Michael F. Brown, Ph.D.

Department of Physics and Department of Chemistry & Biochemistry ♦ University of Arizona ♦ Tucson, Arizona 85721, U.S.A. ♦ +520-621-2163 ♦ mfbrown@u.arizona.edu

A. Background: Michael Brown is Professor of Chemistry and Professor of Physics at the University of Arizona and holds a joint appointment in the Program in Applied Mathematics. He is one of the pioneers of solid-state NMR spectroscopy and nuclear spin relaxation methods as applied to proteins, lipid membranes, surfactants, and liquid crystals. His unique focus is on magnetic-field-dependent solid-state NMR relaxation methods and their applications to molecular dynamics of membrane lipids and proteins. Brown's research also combines solid-state NMR relaxation with ultrafast X-ray diffraction methods based on free-electron lasers (XFELs) for investigating the functional dynamics of biomolecules. His innovation of using solid-state deuterium NMR spectroscopy for exploring the structure and dynamics of liquid-crystalline molecules, including membrane lipids and membrane proteins, has had a substantial impact on biophysical chemistry and molecular spectroscopy. He is also exploring how membrane lipids and water control the functions of proteins through dynamic allostery and energy landscape mechanisms.

Professor Brown has been a Visiting Professor at the University of Lund, Sweden, the University of Würzburg, Germany, the University of Florence, Italy, and the Institute for Protein Research at Osaka University, Japan. Professor Brown has received numerous awards and honors, including a Sloan Fellowship, an NIH Career Development Award, a Fulbright Award, the Röntgen Professorship in Physics of the University of Würzburg, and the Avanti Award of the Biophysical Society. He is an elected fellow of the American Association for the Advancement of Science, the Biophysical Society, and the American Physical Society.

B. Appointments/Positions:

Education and Training

1970	A.B., University of California at Santa Cruz
1975	Ph.D., University of California at Santa Cruz
1976-1978	University of Basel, Switzerland, Postdoctoral: Biophysical Chemistry
1976-1978	Max-Planck-Institute, Heidelberg, Germany, Postdoctoral: Molecular Physics
1979	University of California at Berkeley, Postdoctoral: Chemistry

Positions and Employment

1976-1978	NIH Postdoctoral Fellow (with Prof. J. Seelig), Biozentrum, University of Basel, Switzerland
1976–78	Research Scientist (with U. Häberlen), Max-Planck-Inst. for Mol. Physics, Heidelberg, Germany
1979	NIH Postdoctoral Fellow (with Prof. W.L. Hubbell), Dept. of Chemistry, Univ. of Calif. at Berkeley
1980-1985	Assistant Professor of Chemistry, University of Virginia
1985-1987	Associate Professor of Chemistry, University of Virginia
1987-present	Professor of Chemistry, University of Arizona
1987-present	Visiting Professor of Physical Chemistry, University of Lund, Sweden
2000-2001	Visiting Professor of Physics, University of Würzburg, Germany
2001	Visiting Professor of Physical Chemistry, University of Florence, Italy
2003-2005	Visiting Professor of Molecular Biophysics, Institute for Protein Research, Osaka University, Japan
2003-present	Professor of Physics, University of Arizona
2003-present	Professor of Applied Mathematics, University of Arizona

C. Honors: University of California Scholarship, 1968-69; California State Scholarship, 1968-70; President's Scholarship, University of California, 1969; California State Graduate Fellowship, 1970; University of California Predoctoral Graduate Fellowship, 1970-72; NIH Postdoctoral Fellowship, Univ. of Basel, Switzerland, 1976-78; NIH Postdoctoral Fellowship, U.C. Berkeley, 1979-80; Alfred P. Sloan Foundation Research Fellowship, 1983-85; NIH Research Career Development Award, 1985-90; Richard and Patricia Wood Lecturer, Univ. of South Florida, 1991; Röntgen-Professorship of Physics, Germany, 1999; The Wilhelm Conrad Röntgen Lecture, Univ. of Würzburg, Germany, 1999; Senior Fulbright Scholar, Italy, 2000-01; Fellow of Japan Society for the Promotion of Science, 2003-2004; J. Clarence Karcher Lecturer, Univ. of Oklahoma, 2008; Elected Fellow of American Physical Society, 2011; Elected Fellow of American Association for the Advancement of Science, 2012; Elected Biophysical Society Fellow, 2013; Research Corporation Galileo Circle Fellow, 2013; Biophysical Society Avanti Award, 2014; Nature Conference Speaker, 2019.

D. Other Experience and Professional Memberships: Member of Biophysical Society, 1975-present; NIH Biophysical Chemistry (BBCB) Study Section, 2003-2004; NIH Site Visit Panel for Harvard-MIT Center for Magnetic Resonance, 2004; NIH Beamlines and Magnets Special Emphasis Study Section, 2005; NIH Biology and Diseases of the Posterior Eye Study Section, 2005;' NIH Biology and Diseases of the Posterior Eye Study Section, 2006; Permanent Member NIH Biochemistry and Biophysics of Membranes Study Section, 2006-2010; NIH Site Visit Panel for UCSD BTR Center for NMR and Imaging of Membrane Proteins, 2018; NSF Protein Structure and Dynamics Review Panel, 2020-present.

E. Invited Conference Lectures, Named and Keynote Lectures (recent): *Over 280 conference lectures and seminars: 13th Int. Conf. on Retinal Proteins*, Barcelona, Spain (June, 2008); *23rd Int. Conf. on Magnetic Resonance in Biological Systems*, San Diego, Calif. (Aug., 2008); *Int. Symp. on Molecular Soft Interactions In Biological Systems*, Osaka, Japan (January, 2009); *Int. Symp. on Magnetic Resonance*, Hyderabad, India (Feb., 2009); *50th Exptl. NMR Conf.*, Asilomar, Calif. (Mar., 2009); *Keystone Symp. on G Protein-Coupled Receptors*, Breckenridge, Colorado (April, 2010); *14th Int. Conf. on Retinal Proteins*, Santa Cruz, Calif. (Aug., 2010); *241st ACS National Meeting*, Anaheim, Calif. (Mar. 2011); *52nd Exptl. NMR Conf.*, Asilomar, Calif. (April 2011); *Meeting on Biological Membranes and Membrane Proteins*, Snowmass, Colorado (July, 2011); *56th Annual Biophysical Society Meeting*, San Diego, Calif. (Feb., 2012); *Avanti Award Lecture 58th Annual Biophysical Society Meeting*, San Francisco, Calif. (Feb., 2014); *Pacifichem 2015*, Honolulu, Hawaii (Dec., 2015); *IUPAB Joint Advanced School on Receptors and Signaling*, Spetses, Greece (May, 2016); *5th BioXFEL International Conf.*, New Orleans, Louisiana (Feb., 2018); *257th ACS National Meeting*, Orlando, Florida (Mar. 2019); *Santa Fe Conference on Biological Membranes and Membrane Proteins*, Santa Fe, New Mexico (July, 2019); *Nature Conference on Functional Dynamics-Molecules in Action*, Tempe, Arizona (Nov., 2019); *258th ACS National Meeting*, Philadelphia, Pennsylvania (Mar., 2020; postponed by Covid19); *Biophysical Society Thematic Meeting: Biophysics at the Dawn of Exascale Computers*, Hamburg, Germany (May, 2020; postponed by Covid19).

F. National and International Service—Selected: *Member of Editorial Board of Biophysical Journal.* *Program Director:* UA Chemical Physics Program and UA Biological Physics Program. *Proposal Reviewer:* NSF Division of Chemistry; NSF Molecular & Cellular Bioscience; NSF Division of Physics; Australian Research Council; Deutsche Forschungsgemeinschaft (German Nation Science Foundation); The Welcome Trust (UK); Human Frontier Science Program; United States-Israel Binational Science Foundation; NIH Biophysical Chemistry (BBCB) Study Section, 2003–2004; Permanent Member NIH Biochemistry and Biophysics of Membranes (BBM) Study Section, 2006–2010. *Outreach:* Optics Research Experience for Teachers In Native American Schools (O-RETINAS) program (http://cian-erc.uawebhost.arizona.edu/ret-native-american-students); Keep Engaging Youth in Science (KEYS) program (https://keys.arizona.edu/).

G. Journal Referee—Selected: *Accounts of Chemical Research; Biochemistry; Biochimica et Biophysica Acta; Biophysical Journal; Chemical Physics Letters; Journal of the American Chemical Society; Journal of Biological Chemistry; Journal of Biomolecular NMR Spectroscopy; Journal of Chemical Physics; Journal of Magnetic Resonance; Journal of Physical Chemistry; Langmuir; Nature Structural & Molecular Biology; Physical Review E; Physical Review Letters; Proceedings of the National Academy of Sciences U.S.A.; Soft Matter; Nature Scientific Reports; Nature Chemical Biology.*

H. Patents–Technology Transfer

1. Brown, M. F. (1990), High-Resolution Spectral Signature of Human Arterial Plaque, United States Patent 4,940,055.
2. Brown, M. F., Chawla, U., and Perera, S. M. D. C. (2015), Quasi-elastic Neutron Scattering Reveals Ligand-Induced Mobility of a G-Protein Coupled Receptor, United States Provisional Patent 62/235,335 (pending).
3. Brown, M. F., Chawla, U., and Perera, S. M. D. C. (2015), Method for Generating and Storage of Amphiphilic Protein in Powdered Form, United States Provisional Patent 62/263,295 (pending).
4. Brown, M. F., Chawla, U., and Perera, S. M. D. C. (2015), Powdered G-Protein Coupled Receptors (GPCR), United States Patent application (Ref. No.: UA16-058, UNIA 15.35 PCT-US 15/763,052).
5. Brown, M. F., Chawla, U., and Perera, S. M. D. C. (2020) Detergent-Protein Composition Comprising Lyophilized Detergent-Solubilized Protein, United States Patent 10,526,395.

I. Trainees (Present and Past): Since joining the university as a faculty member, I have supervised 33 graduate students and 27 postdoctoral research scientists, as well as numerous undergraduate research students (> 24) and high school students (> 8). They have gone on to post- or predoctoral fellowships and appointments at Cornell University, University of California at San Diego, Stanford University, University of Illinois, Weizmann Institute of Science, and other institutions. Postdoctoral fellows have included 8 NIH Postdocs; 1 Muscular Dystrophy (MDA) Postdoc; 1 American Heart Association (AHA) Postdoc and 2 Deutsche Forschungsgemeinschaft (DFG) Postdocs. In addition, I have hosted or mentored 3 Undergraduate Exchange Students (from Spain, China, and Norway). Currently, I am supervising 4 Ph.D. students, and am a member of various Ph.D. Supervisory Panels. I have also supervised a number of research students from other research groups working in my laboratory, leading to a number of co-authored papers.

J. Faculty Sabbatical and Research Visitors: Our group has hosted or sponsored 7 research and/or sabbatical research stays from faculty at other institutions (including Institute for Protein Research, Osaka University, Japan; University of Munich, Germany; Free University of Berlin, Berlin, Germany; University of Leipzig, Germany; Indiana University-Purdue University at Indianapolis; Umeå University, Umeå, Sweden; and St. Petersburg State University, Russia).

K. Collaborations with Academic and Industrial Institutions: The Brown group has a strong record of active collaboration with a number of other research groups at the national and international level (including IBM T. J. Watson Research Center; Institute for Protein Research, Osaka University, Japan; University of Leipzig, Germany; University of Florence, Italy; Indiana University-Purdue University Indianapolis; Wabash College; University of Freiburg, Germany; Eidgenössische Technische Hochschule, Paul Scherrer Institute, Switzerland; University of Göteborg, Sweden; Indian Institute of Science, Bangalore, India; University of California at Santa Barbara; and Technical University of Munich, Germany). Currently we are collaborating with research teams at Arizona State University; University of Rochester; State University of New York at Buffalo; St. Petersburg State University, Russia; Virginia Polytechnic Institute and State University; University of California at Santa Cruz; and Humboldt University, Berlin, Germany.

L. Teaching Activities: I am actively engaged in teaching Physical Chemistry at both the undergraduate and graduate levels. Typically, I teach 2 or 3 full-credit courses per year (140–180 contact hours). Besides teaching the undergraduate Physical Chemistry sequence (thermodynamics, kinetics, quantum mechanics, and statistical mechanics), I teach Quantum Mechanics and Mathematical Methods at the advanced graduate level. On a volunteer basis, I also teach an advanced course in Nuclear Magnetic Resonance (NMR) Spectroscopy cross-listed between the Chemistry Department and the Physics department. In the area of non-classroom teaching and Outreach, there are typically 2–3 undergraduate students who conduct thesis research with our group each year. During the summer months, I typically have 1–2 high school students in our laboratory as part of the Keep Engaging Youth in Science (KEYS) high school summer internship program at the University of Arizona (https://keys.arizona.edu/).

M. Outreach and Community Service: The Brown group is active in a number of outreach programs which combine our various educational and research activities. One highlight is outreach with the Native American population within the state of Arizona and with High School students. Each summer we host a teacher for the Optics Research Experience for Teachers In Native American Schools (O-RETINAS) program, which involves both Native American teachers and students (http://cian-erc.uawebhost.arizona.edu/ret-native-american-students), who conduct a project in the Brown lab. We are also active in the Keep Engaging Youth in Science (KEYS) program at the UA, which involves summer research for Arizona High School students (https://keys.arizona.edu/). The Brown lab mentors 1 or 2 students from the KEYS Program every summer to conduct lab research. We participate in the Undergraduate Biology Research Program (UBRP) and mentor at least one research student each year (https://ubrp.arizona.edu/programs/ubrp/). Further, we intend to expand our activities to include students in Arizona's Science, Engineering, and Math Scholars (ASEMS) program, which focuses on promising students who are underrepresented in STEM, especially students who are first in their family to attend college, and women and minorities (https://asems.arizona.edu/). We are involved in the development of workshops for "Chemistry Discovery" program (CHEM 396D) associated with the University of Arizona Flandreau Science Center (planetarium). Here we aim to mentor our undergraduate students to gain experience in teaching chemistry to younger pupils from local middle schools.

N. Contributions to Science: Professor Michael Brown conducts fundamental research in molecular spectroscopy with applications to proteins, lipid membranes, surfactants, and liquid crystals—soft matter in general. Brown's research entails solid-state NMR methods combined with molecular spectroscopy to achieve new insights into the chemistry of soft matter, with an emphasis on membrane lipids and protein dynamics. Novel experiments are put forth together with theory at the leading edge of experimental physical chemistry. He is also combining his solid-state NMR approach with femtosecond time-resolved X-ray studies using a free-electron laser (XFEL) and neutron spin-echo spectroscopy to investigate protein dynamics in surfactant solutions and lipid-surfactant nanodiscs.

1. Pioneering of solid-state deuterium NMR spectroscopy of biomolecules/biomembranes (NIH EY02604)

Brown pioneered the development of solid-state deuterium NMR methods (order parameter analysis, relaxation methods) in the first detailed studies of membrane lipids and proteins their structure, ordering, and dynamics. His innovation of using solid-state ^{2}H NMR spectroscopy for investigating the structure and dynamics of liquid-crystalline molecules, including membrane lipids and membrane proteins, has had a substantial impact on biophysical chemistry and molecular spectroscopy. He also recently extended the solid-state NMR approach through separated-local field ^{13}C NMR spectroscopy, which does not require isotopic labeling. Brown's solid-state NMR approach has been used to study the structural properties and molecular dynamics of membrane lipids, their interactions with cholesterol in raft-like lipid mixtures, and functional lipid-protein interactions.

Before Brown started his work in this area, the idea of an order parameter was completely novel in biophysics. There was essentially no understanding of the connection of spectral parameters to the relaxation times in NMR (or fluorescence) spectroscopy. By introducing a mean-torque model to interpret the order parameters, he achieved a new framework for understanding the material properties of membrane lipids. Through considering how the volumetric bilayer thickness and area per lipid molecule respond to external hydration or osmotic forces, he was able to discover how the moduli for area and curvature elastic deformation emerge from atomistic level interactions. He was also able to apply differential geometry to understand the various lipid nanostructures and their transformations by experimentally considering the principal curvatures of the membrane films. Applications have involved membrane interactions involving antimicrobial peptides, polyunsaturated omega-3 lipids, and proteins such as alpha-synuclein (neurodegeneration), ATP-synthase (molecular motor), and rhodopsin (visual receptor).

1. Mallikarjunaiah, K. J.; Kinnun, J. J.; Petrache, H. I.; **Brown, M. F.** Flexible Lipid Nanomaterials Studied by NMR Spectroscopy, *Phys. Chem. Chem. Phys.* **2019**, *21*, 18422–18457. *Invited review.* https://doi.org/10.1039/C8CP06179C

2. Molugu, T. R.; Lee, S.; **Brown, M. F.** Concepts and Methods of Deuterium NMR Spectroscopy Applied to Biomembranes, *Chem. Rev.* **2017**, *117*, 12087–12132. *Invited review.* https://doi.org/10.1021/acs.chemrev.6b00619 *43 citations.*

3. Bartels, T.; Bittman, R.; Beyer, K.; **Brown, M. F.** Raft–like Mixtures of Sphingomyelin and Cholesterol Investigated by Solid-State ^{2}H NMR Spectroscopy, *J. Am. Chem. Soc.* **2008**, *44*, 14521-14532. https://doi.org/10.1021/ja801789t *101 citations*

4. Huber, T.; Rajamoorthi, K.; Kurze, V.; Beyer, K.; **Brown, M. F**. Structure of Docosahexaenoic Acid-Containing Bilayers as Studied by ^{2}H NMR and Molecular Dynamics Simulations, *J. Am. Chem. Soc.* **2002**, *124*, 298-309. https://doi.org/10.1021/ja011383j *146 citations.*

5. Petrache, H. I.; Dodd, S. W.; **Brown, M. F.** Area per Lipid and Acyl Length Distributions in Fluid Phosphatidylcholines Determined by ^{2}H NMR Spectroscopy, *Biophys. J.* **2000**, *79*, 3172-3192. https://doi.org/10.1016/S0006-3495(00)76551-9 *624 citations.*

2. Introduction of relaxation methods in biomolecular NMR spectroscopy (NIH EY02604)

Before Brown began his work in this area, the problem of interpreting the NMR relaxation times of lipid membranes was viewed as too complicated to be solved in a meaningful way. However, he was able to achieve a solution with clear biophysical significance, using his strength of combining both experiment and theory. Brown's experimental measurements of the magnetic field dependence of the NMR relaxation rates of liquid-crystalline systems have played a crucial role in the refinement of force fields for molecular dynamics (MD) simulations of membrane constituents. He was among the first to develop a theoretical formulation of the nuclear spin relaxation of biomolecules in terms of motional mean-square amplitudes (order parameters) as well as rates of structural fluctuations based on liquid-crystal physics. He was able to discover how the two observables are connected (by a simple square law, a manifestation of Fermi's Golden Rule). For lipid membranes, the new model relates the energy

landscape of the molecular fluctuations to the emergence of elastic properties on the mesoscopic length scale of the stochastic bilayer fluctuations. He also produced an NMR database useful for theoretical molecular mechanics simulations of membrane lipid dynamics. His solid-state NMR measurements continue to impact the development of atomistic and coarse-grained force fields in molecular dynamics (MD) simulations of biomembranes.

6. Struts, A. V., Salgado, G. F. J., **Brown, M. F.** Solid-State ^{2}H NMR Relaxation Illuminates Functional Dynamics of Retinal Cofactor in Membrane Activation of Rhodopsin, *Proc. Natl. Acad. Sci. U.S.A.* **2011**, *108*, 8263-8268. https://doi.org/10.1073/pnas.1014692108 *50 citations*

7. **Brown, M. F**.; Thurmond, R. L.; Dodd, S. W.; Otten, D.; Beyer, K. Elastic Deformation of Membrane Bilayers Probed by Deuterium NMR Relaxation, *J. Am. Chem. Soc.* **2002**, *124*, 8471-8484. https://doi.org/10.1021/ja012660p *111 citations.*

8. Trouard, T. P.; Nevzorov, A. A.; Alam, T. M.; Job, C.; Zajicek, J.; **Brown, M. F.** Influence of Cholesterol on Dynamics of Dimyristoylphosphatidylcholine Bilayers as Studied by Deuterium NMR Relaxation, *J. Chem. Phys.* **1999**, *110*, 8802-8818. https://doi.org/10.1063/1.478787 *130 citations.*

9. **Brown, M. F**. Theory of Spin-Lattice Relaxation in Lipid Bilayers and Biological Membranes. ^{2}H and ^{14}N Quadrupolar Relaxation, *J. Chem. Phys.* **1982**, *77*, 1576-1599. https://doi.org/10.1063/1.443940 *209 citations.*

10. **Brown, M. F**.; Seelig, J.; and Häberlen, U. Structural Dynamics in Phospholipid Bilayers from Deuterium Spin-Lattice Relaxation Time Measurements, *J. Chem. Phys.* **1979**, *70*, 5045-5053. https://doi.org/10.1063/1.437346 *218 citations.*

3. Investigating the role of soft matter in membrane biophysical chemistry (NSF CHE1904125)

Brown first discovered how membrane lipids govern the conformation energetics of membrane proteins in the liquid-crystalline state. He showed how conformational changes of membrane proteins, involving folding, stability, and membrane shape transitions, potentially involve deformation or elastic remodeling of the lipid bilayer. Previously, it was thought that membrane lipids were an inert grease for the actions of membrane proteins, or alternatively that they affected function mainly through molecularly specific interactions, as in the case of so-called lipid rafts. Brown upended the field by providing the first experimental demonstration of how membrane protein function (rhodopsin) is governed by nonspecific biophysical properties of lipid membranes. With rhodopsin as an example, he developed a new Flexible Surface Model (FSM) for lipid-protein and lipid-peptide interactions, based on differential geometry. According to the FSM, there is a two-way coupling of the elastic deformation of the membrane bilayer to the conformational energetics of membrane proteins, including receptors and ion channels. Frustration of the intrinsic curvature of the bilayer is linked to allosteric regulation of membrane proteins. Understanding the attractive and repulsive forces in membrane interactions is also important for membrane fusion of enveloped viruses (Influenza, HIV, Coronavirus), as well as interactions of antimicrobial peptides with lipid bilayers. Influences of bilayer thickness, nonlamellar-forming lipids, detergents, and osmotic stress are all readily explained by the FSM as a new paradigm. Brown's work involving membrane lipid-protein interactions has significantly advanced the field of biophysical chemistry.

11. **Brown, M. F.** Soft Matter in Lipid-Protein Interactions, *Annu. Rev. Biophys.* **2017**, *46*, 379–410. *Invited review.* https://doi.org/10.1146/annurev-biophys-070816-033843 *60 citations.*

12. **Brown, M. F.** Curvature Forces in Membrane Lipid-Protein Interactions, *Biochemistry* **2012**, *51,* 9782–9795. https://doi.org/10.1021/bi301332v *127 citations*

13. Bartels, T.; Ahlstrom, L. S.; Leftin, A.; Kamp, F.; Haass, C.; **Brown, M. F.***; and Beyer, K. The N-Terminus of α-Synuclein Triggers Membrane Binding and Helix Folding, *Biophys. J.* **2010**, *99*, 1-9. **Corresponding author.* https://doi.org/10.1016/j.bpj.2010.06.035 *204 citations.*

14. Botelho, A. V.; Huber, T.; Sakmar, T. P.; and **Brown, M. F.** Curvature and Hydrophobic Forces Drive Oligomerization and Modulate Activity of Rhodopsin in Membranes, *Biophys. J.* **2006**, *91*, 4464-4477. https://doi.org/10.1529/biophysj.106.082776 *266 citations.*

15. **Brown, M. F.** Modulation of Rhodopsin Function by Properties of the Membrane Bilayer, *Chem. Phys. Lipids* **1994**, *73*, 159-180. https://doi.org/10.1016/0009-3084(94)90180-5 *461 citations.*

4. Unraveling the molecular dynamics of membrane proteins (NSF CHE1904125, NIH EY02604)

By combining solid-state NMR studies with molecular dynamics (MD) simulations, Brown showed how we can more fully understand protein function in lipid membranes. When he began this work, the only X-ray structure for a G-protein–coupled receptor (GPCR) was that of rhodopsin in the dark state. Since then, GPCR structures have been appearing at an increasing pace. However, such X-ray structures completely suppress the conformational fluctuations due to the constraints of the crystal lattice. Brown was the first to discover how membrane lipids control GPCR function, and moreover, he showed how a dramatic influx of bulk water into the protein occurs during light activation of rhodopsin. He proposed that an ensemble of conformational states and substates is biased by the lipid composition, mutations of the protein, and bulk membrane water. He then went on to determine the solid-state NMR structures of the retinal ligand of rhodopsin, and the changes triggered by light activation. He used molecular spectroscopy (solid-state NMR, electronic spectroscopy, Fourier transform infrared spectroscopy) to test his energy landscape model (ELM), in which the retinal cofactor biases an ensemble of light-activated states involving collective helix fluctuations in visual signaling. Enhanced ligand flexibility upon light activation gives a ready explanation for the different retinal orientations observed in X-ray crystal structures of active rhodopsin. Understanding GPCR activation involves a key role of dynamics in drug discovery and development.

16. Chawla, U.; Perera, S. M. D. C.; Fried, S. D. E.; Eitel, A. R.; Mertz, B.; Weerasinghe, N.; Pitman, M. C.; Struts, A. V.; and **Brown, M. F**. Activation of the G-Protein-Coupled Receptor Rhodopsin by Water, *Angew. Chem. Int. Ed.,* **2020**, *59*, https://doi.org/10.1002/anie.202003342.

17. Perera, S. M. D. C.; Chawla, U.; **Brown, M. F.** Powdered G-Protein–Coupled Receptors, *J. Phys. Chem. Lett.*, **2016,** *7,* 4230-4235. https://doi.org/10.1021/acs.jpclett.6b02328 *8 citations.*

18. Shrestha, U. R.†, Perera, S. M. D. C.†, Bhowmik, D., Chawla, U., Mamontov, E., **Brown, M. F.***, and Chu, X.-Q.* , Quasi-Elastic Neutron Scattering Reveals Ligand-Induced Protein Dynamics of a G-Protein–Coupled Receptor, *J. Phys. Chem. Lett.* **2016**, *7,* 4130–4136. **Co-corresponding author*. https://doi.org/10.1021/acs.jpclett.6b01632

19. Mahalingam, M., Martínez-Mayorga, K., **Brown, M. F.***, Vogel, R.* Two Protonation Switches Control Rhodopsin Activation in Membranes, *Proc. Natl. Acad. Sci. U.S.A.* **2008**, *105,* 17795-17800. **Co-corresponding author*. https://doi.org/10.1073/pnas.0804541105 *146 citations*

20. Martínez-Mayorga, K., Pitman, M. C., Grossfield, A., Feller, S. E., and **Brown, M. F**. Retinal Counterion Switch Mechanism in Vision Evaluated by Molecular Simulations, *J. Am. Chem. Soc.* **2006**, *28*, 6502-16503. https://doi.org/10.1021/ja0671971 *82 citations*

5. Discovering new insights into visual signaling by rhodopsin (NSF CHE1904125, NIH EY02604)

G-protein–coupled receptors (GPCRs) are the largest family of membrane-bound receptors in the human genome, and are targets of the majority of human drugs and pharmaceuticals. Knowing the atomistic details of the activated state of rhodopsin and other receptors is the primary focus of GPCR biology and pharmacology. Prior to my work in the area, rhodopsin was regarded to be a simple on-off switch as some continue to believe.

Together with my students and coworkers, I applied my experimental and theoretical methods to the GPCR rhodopsin. Through a series of FITR and electronic (optical) spectroscopic measurements, we discovered that activation of rhodopsin is not a simple two-state protein conformational transition. By contrast, an ensemble of conformational states and substates is biased by the membrane lipid composition, mutations of the protein, and bulk membrane water. We then went on to determine the solid-state NMR structure of the retinal ligand of rhodopsin, and the changes triggered by light activation. To explain these observations, we introduced an ensemble activation model, and we proposed that the retinal cofactor initiates collective helix fluctuations on the microsecond-to-millisecond timescale in visual signaling.

Our innovations help to understand how mutations of GPCRs are implicated in a broad spectrum of human diseases. Extension of the approach to other GPCRs can stimulate ligand-based drug discovery. Currently, we are applying solid-state NMR methods to investigate how the local changes in the retinal cofactor drive large-scale fluctuations of transmembrane helices in rhodopsin activation.

21. Perera, S. M. D. C., Chawla, U., Shrestha, U. R., Bhowmik, D., Struts, A. V., Qian, S., Chu, X.-Q, and **Brown, M. F.** Small-Angle Neutron Scattering Reveals Energy Landscape For Rhodopsin Photoactivation, *J. Phys. Chem. Lett.* **2018**, *9,* 7064–7071. https://doi.org/10.1021/acs.jpclett.8b03048

22. **Brown, M. F.;** Struts, A. V. Structural Dynamics of Retinal in Rhodopsin Activation Viewed by Solid-State ^{2}H NMR Spectroscopy, in: *Advances in Biological Solid-State NMR: Proteins and Membrane-Active Peptides*, Separovic, F., and Naito, A. (Eds.), The Royal Society of Chemistry, Cambridge, **2014,** pp. 320–352 *Invited book chapter. Cover article.*
https://doi.org/10.1039/9781782627449-00320

23. Struts, A. V.; Salgado, G. F. J.; Martínez-Mayorga, K.; **Brown, M. F.** Retinal Dynamics Underlie Its Switch from Inverse Agonist to Agonist During Rhodopsin Activation, *Nature Struct. Mol. Biol.* **2011**, *18*, 392-394. https://doi.org/10.1038/nsmb.1982 *76 citations.*

24. Struts, A. V.; Salgado, G. F. J.; **Brown, M. F.** Solid-State ^{2}H NMR Relaxation Illuminates Functional Dynamics of Retinal Cofactor in Membrane Activation of Rhodopsin, *Proc. Natl. Acad. Sci. U.S.A.* **2011,** *108,* 8263-8268. https://doi.org/10.1073/pnas.1014692108 *50 citations.*

25 Salgado, G. F. J.; Struts, A. V.; Tanaka, T.; Krane, S.; Nakanishi, K.; **Brown, M. F.** Solid-State ^{2}H NMR Structure of Retinal in Metarhodopsin I, *J. Am. Chem. Soc.* **2006,** *128*, 11067–11071.
44 citations.

5. Visualizing [the frontiers of] quantum biology with ultrafast X-ray free electron lasers (NSF MCB1817862, NSF STC1231306)

Most recently, Brown has been implementing X-ray free electron laser (XFEL) technology to investigate the dynamics of membrane proteins. Femtosecond optical pump–X-ray probe studies of photosensitive proteins are being conducted with the highly brilliant XFEL beam source of the Linac Coherent Light Source (LCLS). Here visual rhodopsin provides an important archetype, in which coherent nuclear motions are driven by the electron dynamics yielding *cis–trans* isomerization of the retinal cofactor. Using X-ray diffraction methods, Brown provided the first time-resolved structural detection of *cis–trans* isomerization of retinal within the binding pocket of rhodopsin. Molecular dynamics tracking of the light-induced displacement of the amino acid residues indicates the shock wave is due to the *cis–trans* isomerization of retinal and propagates at the speed of sound in proteins. His XFEL investigations of functional protein dynamics are expected to provide important applications to quantum biology, where the scientific frontiers are advanced by the new X-ray science. Addressing both the structural and electron dynamics will answer key questions involving the wave-packet motion from the photo-excited Franck–Condon region to the photoproduct as a critical component of the directed energy flow. Non-stationary states entail correlated electronic motions that affect nuclear motions and vice versa. Experimental X-ray scattering methods based on next-generation XFEL technology are expected to play a prominent role in the big leap to quantum biology.

26. Perera, S. M. D. C., Xu, X., Struts, A. V., Chawla, U., Boutet, S., Carbajo, S., Seaberg, M. D., Hunter, M. S., Martin-Garcia, J. M., Coe, J. D., Wiedorn, M. O., Nelson, G., Chamberlain, S., Deponte, D. P., Fromme, R., Grant, T. D., Kirian, R. A., Fromme, P., and **Brown, M. F.** Time-Resolved Wide-Angle X-ray Scattering Reveals Protein Quake in Rhodopsin Activation, *Biophys. J.* **2017**, *112,* 506a-507a.

27 Grant, T. D., Perera, S. M., Salas-Estrada, L., Struts, A. V.Chawla, U., Xu, X., Fried, S. D., Weerasinghe, N., Mendez, D., Alvarez, R., Karpos, K., Lisova, S., Zaare, S., Nazari, R., Zatsepsin, N. A., Singharoy, A., Boutet, S., Carbajo, S., Hunter, M. S., Liang, M., Seaberg, M. D., Fromme, R., Fromme, P., Grossfield, A., Kirian, R., Brown, M. F. Membrane Protein Dynamics Revealed by X-Ray Scattering with a Femtosecond Free-Electron Laser, *Biophys. J.* **2020**, *118*, 365a.

O. Additional Information:
Ongoing Research Support

NIH grant R01 EY026041-01 Brown (PI) 03/01/2016 – 02/28/2021
"Membrane Basis of Visual Excitation" - U.S. Public Health Service
The goal of this project is to investigate the 3-D structure and dynamics of the retinal chromophore of rhodopsin using solid-state ^{2}H NMR spectroscopy and molecular dynamics (MD) simulations. Interactions of rhodopsin with effector proteins, membrane lipids, and water are studied in relation to activation of transducin by rhodopsin.

NSF grant 1817862 Brown (PI) 07/01/2018 – 06/30/2021
"Light-Induced Protein Quake of Visual Rhodopsin Investigated by Femtosecond Time-Resolved X-Ray Scattering"
- U.S. National Science Foundation

The goal of the project is to investigate the multi-scale activation mechanism of visual rhodopsin by conducting femtosecond time-resolved solution X-ray scattering studies in detergent micelles using a free electron laser.

NSF grant 1817862 Brown (PI) 08/01/2019 – 07/31/2022
"*Essential Role of Water and Lipids in G-Protein-Coupled Receptor Chemistry*" - U.S. National Science Foundation

The goal of this project is to use spectroscopic methods including solid-state NMR, electronic spectroscopy, Fourier transfer infrared spectroscopy (FTIR), and fluorescence-based applications to investigate how of lipids and water control the function of rhodopsin in terms of a Flexible Surface Model (FSM).

NSF grant (BioXFEL NST-STC) Brown 04/01/2019 – 09/30/2020
"*Ultrafast Protein Dynamics Studied by Time-Resolved Solution X-Ray Scattering*" - U.S. National Science Foundation

The goal of this project is to explore the use of time-resolved small/wide-angle solution X-ray scattering (TR-SAXS/WAXS) studies using an XFEL for studies of photoactive proteins. Energy landscapes and dynamic allostery are explored for both globular and membrane proteins in relation to their functions.

E. Scientific Publications:

Our scientific contributions have been described in a total of 170 peer-reviewed publications (10,263 total citations; h-index = 56 in Google Scholar); and 352 published abstracts & conference presentations.

Book Reviews: Four (4) book reviews for *Journal of the American Chemical Society*.

Published Abstracts & Conference Presentations: We have produced a total of 352 abstracts. The Brown group is very active in presenting our work at scientific conferences. Many of the abstracts are published in the *Biophysical Journal* in conjunction with the annual Biophysical Society (BPS) meeting.

Peer Reviewed Articles and Book Chapters: Our publications emphasize journals in Physics (*Physical Review*), Chemistry (*Journal of the American Chemical Society*), and molecular life sciences (*Biophysical Journal, Biochemistry, Journal of Molecular Biology*). Articles are also published in cross-disciplinary journals (*Nature, Proceedings of the National Academy of Sciences USA*). The impact of our work is shown by our h-index (56). Currently we average about 500 citations per year (Google Scholar). Our group is modest in size and highly focused, and we believe these metrics evince a high level of creativity and productivity.

For a complete list of our published work in Google Scholar please see:
http://scholar.google.com/citations?hl=en&user=cLFebLkAAAAJ&view_op=list_works

Scientific Publications –Papers and Book Chapters †—Michael F. Brown

†Selected from a total of >170 papers (10,283 total citations; h-index = 56 in Google Scholar), 4 book reviews in *J. Am. Chem. Soc.*; and >352 published abstracts. Most of these articles have been entirely written by myself and my students and together with our coworkers.
For a complete list of our published work in Google Scholar please see:
http://scholar.google.com/citations?hl=en&user=cLFebLkAAAAJ&view_op=list_works

Chemical Education:

133. Kinnun, J. J.; Leftin, A.; **Brown, M. F.** Solid-State NMR Spectroscopy for the Undergraduate Physical Chemistry Laboratory, *J. Chem. Ed.* **2013**, *90,* 123–128. https://doi.org/10.1021/ed2004774 *25 citations.*

23. Trindle, C.; **Brown, M.**; Newton, M. G.; Use of Algebraic Symbol-Manipulation Programs in Chemical Research and Education, **1984** in *Computer Education of Chemists* (P. Lykos, Ed.), Wiley, New York, pp. 93-107.

Biomolecular Solid-State NMR Spectroscopy:

173. Molugu, T. R.,; Thurmond, R. L.; Alam, T. M.; Trouard, T. P.; **Brown, M. F.** Phospholipid Headgroups Govern Emergent Properties of Bilayers as Seen by Solid-State ^{2}H NMR Spectroscopy, *Biophys. J.*, **2020**, submitted.

162. Mallikarjunaiah, K. J.; Kinnun, J. J.; Petrache, H. I.; **Brown, M. F.** Flexible Lipid Nanomaterials Studied by NMR Spectroscopy, *Phys. Chem. Chem. Phys.* **2019**, *21*, 18422–18457. https://doi.org/10.1039/C8CP06179C *4 citations.*

161. Molugu, T. R.; **Brown, M. F.**, Cholesterol Effects on the Physical Properties of Lipid Membranes Viewed by Solid-State NMR spectroscopy, in: *Cholesterol Modulation of Protein Function,* Rosenhouse-Dantsker, A.; Bukiya, A. (Eds.), *Advances in Experimental Medicine and Biology, Vol. 115*, Springer Nature, Cham, **2019**, pp. 99-133. *Invited book chapter.* https://doi.org/10.1007/978-3-030-04278-3_5 *4 citations.*

160. Molugu, T. R.,;Xu, X.; Leftin, A.; Lee, S. K.; Mallikarjunaiah, K. J.' **Brown, M. F.**, Solid-State ^{2}H NMR Studies of Water-Mediated Lipid Membrane Deformation, in: *Modern Magnetic Resonance*, Webb, G. A. (Ed.), Springer, Heidelberg, **2018**. *Invited review.* https://doi.org/10.1007/978-3-319-28275-6_143-1

156. Perera, S. M. D. C.; Xu, X.; Molugu, T. R.' Mallikarjuniah, K. J.; Struts, A. V.; **Brown, M. F.**, Solid-State Deuterium NMR Spectroscopy of Rhodopsin, in: *Modern Magnetic Resonance*, Webb, G. A. (Ed.), Springer, Heidelberg, **2017**. *Invited review.* https://doi.org/10.1007/978-3-319-28275-6_144-1

154. Molugu, T. R.;Xu, X.; Lefin, A.; Lope-Piedrafita, S.; Martinez, G. V.; Petrache, H. I.; **Brown, M. F.**, Solid-State Deuterium NMR Spectroscopy of Membranes, in: *Modern Magnetic Resonance*, Webb, G. A. (Ed.), Springer, Heidelberg, **2017**. *Invited review.* https://doi.org/10.1007/978-3-319-28275-6_89-1

153. Molugu, T. R.; Lee, S.; **Brown, M. F.** Concepts and Methods of Deuterium NMR Spectroscopy Applied to Biomembranes, *Chem. Rev.* **2017**, *117*, 12087–12132. *Invited review.* https://doi.org/10.1021/acs.chemrev.6b00619 *43 citations.*

148. Struts, A. V.; Barmasov, A. V.; **Brown, M. F.** Spectral Methods for Study of the G-Protein-Coupled Receptor Rhodopsin. II. Magnetic Resonance Spectroscopy, *Opt. Spectrosc.* **2016**, *120,* 286-293. https://doi.org/10.1134/S0030400X16010197 *8 citations.*

143. Kinnun, J. J.; Mallikarjunaiah, K. J.; Petrache, H. I.; **Brown, M. F.** Elastic Deformation and Area Per Lipid of Membranes: Atomistic View From Solid-State Deuterium NMR Spectroscopy, *Biochim. Biophys. Acta* **2015**, *1848*, 246–259. https://doi.org/10.1016/j.bbamem.2014.06.004 *34 citations.*

142. Leftin, A.; Molugu, T. R.; Job, C.; Beyer, K.; **Brown, M. F.**, Area per lipid and cholesterol interactions in membranes from separated local-field ^{13}C NMR spectroscopy, *Biophys. J.* **2014)** *107*, 2274–2286. https://doi.org/10.1016/j.bpj.2014.07.044 *57 citations.*

138. **Brown, M. F.;** Struts, A. V. Structural Dynamics of Retinal in Rhodopsin Activation Viewed by Solid-State ^{2}H NMR Spectroscopy, in: *Advances in Biological Solid-State NMR: Proteins and Membrane-Active Peptides*, Separovic, F., and Naito, A. (Eds.), The Royal Society of Chemistry, Cambridge, **2014,** pp. 320–352 *Invited book chapter. Cover article.* https://doi.org/10.1039/9781782627449-00320

135. Leftin, A.; Job, C.; Beyer, K.; **Brown, M. F.**, Solid-state ^{13}C NMR Reveals Annealing of Raft-Like Membranes Containing Cholesterol by the Intrinsically Disordered Protein α-Synuclein, *J. Mol. Biol.* **2013** *425*, 2973–2987. https://doi.org/10.1016/j.jmb.2013.04.002 *54 citations.*

134. Struts, A. V.; **Brown, M. F.** Activation of Rhodopsin Based on Solid-State NMR Spectroscopy, in *Encyclopedia of Biophysics,* Roberts, G. C. K. (Ed.), Springer-Verlag, Heidelberg, **2013,** pp. 2231–2243. *Invited book chapter.*

125. Leftin, A.; **Brown, M. F.** An NMR Data Base for Simulations of Membrane Dynamics, *Biochim. Biophys. Acta* **2011**, *1808*, 818-839. *Invited review.* https://doi.org/10.1016/j.bbamem.2010.11.027 *83 citations.*

124. Mallikarjunaiah, K. J.; Leftin, A.; Kinnun, J. J.; Justice, M. J.; Rogozea, A. L.; Petrache, H. I.; **Brown, M. F.** Solid-State ^{2}H NMR Demonstrates Correspondence of Hydrostatic and Osmotic Pressures in Lipid Membrane Deformation, *Biophys. J.* **2011,** *100,* 98-107. *35 citations.*

119. Brownholland, D.; Longo, G. S.; Struts, A. V.; Justice, M. J.; Szleifer, I.; Petrache, H. I.; **Brown, M. F.**; Thompson, D. H. Phase Separation in Binary Mixtures of Bipolar and Monopolar Lipid Dispersions Revealed by ^{2}H NMR Spectroscopy, Small Angle X-Ray Scattering, and Molecular Theory, *Biophys. J.* **2009,** *97,* 2700-2709. *25 citations.*

118. **Brown, M. F.**; Martínez-Mayorga, K.; Nakanishi, K.; Salgado, G. F. J.; Struts, A. V., Retinal Conformation and Dynamics in Activation of Rhodopsin Illuminated by Solid-State ^{2}H NMR Spectroscopy, *Photochem. Photobiol.* **2009,** *85,* 442-453. *Invited review. 20 citations.*

115. Bartels, T.; Bittman, R.; Beyer, K.; **Brown, M. F.** Raft–like Mixtures of Sphingomyelin and Cholesterol Investigated by Solid-State ^{2}H NMR Spectroscopy, *J. Am. Chem. Soc* **2008,**. *44*, 14521-14532. https://doi.org/10.1021/ja801789t *101 citations*

113. Kobayashi, M.; Struts, A. V.; Fujiwara, T.; **Brown, M. F.**; Akutsu, H. Fluid Mechanical Matching of H^+-ATP Synthase Subunit *c* Ring with Lipids in Membranes Revealed by ^2H Solid-State NMR, *Biophys. J.* **2008,** *94,* 4339–4347. *18 citations.*

112. Holland, D. P.; Struts, A. V.; **Brown, M. F.**; Thompson, D. H. Bolalipid Membrane Structure Revealed by Solid-State ^2H NMR Spectroscopy, *J. Am. Chem. Soc.* **2008,** *130*, 4584–4585. *25 citations.*

109. **Brown, M. F**.; Heyn, M. P.; Job, C.; Kim, S.; Moltke, S.; Nakanishi, K.; Nevzorov, A. A.; Struts, A. V.; Salgado, G. F. J.; Wallat, I. Solid-State ^2H NMR Spectroscopy of Retinal Proteins in Aligned Membranes, *Biochim. Biophys. Acta* **2007,** *1768*, 2979–3000. *43 citations.*

108. Tanaka, K.; Struts, A. V.; Krane, S.; Fujioka, N.; Salgado, G. F. J.; Karina Martínez-Mayorga, K.; **Brown, M. F**.; Koji Nakanishi, K. Synthesis of CD_3-labeled 11-*cis*-Retinals and Applications to Solid-State Deuterium NMR Spectroscopy of Rhodopsin, *Bull. Chem. Soc. Japan* **2007,** *80,* 2177-2184. *14 citations.*

105. Petrache, H. I.; **Brown, M. F.** X-ray Scattering and Solid-State ^2H NMR Probes of Structural Fluctuations in Lipid Membranes, in: *Methods in Membrane Lipids*, Dopico, A. (Ed.), *Methods in Molecular Biology, Vol. 400*, Humana Press, Totowa, **2007,** pp. 339-351. *Invited review. 14 citations.*

104. Struts, A. V.; Salgado, G. F. J.; Fujioka, N.; Nakanishi, K.; **Brown, M. F.** Structural Analysis and Dynamics of Retinal Chromophore in Dark and Meta I States of Rhodopsin from ^2H NMR of Aligned Membranes, *J. Mol. Biol.* **2007,** *372,* 50–66. *Cover article. 62 citations.*

101. **Brown, M. F.**; Lope-Piedrafita, S.; Martinez, G. V.; Petrache, H. I. Solid-State Deuterium NMR Spectroscopy of Membranes, in: *Modern Magnetic Resonance*, Webb, G. A. (Ed., Springer, Heidelberg, **2006),** pp. 245-256. *Invited review. 25 citations.*

100. Salgado, G. F. J.; Struts, A. V.; Tanaka, T.; Krane, S.; Nakanishi, K.; **Brown, M. F.** Solid-State ^2H NMR Structure of Retinal in Metarhodopsin I, *J. Am. Chem. Soc.* **2006,** *128*, 11067–11071. *44 citations.*

97. Vogel, A.; Katzka, C. P.; Waldmann, H.; Arnold, K.; **Brown, M. F.**; Huster, D. Lipid Modifications of a Ras Peptide Exhibit Altered Packing and Mobility Versus Host Membrane as Detected by ^2H Solid-State NMR, *J. Am. Chem. Soc.* **2005,** *127,* 12263-122. *86 citations.*

96. Rajamoorthi, K.; Petrache, H. I.; McIntosh, T. J.; **Brown, M. F.** Packing and Viscoelasticity of Polyunsaturated ω-3 and ω-6 Phospholipids as Seen by ^2H NMR Spectroscopy and X-Ray Diffraction, *J. Am. Chem. Soc.* **2005,** *127*, 1576–1588. https://doi.org/10.1021/ja046453b *130 citations*

95. Salgado, G. F. J.; Struts, A. V.; Tanaka, K.; Fujioka, N.; Nakanishi, K.; **Brown, M. F.** Deuterium NMR Structure of Retinal in the Ground State of Rhodopsin, *Biochemistry* **2004,** *43,* 12819-12828. *71 citations.*

94. Henzler-Wildman, K. A.; Martinez, G. V.; **Brown, M. F.**; Ramamoorthy, A. Perturbation of the Hydrophobic Core of Lipid Bilayers by the Human Antimicrobial Peptide LL-37, *Biochemistry* **2004,** *43,* 8459-8469. *266 citations.*

85. Huber, T.; Rajamoorthi, K.; Kurze, V.; Beyer, K.; **Brown, M. F**. Structure of Docosahexaenoic Acid-Containing Bilayers as Studied by ^2H NMR and Molecular Dynamics Simulations, *J. Am. Chem. Soc.* **2002**, *124*, 298-309. https://doi.org/10.1021/ja011383j *146 citations.*

84. Petrache, H. I.; Salmon, A. S.; **Brown, M. F.** Structural Properties of Docosahexaenoyl Phospholipid Bilayers Investigated by Solid-State ^{2}H NMR Spectroscopy, *J. Am. Chem. Soc.* **2001,** *123,* 12611-12622. https://doi.org/10.1021/ja011745n *60 citations.*

82. Petrache, H. I.; Dodd, S. W.; **Brown, M. F.** Area per Lipid and Acyl Length Distributions in Fluid Phosphatidylcholines Determined by ^{2}H NMR Spectroscopy, *Biophys. J.* **2000,** *79*, 3172-3192. https://doi.org/10.1016/S0006-3495(0076551-9 *624 citations.*

80. Nevzorov, A. A.; Moltke, S.; Heyn, M. P.; **Brown, M. F.** Solid-State NMR Lineshapes of Uniaxially Oriented Immobile Systems, *J. Am. Chem. Soc.* **1999,***121,* 7636-7643. https://doi.org/10.1021/ja9821910 *53 citations*

78. Moltke, S.; Wallat, I.; Sakai, N.; Nakanishi, K.; **Brown, M. F.**; Heyn, M. P. The Angles Between the C_1–, C_5–, and C_9–Methyl Bonds of the Retinylidene Chromophore and the Membrane Normal Increase in the M Intermediate of Bacteriorhodopsin: Direct Determination with Solid-State ^{2}H-NMR, *Biochemistry* **1999,** *38*, 11762-11772. *28 citations.*

77. **Brown, M. F.**; Nevzorov, A. A. ^{2}H-NMR in Liquid Crystals and Membranes, *Colloids and Surfaces* **1999,** *158,* 281-298. *Invited review. 25 citations.*

75. Hetzer, M.; Gutberlet, T.; **Brown, M. F.**; Camps, X.; Vostrovsky, O.; Schönberger, H.; Hirsch, A.; Bayerl, T. M. Thermotropic Behavior of Lipophilic Derivatized [60]fullerenes Studied by Deuterium NMR, X-ray diffraction, and Microcalorimetry, *J. Phys. Chem. A* **1999,** *103,* 637-642. *38 citations.*

73. Moltke, S.; Nevzorov, A. A.; Sakai, N.; Wallat, I.; Job, C.; Nakanishi, K.; Heyn, M. P.; **Brown, M. F.** Chromophore Orientation in Bacteriorhodopsin Determined from the Angular Dependence of Deuterium Nuclear Magnetic Resonance Spectra of Oriented Purple Membranes, *Biochemistry* **1998,** *37*, 11821-11835. *43 citations.*

71. Nevzorov, A. A.; Moltke, S.; **Brown, M. F.** Structure of the A-Form and B-Form of DNA from Deuterium NMR Lineshape Simulation, *J. Am. Chem. Soc.* **1998**, *120*, 4798-4805. *22 citations.*

66. Job, C.; Zajicek, J.; **Brown, M. F.**, Fast Field Cycling Nuclear Magnetic Resonance Spectrometer, *Rev. Sci. Instr.* **1996** *67,* 2113-2122. https://doi.org/10.1063/1.1147024 *54 citations*

64. **Brown, M. F.** Membrane Structure and Dynamics Investigated with NMR Spectroscopy, in *Biological Membranes: A Molecular Perspective from Computation and Experiment* Merz, K. M., and Roux, B., Eds.), Birkhäuser, Basel, **1996,** pp. 175-252. *Invited book chapter. 55 citations.*

58. Job, C.; Pearson, R.; **Brown, M. F.** A Personal Computer-Based NMR Spectrometer, *Rev. Sci. Inst.* **1994,** *65*, 3354-3362. *28 citations.*

56. Thurmond, R. L.; Otten, D.; **Brown, M. F.;** Beyer, K. Structure and Packing of Phosphatidylcholines in Lamellar and Hexagonal Liquid Crystalline Mixtures with a Nonionic Detergent: A Wide Line NMR Study, *J. Phys. Chem* **1994,** *98*, 972-983. *51 citations.*

55. Thurmond, R. L.; Lindblom, G.; **Brown, M. F.** Curvature, Order, and Dynamics of Lipid Hexagonal Phases Studied by Deuterium NMR Spectroscopy, *Biochemistry* **1993,** *32,* 5394-5410. *90 citations.*

51. Jansson, M.; Thurmond, R. L.; Barry, J. A.; **Brown, M. F.** Deuterium NMR Study of Intermolecular Interactions in Lamellar Phases Containing Palmitoyllysophosphatidycholine, *J. Phys. Chem.* **1992,** *96*, 9532-9544. *43 citations.*

50. Barry, J. A.; Lamparski, H.; Shyamsunder, E.; Osterberg, F.; Cerne, J.; **Brown, M. F.**; O'Brien, D. F. ^{31}P NMR and X-Ray Diffraction Study of the Effect of Photopolymerization on Lipid Polymorphism, *Biochemistry* **1992,** *31,* 10114-10120. *19 citations.*

43. Rajamoorthi, K.; **Brown, M. F.** Bilayers of Arachidonic Acid Containing Phospholipids Studied By ^{2}H and ^{31}P NMR Spectroscopy, *Biochemistry* **1991,** *30,* 4204-4212. *33 citations.*

42. Barry, J. A.; Trouard, T. P.; Salmon, A.; **Brown, M. F.** Low Temperature ^{2}H NMR Spectroscopy of Phospholipid Bilayers Containing Docosahexaenoyl (22:6ω3) Chains, *Biochemistry* **1991),** *30,* 8386-8394. *51 citations.*

41. Thurmond, R. L.; Dodd, S. W.; **Brown, M. F.** Molecular Areas of Phospholipids as Determined By ^{2}H NMR Spectroscopy: Comparison of Phosphatidylethanolamines and Phosphatidylcholines, *Biophys. J.* **1991,** *59*, 108-113. *133 citations.*

40. Thurmond, R. L.; Lindblom, G.; **Brown, M. F.** Influences of Membrane Curvature in Lipid Hexagonal Phases Studied by Deuterium NMR Spectroscopy, *Biochem. Biophys. Res. Commun.* **1990,** *173,* 1231-1238. *24 citations.*

37. Jansson, M.; Thurmond, R. L.; Trouard, T. P.; **Brown, M. F.** Magnetic Alignment and Orientational Order of Dipalmitoylphosphatidylcholine Bilayers Containing Palmitoyllyso-phosphatidylcholine, *Chem. Phys. Lipids* **1990,** *54,* 157-170. *30 citations.*

34. **Brown, M. F.**; Dodd, S. W.; Salmon, A. Deuterium NMR Spectroscopy of Saturated and Polyunsaturated Lipid Bilayers, in *Highlights of Modern Biochemistry* (Kotyk, A., et al., Eds. VSP International, Zeist, **1989,** pp. 725-734.

29. Salmon, A.; Dodd, S. W.; Williams, G. D.; Beach, J. M.; **Brown, M. F.** Configurational Statistics of Acyl Chains in Polyunsaturated Lipid Bilayers From ^{2}H NMR, *J. Am. Chem. Soc.* **1987,***109,* 3600-2609. https://doi.org/10.1021/ja00243a010 *125 citations*

28. Ellena, J. F.; Pates, R. D.; **Brown, M. F.** ^{31}P NMR Spectra of Rod Outer Segment and Sarcoplasmic Reticulum Membranes Show No Evidence of Immobilized Components Due to Lipid-Protein Interactions, *Biochemistry* **1986,** *25,* 3742-3748. *18 citations.*

25. **Brown, M. F.**; Williams, G. D. Membrane NMR: A Dynamic Research Area, *J. Biochem. Biophys. Meth.* **1985,** *11*, 71-81. *30 citations.*

20. Siminovitch, D. J.; Rance, M.; Jeffrey, K. R.; **Brown, M. F**. The Quadrupolar Spectrum of a Spin I=1 in a Lipid Bilayer in the Presence of Paramagnetic Ions, *J. Magn. Res.* **1984,** *58,* 62-75. *61 citations.*

19. Siminovitch, D. J.; **Brown, M. F.**; Jeffrey, K. R. ^{14}N NMR of Lipid Bilayers: Effects of Ions and Anesthetics, *Biochemistry* **1984,** *23,* 2412-2420. *31 citations.*

18. Sefcik M. D.; Schaefer, J.; Stejskal, E. O.; McKay, R. A.; Ellena, J. F.; Dodd, S. W.; **Brown, M. F.** Lipid Bilayer Dynamics and Rhodopsin-Lipid interactions: New Approach Using High-Resolution Solid-State ^{13}C NMR. *Biochem. Biophys. Res. Commun.* **1983,** *114*, 1048-1055. *53 citations.*

15. **Brown, M. F.**; Deese, A. J.; Dratz, E. A. Proton, Carbon-13, and Phosphorus-31 NMR Methods for the Investigation of Rhodopsin-Lipid Interactions in Retinal Rod Outer Segment Membranes, *Methods Enzymol*. **1982,** *81*, 709-728. *Invited book chapter. 45 citations.*

13. Deese, A. J.; Dratz, E. .; **Brown, M. F.** Retinal Rod Outer Segment Lipids Form Bilayers in the Presence and Absence of Rhodopsin: A ^{31}P NMR Study, *FEBS Lett*. **1981,** *124,* 93-99. *59 citations.*

8. **Brown, M. F.;** Seelig, J. Influence of Cholesterol on the Polar Region of Phosphatidylcholine and Phosphatidylethanolamine Bilayers, *Biochemistry* **1978,** *17*, 381-384. *236 citations.*

7. **Brown, M. F.**; Seelig, J. Ion-Induced Changes in Head Group Conformation of Lecithin Bilayers, *Nature* **1977**, *269*, 721-723. https://doi.org/10.1038/269721a0 *161 citations.*

Nuclear Spin Relaxation and Molecular Dynamics:

169. Chakraborty, S.; Doktorova, M.; Molugu, T. R.; Heberle, F.; Scott, H. L.; Dzikovski, B.; Nagao, M.; Stingaciu, L.-R.; Standaert, R. F.; Barrera, F.; Katsaras, J.; Khelashvili, G.; **Brown, M. F.***, Ashkar, R.* How Cholesterol Stiffens Unsaturated Lipid Membranes, *Proc. Natl. Acad. Sci. U.S.A.* **2020**, *117*, 21896–21905. **Co-corresponding author.* https://doi.org/10.1073/pnas.2004807117

167. **Brown, M. F.** Collective Lipid Dynamics in Biomembranes, *Biochim. Biophys. Acta*, **2020,** submitted.

164. Ryazantsev, M. N.; Nikolaev, D. M.; Struts, A. V.; **Brown, M. F.** Quantum Mechanical and Molecular Mechanics Modeling of Membrane-Embedded Rhodopsin, *J. Membr. Biol*. **2019,** *252*, 425–449. https://doi.org/10.1007/s00232-019-00095-0

163. **Brown, M. F.** Collective Dynamics in Lipid Membranes, in: *Characterization of Biological Membranes. Structure and Dynamics*, Nieh, M.-P., Heberle, F. A., Katsaras, J. (Eds.) De Gruyter, Berlin, **(2019),** pp. 231-267. *Invited review.*. https://doi.org/10.1515/9783110544657-007

144. Struts, A. V.; Chawla, U.; Perera, S. M. D. C.; **Brown, M. F**. Investigation of Rhodopsin Dynamics in its Signaling State by Solid-State Deuterium NMR Spectroscopy, in: *Rhodopsin: Methods and Protocols,* Jastrzebska, B. (Ed.), *Methods in Molecular Biology, Vol. 1271,* Springer, New York, **2015,** pp. 133–158. *Invited book chapter.* https://doi.org/10.1007/978-1-4939-2330-4_10

141. Leioatts, N.; Mertz, B.; Martínez-Mayorga, K.; Romo, T. D.; Pitman, M. C.; Feller, S. E.; Grossfield, A.; **Brown, M. F.** Retinal ligand mobility explains internal hydration and reconciles active rhodopsin structures, *Biochemistry* **2014,** *53,* 376–385. https://doi.org/10.1021/bi4013947 *40 citations.*

140. Xu, X.; Struts, A. V.; **Brown, M. F.** Generalized Model-Free Analysis of Nuclear Spin Relaxation Experiments, *eMagRes* **2014,** *3*, 275–286. *Invited review.* https://doi.org/10.1002/9780470034590.emrstm1367

139. Leftin, A.; Xu, X.; **Brown, M. F.** Phospholipid Bilayer Membranes: Deuterium and Carbon-13 NMR Spectroscopy, **2014,** *eMagRes 3,* 199–214. *Invited review.* https://doi.org/10.1002/9780470034590.emrstm1368

130. Mertz, B.; Struts, A. V.; Feller, S. E.; **Brown, M. F.** Molecular Simulations and Solid-State NMR Investigate Dynamical Structure in Rhodopsin Activation, *Biochim. Biophys. Acta* **2012,** *1818*, 241–251. *35 citations.*

129. Olausson, B. E. S.; Grossfield, A.; Pitman, M. C.; **Brown, M. F.**; Feller, S. E.; Vogel, A. Molecular Dynamics Simulations Reveal Specific Interactions of Posttranslational Palmitoyl Modifications with Rhodopsin in Membranes, *J. Am. Chem. Soc.* **2012,** *134,* 4324–4331. *33 citations.*

128. Struts, A. V.; Salgado, G. F. J.; Martínez-Mayorga, K.; **Brown, M. F.** Retinal Dynamics Underlie Its Switch from Inverse Agonist to Agonist During Rhodopsin Activation, *Nature Struct. Mol. Biol.* **2011**, *18*, 392-394. https://doi.org/10.1038/nsmb.1982 *76 citations.*

127. Struts, A. V.; Salgado, G. F. J.; **Brown, M. F.** Solid-State ^{2}H NMR Relaxation Illuminates Functional Dynamics of Retinal Cofactor in Membrane Activation of Rhodopsin, *Proc. Natl. Acad. Sci. U.S.A.* **2011,** *108,* 8263-8268. https://doi.org/10.1073/pnas.1014692108 *50 citations.*

126. Mertz, B., Lu; M.; **Brown, M. F.**; Feller, S. E. Steric and Electronic Influences on the Torsional Energy Landscape of Retinal, *Biophys. J.* **2011,** *101,* L17-L19. *18 citations.*

125. Leftin, A.; **Brown, M. F.** An NMR Data Base for Simulations of Membrane Dynamics, *Biochim. Biophys. Acta* **2011,** *1808,* 818-839. https://doi.org/10.1016/j.bbamem.2010.11.027 *83 citations.*

123. Struts, A. V.; **Brown, M. F.** Retinal Structural Dynamics in Rhodopsin Activation, *Vestnik St. Petersburg Univ.,* Ser. 4 Issue 4, **2011,** 229-233.

120. **Brown, M. F.**; Salgado, G. F. J.; Struts, A. V. Retinal Dynamics During Light Activation of Rhodopsin Revealed by Solid-State NMR Spectroscopy, *Biochim. Biophys. Acta* **2010**, *1798,* 177-193. *35 citations.*

117. **Brown, M. F.**, Lope-Piedrafita, S., Martinez, G. V., and Petrache, H. I. Solid-State Deuterium NMR Spectroscopy of Membranes, in: *Modern Magnetic Resonance*, Webb, G. A. (Ed.), Springer, Heidelberg, **2008,** pp. 249-260. *Invited review. 25 citations.*

110. **Brown, M. F.**; S. I. Chan.. Bilayer Membranes: Deuterium and Carbon-13 NMR. *In* Encyclopedia of Magnetic Resonance. R. K. Harris and R. E. Wasylishen, editors. John Wiley & Sons, Chichester. **2007** DOI: 10.1002/9780470034590.emrstm0023. Published Online: 15 March 2007.

107. Lau, P.-W.; Grossfield, A.; Feller, S. E.; Pitman, M. C.; **Brown, M. F.** Dynamic Structure of Retinylidene Ligand of Rhodopsin Probed by Molecular Simulations, *J. Mol. Biol.* **2007,** *372,* 906–917. *Cover article. 49 citations.*

106. Vogel, A.; Tan, K.-T.; Waldmann, H.; Feller, S. E.; **Brown, M. F.**; Huster, D. Flexibility of Ras Lipid Modifications Studied by ^{2}H Solid-State NMR and Molecular Dynamics Simulations, *Biophys. J.* **2007,** *93,* 2697–2712. *58 citations.*

103. Martínez-Mayorga, K.; Pitman, M. C.; Grossfield, A.; Feller, S. E.; **Brown, M. F.** Retinal Counterion Switch Mechanism in Vision Evaluated by Molecular Simulations, *J. Am. Chem. Soc.* **2006,** *28,* 16502-16503. https://doi.org/10.1021/ja0671971 *80 citations.*

93. Huber, T.; Botelho, A. V.; Beyer, K.; **Brown, M. F.** Membrane Model for the GPCR Rhodopsin: Hydrophobic Interface and Dynamical Structure, *Biophys. J.* **2004,** *86,* 2078-2100. *142 citations.*

92. Martinez, G. V.; Dykstra, E. M.; Lope-Piedrafita, S.; **Brown, M. F.** Lanosterol and Cholesterol-Induced Variations in Bilayer Elasticity Probed by ^{2}H NMR Relaxation, *Langmuir* **2004,** *20,* 1043-1046. *48 citations.*

88. Martinez, G. V.; Dykstra, E. M.; Lope-Piedrafita, S.; Job, C; **Brown, M. F.** NMR Elastometry of Fluid Membranes in the Mesoscopic Regime, *Phys. Rev. E* **2002** *66,* 050902/1–050902/4. https://doi.org/10.1103/PhysRevE.66.050902 *52 citations*

87. **Brown, M. F**.; Thurmond, R. L.; Dodd, S. W.; Otten, D.; Beyer, K. Elastic Deformation of Membrane Bilayers Probed by Deuterium NMR Relaxation, *J. Am. Chem. Soc.* **2002**, *124,* 8471-8484. https://doi.org/10.1021/ja012660p *111 citations.*

85. Huber, T.; Rajamoorthi, K.; Kurze, V.; Beyer, K.; **Brown, M. F.** Structure of Docosahexaenoic Acid-Containing Bilayers as Studied by ^{2}H NMR and Molecular Dynamics Simulations, *J. Am. Chem. Soc.* **2002,** *124,* 298-309. https://doi.org/10.1021/ja011383j *144 citations.*

83. Brown, M. F., Thurmond, R. L., Dodd, S. W., Otten, D., and Beyer , K. (2001), Composite Membrane Deformation on the Mesoscopic Length Scale, *Phys. Rev. E* **64**, 010901-1–10901-4. https://doi.org/10.1103/PhysRevE.64.010901 *36 citations.*

81. Otten, D.; **Brown, M. F.**; Beyer, K. Softening of Membrane Bilayers by Detergents Elucidated by Deuterium NMR Spectroscopy, *J. Phys. Chem. B* **2000,** *104,* 12119-12129. *67 citations.*

76. Trouard, T. P.; Nevzorov, A. A.; Alam, T. M.; Job, C.; Zajicek, J.; **Brown, M. F.** Influence of Cholesterol on Dynamics of Dimyristoylphosphatidylcholine Bilayers as Studied by Deuterium NMR Relaxation, *J. Chem. Phys.* **1999**, *110*, 8802-8818. https://doi.org/10.1063/1.478787 *130 citations.*

72. Nevzorov, A. A.; Trouard, T. P.; **Brown, M. F.** Lipid Bilayer Dynamics from Simultaneous Analysis of Orientation and Frequency Dependence of Deuterium Spin-Lattice and Quadrupolar Order Relaxation, *Phys. Rev. E* **1998,** *58,* 2259-2281. https://doi.org/10.1103/PhysRevE.58.2259 *61 citations.*

68. Nevzorov, A. A.; **Brown, M. F.** Dynamics of Lipid Bilayers from Comparative Analysis of ^{2}H and ^{13}C NMR Relaxation Data as a Function of Frequency and Temperature, *J. Chem. Phys.* **1997**, *107*, 10288-10310. https://doi.org/10.1063/1.474169 *73 citations.*

67. Nevzorov, A. A.; Trouard, T. P.; **Brown, M. F.** Correlation Functions for Lipid Membrane Fluctuations Obtained from NMR Spectroscopy, *Phys. Rev. E* **1997,** *55,* 3276-3282. https://doi.org/10.1103/PhysRevE.55.3276 *17 citations.*

66. Job, C.; Zajicek, J.; **Brown, M. F.** Fast Field Cycling Nuclear Magnetic Resonance Spectrometer, *Rev. Sci. Instr.* **1996,** *67,* 2113-2122. https://doi.org/10.1063/1.1147024 *54 citations.*

63. **Brown, M. F.**; Chan, S. I. Bilayer Membranes: Deuterium & Carbon-13 NMR, in *Encyclopedia of Nuclear Magnetic Resonance* (Grant, D. M., and Harris, R. K., Eds.), Wiley, New York, **1996,** pp. 871-885. *Invited book chapter. 25 citations.*

62. Zajicek, J.; Ellena, J. F.; Williams, G. D.; Khadim, M.; **Brown, M. F.** Molecular Dynamics of Vesicles of Unsaturated Phosphatidylcholines Studied by ^{13}C NMR Spin-Lattice Relaxation, *Collect. Czech. Chem. Commun.* **1995,** *60,* 719-735.

57. Trouard, T. P.; Alam, T. M.; Job, C.; **Brown, M. F.** Angular Dependence of Deuterium Spin-Lattice Relaxation of Dilaurylphosphatidylcholine in the Liquid-Crystalline Phase, *J. Chem. Phys.* **1994,***101,* 5229-5261. https://doi.org/10.1063/1.467378 *49 citations*

49. Trouard, T. P.; Alam, T. M.; Zajicek, J.; **Brown, M. F.** Angular Anisotropy of ^{2}H NMR Spectral Densities in Phospholipid Bilayers Containing Cholesterol, *Chem. Phys. Lett.* **1992,** *189,* 67-75. *38 citations.*

39. B**rown, M. F.** Anisotropic Nuclear Spin Relaxation of Cholesterol in Phospholipid Bilayers, *Mol. Phys.* **1990,** *71,* 903-908. *28 citations.*

36. **Brown, M. F.**; Söderman, O. Orientational Anisotropy of Nuclear Spin Relaxation in Phospholipid Membranes, *Chem. Phys. Lett.* **1990,** *167,* 158-164. *25 citations.*

35. **Brown, M. F.**; Salmon, A.; Henriksson, U.; Söderman, O. Frequency Dependent ^{2}H N.M.R. Relaxation Rates of Small Unilamellar Vesicles, *Mol. Phys.* **1990,** *69,* 379-383. *30 citations.*

27. **Brown, M. F**.; Ellena, J. F.; Trindle, C.; Williams, G. D. Frequency Dependence of Spin-Lattice Relaxation Times of Lipid Bilayers, *J. Chem. Phys.* **1986,** *84,* 465-470. *33 citations.*

26. Williams, G. D., Beach, J. M., Dodd, S. W., and **Brown, M. F.** Dependence of Deuterium Spin-Lattice Relaxation Rates of Multilamellar Phospholipid Dispersions on Orientational Order, *J. Am. Chem. Soc.* **1985,** *107*, 6868-6873. *47 citations*

22. **Brown, M. F.** Unified Picture for Spin-Lattice Relaxation of Lipid Bilayers and Biomembranes, *J. Chem. Phys.* **1984,** *80,* 2832-2836. https://doi.org/10.1063/1.447031 *63 citations.*

21. **Brown, M. F.** Theory of Spin-Lattice Relaxation in Lipid Bilayers and Biological Membranes. Dipolar Relaxation, *J. Chem. Phys.* **1984**, *80*, 2808-2831. https://doi.org/10.1063/1.447030 *107 citations.*

17. **Brown, M. F.**; Ribeiro, A. A.; and Williams, G. D. New View of Lipid Bilayer Dynamics From ^{2}H and ^{13}C NMR Relaxation Time Measurements, *Proc. Natl. Acad. Sci. USA* **1983**, *80*, 4325-4329. https://doi.org/10.1073/pnas.80.14.4325 *186 citations.*

16. **Brown, M. F**. Theory of Spin-Lattice Relaxation in Lipid Bilayers and Biological Membranes. ^{2}H and ^{14}N Quadrupolar Relaxation, *J. Chem. Phys.* **1982**, *77*, 1576-1599. https://doi.org/10.1063/1.443940 *209 citations.*

14. **Brown, M. F**.; Davis, J. H. Orientation and Frequency Dependence of the Deuterium Spin-Lattice Relaxation in Multilamellar Phospholipid Dispersions: Implications for Dynamic Models of Membrane Structure, *Chem. Phys. Lett.* **1981,** *79*, 431-435. *88 citations.*

11. **Brown, M. F.** Deuterium Relaxation and Molecular Dynamics in Lipid Bilayers, *J. Magn. Res.* **1979,** *35,* 203-215. *74 citations.*

10. **Brown, M. F**.; Seelig, J.; and Häberlen, U. Structural Dynamics in Phospholipid Bilayers from Deuterium Spin-Lattice Relaxation Time Measurements, *J. Chem. Phys.* **1979**, *70*, 5045-5053. https://doi.org/10.1063/1.437346 *218 citations.*

4. **Brown, M. F.**; Miljanich, G. P.; Dratz, E. A. Proton Spin-Lattice Relaxation of Retinal Rod Outer Segment Membranes and Liposomes of Extracted Phospholipids, *Proc. Natl. Acad. Sci. USA* **1977,** *74,* 1978-1982. *33 citations.*

Solution NMR Spectroscopy and Magnetic Resonance Imaging:

136. Zook, J. D.; Molugu, T. R.; Jacobsen, N. E.; Lin, G.; Soll, J.; Cherry, B. R.; **Brown, M. F**.; Fromme, P. High-Resolution NMR Reveals Secondary Structure and Folding of Amino Acid Transporter from Outer Chloroplast Membrane, *PLoS ONE* **2013,** *8*, e78116–e78116.

91. Ying, J.; Ahn, J.-M.; Jacobsen, N. E.; **Brown, M. F.**; Hruby, V. J. NMR Solution Structure of the Glucagon Antagonist [desHis[1], desPhe[6], Glu[9]]Glucagon Amide in the Presence of Perdeuterated Dodecylphosphocholine Micelles, *Biochemistry* **2003,** *42,* 2825-2835. *22 citations.*

70. Schroeder, T. B.; Job, C.; **Brown, M. F.**; Glass, R. S.; You, N.; Block, E. ^{1}H-{^{125}Te} Indirect Detection in Nuclear Magnetic Resonance Spectra of Organotellurium Compounds, *Mag. Reson. Chem*. **1997,** *35,* 752-756. *26 citations.*

61. Schroeder, T. B.; Job, C.; **Brown, M. F**.; Glass, R. S. Indirect Detection of Selenium-77 in Nuclear Magnetic Resonance Spectra of Organoselenium Compounds, *Mag. Reson. Chem*. **1995,** *33,* 191-195. *35 citations.*

52. Alexander, A. A.; Pytlewski, V. T.; **Brown, M. F.**; Gmitro, A. F. Detection of Atherosclerosis via Magnetic Resonance Imaging, *Proc. SPIE (Society of Photooptical Engineers), Diagnostic and Therapeutic Cardiovascular Interventions II,* **1992,** *1642,* 26-34.

44. Altbach, M. I.; Mattingly, M.; **Brown, M. F.**; Gmitro, A. F. Magnetic Resonance Imaging of Lipid Deposits in Human Atheroma via a Stimulated-Echo Diffusion Technique, *Magn. Reson. Med*. **1991,** *20,* 319-326. *45 citations.*

33. Merickel, M. B.; Carman, C. S.; Brookeman, J. R.; Mugler, J.; **Brown, M. F**.; Ayers, C. Identification and 3-D Quantification of Atherosclerosis Using Magnetic Resonance Imaging, *Compt. Biol. Med*. **1988,***18,* 89-102. *74 citations.*

31. Pearlman, J. D.; Zajicek, J.; Merickel, M. B.; Carman, C. S.; Ayers, C. R.; Brookeman, J. R.; and **Brown, M. F**. High-Resolution ^{1}H NMR Spectral Signature From Human Atheroma, *Magn. Reson. Med*. **1988,** *7,* 262-279. *74 citations.*

30. Zajicek, J.; Pearlman, J. D.; Merickel, M. B.; Ayers, C. R.; Brookeman, J. R.; **Brown, M. F.** High-Resolution Proton NMR Spectra of Human Arterial Plaque, *Biochem. Biophys. Res. Commun*. **1987,** *149,* 437-442. *18 citations.*

3. **Brown, M. F.**; Miljanich, G. P.;Dratz, E. A. Interpretation of 100- and 360-MHz Proton Magnetic Resonance Spectra of Retinal Rod Outer Segment Disk Membranes, *Biochemistry* **1977,** *16,* 2640-2648. *69 citations.*

2. **Brown, M. F.**; Miljanich G. P.; Franklin, L. K.; Dratz, E. A. ^{1}H-NMR Studies of Protein-Lipid Interactions in Retinal Rod Outer Segment Disc Membranes, *FEBS Lett*. **1976,** *70,* 56-60. *26 citations.*

Rhodopsin and G-Protein-Coupled Receptors

170. Norris, C. E.; Keener, J. E.; Perera, S. M. D. C.; Weerasinghe, N.; Fried, S. D. E.; Resager, W. C.; Rohrbough, J. G.; **Brown, M. F.**; Marty, M. T. Native Mass Spectrometry Reveals the Influences of Lipids and Zinc on Rhodopsin Activation, *Anal. Chem.*, **(2020,** submitted.

166. Perera, S. M. D. C.; Xu, X.; Molugu, T. R.; Struts, A. V.; **Brown, M. F.** Rhodopsin Activation in Lipid Membranes Based on Solid-State NMR Spectroscopy, in: *Encyclopedia of Biophysics,* Roberts, G. C. K., and Watts, A. (Eds.), Springer-Verlag, Heidelberg **2020**. *Invited review.* http://doi.org/10.1007/978-3-642-35943-9_788-1.

159. Navidi, M.; Yadava, S.; Struts, A. V.; **Brown, M. F.**; Nesnas, N. Synthesis of 9-CD_3-9-*cis*-Retinal Cofactor of Isorhodopsin, *Tetrahedron Lett*. **2018,** *59*, 4521–4524. https://doi.org/10.1016/j.tetlet.2018.11.034

158. Perera, S. M. D. C.; Chawla, U.; Shrestha, U. R.; Bhowmik, D.; Struts, A. V.; Qian, S.; Chu, X.-Q.; **Brown, M. F.** Small-Angle Neutron Scattering Reveals Energy Landscape For Rhodopsin Photoactivation, *J. Phys. Chem. Lett*. **2018,** *9,* 7064–7071. https://doi.org/10.1021/acs.jpclett.8b03048 *6 citations.*

152. Perera, S. M. D. C.; Chawla, U.; **Brown, M. F.** Powdered G-Protein–Coupled Receptors, *J. Phys. Chem. Lett.,* **2016,** *7,* 4230-4235. https://doi.org/10.1021/acs.jpclett.6b02328 *8 citations.*

151. Shrestha, U. R.; Perera, S. M. D. C.; Bhowmik, D.; Chawla, U.; Mamontov, E.; **Brown, M. F.**; Chu, X.-Q. Quasi-Elastic Neutron Scattering Reveals Ligand-Induced Protein Dynamics of a G-Protein–Coupled Receptor, *J. Phys. Chem. Lett*. **2016,** *7,* 4130–4136. https://doi.org/10.1021/acs.jpclett.6b01632 *12 citations.*

150. Chawla, U.; Jiang, Y.; Zheng, W.; Kuang, L.; Perera, S. M. D. C.; **Brown, M. F**.; Liang, H. A Usual G-Protein-Coupled Receptor in Unusual Membranes, *Angew. Chem*. **2016,** *128*, 598–602. https://doi.org/10.1002/anie.201508648 *19 citations.*

147. Chawla, U.; Jiang, Y.; Zheng, W.; Kuang, L.; Perera, S. M. D. C.; **Brown, M. F**.; Liang, H. A Usual G-Protein-Coupled Receptor in Unusual Membranes, *Angew. Chem. Int. Ed*. **2015,** *54*, 1–6. https://doi.org/10.1002/anie.201508648 *19 citations.*

146. Feng, J.; **Brown, M. F.**; Mertz, B. Retinal Flip in Rhodopsin Activation?, *Biophys. J*. **2015,** *108*, 2767-2770. https://doi.org/10.1016/j.bpj.2015.04.040 *8 citations.*

145. Struts, A. V.; Barmasov, A. V.; **Brown, M. F.** Spectral Methods for Study of the G-Protein-Coupled Receptor Rhodopsin. I. Vibrational and Electronic Spectroscopy, *Opt. Spectrosc*. **2015,** *118*, 711-717. https://doi.org/10.1134/S0030400X15050240 *10 citations.*

137. Zhu, S.; **Brown, M. F**.; Feller, S. E. Retinal Conformation Governs pK_a of Protonated Schiff Base in Rhodopsin Activation, *J. Am. Chem. Soc*. **2013,** *135,* 9391–9398. https://doi.org/10.1021/acs.chemrev.6b00619 *31 citations*

131. **Brown, M. F.** UV–Visible and Infrared Methods for Investigating Lipid–Rhodopsin Membrane Interactions, in: *Membrane Protein Structure and Dynamics*, Klein-Seetharaman, J., and Vaidehi, N. Eds.), *Methods in Molecular Biology, Vol. 914*, Springer, **2012,** pp. 127–153. *Invited book chapter.*

121. Zaitseva, E.; **Brown, M. F.***; Vogel, R.* Sequential Rearrangement of Interhelical Networks Upon Rhodopsin Activation in Membranes: The Meta II_a Conformational Substate, *J. Am. Chem. Soc.* **2010**, *132,* 4815-4821. **Co-corresponding author.* https://doi.org/10.1021/ja910317a *44 citations.*

116. Subramaniam, V.; D'Ambruoso, G.; Hall, H. K., Jr.; Wysocki, R. J.; **Brown, M. F.**; Saavedra, S. S. Reconstitution of Rhodopsin into Polymerizable Planar Supported Lipid Bilayers: Influence of Dienoyl Monomer Structure, *Langmuir* **2008,** *24,* 11067-11075. *32 citations.*

114. Mahalingam, M.; Martínez-Mayorga, K.; **Brown, M. F.***; Vogel, R.* Two Protonation Switches Control Rhodopsin Activation in Membranes, *Proc. Natl. Acad. Sci. U.S.* **2008,** *A. 105,* 17795-17800. **Co-corresponding author.* https://doi.org/10.1073/pnas.0804541105 *146 citations.*

111. Michel, D.; Subramaniam, V.; McArthur, S.; Bondurant, B.; D'Ambruoso, G. D.; Hall, H. K., Jr.; **Brown, M. F.**; Ross, E. E.; Saavedra, S. S.; Castner, D. G. Ultra-High Vacuum Surface Analysis Study of Rhodopsin Incorporation into Supported Lipid Bilayers, *Langmuir* **2008,** *24,* 4901–4906. *30 citations.*

99. Alves, I. D.; Salgado, G. F. J.; Salamon, Z.; **Brown, M. F.**; Tollin, G.; Hruby, V. J. Phosphatidylethanolamine Enhances Rhodopsin Photoactivation and Transducin Binding in a Solid-Supported Lipid Bilayer as Determined Using Plasmon-Waveguide Resonance Spectroscopy, *Biophys. J.* **2005,** *88,* 198–210. *213 citations.*

98. Subramaniam, V.; Alves, I. D.; Salgado, G. F. J.; Lau, P.-W.; Wysocki, Jr., R. J.; Salamon, Z.; Tollin, G.; Hruby, V. J.; **Brown, M. F.**; Saavedra, S. S. Rhodopsin Reconstituted into a Planar-Supported Lipid Bilayer Retains Photoactivity after Cross-Linking Polymerization of Lipid Monomers, *J. Am. Chem. Soc.* **2005,** *127,* 5320-5321. *58 citations.*

90. Wang, Y.; Botelho, A. V.; Martinez, G. V.; **Brown, M. F**. Electrostatic Properties of Membrane Lipids Coupled to Metarhodopsin II Formation in Visual Transduction, *J. Am. Chem. Soc.* **2002,** *124,* 7690-7701. https://doi.org/10.1021/ja0200488 *55 citations.*

65. Salamon, Z.; Wang, Y.; Soulages, J. L.; **Brown, M. F.**; Tollin, G. Surface Plasmon Resonance Spectroscopy Studies of Membrane Proteins: Transducin Binding and Activation by Rhodopsin Monitored in Thin Membrane Films, *Biophys. J.* **1996,** *71,* 283-294. *96 citations.*

59. Salamon, Z.; Wang, Y.; **Brown, M. F.**; MacLeod, A.; Tollin, G. Conformational Changes in Rhodopsin Probed by Surface Plasmon Resonance Spectroscopy, *Biochemistry* **1994,** *33,* 13706-13711. *94 citations.*

24. Miljanich, G. P.; **Brown, M. F.**; Mabrey-Gaud, S.; Dratz, E. A.; Sturtevant, J. M., Thermotropic Behavior of Retinal Rod Membranes and Dispersions of Extracted Phospholipids, *J. Membrane Biol.* **1985** *85,* 79-86. *76 citations.*

Soft Matter and Biophysical Chemistry:

172. Fried,S. D. E.; Lewis, J. W.; Szundi, I.; Martinez-Mayorga, K.; Mahalingam, M.; Vogel, R; Kliger, D. S.; **Brown, M. F.** Membrane Curvature Revisited—the Archetype of Rhodopsin Studied by Time-Resolved Electronic Spectroscopy, *Biophys. J.* **2020**, in press.

171. Chawla, U.; Perera, S. M. D. C.; Fried, S. D. E.; Eitel, A. R.; Mertz, B.; Weerasinghe, N.; Pitman, M. C.; Struts, A. V.; and **Brown, M. F**. Activation of the G-Protein-Coupled Receptor Rhodopsin by Water, *Angew. Chem. Int. Ed.,* **2020**, *59,* https://doi.org/10.1002/anie.202003342.

165. Molugu, T. R.; Oita, R. C.; Chawla, U.; Wang, T.; **Brown, M. F.***; Garcia, J. G. N. Nicotinamide Phosphoribosyltransferase Purification Using SUMO Expression System, *Anal. Biochem.* **2020,***598*, 113597. **Co-corresponding author.*. https://doi.org/10.1016/j.ab.2020.113597

157. **Brown, M. F**.; Chawla, U.; Perera, S. M. D. C. Membrane Lipid-Protein Interactions, in: *The Biophysics of Cell Membranes: Biological Consequences*, Epand, R. M. and Ruysschaert, J.-M. Eds.), Springer Nature, Singapore, **2017,** pp. 61-84. *Invited review.* https://doi.org/10.1007/978-981-10-6244-5_3

155. **Brown, M. F.** Soft Matter in Lipid-Protein Interactions, *Annu. Rev. Biophys.* **2017***, 46*, 379–410. *Invited review.* https://doi.org/10.1146/annurev-biophys-070816-033843 *60 citations.*

149. Molugu, T. R.; Brown, M. F. Cholesterol-Induced Suppression of Membrane Elastic Fluctuations at the Atomistic Level, *Chem. Phys. Lipids* **2016,** *199*, 39-51. https://doi.org/10.1016/j.chemphyslip.2016.05.001 *15 citations.*

132. **Brown, M. F.** Curvature Forces in Membrane Lipid-Protein Interactions, *Biochemistry* **2012),** *51,* 9782–9795. *Invited review.* https://doi.org/10.1021/bi301332v *127 citations.*

122. Bartels, T.; Ahlstrom, L. S.; Leftin, A.; Kamp, F.; Haass, C.; **Brown, M. F.***; and Beyer, K. The N-Terminus of α-Synuclein Triggers Membrane Binding and Helix Folding, *Biophys. J.* **2010**, *99*, 1-9. **Corresponding author.* https://doi.org/10.1016/j.bpj.2010.06.035 *204 citations.*

102. Botelho, A. V.; Huber, T.; Sakmar, T. P.; **Brown, M. F.** Curvature and Hydrophobic Forces Drive Oligomerization and Modulate Activity of Rhodopsin in Membranes, *Biophys. J.* **2006***, 91*, 4464-4477. https://doi.org/10.1529/biophysj.106.082776 *26 citations.*

89. Endress, E.; Heller, H.; Casalta, H.; **Brown, M. F.**; Bayerl, T. M. Anisotropic motion and molecular dynamics of cholesterol, lanosterol, and ergosterol in lecithin bilayers studied by quasi-elastic neutron scattering, *Biochemistry* **2002,** *41,* 13078-13086. *92 citations.*

86. Botelho, A. V.; Gibson, N. J.; Thurmond, R. L.; Wang, Y.; **Brown, M. F.** Conformational Energetics of Rhodopsin Modulated by Nonlamellar-forming Lipids, *Biochemistry* **2002,** *41,* 6354-6368. https://doi.org/10.1021/bi011995g *188 citations.*

79. Salamon, Z.; **Brown, M. F.**; Tollin, G. Plasmon Resonance Spectroscopy: Probing Molecular Interactions within Membranes, *Trends Biochem. Sci.* **1999,** *24,* 213-219. *Invited review.* *174 citations.*

74. Kasal, A.; Budesinsky, M.; Pelnar, J.; Bruck, M. A.; **Brown, M. F.** Structures and Synthesis of A-Homo-B,19-dinorsteroids by X-Ray Crystallography and NMR Spectroscopy, *Collect. Czech. Chem. Commun.* **1999,** *64,* 2019-2034.

69. **Brown, M. F.** Influence of Nonlamellar-Forming Lipids on Rhodopsin, in: *Lipid Polymorphism and Membrane Properties* (Epand, R. M., Ed.), *Current Topics in Membranes, Vol. 44,* Academic Press, San Diego, **1997,** pp. 285-356. *Invited book chapter.* *78 citations.*

60. **Brown, M. F.** Modulation of Rhodopsin Function by Properties of the Membrane Bilayer, *Chem. Phys. Lipids* **1994**, *73*, 159-180. https://doi.org/10.1016/0009-3084(9490180-5 *461 citations.*

54. Gibson, N. J.; **Brown, M. F.** Lipid Headgroup and Acyl Chain Composition Modulate the MI-MII Equilibrium of Rhodopsin in Recombinant Membranes, *Biochemistry* **1993,** *32,* 2438-2454. *195 citations.*

53. **Brown, M. F.;** Gibson, N. J. Biological Function of Docosahexaenoic Acid in the Retinal Rod Disk Membrane, in *Essential Fatty Acids and Eicosanoids* (Sinclair, A., and Gibson, R., Eds.), American Oil Chemist's Society Press, Champaign, Illinois, **1992,** pp. 134-138. *Invited review.*

48. Lamparski, H.; Liman, U.; Barry, J. A.; Frankel, D. A.; Ramaswami, V.; **Brown, M. F.**; O'Brien, D. F. Photoinduced Destabilization of Liposomes, *Biochemistry* **1992,** *31,* 685-694. *106 citations.*

47. Gibson, N. J.; **Brown, M. F.** Role of Phosphatidylserine in the MI-MII Equilibrium of Rhodopsin, *Biochem. Biophys. Res. Commun.* **1991,** *176,* 915-921. *34 citations.*

46. Thurmond, R. L.; Lindblom, G.; **Brown, M. F.** Effect of Bile Salts on Monolayer Curvature of a Phosphatidylethanolamine/Water Model Membrane System, *Biophys. J.* **1991,** *60,* 728-732. *28 citations.*

45. Gibson, N. J.; **Brown, M. F.** Membrane Lipid Influences on the Energetics of the MI and MII Conformational States of Rhodopsin Probed by Flash Photolysis, *Photochem. Photobiol.* **1991,** *54,* 985-992. *37 citations.*

38. Gibson, N. J.; **Brown, M. F.** Influence of pH on the MI-MII Equilibrium of Rhodopsin in Recombinant Membranes, *Biochem. Biophys. Res. Commun.* **1990,** *169,* 1028-1034. *21 citations.*

32. Wiedmann, T. S.; Pates, R. D.; Beach, J. M.; Salmon, A.; **Brown, M. F.** Lipid-Protein Interactions Mediate Photochemical Function of Rhodopsin, *Biochemistry* **1988,** *27,* 6469-6474. *179 citations.*

12. Fleischer, S.; Wang, C.-T.; Hymel, L.; Seelig, J.; **Brown, M. F**.; Herbette, L.; Scarpa, A.; McLaughlin, A. C.; Blasie, J. K. Structural Studies of the Sarcoplasmic Reticulum Membrane Using the Reconstitution Approach, in *Function and Molecular Aspects of Biomembrane Transport* (Quagliariello, E., et al., Eds.) Elsevier/North-Holland, Amsterdam, **1979,** pp. 465-485. *Invited book chapter.*

9. Omar, S.; **Brown, M. F.**; Silver, P.; Schleich, T. Histidyl and Tyrosyl Residue Ionization Studies of Subtilisin Novo, *Biochim. Biophys. Acta* **1979,** *578,* 261-268.

6. **Brown, M. F.**; Schleich, T. Resolution of Independently Titrating Spectral Components in the Ultraviolet Circular Dichroism of Subtilisin Enzymes by Matrix Rank Analysis, *Biochim. Biophys. Acta* **1977,** *485,* 37-51.

5. **Brown, M. F**.; Omar, S.; Raubach, R. A.; Schleich, T. Quenching of The Tyrosyl and Tryptophyl Fluorescence of Subtilisins Carslberg and Novo by Iodide, *Biochemistry* **1977,** *16,* 987-992. *26 citations.*

1. **Brown, M. F.**; Schleich, T. Circular Dichroism and Gel Filtration Behavior of Subtilisin Enzymes in Concentrated Solutions of Guanidine Hydrochloride, *Biochemistry* **1975,** *14,* 3069-3074. *20 citations.*