VITA

**Wayne D. Frasch**

Biomedicine & Biotechnology Faculty Leader

School of Life Sciences, Arizona State University

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**Education:**

B.A. Hope College, Holland, MI 1972

Ph.D. University of Kentucky, Lexington, KY 1979

**Professional Experience:**

ASU, SoLS Faculty Leader of Biomedicine & Biotechnology 2004-2007 & 2011-currently

Arizona State University, Professor, School of Life Sciences currently

Attometrics LLC Founder and CEO currently

Sabbatical Fall Term 2011

Mayo Clinic-Scottsdale, AZ, Sabbatical with John Riordan 1997

University of Michigan, Ann Arbor, Asst. Prof. Cell/Molecular Biology 1982

University of Wisconsin, Madison, Biochemistry Dept., Postdoctoral Scholar 1979

Marine Biological Laboratory, Woods Hole, MA, Research Fellow 1975

**Honors and Awards**:

Gordon Research Conference on Bioenergetics Vice-Chair (Chair 2019) 2017

Arizona Bioscience Researcher of the Year 2015

Arizona Governor’s Innovator of the Year Award 2012

The 2012 ASU Foundation Faculty Achievement Research Award 2012

Editorial Review Board, Journal of Biological Chemistry 2010-2015

NIH Study Section Member, Biophysics and Biochemistry of Membranes 2005-2008

NIH Study Section Member, Physical Biochemistry 2003-2004

NIH Study Section Member, Special Study Section B 2001

Golden Key National Honor Society Award for Teaching 1994

NSF/USDA/DOE Plant Science Centers Organizational Committee Member 1985-1986

Eli Lilley Foundation Fellow 1984

National Science Foundation Travel Award 1983

Horace H. Rackham Foundation Fellow 1981

National Science Foundation Predoctoral Fellow 1975

**Patents:**

1. Chapsky, L., Frasch, W. D., Chou, C., Zenhausern, F., and Goronkin, H. “Single-Molecule Detection of Biological Warfare Agents Using the F1-ATPase Biomolecular Motor”

Patent 6,989,235 issued 1/24/06.

2. Frasch, W. D. and Chapsky, L.“Polarization-Enhanced Detector with Gold Nanorods for Detecting Nanoscale Rotational Motion and method therefor”

Patent 8,003,316 issued 8/23/11.

3. Frasch, W. D. and He, Liyan “Single Molecule Detection using Molecular Motors”

Patent 8,076,079 issued 12/13/11.

4. Frasch, W. D., Spetzler, D., and York, J. “High Speed, High Fidelity, High Sensitivity Nucleic Acid Detection”,

Patent 8,084,206 issued 12/27/11.

5. Frasch, W. D., Spetzler, D., and York, J., Xiong, F. “Methods for Generating a Distribution of Optimal Solutions to Nondeterministic Polynomial Optimization Problems”

Patent 8,126,649 issued 2/28/12.

6. Frasch, W. D. and Chapsky, L.“Polarization-Enhanced Detector with Gold Nanorods for Detecting Nanoscale Rotational Motion and method therefor”

Patent 8,192,936 issued 6/5/12.

7. Frasch, W. D. and Chapsky, L. “Polarization-Enhanced Detector with Gold Nanorods for Detecting Nanoscale Rotation and Method Therefore”

Patent 8,207,323 issued 6/26/12.

8. Frasch, W. D., Spetzler, D., and York, J., Xiong, F. “Methods for Generating a Distribution of Optimal Solutions to Nondeterministic Polynomial Optimization Problems”

Patent 8,126,649 issued 04/16/13.

9. Frasch, W. D., Spetzler, D., and York, J. “High Speed, High Fidelity, High Sensitivity Nucleic Acid Detection”,

Patent 8,530,199 issued 09/10/13.

10. Frasch, W. D. “Detection of Target Metabolites,” US Nationalized PCT application

13/808,567 filed 04/01/13.

11. Xiong, F. and Frasch, W. D. “Telomere Measuring Nanodevice and Method Therefor,”

Published, 01/05/2017, filed 01/05/16.

**Publications:**

1. Frasch, W. D. and Grunwald, C. (1976) "Acylated Steryl Glycoside Synthesis in Seedlings of *Nicotiana tabacum L*.", **Plant Physiol.** *58*, 744-748.

2. Frasch, W. D. and Cheniae, G. M. (1980) "The Mechanism of Inactivation of the O2 Evolving System by Tris", **Plant Physiol.** *65*, 735-745.

3. Frasch, W. D., DeLuca, C., Kulzick, M. and Selman, B. R. (1980) "A Quantitative Estimation of Chloroplast Thylakoid-Bound Coupling Factor 1 by Rocket Immunoelectrophoresis", **FEBS Lett.** *122*, 125-128.

4. Frasch, W. D. and Selman, B. R. (1981) "The Use of Chromium Adenine Nucleotide Complexes to Study the Mechanism of Chloroplast Coupling Factor 1", **Prog. Photosyn. Res.** *2*, 811-819.

5. Frasch, W. D. (1981) "Stereochemistry and Substrate Specificity of Coupling Factor 1", in *Energy Coupling in Photosynthesis*, Selman, B. R. and Selman-Reimer, S. S., eds., Elsevier North Holland, pp. 157-167.

6. Frasch, W. D. and Selman, B. R. (1982) "The Reaction Mechanism of Soluble Coupling Factor 1- Stereochemistry", **Biochemistry** *20*, 3636-3643.

7. Frasch, W. D and Sharp, R. R. (1983) "Analysis of Amino Acids at the Active Site of Chloroplast Coupling Factor One- A Spin-Echo NMR Study" **Prog. in Photosyn. Res**. *3*, 591-594.

8. Sharp, R. R. and Frasch, W. D. (1985) "Selective Detection of Mobile Amino Acid Resonances of the Chloroplast ATP Synthase by 1H Spin-Echo NMR", **Biochemistry** *24*, 5449-5454.

9. Frasch, W. D. and Sharp, R. R. (1985) "Nucleotide Binding to the Chloroplast ATP Synthase: Effect on the Proton Spin-Echo NMR Spectrum", **Biochemistry** *24*, 5454-5458.

10. Haddy, A. B., Frasch, W. D. and Sharp, R. R. (1985) "Cooperative Binding of Manganese to the Soluble Chloroplast ATP Synthase Measured by NMR Proton Relaxation Enhancement", **Biochemistry** *24*, 7926-7930

11. Bowlby, N. R. and Frasch, W. D. (1986) "Isolation of a Manganese Containing Protein Complex from Photosystem II Preparations of Spinach", **Biochemistry** *25*, 1402-1407.

12. Frasch, W. D., Larsen, J., Bowlby, N. R., Apel, I. and Jones, J. D. (1987) "A Technique for the Determination of Protein Concentration by Neutron Activation Analysis of Silver Binding," **J. Radioanalytical and Nuclear Chem.** *112*, 56-62.

13. Apel, I., Mejia, A. and Frasch, W. D. (1987) "Purification of the  Subunit of the Chloroplast H+-Translocating ATPase of Spinach Thylakoids", **Prog. Photosynth. Res.** *3*, 75-78.

14. Apel, I., Sharp, R.R. and Frasch, W. D. (1987) "Proton Spin-Echo NMR Spectra of the Isolated  Subunit of the Chloroplast Proton Translocating ATPase", **Prog. Photosyn. Res.** *3*, 71-74.

15. Haddy, A., Sharp, R. R. and Frasch, W. D. (1987) "Characterization of the Mn(II) Binding Site of Chloroplast Coupling Factor One: Proton Magnetic Relaxation Field Dependence", **Prog. Photosynth. Res.** *3*, 119-122.

16. Bowlby, N. R. and Frasch, W. D. (1987) "A Manganese Containing Protein Complex Isolated from Photosystem II Preparations of Spinach" **Prog. Photosynth. Res.** *1*, 693-696.

17. Baier, L. J. and Frasch, W. D. (1987) "Analysis of Photosystem II Proteins by Two-Dimensional Electrophoresis", **Prog. Photosynth. Res.** *2*, 117-120.

18. Frasch, W. D. and Mei, R. (1987) "Hydrogen Peroxide as an Alternate Substrate for the Oxygen-Evolving Complex", **Biochim. Biophys. Acta** *891*, 8-14.

19. Frasch, W. D. and Mei, R. (1987) "Kinetics of O2 Evolution from H2O2 Catalyzed by the Oxygen-Evolving Complex: Investigation of the S1-Dependent Reaction", **Biochemistry** *26*, 7321-7325.

20. Frasch, W. D., Mei, R. Sanders, and M. A. (1988) "Oxidation of Alcohols Catalyzed by the Oxygen-Evolving Complex", **Biochemistry** *27*, 3715-37.

21. Frasch, W. D., Green, J. P. and Mei, R. (1988) "The Manganese-Binding Proteins of the Oxygen-Evolving Complex" in *Light-Energy Transduction in Photosynthesis: Higher Plants and Bacterial Models*, Stevens, S. E., ed., pp. 373-376.

22. Frasch, W. D., Caguiat, J. and Mejia, A. (1988) "Isolation of the  Subunit from the Spinach CF1Fo ATP Synthase in a Form that Retains ATPase Activity", in *Light-Energy Transduction in Photosynthesis: Higher Plants and Bacterial Models*, Stevens, S. E., ed., pp. 380-383.

23. Frasch, W. D., Green, J. P., Caguiat, J. and Mejia, A. (1989) "ATP Hydrolysis Catalyzed by a  Subunit Preparation Purified from CF1Fo ", **J. Biol. Chem.** *264*, 5064-5069.

24. Haddy, A. E., Frasch, W. D. and Sharp, R.R. (1989) "Properties of the Manganese(II) Binding Site in Ternary Complexes of Mn.ADP and Mn.ATP with Chloroplast Coupling Factor 1: Magnetic Field Dependence of Solvent 1H and 2H NMR Relaxation Rates" **Biochemistry** *28*, 3664-3669.

25. Mei, R., Green, J. P., Sayre, R. E. and Frasch, W. D. (1989) "Manganese-Binding Proteins of the Oxygen-Evolving Complex", **Biochemistry** *28*, 5560-5567.

26. Fine, P. L. and Frasch, W. D. (1990) "The Mechanism of H2O2 Production by the Oxygen-Evolving Complex", **Curr. Res. in Photosyn.** *I.3,* 905-908.

27. Dolan, E., Green, J. and Frasch, W. (1990) "Low Temperature EPR Spectra of PSII Preparations that Contain Fractional Amounts of Manganese", **Curr. Res. in Photosyn**. *I.3*, 781-784.

28. Green, J. and Frasch, W. D. (1990) "The Effect of Na+ on the Activation of Water Oxidation by Ca2+ and Sr2+", **Curr. Res. Photosyn.** *I.3,* 725-728.

29. Frasch, W. D. and Green, J. P. (1990) Crystallization of the Functional  Subunit from CF1Fo", **Curr. Res. in Photosyn.** *III.9*, 9-14.

30. Bradley, R. L., Long, K. M. and Frasch, W. D. (1991) "The Involvement of Photosystem II-Generated H2O2 in Photoinhibition.", **FEBS Lett.** *286*, 209-213.

31. Frasch, W. D. (1991) "Alternate Substrates as Probes of the Mechanism of the Oxygen-Evolving Complex" in, *Manganese Redox Enzymes*, Pecoraro, V. L., ed., VCH publisher, pp. 47-70. **Invited Review**

32. Fine, P. L. and Frasch, W. D. (1992) "The Oxygen-Evolving Complex Requires Cl- to Prevent Hydrogen Peroxide Formation.", **Biochemistry** *31*, 12204-12210.

33. Frasch, W. D., LoBrutto, R. and Roskelley, A. (1992) "Characterization of the Metal Ligands at Nucleotide Binding Sites of CF1." **Res. in Photosynth**. *II.8*, 745-748.

34. Frasch, W. D. (1993) "The F-type ATPase in Cyanobacteria: Pivotal Point in the Evolution of a Universal Enzyme." in *Photosynthesis of the Cyanobacteria*, D. Bryant, ed., Kluwer Acad. Publ., 361-380. **Invited Review**

35. Houseman, A., Morgan, L., LoBrutto, R. and Frasch, W. D. (1994) "Characterization of Ligands of a High Affinity Metal Binding Site in the Latent Chloroplast F1-ATPase by EPR Spectroscopy of Bound VO2+." **Biochemistry** *33*, 4910-4917.

36. Houseman, A., LoBrutto, R. and Frasch, W. D. (1994) "The Coordination of Nucleotides to the Metals at the M2 and M3 Metal-Binding Sites of the Spinach Chloroplast F1-ATPase", **Biochemistry** *33*, 10000-10006.

37. Houseman, A., LoBrutto, R. and Frasch, W. D. (1995) "Effects of Nucleotides on the Ligands of the Metals at the M2 and M3 Metal-Binding Sites of the Spinach Chloroplast F1-ATPase", **Biochemistry** *34*, 3277-3285.

38. Frasch, W. D., Spano, M., and LoBrutto, R. (1995) "VO2+ as a Probe of Metal Binding Sites in Rubisco Activase.", **Photosynthesis: from Light to Biosphere** *V*, 257-260.

39. Houseman, A. L. P., Bell, M. K., LoBrutto, R., and Frasch, W. D. (1995) "The Participation of Metals in the CF1-ATPase Mechanism." **Photosynthesis: from Light to Biosphere** *III,* 127-130.

40. Hu, C.-Y., Houseman, A. L. P., Morgan, L., Webber, A. N., and Frasch, W. D. (1995) "Catalytic Function of a Vital Carboxylate Residue in the  Subunit of the CF1-ATPase from *C. reinhardtii.*" **Photosynthesis: from Light to Biosphere** *III,* 131-134.

41. Hatch, C., Grush, M., Bradley, R., LoBrutto, R., Cramer, S., and Frasch, W. D. (1995) "Terbium Substitution of the Calcium-Binding Sites in the Oxygen-Evolving Complex of Photosytem II." **Photosynthesis: from Light to Biosphere** *II*, 425-429.

42. Hu, C.-Y., Houseman, A. L. P., Morgan, L., Webber, A. N., and Frasch, W. D. (1996) "Catalytic and EPR Studies of the E204Q mutant of the  Subunit of the chloroplast F1-ATPase from *Chlamydomonas reinhardtii.*", **Biochemistry** *35*, 12201-12211.

43. Hamstra, B. J., Houseman, A. L. P., Colpas, G. J., LoBrutto, R., Frasch, W. D., and Pecoraro, V. L. "Structural and Solution Characterization of Mononuclear Vanadium(IV) Complexes that Help to Elucidate the Active Site Structure of the Reduced Vanadium Haloperoxidases." (1997) **Inorganic Chem.** *36*, 4866-4874.

44. LoBrutto, R., Hamstra, B. J., Colpas, G. J., Pecoraro, V. L., and Frasch, W. D. (1998) "Electron Spin Echo Envelope Modulation Spectroscopy Reveals and Distinguishes Equatorial and Axial Nitrogen Ligands Bound to VO2+." **J. Am. Chem. Soc.** *120*, 4410-4416.

45. Chen, W., LoBrutto, R., and Frasch, W. D. (1999) “EPR Spectroscopy of VO2+-ATP Bound to Catalytic Site 3 of Chloroplast F1-ATPase from *Chlamydomonas* Reveals Changes in Metal Ligation Resulting from Mutations to the Phosphate-binding Loop Threonine (T168).”**J. Biol. Chem.** *274*, 7089-7094.

46. Hu, C.-Y., Chen, W., and Frasch, W. D. (1999) “Metal Ligation by Walker Homology B Aspartate D262 at Site 3 of the Latent but not Activated Form of the Chloroplast F1-ATPase from *Chlamydomonas reinhardtii*” **J. Biol. Chem.** *274*, 30481-30486.

47. Frasch, W. D. (2000) “The Participation of Metals in the Mechanism of the F1-ATPase” **Biochim. Biophys. Acta***,* *1458*, 310-325.

48. Chen, W., Hu, C.-H., Crampton, D. J., and Frasch, W. D. (2000) “Characterization of the Metal Binding Environment of Catalytic Site 1 of Chloroplast F1-ATPase from Chlamydomonas“, **Biochemistry** *39*, 9393-9400

49. Frasch, W. D. (2000) “Vanadyl as a Probe of the Function of the F1-ATPase-Mg2+ Cofactor” **J. Bioenergetics and Biomembranes** *32*, 539-546.

50. Crampton, D. J., LoBrutto, R., and Frasch, W. D. (2001) “Identification of the P-loop Lysine as a Metal Ligand in the Absence of Nucleotide at Catalytic Site 3 of Chloroplast F1-ATPase from *Chlamydomonas reinhardtii*”, **Biochemistry** *40*, 3710-3716.

51. Chen, W. and Frasch, W. D. (2001) “Interaction of the Catch-Loop Tyrosine Y317 with the Metal at Catalytic Site 3 of *Chlamydomonas* Chloroplast F1-ATPase”, **Biochemistry** *40*, 7729-7735.

52. Frasch, W.D. and Sayre, R.E. (2002) “Remembering George Cheniae Who Never Compromised His High Standards of Science.” **Photosynthesis Research** *70*, 245-247.

53. Greene, M. D. and Frasch, W. D. (2003) “Interactions between R268, Q269 and the  Subunit Catch-Loop of *E. Coli* F1-ATPase are Critical for Catalytic Activity, **J. Biol. Chem.** *278*, 51594-51598.

54. Frasch, W. D. (2004) “ATP and NADP” in, *Encyclopedia of Plant and Crop Science*, Marcel Dekker, Inc., New York, NY, 68-70. **Invited Review**

55. Lowry, D. and Frasch, W. D. (2005) “Interactions between D372 and -Subunit N-terminus residues K9 and S12 are Important for ATP Synthase Activity Catalyzed by the *E. coli* FoF1 ATP Synthase” **Biochemistry** *44*, 7275-7281.

56. Boltz, K. W. and Frasch, W. D. (2005) “Interactions of T273 and E275 with the  Subunit PSAV Segment that Links the -Subunit to the Catalytic Site Walker Homology B Aspartate are Important to the Function of *Escherichia coli* F1Fo ATP Synthase”, **Biochemistry** *44*, 9497-9506.

57. Spetzler, D., York, J., Lowry, D., Daniel, D., Fromme, R. and Frasch, W. D. (2006) “Microsecond Time Resolution of Single Molecule F1-ATPase Rotation”, **Biochemistry** *45,* 3117-3124. **DOI:** 10.1021/bi052363n. **Accelerated publication designated a Hot Article by the ACS based on top-10 down loads from the journal.**

58. Boltz, K. and Frasch, W.D. (2006) “Hydrogen Bonds between the  and  Subunits of the F1-ATPase Allow Communication between the Catalytic site and the Interface of the  Catch Loop and the  Subunit.” **Biochemistry** *45*, 11190-11199.

59. Spetzler, D., Xiong, F., and Frasch, W.D. (2007) “Probabilistic DNA Computing Solution to a Fully Connected 10-City Asymmetric Traveling Salesman Problem” **Proc. DNA 13**, 9-18.

60. Xiong, F., Spetzler, and Frasch, W. D. (2007) “Elimination of Secondary Structures for DNA Computing”, **Proc. DNA 13**, 241-249.

61. Spetzler, D., York, J., Dobbin, C., Martin, J., Xiong, F., Ishmukhametov, R., Day, L., Yu, J., Kang, H., Porter, K., Hornung, T., and Frasch, W.D. (2007) “Recent Developments of Biomolecular Motors as On-Chip Devices using Single Molecule Techniques”, **Lab. Chip** *7*, 1633-1643. **Among top 10 most accessed LOC articles in 2007.**

62. York, J., Spetzler, D., Hornung, T., Ishmukhametov, R., Martin, J., and Frasch, W.D. (2007) “Abundance of Escherichia coli F1-ATPase Molecules Observed to Rotate via Single-Molecule Microscopy with Gold Nanorod Probes”, **J. Bioenergetics and Biomembranes**, *39*, 435-439.

63. Spetzler, D., Xiong, F., and Frasch, W. D. (2008) “Heuristic solution to a 10-City Traveling Salesman Problem Using Probabilistic DNA Computing”, **LNCS** *4848*, 152-160.

64. York, J., Spetzler, D., Xiong, F., and Frasch, W. D. (2008) “Single Molecule Detection of DNA via Sequence-Specific Links between F1-ATPase Motors and Gold Nanorod Sensors”, **Lab. Chip** *8***,** 415-419. **Among top-10 LOC articles accessed on-line. Highlighted in *Chemical Biology*, a Royal Society of Chemistry news magazine that provides a snapshot of the latest, most exciting, chemical biology developments.**

65. Hornung, T., Ishmukhametov, R., Spetzler, D., Martin, J., and Frasch, W. D. (2008) “Determination of Torque Generation from the Power Stroke of *Escherichia coli* F1-ATPase.” **Biochim. Biophys. Acta- Bioenergetics** *1777*, 579-582.

66. Spetzler, D., York, J., Martin, J., Ishmukhametov, R., and Frasch, W.D. (2008) “Microsecond resolution of enzymatic conformational changes using dark-field microscopy” **Methods** DOI:10.1016/j. ymeth.2008.05.004.

67. Xiong, F., Spetzler, D., and Frasch, W. D. (2009) “Solving the Fully-Connected 15-City TSP using Probabilistic DNA Computing”, **Integr. Biol**., **1**, 275-280 DOI:10.1039/B821735C

68. Spetzler, D., Ishmukhametov, R., Day, L. J., Hornung, T., Martin, J., and Frasch, W. D. (2009) “Single Molecule Measurements of F1-ATPase Reveal an Interdependence between the Power Stroke and the Dwell Duration”, **Biochemistry** *49,* 7979-7985*.* **DOI:**10.1021/bi9008215

69. Ishmukhametov, R., Hornung, T., Spetzler, D., and Frasch, W. D. (2010), “Direct Observation of stepped proteolipid ring rotation in *E. coli* FoF1-ATP synthase”, **EMBO J** *29*, 3911-3923.

70. Xiong, F. and Frasch, W. D. (2010) “Padlock Probe-Mediated qRT-PCR for DNA Computing Answer Determination”, **Natural Computing** *10*, 947-959 (DOI 10.1007/s11047-010-9227-8).

71. Hornung, T., Martin, J., Ishmukhametov, R., Spetzler, D., and Frasch, W. D. (2011) “Microsecond Resolution of Single Molecule Rotation Catalyzed by Molecular Motors”, **Methods in Molecular Biology** *778*, 273-289 (DOI 10.1007/978-1-61779-261-8\_18)

72. Spetzler, D., Ishmukhametov, R., Hornung, T., Martin, J., York, J., Jin-Day, L., and Frasch, W. D. (2012) “Energy Transduction by the Two Molecular Motors of the F1Fo ATP Synthase”, in *Photosynthesis: Plastid Biology, Energy Conversion and Carbon Assimilation*, Eaton-Rye, J. J. and Tripathy, B. C., and Sharkey. T. D. eds., Springer, **Advances in Photosynthesis and Respiration** *34***,** Dordrecht, The Netherlands, Chapter 22, pp. 561-590. (DOI 10.1007/978-94-007-1579-0­\_22)

73. Martin, J., Ishmukhametov, R., Hornung, T., Ahmad, Z., and Frasch, W. D. (2014) “Anatomy of F1-ATPase Powered Rotation” **Proc. Natl. Acad. Sci. USA** *111*, 3715-3720.

74. Martin, J., Hudson, J., Hornung, T., and Frasch, W.D. (2015) “Fo-driven Power Stroke Rotation Occurs against the Force of F1ATPase-dependent rotation in the FoF1 ATP synthase”, **J. Biol. Chem.,** *290,* 10717-10728.

75. Sielaff, H., Martin, J., Grüber, G., and Frasch, W.D., (2016) “Power Stroke Angular Velocity Profiles of Archaeal A-ATP Synthase *Versus* Thermophilic and Mesophilic F-ATP Synthase Molecular Motors” **J. Biol. Chem.** *291*, 25351-25363.

76. Ragunathan, R., Sielaff, H., Sundararaman, L., Biukovic, G., Sony, M., Manimekalai, S., Singh, D., Kundu, S., Wohland, T., Frasch, W.D., Dick, T., and Grüber, G. (2017) “The Uniqueness of Subunit  of Mycobacterial F-ATP synthases: An evolutionary Variant for Niche Adaptation”, **J. Biol. Chem.** *292*, 11262-11279.

77. Yanagisawa, S. and Frasch, W.D. (2017) “Protonation Dependent Stepped Rotation of the F-type ATP synthase c-Ring Observed by Single-Molecule Measurements”, **J. Biol. Chem.**, 292, 17093-17100.

78. Martin, J., Hornung, T., Ishmukhametov, R., Spetzler, D., and Frasch, W. D. (2018) “Elastic Coupling Power Stroke Mechanism of the F1-ATPase”, **Proc. Natl. Acad. Sci.** USA, *115*, 5750-5755.

**Invited Seminars and Conference Symposia:**

1984 Biology Department, Hope College, Holland, MI: "Analysis of Amino Acids at the Active Site of Chloroplast Coupling Factor One- A Spin-Echo NMR Study"

1986 Midwest Photosynthesis Conference, French Lick Springs, IN: "Recent Advances in the Structure and Mechanism of the F1Fo ATP Synthase."

1987 Midwest Photosynthesis Conference, Turkey Run, IN: "The Oxygen-Evolving Complex of Photosystem II."

1988 Department of Chemistry, University of Maryland, College Park, MD: "Alternate Substrates as Probes of the Mechanism and Structure of the Oxygen-Evolving Complex."

1989 Department of Biology, Wayne State University, Detroit, MI: "Alternate Substrates as Probes of the Mechanism and Structure of the Oxygen-Evolving Complex."

1989 VIIIth International Conference on Photosynthesis, Stockholm, Sweden: "Crystallization of the Beta Subunit of CF1."

1991 Plant Sciences Seminar Series, University of Arizona, Tucson, AZ: "Alternate Substrates as Probes of the Mechanism of the Oxygen-Evolving Complex."

1993 Department of Biochemistry, University of Kansas, Lawrence, KA: "Characterization of Metal Binding Sites of the Chloroplast F1-ATPase."

1995 Mayo Clinic-Scottsdale, AZ: "The Participation of Metals in the Mechanism of the F1-ATPase."

1996 Medical Research Council, Cambridge University, England: "The Participation of Metals in the Mechanism of the F1-ATPase."

1997 Department of Chemistry and Biochemistry, Utah State University, Logan, UT: "The Participation of Metals in the Mechanism of the F1-ATPase."

1997 Department of Chemistry, University of Utah, Salt Lake City, UT: "The Participation of Metals in the Mechanism of the F1-ATPase."

1998 Max-Volmer Institute for Biophysics and Physical Chemistry, Berlin, Germany: “The Role of Metals in the F1-ATPase Mechanism”

1999 Western Photosynthesis Conference, Pacific Grove, CA "The Participation of Metals in the Mechanism of the F1-ATPase."

1999 Gordon Research Conference on Enzymes, Coenzymes and Metabolic Pathways, Meriden, NH: “The Role of the Metal Cofactor in the Mechanism of the Chloroplast F1-ATPase”

2001 Department of Biochemistry, University of Illinois, Champaign-Urbana IL “Mechanistic Studies of the F1-ATPase Molecular Motor”

2001 Department of Biochemistry, University of Nebraska, Lincoln, NE “Mechanistic Studies of the F1-ATPase Molecular Motor”

2002 Gordon Research Conference- Biochemical Aspects of Photosynthesis, Roger Williams U., Bristol, RI “Stabilization of Intermediate States of the F1-ATPase Rotary Motor”

2003 Biomolecular Motors Conference, San Francisco, CA “Single Molecule Detection of Biological Warfare Agents Using the F1-ATPase Biomolecular Motor.”

2003 29th Steenbock Symposium on Coenzymes, Cofactors, and Catalysis, Madison, WI, Session Chair, “Identification of H-bonds between  and , subunits that affect EF1-ATPase.”

2004 Gordon Research Conference on Cellular/molecular aspects of Bioenergetics, Proctor Academy, Andover, NH “Rotational Mechanism of the F1-ATPase Molecular Motor.”

2004 Biomolecular Motors Conference, Jackson Hole, WY “Single Molecule DNA Detection Using the F1 BioMolecular Motor Semaphore Device.”

2005 Biomolecular Motors Conference, Monterey, CA “Use of the Molecular Semaphore Device to Detect Single Molecules of DNA.”

2005 FASEB Summer Research Conference on Transport ATPases: Genomics, Mechanisms, and Relevance to Diseases, Saxtons river, VT “Single Molecule Measurements of the Rate of *E. coli* F1ATPase  Subunit Rotation Resolved on the Microsecond Time Scale.”

2005 Experts Workshop on the Physics of Biological Force Generation sponsored by the University of California Institute for Complex Adaptive Matter, Snowmass, CO “Observing Single-Molecule ATP Synthase Trajectories in Real Time”

2006 Biomimetic, Biomaterial and Biointerfacial Conference, Duck Key, FL “Use of the Molecular Semaphore Device in DNA Computing”

2006 Biomagnet/Biomolecular Motors Meeting, Arlington, VA “DNA Computing using the Molecular Semaphore Device”

2006 Gordon Research Conference on Molecular and Cellular Bioenergetics, Andover, NH “Origins of Torque Generation in the F1-ATPase”

2006 Spirit of the Senses Science Salons, Phoenix, AZ “DNA Computing”

2006 9th International Detection Technologies Conference, San Diego, CA,

“Biomolecular Motor-Based Nanodevices for Single Molecule DNA Detection”

2007 Biomimetic, Biomaterial and Biointerfacial Conference, Duck Key, FL “Construction of a DNA Computer to Solve a 10 City Traveling Salesman Problem”

2007 U.S. Army Research Office, Life Sciences Division, Research Triangle Park, NC “DNA Computing”

2007 Edgewood Chemical Biological Center, U. S. Army RDECOM, Edgewood, MD, “Single-Molecule Detection of DNA via Sequence-Specific Links between F1-ATPase Motors and Gold Nanorod Sensors”

2007 University of Pittsburgh, Department of Structural Biology, “The F1Fo ATP synthase- two molecular motors with two intertwined mechanisms.”

2007 13th International Meeting on DNA Computing (DNA13), Memphis, TN, “Probabilistic DNA Computing Solution to a Fully Connected 10-City Traveling Salesman Problem.”

2007 FASEB Summer Research Conference on Transport ATPases: Genomics, Mechanisms, and Relevance to Diseases, Saxtons River, VT “Mechanism of Torque Generation by *E. coli* F1ATPase Biomolecular Motor.”

2007 Gordon Research Conference on Molecular and Cellular Bioenergetics, Andover, NH, “Mechanism of Torque Generation by *E. coli* F1ATPase Biomolecular Motor.”

2007 University of Illinois Urbana Champaign, Department of Biophyics, “Biomolecular motor-powered nanodevices for DNA detection, and their application for DNA Computing.”

2007 University of Illinois Urbana Champaign, Department of Biochemistry, “Single Molecule Studies to Investigate the Rotary Mechanism of the F1Fo molecular motor.”

2007 University of North Carolina-Chapel Hill, NC, Department of Biochemistry and Biophysics, “Single Molecule Studies to Investigate the Rotary Mechanism of the F1Fo molecular motor.”

2008 Biomimetic, Biomaterial and Biointerfacial Conference, Key West, FL “DNA Computing to Solve Optimization Problems”

2008 University of Arizona, Tucson, AZ, Department of Biochemistry and Molecular Biophysics, “Single Molecule Studies to Investigate the Rotary Mechanism of the F1Fo molecular motor.”

2008 University of Nebraska-Lincoln, Department of Biochemistry, “Single Molecule Studies to Investigate the Rotary Mechanism of the F1Fo molecular motor.”

2008 University of California-Santa Cruz, Department of Chemistry and Biochemistry, “Single Molecule Studies to Investigate the Rotary Mechanism of the F1Fo molecular motor.”

2008 International Conference on Nanoscience and Technology, Keystone, CO, declined due to conflict with EBEC 2008.

2008 European Bioenergetics Conference (EBEC 2008), Dublin, Ireland, “Mechanistic Insights of F1-ATPase Rotation from Single-Molecule Measurements of the Powerstroke.”

2008 11th International Detection Technologies Conference, Phoenix, AZ, “Development of the Double-Lock Probe to Quantify Amounts of Short Target DNA Sequences by RT-PCR.”

2009 Natural Materials, Systems, and Extremophiles Conference, Washington, D.C. “Construction of a DNA Computer with Scalable Architecture.”

2009 AZTe Tech Forum Symposium, Phoenician Hotel, Scottsdale, AZ, “Attometrics Incorporated Single Molecule Diagnostic Nanodevice Technology”

2009 Nanotech India 2009, Cochin, India, “Rapid, Sensitive Pathogen Detection using a Self-Assembling Nanodevice.”

2009 Indian Institute for Technology, Delhi, Department of Biochemical Engineering & Biotechnology, “Single-Molecule Measurements of Biomolecular Motor Rotation for Mechanistic Studies and Nanotechnology Applications.”

2011 Gordon Research Conference on Molecular and Cellular Bioenergetics, Andover, NH, “Exercising Restraint- Load Dependent Stepping of the Fo Motor.”

2011 University of Illinois, Urbana-Champaign, Department of Biochemistry, “It Takes Two- Mechanisms of the Opposed Fo and F1 Molecular Motors of the ATP synthase.”

2012 Gordon Research Conference on Protons and Membrane Reactions, Ventura, CA, “Functional Consequences of Releasing the Fo-Leash on the FoF1ATP synthase”

2012 WiseGuise Salon, Scottsdale, AZ, “Nanodevices that Solve Difficult Problems.”

2012 European Bioenergetics Conference (EBEC 2012), Freiburg, Germany, Plenary Lecture, “Anatomy of F1-ATPase Dependent Rotation.”

2013 Weizmann Institute of Science, Rehovot, Israel, Department of Biological Chemistry, “A tale of two motors- the mechanism of the FoF1 ATP synthase.”

2013 Gordon Research Conference on Molecular and Cellular Bioenergetics, Andover, NH “Anatomy of F1-ATPase Dependent Rotation.”

2014 European Bioenergetics Conference (EBEC 2014), Lisbon, Portugal, “Fo-Dependent Clockwise Rotation against the force of F1-ATPase Counterclockwise Rotation.”

2014 Department of Biochemistry, Southern Methodist University, Dallas, TX, “A Tale of Two Motors- Mechanisms of the FoF1 ATP synthase.”

2015 Single Molecule Biophysics Conference, Aspen, CO, “Fo-Dependent Clockwise Rotation against the force of F1-ATPase Counterclockwise Rotation.”

2015 Technical Community Organization, Dow Chemical Co. Northeast Technology Center, Collegeville, PA, “Single-Molecule Measurements of the F1 Molecular Motor and its Use in Molecular Motor-Powered Nanodevices (MONA) Technology”

2015 Gordon Research Conference on Molecular and Cellular Bioenergetics, Andover, NH “Structure-Mechanism Relationships of ATP synthase Molecular Motors.”

2015 Department of Biochemistry, University of New Mexico School of Medicine, “Single-Molecule Measurements of the F1 Molecular Motor and its Use in Molecular Motor-Powered Nanodevices (MONA) Technology”

2016 European Bioenergetics Conference (EBEC 2016), Riva la Garda, Italy, “Mechanisms of Rotary ATPases Revealed by Single-Molecule Studies.”

2017 Gordon Research Conference on Molecular and Cellular Bioenergetics, Andover, NH “Elastic Coupling Mechanism of the F1-ATPase Molecular Motor.”

2017 Mayo Clinic, Rochester MN, “Rotary Molecular Motor Mechanisms and Their Use in Biomedical Nanotechnology Devices."

2017 Translational Genomics Institute, AZ “Telomere Length Computation by -qPCR”

2018 European Bioenergetics Conference (EBEC 2018), Budapest, Hungary, “The rotary mechanism of the F1-ATPase as revealed by single-molecule measurements.”