

KENNETH J. ROTHSCHILD

EDUCATION AND TRAINING

- Postdoctoral, Harvard-MIT Program in Health Sciences and Technology, 1974-1976
- Ph.D., Massachusetts Institute of Technology, Physics, 1974
- B.A., Rensselaer Institute of Technology, Physics, 1969

POSITIONS

- Professor of Physics, Boston University, 1987-present
- Associate Professor of Physiology, Boston University School of Medicine, 1982-present
- Center for Bioinformatics, Faculty, 2003-present
- Director, NIH Molecular Biophysics Training Program, 1994-1999
- Director, Molecular Biophysics Laboratory, 1992-present
- Center for Photonics, Faculty, 1994-present
- Director, Ph.D. Program in Cellular Biophysics, B.U., 1984-88
- Associate Professor of Physics, Boston University, 1982-1987
- Center for Polymer Physics, Faculty, 1977-present
- Assistant Professor of Physics, Boston University, 1977-1972
- Assistant Professor of Physiology, B.U. School of Medicine, 1977-1982
- Research Assistant, Harvard-MIT H.S.T. Program, 1974-1977

DISTINCTIONS

- Elected Fellow of the National Academy of Inventors 12/13/2016
- Awarded over 15 million funding in NIH grants as Principle Investigator
- 57 U.S. patents issued and 50 pending in biophysics, biotechnology and nanotechnology
- Co-Chair, 15th Annual Future of Light Symposium, BU Photonics Center 12/1/2011
- Founder, AmberGen, Inc., a Photonics Center Affiliate Biotechnology Company in 1995.
- P.I.- MURI Research Initiative Project Grant from DOD, 1992-1997
- Fellow of the American Physical Society, 1991
- NSF Panel Member for Molecular and Cellular Biophysics, 1992-1997
- Netherlands Foundation for Basic Science Visiting Fellow Award, 1980
- P.I. -National Institutes of Health, National Science Foundation, Office of Naval Research, Army Research Office, 1976-present
- Established Investigator of the American Heart Association, 1979-84
- Fellow, National Institutes of Health, 1977
- Fellow, National Research Council, 1974-76
- Fellow, Massachusetts Institute of Technology, 1971-74
- Fellow, Sloan Foundation, 1969-79
- General Motors Scholar, 1966-69

RESEARCH HIGHLIGHTS

- Developed and introduced in 1981 FTIR-difference spectroscopic approach to studying biological membranes; currently over 1000 papers reported in field using this methodology.
- Elucidated basic mechanism of light-driven proton transport in bacteriorhodopsin in collaboration with H.G. Khorana group -1988
- Introduced biomembrane nanolithography for production of tailored masks in collaboration with N.A. Clark (1989); one of earliest US patents in nanotechnology

- Developed photocleavable biotin and photocleavable phosphoramidites and associated derivatives for biomolecular isolation and activation extensively used in biotechnology (1995),
- Developed diagnostic assay for scanning chain truncating mutations (ELISA-PTT) for inherited cancers currently being evaluated at Mayo Clinic (2003)
- Developing bead-based methods in MALDI-MS for proteomics and drug discovery (2013)
- Current research focus on optogenetic applications of microbial rhodopsins to understand brain function and pathology.

SELECTED SPONSORED RESEARCH

- 2013-2017 Principle Investigator on NSF grant in Biophotonics to develop new optogenetic rhodopsins for mapping brain circuitry
- 2012-2017 Principle Investigator on NIH subcontract (with U. Texas) to study the molecular mechanism of sensory rhodopsins.
- 2010-2014, Principle Investigator on NIH grant to study Melanopsin Using FTIR spectroscopy
- 2008-2011 Principle Investigator, NSF-MRI to Develop Ultrafast Spectrometer
- 2005/2009 Principal Investigator, FTIR Spectroscopy of Signal Transduction in Sensory Rhodopsin, NIH R01GM069969,
- 2004/2006 Principal Investigator, FTIR Spectroscopy of Photoreceptor Membranes. NIH R01EY05499
- 1996/1999, Principle Investigator, FTIR Spectroscopy of Isotope Labeled Membrane Proteins, NIH R01 GM4757
- 1995/1999, Principle Investigator, FTIR Spectroscopy of Purple Membrane, NSF MCB-9419059
- 1992/1999, Principle Investigator, New Biophysical and Genetic Methods for Advanced Material Development, ARO-MURI, DAAL03-97-G-0172

INTERDISCIPLINARY EDUCATIONAL ACTIVITIES:

- Molecular Biophysics Laboratory (Director) This laboratory is a focal point for interdisciplinary research and involves undergraduate, graduate and postdoctoral researchers from various disciplines including physics, biology, chemistry, bioinformatics and medicine. Students learn advanced techniques in biomolecular spectroscopy with the goal of understanding light driven ion transport and signal transduction.
- Cellular Biophysics Program (ex-Director) This Ph.D. program was designed for students with undergraduate degrees in the physical sciences offers a highly interdisciplinary training program which bridges faculty and resources at the Biophysics & Physiology Department at the Medical School and the Physics Department at the Charles River Campus

GRADUATE STUDENT AND POSTDOCTORAL TRAINEES (partial list):

P. Ahl, Research Group Head, Merck; J. Amsden, Postdoctoral, Tufts, P. Argade, Senior Staff Scientist, Lucent; M. Braiman, Professor of Biochemistry, Syracuse U.; T. Earnest, Senior Staff Scientist, UC Berkeley; T.L. Hsio, Dallas Oil Company; H. Marerro, Assistant Professor, UMass Medical School; P. Roepe, Associate Professor, Georgetown U.; R. Sanches, Professor of Biophysics, U. of Sao Paulo; J. Gillespie, Director of Research, J&J; M. Zagaeski, Postdoctoral Fellow, Harvard University; Yiwu He, Program Director for Bill and Melinda Gates Foundation; O. Bousche, Senior Staff Scientist, Shell Oil; M. Coleman, Staff Scientist, LLNL; N. Patel*, Staff Scientist, NIH; T. Russell, CEO, Makoto Life Sciences Inc.; M. Dunach, Senior Research Scientist, U. Barcelona; J. Baenziger, Associate Professor, University of Ottawa; W. Fischer, Lecturer, Oxford University; S. Sonar, Professor, IIT India; P. Rath, Senior Staff Scientist, Emisphere Technologies; J. Olejnik, CSO, Intelligent Biosystems, Inc. V. Bergo, CEO of Biotechnology Industry Start-up.; S.

Mamaev, President, SibEnzyme, USA, Senior Postdoctoral Research Scientist, Boston University; J. Kralj, faculty U.C. Boulder; J. Ogren, postdoc at MIT

SELECTED PUBLICATIONS

1. **Rothschild, K. J.**, I. M. Asher, E. Anastassakis, and H. E. Stanley. 1973. Raman spectroscopic evidence for two conformations of uncomplexed valinomycin in the solid state. *Science (New York, N.Y)* 182:384-386.
2. Asher, I. M., **K. J. Rothschild**, and H. E. Stanley. 1974. Raman spectroscopic study of the valinomycin--KSCN complex. *Journal of molecular biology* 89:205-222.
3. **Rothschild, K. J.**, and H. E. Stanley. 1974. Raman spectroscopic investigation of gramicidin A' conformations. *Science (New York, N.Y)* 185:616-618.
4. **Rothschild, K. J.**, and H. E. Stanley. 1975. Models of ionic transport in biological membranes. Raman spectroscopy as a probe of valinomycin, gramicidin A', and rhodopsin conformations. *American journal of clinical pathology* 63:695-713.
5. **Rothschild, K. J.**, J. R. Andrew, W. J. De Grip, and H. E. Stanley. 1976. Opsin structure probed by raman spectroscopy of photoreceptor membranes. *Science (New York, N.Y)* 191:1176-1178.
6. Asher, I. M., **K. J. Rothschild**, E. Anastassakis, and H. E. Stanley. 1977. Raman spectroscopy of uncomplexed valinomycin. I. The solid state. *Journal of the American Chemical Society* 99:2024-2032.
7. **Rothschild, K. J.**, I. M. Asher, H. E. Stanley, and E. Anastassakis. 1977. Raman spectroscopy of uncomplexed valinomycin. 2. Nonpolar and polar solution. *Journal of the American Chemical Society* 99:2032-2039.
8. **Rothschild, K. J.**, and N. A. Clark. 1979. Anomalous amide I infrared absorption of purple membrane. *Science (New York, N.Y)* 204:311-312.
9. **Rothschild, K. J.**, and N. A. Clark. 1979. Polarized infrared spectroscopy of oriented purple membrane. *Biophysical journal* 25:473-487.
10. Clark, N. A., **K. J. Rothschild**, D. A. Luippold, and B. A. Simon. 1980. Surface-induced lamellar orientation of multilayer membrane arrays. Theoretical analysis and a new method with application to purple membrane fragments. *Biophysical journal* 31:65-96.
11. Hsiao, T. L., and **K. J. Rothschild**. 1980. Circular dichroism of oriented photoreceptor membrane film. *Biochemical and biophysical research communications* 94:618-624.
12. **Rothschild, K. J.**, N. A. Clark, K. M. Rosen, R. Sanches, and T. L. Hsiao. 1980. Spectroscopic study of photoreceptor membrane incorporated into a multilamellar film. *Biochemical and biophysical research communications* 92:1266-1272.
13. **Rothschild, K. J.**, W. J. DeGrip, and R. Sanches. 1980. Fourier transform infrared study of photoreceptor membrane. I. Group assignments based on rhodopsin delipidation and reconstitution. *Biochimica et biophysica acta* 596:338-351.
14. **Rothschild, K. J.**, S. A. Ellias, A. Essig, and H. E. Stanley. 1980. Nonequilibrium linear behavior of biological systems. Existence of enzyme-mediated multidimensional inflection points. *Biophysical journal* 30:209-230.
15. **Rothschild, K. J.**, K. M. Rosen, and N. A. Clark. 1980. Incorporation of photoreceptor membrane into a multilamellar film. *Biophysical journal* 31:45-52.
16. **Rothschild, K. J.**, R. Sanches, T. L. Hsiao, and N. A. Clark. 1980. A spectroscopic study of rhodopsin alpha-helix orientation. *Biophysical journal* 31:53-64.
17. Argade, P. V., **K. J. Rothschild**, A. H. Kawamoto, J. Herzfeld, and W. C. Herlihy. 1981. Resonance Raman spectroscopy of specifically [ϵ -¹⁵N]lysine-labeled bacteriorhodopsin.

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18. **Rothschild, K. J.**, M. Zagaeski, and W. A. Cantore. 1981. Conformational changes of bacteriorhodopsin detected by Fourier transform infrared difference spectroscopy. *Biochemical and biophysical research communications* 103:483-489.
 19. Gruner, S. M., **K. J. Rothschild**, and N. A. Clark. 1982. X-ray diffraction and electron microscope study of phase separation in rod outer segment photoreceptor membrane multilayers. *Biophysical journal* 39:241-251.
 20. **Rothschild, K. J.**, P. V. Argade, T. N. Earnest, K. S. Huang, E. London, M. J. Liao, H. Bayley, H. G. Khorana, and J. Herzfeld. 1982. The site of attachment of retinal in bacteriorhodopsin. A resonance Raman study. *The Journal of biological chemistry* 257:8592-8595.
 21. **Rothschild, K. J.**, and H. Marrero. 1982. Infrared evidence that the Schiff base of bacteriorhodopsin is protonated: bR570 and K intermediates. *Proceedings of the National Academy of Sciences of the United States of America* 79:4045-4049.
 22. **Rothschild, K. J.**, W. A. Cantore, and H. Marrero. 1983. Fourier transform infrared difference spectra of intermediates in rhodopsin bleaching. *Science (New York, N.Y)* 219:1333-1335.
 23. **Rothschild, K. J.**, H. Marrero, M. Braiman, and R. Mathies. 1984. Primary photochemistry of bacteriorhodopsin: comparison of Fourier transform infrared difference spectra with resonance Raman spectra. *Photochemistry and photobiology* 40:675-679.
 24. **Rothschild, K. J.**, P. Roepe, J. Lugtenburg, and J. A. Pardoen. 1984. Fourier transform infrared evidence for Schiff base alteration in the first step of the bacteriorhodopsin photocycle. *Biochemistry* 23:6103-6109.
 25. de Grip, W. J., J. Gillespie, and **K. J. Rothschild**. 1985. Carboxyl group involvement in the meta I and meta II stages in rhodopsin bleaching. A Fourier transform infrared spectroscopic study. *Biochimica et biophysica acta* 809:97-106.
 26. **Rothschild, K. J.**, P. Roepe, and J. Gillespie. 1985. Fourier transform infrared spectroscopic evidence for the existence of two conformations of the bacteriorhodopsin primary photoproduct at low temperature. *Biochimica et biophysica acta* 808:140-148.
 27. Earnest, T. N., P. Roepe, M. S. Braiman, J. Gillespie, and **K. J. Rothschild**. 1986. Orientation of the bacteriorhodopsin chromophore probed by polarized Fourier transform infrared difference spectroscopy. *Biochemistry* 25:7793-7798.
 28. **Rothschild, K. J.** 1986. Fourier transform infrared studies of an active proton transport pump. *Methods in enzymology* 127:343-353.
 29. **Rothschild, K. J.**, P. Roepe, P. L. Ahl, T. N. Earnest, R. A. Bogomolni, S. K. Das Gupta, C. M. Mulliken, and J. Herzfeld. 1986. Evidence for a tyrosine protonation change during the primary phototransition of bacteriorhodopsin at low temperature. *Proceedings of the National Academy of Sciences of the United States of America* 83:347-351.
 30. Braiman, M. S., P. L. Ahl, and **K. J. Rothschild**. 1987. Millisecond Fourier-transform infrared difference spectra of bacteriorhodopsin's M412 photoproduct. *Proceedings of the National Academy of Sciences of the United States of America* 84:5221-5225.
 31. Marrero, H., and **K. J. Rothschild**. 1987. Conformational changes in bacteriorhodopsin studied by infrared attenuated total reflection. *Biophysical journal* 52:629-635.
 32. Roepe, P., P. L. Ahl, S. K. Das Gupta, J. Herzfeld, and K. J. Rothschild. 1987. Tyrosine and carboxyl protonation changes in the bacteriorhodopsin photocycle. 1. M412 and L550 intermediates. *Biochemistry* 26:6696-6707.
 33. Roepe, P., P. Scherrer, P. L. Ahl, S. K. Das Gupta, R. A. Bogomolni, J. Herzfeld, and **K. J. Rothschild**. 1987. Tyrosine and carboxyl protonation changes in the bacteriorhodopsin photocycle. 2. Tyrosines-26 and -64. *Biochemistry* 26:6708-6717.
 34. **Rothschild, K. J.**, J. Gillespie, and W. J. DeGrip. 1987. Evidence for rhodopsin refolding during the decay of Meta II. *Biophysical journal* 51:345-350.

35. Ahl, P. L., L. J. Stern, D. Doring, T. Mogi, H. G. Khorana, and **K. J. Rothschild**. 1988. Effects of amino acid substitutions in the F helix of bacteriorhodopsin. Low temperature ultraviolet/visible difference spectroscopy. *The Journal of biological chemistry* 263:13594-13601.
36. Braiman, M. S., T. Mogi, T. Marti, L. J. Stern, H. G. Khorana, and **K. J. Rothschild**. 1988. Vibrational spectroscopy of bacteriorhodopsin mutants: light-driven proton transport involves protonation changes of aspartic acid residues 85, 96, and 212. *Biochemistry* 27:8516-8520.
37. Braiman, M. S., T. Mogi, L. J. Stern, N. R. Hackett, B. H. Chao, H. G. Khorana, and **K. J. Rothschild**. 1988. Vibrational spectroscopy of bacteriorhodopsin mutants: I. Tyrosine-185 protonates and deprotonates during the photocycle. *Proteins* 3:219-229.
38. Braiman, M. S., and **K. J. Rothschild**. 1988. Fourier transform infrared techniques for probing membrane protein structure. *Annual review of biophysics and biophysical chemistry* 17:541-570.
39. DeGrip, W. J., D. Gray, J. Gillespie, P. H. Bovee, E. M. Van den Berg, J. Lugtenburg, and **K. J. Rothschild**. 1988. Photoexcitation of rhodopsin: conformation changes in the chromophore, protein and associated lipids as determined by FTIR difference spectroscopy. *Photochemistry and photobiology* 48:497-504.
40. Roepe, P. D., P. L. Ahl, J. Herzfeld, J. Lugtenburg, and **K. J. Rothschild**. 1988. Tyrosine protonation changes in bacteriorhodopsin. A Fourier transform infrared study of BR548 and its primary photoproduct. *The Journal of biological chemistry* 263:5110-5117.
41. **Rothschild, K. J.**, O. Bousche, M. S. Braiman, C. A. Hasselbacher, and J. L. Spudich. 1988. Fourier transform infrared study of the halorhodopsin chloride pump. *Biochemistry* 27:2420-2424.
42. Ahl, P. L., L. J. Stern, T. Mogi, H. G. Khorana, and **K. J. Rothschild**. 1989. Substitution of amino acids in helix F of bacteriorhodopsin: effects on the photochemical cycle. *Biochemistry* 28:10028-10034.
43. **Rothschild, K. J.**, M. S. Braiman, T. Mogi, L. J. Stern, and H. G. Khorana. 1989. Conserved amino acids in F-helix of bacteriorhodopsin form part of a retinal binding pocket. *FEBS letters* 250:448-452.
44. **Rothschild, K. J.**, D. Gray, T. Mogi, T. Marti, M. S. Braiman, L. J. Stern, and H. G. Khorana. 1989. Vibrational spectroscopy of bacteriorhodopsin mutants: chromophore isomerization perturbs tryptophan-86. *Biochemistry* 28:7052-7059.
45. **Rothschild, K. J.**, Y. W. He, D. Gray, P. D. Roepe, S. L. Pelletier, R. S. Brown, and J. Herzfeld. 1989. Fourier transform infrared evidence for proline structural changes during the bacteriorhodopsin photocycle. *Proceedings of the National Academy of Sciences of the United States of America* 86:9832-9835.
46. Stern, L. J., P. L. Ahl, T. Marti, T. Mogi, M. Dunach, S. Berkowitz, **K. J. Rothschild**, and H. G. Khorana. 1989. Substitution of membrane-embedded aspartic acids in bacteriorhodopsin causes specific changes in different steps of the photochemical cycle. *Biochemistry* 28:10035-10042.
47. Dunach, M., S. Berkowitz, T. Marti, Y. W. He, S. Subramaniam, H. G. Khorana, and **K. J. Rothschild**. 1990. Ultraviolet-visible transient spectroscopy of bacteriorhodopsin mutants. Evidence for two forms of tyrosine-185----phenylalanine. *The Journal of biological chemistry* 265:16978-16984.
48. Dunach, M., T. Marti, H. G. Khorana, and **K. J. Rothschild**. 1990. Uv-visible spectroscopy of bacteriorhodopsin mutants: substitution of Arg-82, Asp-85, Tyr-185, and Asp-212 results in abnormal light-dark adaptation. *Proceedings of the National Academy of Sciences of the United States of America* 87:9873-9877.
49. Earnest, T. N., J. Herzfeld, and **K. J. Rothschild**. 1990. Polarized Fourier transform infrared spectroscopy of bacteriorhodopsin. Transmembrane alpha helices are resistant to hydrogen/deuterium exchange. *Biophysical journal* 58:1539-1546.

50. Hamel, R., S. Koos, M. Wolff, R. Land, J. LaPuma, H. Woods, L. Churchill, H. Hathout, J. C. Fletcher, S. Harakas, F. Rouse, W. Albers, D. Thomasma, J. J. Ring, **K. Rothschild**, F. D. Lueking, S. Fitzsimmons, J. Bopp, A. Caplan, H. T. Engelhardt, D. Feldman, T. Murray, and S. Wright. 1990. A time to die: the cases of Nancy Cruzan and Janet Adkins. *Bulletin of the Park Ridge Center* 5:16-31.
51. **Rothschild, K. J.**, M. S. Braiman, Y. W. He, T. Marti, and H. G. Khorana. 1990. Vibrational spectroscopy of bacteriorhodopsin mutants. Evidence for the interaction of aspartic acid 212 with tyrosine 185 and possible role in the proton pump mechanism. *The Journal of biological chemistry* 265:16985-16991.
52. **Rothschild, K. J.**, Y. W. He, T. Mogi, T. Marti, L. J. Stern, and H. G. Khorana. 1990. Vibrational spectroscopy of bacteriorhodopsin mutants: evidence for the interaction of proline-186 with the retinylidene chromophore. *Biochemistry* 29:5954-5960.
53. Bousche, O., M. Braiman, Y. W. He, T. Marti, H. G. Khorana, and **K. J. Rothschild**. 1991. Vibrational spectroscopy of bacteriorhodopsin mutants. Evidence that ASP-96 deprotonates during the M \rightarrow N transition. *The Journal of biological chemistry* 266:11063-11067.
54. Bousche, O., E. N. Spudich, J. L. Spudich, and **K. J. Rothschild**. 1991. Conformational changes in sensory rhodopsin I: similarities and differences with bacteriorhodopsin, halorhodopsin, and rhodopsin. *Biochemistry* 30:5395-5400.
55. Braiman, M. S., O. Bousche, and **K. J. Rothschild**. 1991. Protein dynamics in the bacteriorhodopsin photocycle: submillisecond Fourier transform infrared spectra of the L, M, and N photointermediates. *Proceedings of the National Academy of Sciences of the United States of America* 88:2388-2392.
56. Rath, P., O. Bousche, A. R. Merrill, W. A. Cramer, and **K. J. Rothschild**. 1991. Fourier transform infrared evidence for a predominantly alpha-helical structure of the membrane bound channel forming COOH-terminal peptide of colicin E1. *Biophysical journal* 59:516-522.
57. Subramaniam, S., D. A. Greenhalgh, P. Rath, **K. J. Rothschild**, and H. G. Khorana. 1991. Replacement of leucine-93 by alanine or threonine slows down the decay of the N and O intermediates in the photocycle of bacteriorhodopsin: implications for proton uptake and 13-cis-retinal \rightarrow all-trans-retinal reisomerization. *Proceedings of the National Academy of Sciences of the United States of America* 88:6873-6877.
58. Subramaniam, S., T. Marti, S. J. Rosselet, **K. J. Rothschild**, and H. G. Khorana. 1991. The reaction of hydroxylamine with bacteriorhodopsin studied with mutants that have altered photocycles: selective reactivity of different photointermediates. *Proceedings of the National Academy of Sciences of the United States of America* 88:2583-2587.
59. Baenziger, J. E., K. W. Miller, M. P. McCarthy, and **K. J. Rothschild**. 1992. Probing conformational changes in the nicotinic acetylcholine receptor by Fourier transform infrared difference spectroscopy. *Biophysical journal* 62:64-66.
60. Baenziger, J. E., K. W. Miller, and **K. J. Rothschild**. 1992. Incorporation of the nicotinic acetylcholine receptor into planar multilamellar films: characterization by fluorescence and Fourier transform infrared difference spectroscopy. *Biophysical journal* 61:983-992.
61. Bousche, O., S. Sonar, M. P. Krebs, H. G. Khorana, and **K. J. Rothschild**. 1992. Time-resolved Fourier transform infrared spectroscopy of the bacteriorhodopsin mutant Tyr-185 \rightarrow Phe: Asp-96 reprotonates during O formation; Asp-85 and Asp-212 deprotonate during O decay. *Photochemistry and photobiology* 56:1085-1095.
62. **Rothschild, K. J.** 1992. FTIR difference spectroscopy of bacteriorhodopsin: toward a molecular model. *Journal of bioenergetics and biomembranes* 24:147-167.
63. **Rothschild, K. J.**, Y. W. He, S. Sonar, T. Marti, and H. G. Khorana. 1992. Vibrational spectroscopy of bacteriorhodopsin mutants. Evidence that Thr-46 and Thr-89 form part of a transient network of hydrogen bonds. *The Journal of biological chemistry* 267:1615-1622.

64. Baenziger, J. E., K. W. Miller, and **K. J. Rothschild**. 1993. Fourier transform infrared difference spectroscopy of the nicotinic acetylcholine receptor: evidence for specific protein structural changes upon desensitization. *Biochemistry* 32:5448-5454.
65. He, Y., M. P. Krebs, W. B. Fischer, H. G. Khorana, and **K. J. Rothschild**. 1993. FTIR difference spectroscopy of the bacteriorhodopsin mutant Tyr-185-->Phe: detection of a stable O-like species and characterization of its photocycle at low temperature. *Biochemistry* 32:2282-2290.
66. Rath, P., L. L. DeCaluwe, P. H. Bovee-Geurts, W. J. DeGrip, and **K. J. Rothschild**. 1993. Fourier transform infrared difference spectroscopy of rhodopsin mutants: light activation of rhodopsin causes hydrogen-bonding change in residue aspartic acid-83 during meta II formation. *Biochemistry* 32:10277-10282.
67. Rath, P., M. P. Krebs, Y. He, H. G. Khorana, and **K. J. Rothschild**. 1993. Fourier transform Raman spectroscopy of the bacteriorhodopsin mutant Tyr-185-->Phe: formation of a stable O-like species during light adaptation and detection of its transient N-like photoproduct. *Biochemistry* 32:2272-2281.
68. Rath, P., T. Marti, S. Sonar, H. G. Khorana, and **K. J. Rothschild**. 1993. Hydrogen bonding interactions with the Schiff base of bacteriorhodopsin. Resonance Raman spectroscopy of the mutants D85N and D85A. *The Journal of biological chemistry* 268:17742-17749.
69. **Rothschild, K. J.**, T. Marti, S. Sonar, Y. W. He, P. Rath, W. Fischer, and H. G. Khorana. 1993. Asp96 deprotonation and transmembrane alpha-helical structural changes in bacteriorhodopsin. *The Journal of biological chemistry* 268:27046-27052.
70. Sonar, S., M. P. Krebs, H. G. Khorana, and **K. J. Rothschild**. 1993. Static and time-resolved absorption spectroscopy of the bacteriorhodopsin mutant Tyr-185-->Phe: evidence for an equilibrium between bR570 and an O-like species. *Biochemistry* 32:2263-2271.
71. Sonar, S., N. Patel, W. Fischer, and **K. J. Rothschild**. 1993. Cell-free synthesis, functional refolding, and spectroscopic characterization of bacteriorhodopsin, an integral membrane protein. *Biochemistry* 32:13777-13781.
72. Fischer, W. B., S. Sonar, T. Marti, H. G. Khorana, and **K. J. Rothschild**. 1994. Detection of a water molecule in the active-site of bacteriorhodopsin: hydrogen bonding changes during the primary photoreaction. *Biochemistry* 33:12757-12762.
73. Rath, P., P. H. Bovee-Geurts, W. J. DeGrip, and **K. J. Rothschild**. 1994. Photoactivation of rhodopsin involves alterations in cysteine side chains: detection of an S-H band in the Meta I-->Meta II FTIR difference spectrum. *Biophysical journal* 66:2085-2091.
74. Rath, P., K. D. Olson, J. L. Spudich, and **K. J. Rothschild**. 1994. The Schiff base counterion of bacteriorhodopsin is protonated in sensory rhodopsin I: spectroscopic and functional characterization of the mutated proteins D76N and D76A. *Biochemistry* 33:5600-5606.
75. Sonar, S., C. P. Lee, M. Coleman, N. Patel, X. Liu, T. Marti, H. G. Khorana, U. L. RajBhandary, and **K. J. Rothschild**. 1994. Site-directed isotope labelling and FTIR spectroscopy of bacteriorhodopsin. *Nature structural biology* 1:512-517.
76. Sonar, S., T. Marti, P. Rath, W. Fischer, M. Coleman, A. Nilsson, H. G. Khorana, and **K. J. Rothschild**. 1994. A redirected proton pathway in the bacteriorhodopsin mutant Tyr-57-->Asp. Evidence for proton translocation without Schiff base deprotonation. *The Journal of biological chemistry* 269:28851-28858.
77. Arkin, I. T., M. Rothman, C. F. Ludlam, S. Aimoto, D. M. Engelman, **K. J. Rothschild**, and S. O. Smith. 1995. Structural model of the phospholamban ion channel complex in phospholipid membranes. *Journal of molecular biology* 248:824-834.
78. Coleman, M., A. Nilsson, T. S. Russell, P. Rath, R. Pandey, and **K. J. Rothschild**. 1995. Asp 46 can substitute Asp 96 as the Schiff base proton donor in bacteriorhodopsin. *Biochemistry* 34:15599-15606.

79. DeCaluwe, G. L., P. H. Bovee-Geurts, P. Rath, **K. J. Rothschild**, and W. J. de Grip. 1995. Effect of carboxyl mutations on functional properties of bovine rhodopsin. *Biophysical chemistry* 56:79-87.
80. Liu, X. M., S. Sonar, C. P. Lee, M. Coleman, U. L. RajBhandary, and **K. J. Rothschild**. 1995. Site-directed isotope labeling and FTIR spectroscopy: assignment of tyrosine bands in the bR-->M difference spectrum of bacteriorhodopsin. *Biophysical chemistry* 56:63-70.
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