Cochlear Afferents: Synaptic Structure and Function*

NIH/NIDCD, R01: 2R01DC013048 (PI: Rubio; Co-I: Rutherford)  
8/19 – 7/24 subaward \$285,960 over 5 years (year one budget \$57,285)  
*Mechanisms of Hypersensitivity to Sound-induced Cochlear Damage*

Children's Discovery Institute (CDI) micro-grant (Rutherford, Fitzpatrick)  
1/18 – 1/21 \$8,000  
*Innervation of mammalian cochlea: 3D EM in the inner spiral plexus, ground truth for assessment of therapeutic interventions*

NIH/NIA, R01 Supplement, 3R01DC014712 (Rutherford)  
6/19-3/21 \$250,000  
*Alzheimer's Disease Supplement for Grants Not Focused on Alzheimer's Disease: Excitation and Excitotoxicity in Type I Cochlear Afferents: Synaptic Structure and Function*

### Completed

Wash. U. Institute for Clinical and Translational Sciences  
Just in time funding (Rutherford)  
4/19 – 3/20 \$5,000  
*Innervation of mammalian cochlea: ground truth for assessment of therapeutic interventions*

Hearing Health Foundation, Emerging Research Grant (Rutherford, V-Ghaffari)  
6/18 – 6/19 \$29,992  
*Enhancing cochlear implant performance through development of improved auditory nerve fiber biophysical models with a combined wet lab and dry lab approach*

Decibel Therapeutics Inc. (Rutherford, Fitzpatrick)  
6/18 – 6/19 \$10,000  
*3D Electron Microscopic Imaging*

Completed (*continued*)

Wash. U. Center for Investigation of Membrane Excitability Disorders

Pilot Grant (Rutherford, Lingle)

1/17-12/17 \$25,000

*Auxiliary subunits and functional roles of BK channels in cochlear hair cells*

Action on Hearing Loss, International Project Grant (Rutherford)

04/14 – 03/17 £144,000 over 3 years

*Mechanisms of Diversity in Spiral Ganglion Neuron Excitability and Susceptibility to Excitotoxicity*

The McDonnell Center, Small Grant (Rutherford)

07/15 – 06/16 \$40,000 for one year

*Effects of aging and noise exposure on the molecular anatomy of action potential generation in the mammalian cochlea*

Shared Instrumentation Grant (SIG), 1 S10 OD021629-01 PAR 16-054

Project title: ZEISS LSM880 AIRYSCAN MICROSCOPE FOR SHARED BIOMEDICAL RESEARCH

Fitzpatrick, Director of Washington University Center for Cellular Imaging (WUCCI)

Rutherford, Major User: *Molecular Anatomy of Cochlear Synapses in Models of Noise-Induced Hearing Loss*

American Hearing Research Foundation (Rutherford, Kaur)

Feb. 2014 – Jan. 2015 \$20,000

*Role of resident immune cells in development of cochlear innervation*

Alexander von Humboldt Foundation (Rutherford, Moser)

Postdoctoral Fellowship March 2010 – Feb. 2012 €80,000

*Synaptic mechanisms in the auditory periphery that underlie encoding of sound amplitude*

## **Service and Affiliations**

Bioengineering of Neuroscience, Vision and Low Vision Technologies Study Section

Emerging Technologies and Training Neurosciences Integrated Review Group

CENTER FOR SCIENTIFIC REVIEW BNVT

Agenda Seq Num – 376387 10/10/2019 - 10/11/2019 ad hoc

Washington University Division of Biology and Biomedical Sciences Curriculum Taskforce, Pedagogy and Assessment Subcommittee, 2018 – 2019.

Grant Review: Action on Hearing Loss, 2014 – present.

DoD CDMRP HRRP Review Panel January 2019  
Dept. of Defense, Army Materiel Command, Congressionally Directed Medical Research Program, Hearing Restoration Research Program, Focused Applied Research, and Basic/Developmental and Translational Research Awards

NIDCD Hearing and Balance Fellowship Application Review Panel  
NIDCD ZDC1 SRB-Y (51) October 2018

NIH SMI Study Section June 2017 ad hoc

NIH AUD Study Section Oct. 2016 ad hoc

ARO Long Range Planning Committee Member, ARO, 2015 – 2018

Peer Review: *Journal of Neuroscience*, *Journal of Neurophysiology*, *Journal of the Association for Research in Otolaryngology*, *Journal of Human Molecular Genetics*, *Journal of Physiology*, *Hearing Research*, *Synapse*, *PNAS*, *eLife*, *Scientific Reports*, *Current Opinion in Physiology*

Meeting organization: Calcium and Senses Symposium, Goettingen 2010;  
Ribbon Synapses Symposium, Goettingen 2011, 2013, 2019

Societies: Association for Research in Otolaryngology, Society for Neuroscience, Alexander von Humboldt Foundation

## **Teaching and Mentoring**

Fall 2020: Course organizer and instructor for Wash. U. MSTP MD/PhD graduate students in the Markey Pathway – called “Human Pathology of Hearing Loss,” to help bridge the gap between clinical and basic research.

July 2020 – June 2022: I am mentoring and advising T32 postdoc Amit Walia, an ENT physician scientist. Amit joined my lab full-time for 2 years. We are working together on the drug discovery project, screening novel compounds in HEK cells. I am training Dr. Walia in patch-clamp and imaging techniques.

2019: Course Instructor for Hair Cell Function Curriculum, Biology of the Inner Ear Summer Course, Marine Biological Laboratory, Woods Hole, MA. August 2019.

2014 – 2016: Postdoc Kyunghye Kim. We published two papers about ion channel topographies in the auditory nerve and about glutamate excitotoxicity in the organ of Corti. Dr. Kim continues to study auditory electrophysiology and anatomy with Christoph Schreiner at UCSF.

2017 – 2019: Postdoc Babak V-Ghaffari. We worked toward improving the function of cochlear implants with multicompartamental biophysical models of auditory nerve fibers with realistic ion channel topographies. Dr. V-Ghaffari is an electrical engineer and computational neuroscientist.

Graduate **Program for Audiology and Communication Studies (PACS)**: Wash. U. has an Audiology PhD program called PACS that offers opportunities for training and mentoring. I lecture for the group of students each year.

2016 – 2017: PACS student Allison Schwed did her audiology degree capstone project in my lab. The output includes a written thesis on quantification of spiral ganglion neurons.

2017 – 2019: PACS student Bethany Davis worked full-time in my lab summer 2017 supported by the T35 training grant. She has presented a poster on our work at the 2018 Conference of the American Auditory Society, focused on factors influencing recovery of cochlear function after noise induced damage. She contributed as an author on work published in J. Neurosci. She finished her audiology degree capstone project in Spring 2019, performing auditory functional testing on mice.

Summer 2017 – present: each semester I host 4-6 Wash U. undergrad students in my laboratory. They each work 8-16 hours per week for course credit in Wash. U. Bio 200/500: Undergraduate Independent Research. I am their instructor. In most cases, this is their first wet lab experience. They receive one on one instruction in order to develop their own project for independent study. Students learn a variety of techniques in the lab including organ of Corti dissection, video microscopy of paraffin embedded slides, quantification of spiral ganglion neurons, segmentation of cellular structures in our 3-dimensional electron microscopy data set at the Wash. U. Center for Cellular Imaging (WUCCI), and molecular biology techniques, for example PCR for genotyping mice. Students have included Guhan Iyer, Jason Carlquist, Sonali Guttani, Honey Patel, Natalie Skigen, Matt Nester, Kya Vaughn, Devon Chen, Sofia Kling, Heather Chung, and Atri Battacharyya. All students have returned for a 2<sup>nd</sup> or 3<sup>rd</sup> semester. Most of them are pre-Med. Jason Carlquist and Natalie Skigen have been accepted to medical school at University of Iowa and Duke, respectively. They both start Fall 2020. Several students have contributed as co-authors.

Winter 2017-2018: I advised Wash U Medical School Resident Jay Gantz for his T32 research project. Jay's focus was on analysis of confocal immunofluorescence images of cochlear synapses. His work was published in J. Neurosci.

Fall 2017: I co-organized with Keiko Hirose a course for Wash U Division of Biology and Biomedical Sciences graduate students. This 8-week course on



Hearing Loss was taught by 7 instructors: Buchman, Lichtenhan, Chole, Rutherford, Hirose, Gratton, and Sheets.

Spring 2018: Lecture for 1<sup>st</sup> and 2<sup>nd</sup> year Wash U. graduate students in the Medical Scientist Training Program (MSTP): “Introduction to Sound Encoding – Rutherford Lab – Mechanisms of Auditory Nerve Fiber Diversity and Excitotoxicity.”

Fall 2018: Hosting research stay of visiting PhD student Luis Boero from the lab of Dr. Juan Goutman in Buenos Aires, Argentina. The goal of Luis’ visit was to measure exocytosis from mouse inner hair cells after noise exposure. He contributed as co-author to work published in PNAS.

2018 – 2019: Co-advisor for ENT Resident and T32 Postdoctoral Researcher Carla Valenzuela for her project on the relationship between endolymphatic hydrops and cochlear synaptopathy.

2014 – 2019: **Auditory and Vestibular Neuroscience (AuVeN) Group Meeting:** I organized a multi-laboratory group meeting where we voluntarily shared data from our labs, discussing news from conferences attended, presenting a journal club article, practicing a talk, etc. It was attended by PIs, postdocs, technicians, graduate students, and undergraduates. In 5 years we had 64 meetings including guests from other institutions.

### **Conference Symposia (invited)**

“Cochlear Excitability and Excitotoxicity.” Keynote - Young Investigator Symposium, *Association for Research in Otolaryngology Annual Conference*, San Jose, CA. January 27, 2020.

“Cochlear afferent and efferent synapses.” *Biology of the Inner Ear Summer Course*, Marine Biological Laboratory, Woods Hole, MA. August 15, 2019.

“Ribbon synapse morphology before and after noise exposure in Vglut3 WT and KO IHCs: Glutamate-dependent and glutamate-independent effects.” *Midwest Auditory Research Conference*. Southern Illinois University, Springfield, Illinois. July 13, 2019.

“Synaptic Heterogeneities of AMPA Receptors in Auditory Nerve Fibers.” *Molecular Biology of Hearing and Deafness Satellite: Channels and Synapses Symposium*. Max Planck for Biophysical Chemistry, Goettingen, Germany. May 19, 2018.

“Excitotoxicity and Recovery at the Hair Cell Ribbon Synapse.” *Hearing and Deafness: from Basic to Clinic*. Tsinghua University, Beijing, China. November 1, 2017.

"Synapse Loss and Recovery in the Noise Exposed Cochlea." *3<sup>rd</sup> Chinese Hearing Science Conference: From Cochlear Hair Cells to Brain Cortex, from Basic Science to the Clinic. Nanjing Drum Tower Hospital. Nanjing, China. October 26-29, 2017.*

"Molecular anatomy and physiology of action potential generation in auditory nerve fibers" Ribbon Synapses Symposium, 2015, Goettingen, Germany.

"Auditory nerve fibers, what makes them different from each other?" Midwest Audiology Research Conference – Midwest Auditory Neuroscience Symposium (MARC-MANS), 2015, Omaha, NE.

"Action potential generation in spiral ganglion neurons." Mid-west Audiology Research Conference – Midwest Auditory Neuroscience Symposium (MARC-MANS), 2014. St. Louis, MO.

"Action potential generation in spiral ganglion neurons." *Gordon Research Conference: Auditory System*, 2014, Lewiston, ME.

"Fine-timing control of spike generation in the cochlea by a powerful unitary synapse." *Gordon Research Conference: Synaptic Transmission*, 2012, Waterville Valley, NH.

"Spike generation in the spiral ganglion neuron - at the origin of the auditory code." *Association for Research in Otolaryngology Annual Conference, Symposium: Molecular Anatomy and Physiology of the Ribbon Synapse*, 2012, San Diego, CA.

"Spike encoding of inner hair cell exocytosis timing in spiral ganglion neurons of the cochlea." *Ribbon Synapses Symposium*, 2011, Goettingen, Germany.

"Synaptic disorganization in Bassoon mutant mice." *Gordon Research Conference: Auditory System*, 2010, New London, NH.

"The source of regularly timed background neural activity in the frog sacculus." *Association for Research in Otolaryngology Annual Conference, Symposium: Hair Cell Afferent Synaptic Transmission*, 2008, Phoenix, AZ.

### **Institutional Seminars (invited)**

"Excitability and Excitotoxicity at Afferent Synapses in the Cochlea." *CIMED Excite Seminar Series, Washington University Center for Investigation of Membrane Excitability Diseases*. St. Louis, MO., November 5, 2018.

"The Role of Glutamate and Glutamate Receptor Heterogeneity in Cochlear Synaptic Excitotoxicity." *Washington University Department of Otolaryngology Research Seminar*. St. Louis, MO., October 19, 2018.

"Molecular-Anatomical Heterogeneities Underlying Cochlear Electrophysiology and Hearing Function." *University of Michigan, Kresge Hearing Research Institute: Schacht Lectureship*. Ann Arbor, MI. April 19, 2018.

"Sound-induced Synaptic Disintegration in the Cochlea." *Northwestern University Dept. of Otolaryngology: Knowles Lectureship*. Chicago, IL. March 13, 2017.

"Sound-induced synaptic disintegration in the cochlea." *Washington University Department of Otolaryngology Research Seminar*. St. Louis, MO., April 21, 2017.

"Mechanisms of Sound-Induced Synaptic Disintegration in the Organ of Corti." *University of Utah Inner Ear Research Group Seminar Series*. Salt Lake City, Utah. Feb. 6, 2017.

"Excitability and Excitotoxicity at Cochlear Ribbon-type Synapses." *Southern Illinois University, Dept. of Pharmacology Seminar*. Springfield, IL. August 30, 2016.

"Spike generation in the osseous spiral lamina, yet nothing shocking." *Washington University Department of Otolaryngology Research Seminar*. St. Louis, MO. April 3, 2015.

"The axon initial segment of the auditory nerve." *University of Iowa Department of Biology*, Iowa City, IA. September 11, 2015.

"Molecular anatomy and physiology of synaptic transmission and spike generation in the cochlea." *Washington University Department of Otolaryngology*. St. Louis, MO. March 14, 2012.

"Spike generation in the peripheral segment of the spiral ganglion neuron: an intracellular patch clamp study in a synaptic context." *Eaton Peabody Laboratory, Harvard-MIT Massachusetts Eye and Ear Infirmary*. Boston, MA. March 8, 2012.

"Synaptic disorganization in bassoon mutant mice." *Otolaryngology Dept., Stanford University*. Palo Alto, CA. June 25, 2010.

"Periodic synaptic excitation from hair cells triggers background spikes in afferent neurons of the isolated frog sacculus." *Bernstein Center for Computational Neuroscience. University of Goettingen*. Goettingen, Germany. September 9, 2008.

"Frequency selectivity and background activity in the frog sacculus." *Hudspeth Lab. Rockefeller University*. New York, NY. June 26, 2008.

"Ongoing presynaptic voltage oscillations in hair cells "at rest" create rhythmic postsynaptic activity in saccular afferent fibers of the 8th nerve." *Cochlear Neurotransmission Laboratory. Johns Hopkins. Baltimore, MD. June 9, 2007.*

### **Conference Podium Talks / Poster Abstracts**

"The Requirement for Glutamate in Pre- and Postsynaptic Trauma at Cochlear Ribbon Synapses." *Association for Research in Otolaryngology Annual Conference Podium Talk, 2017, Baltimore, MD.*

"Frequency selectivity of synaptic exocytosis in frog saccular hair cells." *Association for Research in Otolaryngology Annual Conference Podium Talk, 2006, Baltimore, MD.*

"Synaptic vesicle pools at a ribbon synapse: exocytosis in frog saccular hair cells." *Society for Neuroscience Annual Conference Podium Talk, 2004, San Diego, CA.*

Juan Goutman, Shelby Payne, Babak V-Ghaffari, Shashank Chepurwar, Adish Dani, Mark Rutherford. Physiology and Anatomy of Glutamate Receptors at the Inner Hair Cell to Auditory Nerve Fiber Synapse Suggest GluA2-lacking, Ca<sup>2+</sup>-permeable AMPA Receptors Contribute to Transmission in the Mammalian Cochlea. *Association for Research in Otolaryngology Annual Conference Poster Abstract, 2020, San Jose, CA.*

Luis E. Boero, Shelby Payne, Eugenia Gómez-Casati, Mark Rutherford, Juan Goutman. Effects of Acoustic Trauma on Neurotransmitter Release by Inner Hair Cells. *Association for Research in Otolaryngology Annual Conference Poster Abstract, 2020, San Jose, CA.*

Jay A. Gantz, Jason Carlquist, Babak V-Ghaffari, Mark Rutherford. Position Dependence of Synaptic Volume in the Organ of Corti under Different Conditions. *Association for Research in Otolaryngology Annual Conference Poster Abstract, 2020, San Jose, CA.*

Shelby Payne, Natalie Skigen, Jason Carlquist, Sonali Gattani, Guhan Iyer, Bethany Davis, Honey Patel, Allison Schwed, Heather Chung, Matt Nester, Atri Bhattacharyya, Mark Rutherford. Three-dimensional electron microscopy of inner hair cell synapse and afferent morphology from hearing onset to maturation. *Association for Research in Otolaryngology Annual Conference Poster Abstract, 2020, San Jose, CA.*

Ian C. Bruce, Daniel Shields, Laura Green, Babak V-Ghaffari, Mark Rutherford. Simulating the Effects of KLT, HCN and M-current Channels in Auditory Nerve Fibers. *Association for Research in Otolaryngology Annual Conference Poster Abstract, 2020, San Jose, CA.*

Benjamin Shuster; Ryan Casserly; Shaun Viechweg; Erika Lipford; Kanisa

Davidson; Rafal Olszewski; Jennifer Enoch; Mark McMurray; Beatrice Milon; Mark Rutherford; Kevin Ohlemiller; Michael Hoa; Didier Depireux; Jessica Mong; Ronna Hertzano. Evaluating Estrogen's Multi-Modal Modulatory Potential: A Framework for Understanding Protection from Noise-Induced Hearing Loss. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2020, San Jose, CA.

Ian C. Bruce, Laura Green, Babak Vazifekhah Ghaffari, Mark A. Rutherford. Simulating the effects of "M-current" potassium channels in cochlear implant excitation of auditory nerve fibers. *Conference on Implantable Auditory Prostheses*, 2019, Lake Tahoe, CA.

Mark A. Rutherford, Shashank Chepurwar, Shelby Payne, Madhusudan Savaikar, Adish Dani. Molecular Anatomy of Inner Ear Ribbon Synapses. *Ribbon Synapses Symposium*, 2019, Goettingen, Germany.

Samantha Skobel, Hou-Ming Cao, Mark A. Rutherford, Maria E. Rubio. Altered AMPAR Subunit Expression and Sex-Specific Vulnerability to Noise-Induced Synapse Loss and Deafness in GluA3 KO Mice. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2019, Baltimore, MD.

Jay Gantz, Jason Carlquist, Babak V-Ghaffari, Kyunghee X. Kim, Mark A. Rutherford. Ribbon Synapse Morphology Before and After Noise Exposure in Vglut3 WT and KO IHCs: Glutamate-dependent and Glutamate-independent Effects. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2019, Baltimore, MD.

Shelby Payne, Cathy Sung, Song Zhe Li, Mark Rutherford, William Britt, Keiko Hirose. CMV in Newborn Mice Induces Loss of Synapses Followed by Reduction in Spiral Ganglion Cells Accompanied by Progressive Hearing Loss. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2019, Baltimore, MD.

Christopher J. Lingle, Aizhen Yang-Hood, Shelby Payne, Xiaoming Xia, Mark A. Rutherford. The Unique Gating Range of Inner Hair Cell Calcium- and Voltage-activated BK Channels is Defined by Gamma2, but not Gamma1, Regulatory Subunits. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2019, Baltimore, MD.

Bethany Davis, Shelby Payne, Aizhen Yang-Hood, Song-Zhe Li, Kyunghee X. Kim, Kevin K. Ohlemiller, Keiko Hirose and Mark A. Rutherford. Noise Damage and Repair in Vglut3 wild-type, heterozygous, and knockout mice. *American Auditory Society Annual Conference Poster Abstract*, 2018, Scottsdale, AZ.

Samantha Skobel, Hou-Ming Cao, Mark A. Rutherford, Maria E. Rubio. Altered AMPAR Subunit Expression and Sex-Specific Vulnerability to Noise-Induced

Synapse Loss and Deafness in GluA3 KO Mice. *Gordon Research Conference: Auditory System*, 2018.

Shelby A. Payne and Mark A. Rutherford. Three-dimensional electron microscopy of hair cell synapses in the inner spiral plexus. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2018, San Diego, CA.

Aizhen Yang-Hood, Shelby Payne, Song-Zhe Li, Bethany Davis, Kyunghee Kim, Kevin Ohlemiller, Keiko Hirose, Mark A. Rutherford. Noise damage and repair in Vglut3 wild-type, heterozygous, and knockout mice. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2018, San Diego, CA.

Shelby A. Payne, Kyunghee X. Kim, Jason Carlquist, Guhan Iyer, Honey Patel, Sonali Gattani, Madhusudan Savaikar, Adish Dani, and Mark A. Rutherford. 3D Super-resolution of cochlear afferent synapses reveals AMPAR subunit molecular anatomy. Washington University Neuroscience Retreat, 2017.

Lars Becker, Sara Talaei, Willy Sun, Mark Rutherford, Michael Schnee, Mamiko Niwa, Stephan Maxeiner, Bechara Kachar, Anthony J. Ricci. What Is the Ribbon Needed For? Functional Deletion of RIBEYE Leads to a Mild Auditory Phenotype. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2017, Baltimore, MD.

Michael Schnee, Mamiko Niwa, Lars Becker, Sara Talaei, Willy Sun, Mark Rutherford, Bechara Kachar, Anthony J. Ricci. Deletion of the RIBEYE Specific A Domain Reduces Synaptic Release in Mouse Inner Hair Cells. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2017, Baltimore, MD.

Mark Rutherford, Tzu-Lun Ohn, Zhizi Jing, Sangyong Jung, Carlos Duque-Afonso, Gerhard Hoch, Magdalena Picher, Anja Scharinger, Nicola Strenzke, Tobias Moser. Hair Cells Use Active Zones with Different Voltage-dependence of Ca<sup>2+</sup> Influx to Decompose Sounds into Complementary Neural Codes. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2017, Baltimore, MD.

Mark Rutherford. AMPA Receptors of Auditory Nerve Fiber Postsynaptic Densities appear to have Nanodomains that Lack the Ca<sup>2+</sup>-limiting GluA2 Subunit. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2017, Baltimore, MD.

Kim, K.X., Rutherford, M.A. Maturation of NaV and KV Channel Topographies in the Auditory Nerve Spike Initiator before and after Developmental Onset of Hearing Function. *Molecular Biology of Hearing and Deafness Conference Poster Abstract*, 2016, Cambridge, UK.

Kim, K.X., Rutherford, M.A. Voltage-gated Na<sup>+</sup> and K<sup>+</sup> Channel Topographies in Auditory Nerve Fibers. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2016, San Diego, CA.

Rutherford, M.A., Kim, K.X. The Spike Generator of the Auditory Nerve Matures Anatomically After Hearing Onset. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2016, San Diego, CA.

Kim, K.X., Rutherford, M.A. The Spike Generator of Type I Cochlear Afferents. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2015, Baltimore, MD.

Wong, A.B., Rutherford, M.A., Jing, Z., Gabrielaitis, M., Pangršič, T., Frank, T., Göttfert, F., Michanski, F., Hell, S., Wolf, F., Wichman, C., Strenzke, N., Moser, T. Anatomical and Physiological Maturation of Inner Hair Cell Ribbon Synapses. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2014, San Diego, CA.

Li, S.Z., Suzuki, H., Koeritzer, M., Rutherford, M.A., Hirose, K. CD36 is not Needed for Hair Cell Phagocytosis and Plays a Role in Hair Cell Vulnerability to Ototoxic Agents. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2014, San Diego, CA.

Wang, T.-L., Rutherford, M.A., Moser, T. Mechanisms Underlying Heterogeneity of Ca<sup>2+</sup> signaling Among Hair Cell Active Zones. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2013, Baltimore, MD.

Wong, A., Rutherford, M.A., Jing, Z., Frank, T., Strenzke, N., Wichmann, C., Moser, T. From Pattern Generator to Sound Receptor, Hair Cells Adjust Ca<sup>2+</sup> Signaling to Their Function During Development. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2013, Baltimore, MD.

Rutherford, M.A., Wang, T.-L., Hoch, G., Wichman, C., Moser, T. Analysis of Fluorescently-Labeled Protein Puncta in Hair Cells: Synaptic Strength & Systematic Artifacts. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2013, Baltimore, MD.

von Ameln, S., Wang, G., Boulouiz, R., Rutherford, M.A., Smith, G.M., Li, Y., Pogoda, H.M., Nürnberg, G., Volk, A.E., Stiller, B., Hong, J.S., Goodyear, R.J., Nürnberg, P., Richardson, G.P., Hammerschmidt, M., Moser, T., Wollnik, B., Koehler, C.M., Teitell, M.A., Barakat, A., Kubisch, C. A Mutation in *PNPT1*, Encoding Mitochondrial-RNA-Import Protein PNPase, Causes Hereditary Hearing Loss. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2013, Baltimore, MD.

Rutherford, M.A., Chapochnikov, N.M., Moser, T. Spike Encoding of Neurotransmitter Release Timing by Spiral Ganglion Neurons of the Cochlea. *Gordon Research Conference: Auditory System*, 2012, Lewiston, ME.

Rutherford, M.A., Chapochnikov, N.M., Moser, T. Spike Encoding of Neurotransmitter Release Timing by Spiral Ganglion Neurons of the Cochlea. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2012, San Diego, CA.

Jing, Z., Rutherford, M.A., Frank, T., Moser, T., Strenzke, N. Bassoon as an Organizer of Inner Hair Cell Presynaptic Structure. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2012, San Diego, CA.

Rutherford, M.A., Chapochnikov, N.M., Moser, T. Spike Encoding of Neurotransmitter Release Timing by Spiral Ganglion Neurons of the Cochlea. *Society for Neuroscience Annual Conference Poster Abstract*, 2011, Washington, DC.

Wang, T.-L., Wong, A.B., Rutherford, M.A., Frank, T., Reuter, K., Kügler, S., Moser, T. Synaptic heterogeneity of hair cell ribbon synapses. *Society for Neuroscience Annual Conference Poster Abstract*, 2011, Washington, DC.

Rutherford, M.A., Frank, T., Strenzke, N., Neef, A., Pangršič, T., Khimich, D., Fetjova, A., Gundelfinger, E.D., Liberman, M.C., Harke, B., Bryan, K.E., Lee, A., Egner, A., Riedel, D., Moser, T. Bassoon and the Synaptic Ribbon Organize Ca<sup>2+</sup> Channels and Vesicles to Add Release Sites and Promote Refilling. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2011, Baltimore, MD.

Rutherford, M. A., Frank, T., Strenzke, N., Riedel, D., Pangršič, T., Khimich, D., Gundelfinger, E. D., Liberman, C. M., Harke, B., Egner, A., Neef, A., Moser, T. Ribbon-associated scaffolds promote synaptic vesicle docking and Ca<sup>2+</sup> channel clustering. *Federation of European Neurosciences Forum Poster Abstract*, 2010, Amsterdam, Holland.

Rutherford, M.A., Roberts, W.M. Spiking hair cells and bursts of afferent synaptic excitation in the frog sacculus. *Ribbon Synapses Symposium*, 2009, Goettingen, Germany.

Rutherford, M.A., Roberts, W.M. Background and driven synaptic activity in the frog sacculus. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2008, Phoenix, AZ.

Rutherford, M.A., Roberts, W.M. EPSCs in afferents of the isolated frog sacculus. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2007, Denver, CO.



Rutherford, M.A., Roberts, W.M. Frequency selectivity of synaptic exocytosis in frog saccular hair cells. *Ribbon Synapses Symposium*, 2005, Goettingen, Germany.

Rutherford, M.A., Roberts, W.M. Effects of ATP-gamma-S on exocytosis and endocytosis in frog saccular hair cells. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2005, New Orleans, LA.

Rutherford, M.A., Roberts, W.M. Kinetics of Synaptic Vesicle Exocytosis and Membrane Retrieval in Frog Saccular Hair Cells. *Association for Research in Otolaryngology Annual Conference Poster Abstract*, 2004, New Orleans, LA.

Rutherford, M.A., Roberts, W.M. Measuring Calcium-evoked Capacitance Increases in Auditory Hair Cells of the *Rana pipiens* Semi-intact Saccular Epithelium. *Oregon Society for Neuroscience Annual Conference Poster Abstract*, 2003.

Rutherford, M.A., Bucknell-Pogue, T., Rodrigues, E.M., Weeks, J.C. Mitochondrial events during the steroid-mediated programmed cell death of motoneurons. *Society for Neuroscience Annual Conference Poster Abstract*, 2002, San Diego, CA.

Bucknell-Pogue, T., Rutherford, M.A., Kinch, G., Hoffman, K., Weeks, J. A novel system for investigating steroid-induced, cell-autonomous programmed cell death of neurons and the role of mitochondria. *SAGE Meeting Abstract*, 2002.