BARRY MATTHEW WILLARDSON

CONTACT INFORMATION

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EDUCATION

Purdue University, West Lafayette, Indiana
Aug. 1984 - Jan. 1990; Ph. D. degree in Biological Chemistry January 1990.
Brigham Young University, Provo, Utah
Sept. 1978 - April 1979 and Oct. 1981 - Aug. 1984; B.A. degree in Chemistry, minor in French.

EMPLOYMENT

Brigham Young University
Professor: Sept. 2006 - present
Associate Professor: Sept. 2002-Sept. 2006
Assistant Professor: July 1996-Sept. 2002
University of California/Los Alamos National Laboratory
Scientific Staff Member: March 1992-June 1996.
Post Doctoral Fellow: Jan 1990-March 1992.
Purdue University
Graduate Research Assistant: May 1985-Dec. 1989.
Graduate Teaching Assistant: Aug. 1984-Dec. 1987.
Brigham Young University
Undergraduate Research Assistant: Jan. 1984-Aug. 1984.
Undergraduate Teaching Assistant in French: Jan. 1982-Aug. 1984.

HONORS

David Ross Graduate Student Fellowship, Purdue University 1989
College Junior Faculty Teaching Award, Brigham Young University 1999
John A. Widtsoe Fellowship, Brigham Young University 2005
Sponsored Research Achievement Award, Brigham Young University 2010
Wesley P. Lloyd Distinction in Graduate Education Award, Brigham Young University 2014
Issat/Christensen Distinguished Faculty Lecture, Brigham Young University 2016

ADMINISTRATIVE EXPERIENCE

Associate chair, BYU Department of Chemistry and Biochemistry 2016 – present.
Biochemistry area chair, BYU Department of Chemistry and Biochemistry 2004 – 2012.
BYU Institutional biosafety committee chair 2006 – 2008.

CRITICALLY REVIEWED JOURNAL PUBLICATIONS

42. Cuéllar, J., Ludlam, W. G., Tensmeyer, N. C., Aoba, T., Dhavale M., Bueno-Carrasco, T., Santiago, C. Plimpton, R. L., Makaju, A., Mann, M. Franklin[3], S., Willardson, B. M. and Valpuesta, J. M. "Structural and functional analysis of the role of the chaperonin CCT in mTOR complex assembly" *Nature Communications* 10, 2865.

41. Aoba, T., Cuéllar, J., Ludlam, W. G., Bueno, M. T., Makaju, A., Moody, J. D., Franklin, S., Valpuesta, J. M. and Willardson, B. M. (2019) "Molecular Architecture of the Bardet-Biedl syndrome protein core complex" *J. Biol. Chem.* under review.

40. Lord, N. P., Plimpton, R. L., Sharkey, C. R., Suvorov, A., Lelito, J. P., Willardson, B. M. and Bybee, S. M. (2016) "A cure for the blues: opsin duplication and subfunctionalization for short-wavelength sensitivity in jewel beetles (Coleoptera: Buprestidae)" BMC Evol. Biol. 16, 107.

39. Xie, K., Masuho, I., Shih, C. C., Cao, Y., Sasaki, K., Lai, C. W., Han, P. L., Ueda, H., Dessauer, C. W., Ehrlich, M. E., Xu. B., Willardson, B.M. and Martemyanov, K. A. (2015) "Stable G protein-effector complexes in striatal neurons: mechanism of assembly and role in neurotransmitter signaling." eLife 10.7554/eLife.10451.

38. Plimpton, R. L.*, Cuéllar, J.*, Lai, C. W. J., Aoba, T., Makaju, A., Franklin, S., Mathis, A. D., Prince, J. T., Carrascosa, J. L., Valpuesta, J. M. and Willardson, B. M. (2015) "Structures of the Gβ-CCT and PhLP1-Gβ-CCT Complexes Reveal a Molecular Mechanism for G protein β Subunit Folding and βγ Dimer Assembly". *Proc. Natl. Acad. Sci. U.S.A.* 112, 2413-2418 *Equal contribution of these two authors

37. Tracy, C. M.*, Kolesnikov A. V.*, Blake D. R., Chen, C.-K., Baehr, W., Kefalov, V. J. and Willardson B. M. (2015) "Retinal cone photoreceptors require phosducin-like protein 1 for G protein complex assembly and signaling." *PLOS ONE* 10, e0117129. *Equal contribution of these two authors

36. Tracy, C. M., Gray A. J., Cuellar, J., Shaw, T.S., Howlett, A.C., Taylor, R.M., Prince, J.T., Ahn, N.G., Valpuesta, J.M. and Willardson, B.M. (2014) "Programmed cell death protein 5 interacts with the chaperonin CCT to regulate β-tubulin folding." *J. Biol. Chem.* 289, 4490-4502. *Selected as paper of the week

35. Lai, C. W. J., Kolesnikov, A.V., Frederick, J.M., Blake, D.R., Li, J., Stewart, J., Chen, C.-K., Barrow, J.R., Baehr, W., Kefalov, V.J. and Willardson, B.M. (2013) "Phosducin-like protein 1 is essential for G protein assembly and signaling in retinal rod photoreceptors." *J. Neurosci.* **33**, 7941-7951. *Selected in Faculty of 1000

34. Javadi, M., Pitt, W.G., Tracy, C.M., Barrow, J.R., Willardson, B.M., Hartley, J.M. and Tsosie, N.H. (2013) "Ultrasonic gene and drug delivery using eLiposomes" *J. Control. Release* **167**, 92-100.

33. Zhou X., Shapiro L., Fellingham G., Willardson B.M. and Burton G.F. (2011) "HIV Replication in CD4+ T Lymphocytes in the Presence and Absence of Follicular Dendritic Cells: Inhibition of Replication Mediated by α-1-Antitrypsin through Altered IκBα Ubiquitination." *J. Immunol.* **186**, 3148-3155.

32. Smrcka, A. V., Kichik, N., Tarrago, T., Burroughs, M., Park, M., Stern, H., Itoga, N. K. Willardson, B. M. and Giralt, E. (2010) "NMR Analysis of G Protein βγ Subunit Complexes Reveals a Dynamic Gα-Gβγ Subunit Interface and Multiple Protein Recognition Modes" *Proc. Natl. Acad. Sci. U. S. A.* **107**, 639-644.

31. Howlett, A. C., Gray, A. J., Hunter, J. M. and Willardson, B. M. (2009) "Role of Molecular Chaperones in G protein β5/Regulator of G protein Signaling Dimer Assembly and G protein βγ Dimer Specificity" *J. Biol. Chem.* **284**, 16386-16399.

30. Willardson, B. M. and Howlett, A. C. (2007) "Function of phosducin-like proteins in G protein signaling and chaperone-assisted protein folding" *Cell Signal.* **19**, 2417-2427.

29. Becerril, H. A., Ludtke, P., Willardson, B. M., Woolley, A. T. (2006) "DNA-templated nickel nanostructures and protein assemblies*" Langmuir* **22**, 10140-10144.

28. Lukov, G. L., Baker, C. M., Ludtke, P. J., Hu, T., Carter, M. D., Hackett, R. A., Thulin, C. D. and Willardson, B. M. (2006) "Mechanism of Assembly of G Protein βγ subunits by Protein Kinase CK2-phosphorylated Phosducin-like Protein and the Cytosolic Chaperonin Complex" *J. Biol. Chem.* **281**, 22261-22274.

27. Lukov, G. L., Hu, T., McLaughlin, J. N., Hamm, H. E. and Willardson, B. M. (2005) "Phosducin-like protein acts as a molecular chaperone for G protein βγ dimer assembly" *EMBO J.* **24**, 1965-1975.

26. Carter, M.D., Southwick, K., Lukov, G., Willardson, B. M. and Thulin, C. D. (2004) "Identification of phosphorylation sites on phosducin-like protein by QTOF mass spectrometry" *J. Biomol. Tech.* **15**, 257-264.

25. Martin-Benito, J., Bertrand, S., Hu, T., Ludtke, P., McLaughlin, J.N., Willardson, B.M., Carrascosa, J. L. and Valpuesta, J.M. (2004) "Structure of the complex between phosduin-like protein and the cytosolic chaperonin complex" *Proc. Natl. Acad. Sci.* **101**, 17410-17415.

24. Lee, B.Y., Thulin, C. D. and Willardson B. M. (2004) "Site-specific phosphorylation of phosducin in intact retina -- dynamics of phosphorylation and effects on G protein βγ dimer binding" *J. Biol. Chem.* **279**, 54008-54017.

23. Lukov, G.L., Myung, C.-S., McIntire, W.E., Shao, J., Zimmerman, S.S., Garrison, J.C. and Willardson, B.M. (2004) "Role of the Isoprenyl Pocket of the G protein βγ Subunit Complex in the Binding of Phosducin and Phosducin-like Protein" *Biochemistry* **43**, 5651-5660.

22. Obin, M., Lee, B.Y., Meinke, G., Bohm, A., Lee, R.H., Gaudet, R., Hopp, J.A., Arshavsky, V.Y. Willardson, B.M. and Taylor, A. (2002) "Ubiquitylation of the transducin beta gamma subunit complex: Regulation by phosducin"*J Biol Chem* **277**, 44566-44575.

21. McLaughlin J.N., Thulin C.D., Bray S.M., Martin M.M., Elton T.S., and Willardson, B.M. (2002) "Regulation of Angiotensin II-induced G Protein Signaling by Phosducin-like Protein" *J Biol Chem* **277**, 34885-95.

20. J.N. McLaughlin, C.D. Thulin, S.J. Hart, K.A. Resing, N.G. Ahn and B.M. Willardson (2002) "Regulatory Interaction of Phosducin-like Protein with the Cytosolic Chaperonin Complex" *Proc. Natl. Acad. Sci. U.S.A.* **99**, 7962-7967.

19. C.D. Thulin, J.R. Savage, J.N. McLaughlin, S.M. Truscott, W.M. Old, N.G. Ahn, K.A. Resing, H.E. Hamm, M.W. Bitensky and B.W. Willardson (2001) "Modulation of the G Protein Regulator Phosducin by Calcium/Calmodulin-Dependent Protein Kinase II Phosphorylation and 14-3-3 Protein Binding" *J. Biol. Chem.* **276**, 23805-23815.

18. M. M. Martin, B.M. Willardson, G.F. Burton, C.R. White, J.N. McLaughlin, S.M. Bray, J.W. Ogilvie, Jr. and T.S. Elton (2001) "Human angiotensin II type 1 receptor isoforms resulting from alternatively spliced mRNAs are functionally distinct." *Mol. Endocrin.* **15**, 281-293.

17. J.R. Savage, J.N. McLaughlin, N. Skiba, H.E. Hamm and B. M. Willardson (2000) "Functional Roles of the Two Domains of Phosducin and Phosducin-like Protein" *J. Biol. Chem.* **275**, 30399-30407.

16. M.E. Lazarov, M. M. Martin, B. M. Willardson and T.S. Elton (2000) "Molecular Cloning and Characterization of the Human Phosducin-like Protein Promoter" *Biochim. Biophys. Act*, **1492**, 460-464.

15. C.D. Thulin, K. Howes, C.D. Driscoll, J.R. Savage, T.A. Rand, W. Baehr and B. M. Willardson. (1999) "The Localization and Divergent Roles of Phosducin and Phosducin-like Protein in the Retina" *Mol. Vision*, 5, 40. http://www.molvis/v5/p40/

14. M.E. Lazarov, M. M. Martin, B. M. Willardson and T.S. Elton (1999) "Human Phosducin-like Protein Messenger RNA Stability is Regulated by cis-Acting Instability Elements Present in the 3'-Untranslated Region" *Biochim. Biophys. Acta* **1446**, 253-264.

13. R. Gaudet, J. R. Savage, J. N. McLaughlin, B. M. Willardson and P. B. Sigler (1999) "A Molecular Mechanism for the Phosphorylation-Dependent Regulation of Heterotrimeric G-Proteins by Phosducin" *Mol. Cell* **3**, 649-660.

12. C. Li, L. P. Budge, C. D. Driscoll, B.M. Willardson, G. W. Allman and P. B. Savage (1998) "Incremental Conversion of Outer-Membrane Permeabilizers into Potent Antibiotics for Gram-Negative Bacteria" *J. Am. Chem. Soc.* **121**, 931-940.

11. B.M. Willardson, J.F. Wilkins, T.A. Rand, J.M. Schupp, K.K. Hill, P. Keim, and P.J. Jackson (1998) "Development and Testing of a Bacterial Biosensor for Toluene-based Environmental Contaminants" *Appl. Environ. Microbiol.* **64**, 1006-1012.

10. J.F. Wilkins, M.W. Bitensky and B.M. Willardson (1996) "Regulation of the Kinetics of Phosducin Phosphorylation in Retinal Rods" *J. Biol. Chem.* **271**, 19232-19237.

9. B.M. Willardson, J.F. Wilkins, T. Yoshida and M.W. Bitensky (1996) "Regulation of Phosducin Phosphorylation in Retinal Rods by Ca^{2+}/Calmodulin-Dependent Adenylyl Cyclase" *Proc. Natl. Acad. Sci. USA*, **93**, 1475-1479.

8. T. Yoshida*, B.M. Willardson*, J.F. Wilkins, G.J. Jensen, B. D. Thornton, and M.W. Bitensky (1994) "The Phosphorylation State of Phosducin Determines its Ability to Block Transducin Subunit Interactions and Inhibit Transducin Binding to Activated Rhodopsin" *J. Biol. Chem.* **269**, 24050-24057. *equal contribution of these two authors.

7. B. M. Willardson, B. Pou, T. Yoshida, and M. W. Bitensky (1993) "Cooperative Binding of the Retinal Rod G-protein, Transducin, to Light-activated Rhodopsin" *J. Biol. Chem.* **268**, 6371-6382.

6. C. R. Lombardo, B. M. Willardson, P. S. Low (1992) "Localization of the Protein 4.1-binding Site on the Cytoplasmic Domain of Erythrocyte Membrane Band 3" *J. Biol. Chem.*, **267**,9540-9546.

5. P. S. Low, B. M. Willardson, N. Mohandas, M. Rossi, and S. Shohet (1991) "Contribution of the Band 3-Ankyrin Interaction to Erythrocyte Membrane Mechanical Stability" *Blood*, **77**, 1581-1586.

4. B. J.-M. Thevenin, B. M. Willardson, and P. S. Low (1989) "The Redox State of Cysteines 201 and 317 of the Erythrocyte Anion Exchanger is Critical for Ankyrin Binding", *J. Biol. Chem.*, **264**, 15886-15892.

3. B. M. Willardson, B. J.-M. Thevenin, M. L. Harrison, W. H. Kuster, M. D. Benson, and P. S. Low (1989) "Localization of the Ankyrin Binding Site on Erythrocyte Membrane Protein, Band 3" *J. Biol. Chem.*, **264**, 15886-15892.

2. P. S. Low, D. P. Allen, T. F. Zioncheck, P. Chari, B. M. Willardson, R. L. Geahlen, and M. L. Harrison (1987) "Tyrosine Phosphorylation of Band 3 Inhibits Peripheral Protein Binding" *J. Biol. Chem.*, **262**, 4592-4596.

1. S. M. Waugh, B. M. Willardson, R. Kannan, R. Labotka, and P. S. Low (1986) "Heinz Bodies Induce Clustering of Band 3, Glycophorin, and Ankyrin in Sickle Cell Erythrocytes" *J. Clin. Invest.*, **78** 1155-1160.

BOOK CHAPTERS

8. R.L. Plimpton, J.M. Valpuesta and B.M. Willardson (2018) "Mechanism of Folding by Type II Chaperonins" In: Frontiers in Structural Biology – Role of Molecular Chaperones in Structural Folding, Biological Functions, and drug interactions of client proteins. 1, 190-213. Ed. M. D. Galigniana, Bentham Science.

7. B.M. Willardson and N.C. Tensmeyer (2017) "G proteins". In: eLS. John Wiley & Sons, Ltd: Chichester. DOI: 10.1002/9780470015902.a0027195.

6. B.M. Willardson and C.M. Tracy (2012) "Chaperone-mediated Assembly of G protein complexes" Subcell. Biochem. 63, 131-53.

5. B.M. Willardson (2002) "Phosducin" In "Encylcopedia of Molecular Medicine" Wiley, New York. pp. 2462-2465.

4. B.M. Willardson, J.F. Wilkins, Tatsuro Yoshida and Mark W. Bitensky (1997) "Regulation of G-protein Activation in Retinal Rods by Phosducin" In "Structure and Function of Interacting Protein Domains in Signal

and Energy Transduction" Ed. L. M. G. Heilmeyer, Springer-Verlag, Berlin-Heidelberg- New York- Tokyo. pp. 223-226.

3. B.M. Willardson, T. Yoshida and M. W. Bitensky (1995) "Measuring the Cooperative Binding of the Retinal Rod G-protein, Transducin, to Light Activated Rhodopsin" *Methods in Neurosci.* **29**, 264-279.

2. B.M. Willardson, T. Yoshida and M.W. Bitensky (1995) "Cyclic Nucleotides as Regulators of Light-Adaptation in Photoreceptors" *Behavioral and Brain Sciences* **18**, 493-494.

1. P. S. Low, B. M. Willardson, B. J.-M. Thevenin, R. Kannan, E. Melher, R. L. Geahlen, and M. Harrison (1989) "The Other Functions of Erythrocyte Membrane Band 3" In *Anion Transport Protein of the Red Blood Cell Membrane*, pp. 103-118. eds. N. Hamasaki, and M. Jennings, Elsevier Press, Amsterdam.

EXTERNALLY AWARDED FUNDING

"Beckman Scholars Undergraduate Research Award" Arnold and Mabel Beckman Foundation. 4/2017 – 8/2020, $130,000.

"Mechanisms of assembly of photoreceptor G protein complexes" National Eye Institute, National Institutes of Health R01 continuation. 1/2016 – 12/2019, $1,000,000 plus indirect.

"Mechanisms of assembly of photoreceptor G protein complexes" National Eye Institute, National Institutes of Health R01 continuation. 4/2011 – 3/2016, $1,000,000 plus indirect.

"Co-chaperone Role of Phosducin-like Protein in G Protein Subunit Assembly" National Institute of General Medical Sciences. ARRA Supplement to R01 9/2009-7/2011. $135,000 plus indirect.

"Co-chaperone Role of Phosducin-like Protein in G Protein Subunit Assembly" National Institute of General Medical Sciences. R01 9/2007-8/2011. $755,000 plus indirect.

"Physiological Role of Phosducins in the Retina" National Eye Institute, National Institutes of Health. R01 continuation. 5/2004-4/2009, $600,000 plus indirect.

"LC/quadrupole ion trap mass spectrometer" National Center for Research Resources, National Institutes of Health. Shared Instrument award. 4/2002-3/2003 $245,940.

"Regulation of the Cytoplasmic Chaperonin Complex by Phosducin-like Protein" National Science Foundation, Molecular and Cellular Biosciences 4/2002 to 3/2006, $219,000 plus indirect.

"Regulation of Visual Signal Transduction by Phosducin" National Eye Institute, National Institutes of Health. R01 Award. 5/1999-4/2004, $566,000 plus indirect.

"Regulation of Ang II-Mediated Cell Growth by Phosducin, a Potent G-Protein Signaling Pathway Modulator" American Heart Association Affiliate Award. 7/1997 to 6/1998, $30,000.

"Light-Regulated retinal enzymes" National Eye Institute, National Institutes of Health subcontract from Mark W. Bitensky. 1996-1998, $80,000 plus indirect.