Bob Eisenberg

(more formally, Robert S. Eisenberg)

Curriculum Vitae

October 5, 2016

Work co-ordinates

Address

Department of Molecular Biophysics and Physiology
Rush University
1750 West Harrison, Room 1577a Jelke
Chicago IL 60612

Phone numbers

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Skype name: beisenbe
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Alternative email: bob.eisenberg@gmail.com

Education

Elementary School: New Rochelle, New York

High School, 1956-59. Horace Mann School, Riverdale, New York City, graduated in three years with honors and awards in Biology, Chemistry, Physics, Mathematics, Latin, English, and History. An interviewer of J.R. Pappenheimer on American Heart Sponsored television program, ~1957.

Undergraduate, 1959-62. Entered Harvard College with Advanced Placement as a sophomore, concentrated in Biochemical Sciences, Prof. J.T. Edsall tutor and mentor; advisor in Physiology Prof. J.R. Pappenheimer; graduated in three years A.B., *summa cum laude*.

Summer work, 1960-61. Nerve Muscle Program at Marine Biological Laboratory directed by Prof. S.W. Kuffler.

Doctoral work: University College London 1962-65 (Ph.D. in Biophysics: B. Katz, Chairman); Supervisor, P. Fatt; External Examiner, A.L. Hodgkin. Mentor (over several decades): A.F. Huxley.

Academic Positions

Main Positions

Rush Medical College, Chicago IL. Rush Employee ID 010207

2015 - …	Chairman *emeritus,* Molecular Biophysics and Physiology
1995- 2015	Chairman of Molecular Biophysics and Physiology *(Department renamed)*
1976 -…	Endowed Chair "The Francis N. and Catherine O. Bard Chair of Physiology "
1976-1995	Chairman of Physiology: first and founding Chairman

University of California at Los Angeles

1975-1976	Professor of Biomathematics and Physiology, Chairmen: Carol Newton, W. Mommaerts
1970-1975	Associate Professor, Department of Physiology

1968-1970 Assistant Professor, Department of Physiology

Duke University, Durham NC

Associate, 1965-1968. Dept. of Physiology, Duke University, Chairman: D. Tosteson. Post-doctoral fellow of P. Horowicz, along with P. Gage, C. Armstrong, etc.

Secondary Positions

Visiting Scientist, long term. Mathematical Biology Institute. Ohio State University (2015)

eisenberg.77@osu.edu

Adjunct Professor, Dept of Bioengineering, University of Illinois Chicago 2007- …

UIN 658809751

Miller Institute Professor, University of California, Berkeley, October, 2012-February 2013, sponsored by Department of Chemistry, Rich Saykally in particular. ID 012503669

Visiting Scholar, Dept of Mathematics, Pennsylvania State University 2011.ID 9 82583348

Senior Scientist, Argonne National Laboratory (Mathematics and Computer Science Division, 2005 – 2011 Badge number B0 56980 A

Schlumberger Visiting Professor, University of Cambridge (UK) 2002

Visiting Fellow, Corpus Christi College, University of Cambridge (UK) 2002

Visiting Professor, 2000-2003 Computational Electronics, Beckman Institute, University of Illinois, Urbana Champaign

Visiting Scientist, 1991-1995. Physics, Brookhaven National Laboratory, Upton, NY.

Honors

Visiting Scientist, long term. Mathematical Biosciences Institute. Ohio State University.

Lakeside Lecture, Academia Sinica and Depatment of Mathematics, National Taiwan University, 2013. Organizers: Yi -Chiuan Chen, Chen -Yu Chi, Chun -Chung Hsieh, Jeng -Daw Yu

Keynote Speaker, Science Week, Loyola University (Chicago), 2013.

Miller Visiting Professor, Miller Institute for Basic Research in Science and Department of Chemistry, University of California, Berkeley, October-February, 2012-2013.

Keynote and Summary Speaker, National Taiwan University Taipei “Workshop on Mathematical Models of Electrolytes Applied to Molecular Biology”, January, 2012; December, 2013. Tai-Chia Lin 林太家 Organizer)

Keynote Speaker, Lancaster University: Conference on Fluctuations and Coherence. (2011) see www.physics.lancs.ac.uk/FluctuationsConference2011/talks.htm

Keynote Speaker, Oak Ridge National Laboratory and University of Tennessee, Knoxville. Summer School on Biophysics: Computational and Theoretical Challenges (2010).

Institute of Medicine of Chicago

Senior and Life Member of the IEEE

Argonne National Laboratory: Director’s Seminar

Fellow, American Physical Society (Division of Biological Physics)

Member Executive Board, American Physical Society (2002-2004)

Plenary Lecture at European Mathematics Society/AMAM 2003

Schlumberger Medal, Physical Chemistry, University of Cambridge, UK

Schlumberger Visiting Professor, University of Cambridge (UK)

Visiting Fellow, Corpus Christi College, University of Cambridge (UK)

Associate Editor, News in Physiological Sciences, 1988-1992

Associate Editor, Comments on Theoretical Biology, 1987-1992

Editorial Board, Journal of General Physiology, 1970-1991

Editorial Board, Journal of Computational Electronics, 2001-2013

Senior Common Room Award for "Most Promising Scholar"
L.J. Henderson award for thesis in Biochemical Sciences
A.B. received *summa cum laude*, after three years at Harvard College.
Harvard College Scholarship
Phi Beta Kappa: member of "Senior Sixteen", in second year at Harvard College.

Personal

Home co-ordinates:

Address: 7320 Lake Street, Unit 5, River Forest IL 60305
Phone: (708)-366-6332
Personal FAX: (801)-504-8665 and also (775)-256-9463

Born in Brooklyn, New York, April 25, 1942: Citizen of the United States.
Social Security Number 075-xx-xxxx.
Married Ardyth Eisenberg, 1991.

Children (mother, Brenda Russell, formerly Brenda R. Eisenberg, from 1964 to 1988):
Benjamin Russell Eisenberg, born March 17, 1969.
Grandchild, mother Angelle Moutoussamy
Crystal Lynn Moutoussamy, born March 19, 1994
Emily Ruth Eisenberg, born February 8, 1973. Husband, Benjamin Taylor
Jill Anna Trowbridge (formerly Jill A. Eisenberg), born November 7, 1974.
Grandchildren, father John Trowbridge
James Louis Trowbridge, born August 15, 1997.
Holly Sophia Trowbridge, born July 11, 2000.
Henry Samuel Trowbridge, born January 15, 2004.
Alastair Solomon Trowbridge, born January 10, 2006
Sally Lynn Eisenberg, born June 20, 1979.

Family Christmas Letters: [2001] [2003] [2004] [2005] [2006] [2007] [2008] [2009] [2010] [2011] [2012] [2013] [2014] [2015]

Family Photos (unedited) from many years are at *Family photos* or *https://picasaweb.google.com/111845037112506820480*

Life Glimpsed through Ion Channels

A Super Short Scientific Biography

See Living History
http://www.the-aps.org/mm/Membership/Living-History/Robert-Eisenberg
or
https://www.youtube.com/watch?v=wj7QiLAv61E

I have been interested in how physical things work as long as I can remember, and in how living things work nearly as long, from the day my father (a physician and then psychiatrist) showed me that was the best way to mold my interests to his approval.

At Harvard John Edsall was my tutor, and he did in fact tutor me, biweekly at first and then (nearly) weekly, nominally in biology, but really in the wisdom of science. (John Edsall was born the son of a Dean of Harvard Medical School, and was a fulcrum for the pivotal change from macroscopic to molecular biology at Harvard and elsewhere, training Bruce Alberts, David Eisenberg, and Jared Diamond among many other distinguished scientists.) My coursework was in physics, chemistry, applied mathematics, and electrical engineering, but, if my memory serves me correctly, not in biology at all. (I actually love evolutionary and descriptive biology as I love collecting classical CD's but those loves are hobbies more than anything else.) My undergraduate thesis solved the cable equation of physiology (the transmission line equations of engineering) with a Green's function, reproducing in an elegant but useless way what I had learned from Morse & Feshbach about heat equations.

My graduate work was experimental at University College London, where my department chairman Bernard Katz was to win the Nobel Prize a few years later. Fortunately, Andrew Huxley (Chair of Physiology at UCL, winner of the Nobel Prize with Alan Hodgkin in 1964 a year or two before Bernard Katz, if I remember correctly) had solved the cable equations the way I had, but much earlier and much more originally and insightfully, and so was happy to spend many hours teaching me, on the side, as if he didn't have enough else to do. My experimental work measured the spread of current in crab muscle fibers over a range of frequencies, using impedance spectroscopy, as it is now rather pretentiously named.

I will not bore you with the many decades of experimental work I did analyzing the flow of current in muscle fibers and then the lens of the eye. I became a Department Chairman at Rush Medical College in Chicago in 1976: the temptation of an Endowed Chair was enough to make a 34 year old move from the perpetual spring of Brentwood (LA) to the recurrent vagaries of midwestern weather. In the 1980's, I started thinking about the theoretical problem of describing ion movement through the water filled tunnels of charge we call ionic channels.

The ionic channel is where we still are; but gazing through this narrow hole has proven to be rather like looking through a keyhole in a door. The closer you get to it, the further you can see, even glimpsing the horizon (of knowledge) occasionally, even seeing a star or two, when all else seems dark.

Scientific Biography

I received my A.B. (summa cum laude) at Harvard College after three years of study with John Edsall as tutor. I started studying electrical properties of cells at Harvard Medical School (Physiology) with John Pappenheimer and at his recommendation I was accepted into Steve Kuffler's Nerve Muscle Training Program at the Marine Biological Laboratory, Woods Hole. At the MBL for three summers, I got to know Alan Hodkin, Bob Taylor, K.C. Cole, John Moore, and too many others to name. I went to University College London for my Ph.D. with Paul Fatt as supervisor, where Bernard Katz was Chairman. Alan Hodgkin was my external examiner (and scientific hero!) and Andrew Huxley my mentor, for many years. My Ph.D. thesis and later work for a decade or two used engineering methods (impedance measurements: dielectric spectroscopy of single cells) to determine the electrical structure of cells and tissues (skeletal muscle, cardiac muscle, lens of the eye). I developed mathematical models to describe the electrical and physical structure mostly using methods of singular perturbation theory (working with Julian Cole, Victor Barcilon, and Art Peskoff). I helped Brenda Eisenberg use statistical sampling methods of stereology to measure the structure. As a postdoc at Duke (Physiology), Brenda and I showed that glycerol treatment disconnected the T-tubular system of skeletal muscle, and Peter Gage and I studied the electrical properties of the resulting detubulated preaparation. I rose through the academic ranks at UCLA, and was appointed the first Chairman of the Department of Physiology at Rush Medical College in Chicago when I was 33 years old. I am still there, in the same position.

I served as Chairman of the Physiology Study Section of the NIH for several years, and Director of Research (etc) for the American Heart Association (Chicago Branch). After single channel recording was discovered, I introduced Alan Finkel (Axon Instruments), Rick Levis, and Jim Rae to the patch clamp technique, and invented the integrating headstage after thinking hard about how to increase the impedance and reduce the noise of the feedback element in a current to voltage converter. Together we designed the Axopatch amplifier that is used by thousands of channologists to this day.

I have spent many years working on ion channels, which are protein nanovalves that control an enormous range of biological function. I am trying to understand the current that flows through the channel, in a range of solutions of different composition, over a range of voltages. Working with Zeev Schuss, I showed how the flux over a potential barrier of any shape could be evaluated analytically, starting from a description of the stochastic trajectories of diffusion. 'Eyring models' of transition state theory arise as a special case of very high symmetrical barriers and it is hardly easier to compute than the general formulas.

Zeev Schuss, Boaz Nadler, Amit Singer, and I went on to show how mean field models can be derived from a model of the stochastic trajectories of ions in solution, using the techniques of probability theory and a classical closure approximation.

I adopted the drift diffusion equations of semiconductor physics, introduced them with their use of doping to represent the permanent charge of side chains of proteins (e.g., the acidic and

basic side chains glutamate and lysine), and gave them the nickname PNP to remind people that proteins could have charge distributions like those of transistors and might (conceivably) function that way.

Working with Wolfgang Nonner, then Dirk Gillespie, Dezső Boda, Doug Henderson and others, I showed how the properties of concentrated electrolytes (as summarized in the primitive model of ionic solutions) can account for selectivity of two important types of channels, the L-type calcium channel of the heart and the voltage activated Na^+ channel of nerve.

I also

(1) helped design and build selective channels using nonselective bacterial channels (ompF porin) as the 'substrate' (with Hank Miedema, et al, from Groningen),

(2) helped design abiotic ionic channels (which Zuzanna Siwy builds),

(3) helped Weishi Liu apply geometric perturbation theory to ion channels,

(4) used the mathematics of inverse problems to design the selectivity and permanent charge of channels, assisting Heinz Engl and Martin Burger. This paper is particularly unusual since it is one of the few cases in which an inverse problem of significance to biology could be solved in detail and with quite robust results.

(5) worked with Dezső Boda, Doug Henderson, Dirk Gillespie and Wolfgang Nonner to extend the crowded charge model of selectivity from calcium channels to the Na channel of nerve, showing that the same model can explain both (very different) types of channels ***without changing any parameters***, just by reproducing the mutation (known from experiment) to change one channel type into another, EEEA ↔ DEKA, i.e. Glu-Glu-Glu-Ala ↔ Asp-Glu-Lys-Ala. This work shows that a single model with just one set of never changing parameters can account for the selectivity properties of two very different types of channels (Na channel of nerve and Ca channel of muscle). When the side chains in the channel protein are changed in the model, the protein changes selectivity just as it does in life. This work also reveals control parameters for the Na channel: the dielectric coefficient changes the contents of the channel, and has almost no effect on Na^+ *vs.* K^+ selectivity. The diameter of the selectivity filter changes the Na^+ *vs.* K^+ selectivity and has almost no effect on the contents of the channel.

(6) showed (with the same collaborators) that calcium selectivity does not arise from models of the L-type Ca channel that do not allow Glu residues to mix with ions.

(7) suggested that the simple model of selectivity works so well because it computes the important structures of the selectivity filter. These models put the 'side chains' into their optimal position (with minimal free energy) and thus determines the 'optimal' relation of side chains and permeating ions. These methods compute a self-organized selectivity filter in which the induced fit of side chains and ions is determined by the positions of the ions and side chains at thermodynamic equilibrium. The model computes the structure of the selectivity filter and that structure changes significantly from one solution to another.

(8) started to apply the energy variational principle developed by Chun Liu and collaborators to

problems in ion permeation, selectivity, gating (with YunKyong Hyon and Chun) and to new subjects of water movement (with Yoichiro Mori and Chun) and vesicle formation and fusion (with Fred Cohen, Rolf Ryham, and Chun). The variational principle allows the coupling of different interacting structures and different physical properties of a single system in a mathematically well defined and (automatically) self-consistent way. It produces different partial differential equations and boundary conditions depending on the structures, physics, and coupling included in the underlying model. It thus seems ideally suited to the complexity of ions and water in solution, channels, and tissues, as well as to the interactions of multiple systems and physics that produce flow of ions and water and movement of membranes and cells and tissues in biological systems.

(9) Along the way, I helped Amit Singer (working with Zeev Schuss) show why the charge distribution of table salt (NaCl) does not produce sparks and electrocute those who touch it. Safety in salt is a consequence of probability theory, among other things, as all salt eaters should be glad to know.

(10) Moving to new methods and questions, I grew curious about the density of charged amino acids in active sites. The density of charge is enormous in ion channels and I wondered if it was also high in active sites of enzymes in general. Jie Liang, David Jimenez-Morales and I have used some wonderful search algorithms designed and implemented by Jie and David and found huge densities of acid (presumably negative) and basic (presumably positive) side chains in active sites, some 20 Molar (for comparison solid sodium chloride is 37 Molar). This very special charged environment seems likely to have been selected by evolution for a particular physical reason that we do not know.

(11) The traditional laws of chemistry do not apply well in environments as crowded as ion channels or active sites so I looked up the derivation of the classical ‘law’ of mass action that is taught to every graduate student in chemistry and most undergraduates as well. I found to my horror that the law is true (with constant rate constants) only when solutions are infinitely dilute and have no interactions between solutes. Since all ionic solutions have solutes that interact through the electric field, ionic solutions should not be described as they almost always have been in biochemistry and physiology. Ionic solutions do not obey the ‘law’ of mass action (with constant rate constants). Thousands of papers explain interactions by invoking conformation changes of enzymes and channels, or assuming complex reaction schemes and allosteric interactions (for example). Those explanations and schemes nearly always use rate constants that are constant. If they used variable rate constants that capture physical interactions of ions, the schemes and explanations would surely change dramatically, and might disappear altogether in some cases.

(12) Thinking about the law of mass action, I realized the obvious. It is incompatible with Kirchoff’s current law which is nearly the same as Maxwell’s equations. Maxwell/Kirchoff are about conservation of charge. (Indeed, ‘charge’is an abstract quantity, unlike mass, that assumes different physical form in different settings. The charge flowing in a vacuum capacitor is not the charge flowing in a wire, or the charge flowing in an ionic solution. Maxwell’s equations apply to the abstraction charge not just to electrons, ions, etc.) Maxwell and Kirchoff are global, involving locations far apart. Mass action is about conservation of mass. Mass action is local involving only

locations of reactants and products, close together. It is obvious once all this is stated, that the law of mass action (applied to a series of chemical reactions ***at different physical locations*** and with rate constants that are constant) is incompatible the Kirchoff's current law. It is easy to prove this by writing out the flux in such reactions and comparing it to the flow of current. They cannot be identical in general because one depends on the charge on the reactants (e.g., 'the valence') and one does not. The implications are profound because Maxwell's equations (nearly) always involve boundary conditions often far far away from a particular place. Chemical reactions are usually thought to be local, but if they involve charge movement from one place to another, they must satisfy Maxwell's equations and be described by global equations that usually depend on conditions far far away. The local law of mass action must be replaced then by chemical laws in which everything interacts with everything else according to Maxwell, and current flows in loops as described by Kirchoff's current law.

(12) Many of the properties of open channels are determined by the balance between electrostatic and steric forces among the ions and side chains crowded into a narrow space. 'Everything interacts with everything else' in systems like this and so the mathematics used to simulate or compute models must deal consistently with interactions. That is, every variable must satisfy every equation and boundary condition in all experimental situations. Such consistency is very difficult to satisfy in simulations that have full atomic detail and in fact very few checks of such consistency have been made and none (that I know of) in realistic ionic conditions, including the ionic mixtures (that involve calcium ions) actually found on either side of a channel.

Theories can ensure consistency if they are derived by the Energy Variational methods that include dissipation (i.e., friction) but those theories compute steric forces explicitly (in three dimensions) from Lennard Jones or Yukawa type models of atom atom interaction. Such computations are very difficult because the steric forces vary so steeply with location. Another approach is to replace those calculations with a careful treatment of the main consequence of steric forces. The main consequence is that ions cannot overfill a volume: there is a maxium number of ions that can fit in a volume. The concentration in a volume saturates. This approach depends on the calculation of the free energy of mixtures of spheres of any diameter in any concentrations. Jinn-Liang Liu has led the way in such calculations.

Internet Coordinates ***Web Sites***

Departmental Site: http://www.phys.rush.edu/
leading to Personal Site http://www.phys.rush.edu/RSEisenberg/
Living History http://www.the-aps.org/mm/Membership/Living-History/Robert-Eisenberg

***FTP* Sites**

1) Reprints available on this hyperlink
   or by anonymous ftp from ftp.rush.edu.
   (sign on as anonymous, for password; use your email address)
   Migrate to /molebio/Bob_Eisenberg/Reprints
   or just click on this hyperlink
2) *PNP* is available in various flavors,
   a. from ftp.rush.edu at
   /pub/PNP/; /pub/Hollerbach/; /pub/Nonner/,
   thank you: D. Chen, U. Hollerbach, W. Nonner and S-W. Chiu.
   b. See a much more modern (2008) version from Department of Chemistry, Northwestern University, Laboratories of Mark Ratner and George Schatz labs https://www.nanohub.org/resources/2469
3) Files of single channel currents with noise are in /pub/Noise, written in collaboration with Rick Levis *(deceased, 2005*).

Grant Support

Continuous Grant Support (without interruption) thanks to a combination of NSF, NIH, and DARPA from approximately 1970 to 2011. Miscellaneous additional grants from AHA, MDA, Chicago Heart, etc.

Scientific Administration

FIRST CHAIRMAN OF DEPARTMENT OF MOLECULAR BIOPHYSICS AND PHYSIOLOGY**,** 1976-2014, see science at http://www.phys.rush.edu/physiofac.html

AMERICAN PHYSICAL SOCIETY
Councilor (First term: 2000-2004)
Councilor (Second term: 2005-2009)
Member of Executive Board (2002-2004)
Member, Committee on Committees (2003- 2006, 2009)
Member, Audit Committee (2004 - 2007), Chair Audit Committee (2005 – 2006)
Division of Biological Physics, Executive Board (2001- 2010)

BIOPHYSICAL SOCIETY
Member of U.S. National Committee International Union of Pure and Applied Biophysics (1978-1983)
Member of Council (1983-1986).
Member of Executive Board (1983-1986).
Member of Program Committee (1984).

Chairman of Nominating Committee (1985).
Chairman of Science Public Policy Committee (1985-1987).

CHICAGO CHAPTER OF SOCIETY FOR NEUROSCIENCE
Member of Council (1981-1984), Meeting Organizer, then President.

CHICAGO HEART ASSOCIATION
Member, Vice Chairman, then Chairman of the Research Council (1982-1986).
Member, Vice Chairman, then Chairman of Research Review Committee (1976-1986; 1989).

NATIONAL ACADEMY OF SCIENCES
Chairman Proposal Review for Allocation of Supercomputer Time for the Study of Molecular Dynamics: 2015 (ANTON 1), 2016 (ANTON 2)

NATIONAL INSTITUTES OF HEALTH
Member (1979-1981), then Chairman (1981-1983) of Physiology Study Section.
Member *ad hoc* (2004) Modeling & Analysis of Biological Systems Study Section.

NATIONAL SCIENCE FOUNDATION
Member, Steering Committee on Biology and Mathematics (1989, 1996).

PENNSYLVANIA MUSCLE INSTITUTE
Member (1980-1982; 1989-1990), then Chairman (1982-1987; 1989-1990) of the External Advisory Board, University of Pennsylvania, Director: A. Somlyo (1980-1987); Y. Goldman (1989-1990).

SOCIETY OF GENERAL PHYSIOLOGISTS
Councilor; Chairman, Membership Committee.

UNIVERSITY OF MIAMI
External review of Graduate Program, Department of Physiology (1988).

Invited Lectures On-Line ***click here [PPTX] and/or***

(1) Miscellaneous slides at SlideShare http://www.slideshare.net/: search for Bob Eisenberg
(2) Thanks to the Fields Institute, University of Toronto, a **three hour tutorial and lecture** with slides are available for viewing at links Part 1a or Part 1b and Part 2a or Part 2b.

(3) Thanks to Joe Cychosz of Nanohub, Electrical and Computer Engineering ECE Purdue, **lectures from January, 2014** in (1) Chemistry, [Slides: PDF] (2) Mathematics [Slides: PDF] and (3) a Student Talk in Engineering, [Slides: PDF], are all available at https://nanohub.org/members/16305/contributions

(4) Thanks to Lancaster University Physics Department. Slides from Bob's lecture of July, 2011 at Lancashire July 2011. i.e., www.physics.lancs.ac.uk/FluctuationsConference2011/talks.htm

(5) Thanks to the Mathematical Biology Institute, Ohio State University, my lecture (with slides) from April 2011 is available at MBI April 2011, i.e.,
http://beta.mbi.ohio-state.edu/video/player/?id=549&title=Ions+in+Channels%3A+important+biology+ready+for+mathematical+analysis

(6) Thanks to Institute for Mathematics and its Applications, University of Minnesota, my lecture of December 2008 is available (with slides) at [Talks and PDF], i.e., http://www.ima.umn.edu/2008-2009/W12.8-12.08/abstracts.html#Eisenberg-Robert

(7) Thanks to Joe Cychosz of Nanohub, Electrical and Computer Engineering ECE Purdue, lecture from 2008 is available for viewing at http://www.nanohub.org/resources/4726/ [Talk]: *"Ionic Selectivity in Channels: complex biology created by the balance of simple physics."* Nanotechnology 501 Lecture Series: Purdue University.

(8) Thanks to Institute for Mathematics and its Applications, University of Minnesota, my lecture of July 2015 is available (with slides) at [Talks] and [PDF]. i.e., http://www.ima.umn.edu/videos/?id=3028

(9) Thanks to Shanghai Jiao Tong University, slides from 2016 short course are on Lectures Day 1, Day 2, Day 3

Invited Lectures (approximately 360 as of December, 2015)

Academia Sinica and Depatment of Mathematics, Lakeside Lecture, National Taiwan University, 2013. Organizers: Yi -Chiuan Chen, Chen -Yu Chi, Chun -Chung Hsieh, Jeng -Daw Yu
Albert Einstein College of Medicine
American Chemical Society, National Meeting, Division of Physical Chemistry
American Chemical Society, National Meeting, 2008, Division of Physical Chemistry Symposium: Water Mediated Interactions, Dor Ben-Amotz, H. Asbaugh, Organizers.
American Heart Association
AMA Institute (1966)
American Mathematical Society, 2012, Central Section, co-organizer (with Weishi Liu and Chun Liu) and speaker in "Special Session on Mathematics of Ion Channels: Life's Transistors"
American Mathematical Society, 2015, Central Sectional Meeting, Lead-off speaker,
American Physical Society (Division of Biological Physics) March Meeting, 2000
American Physical Society (Division of Biological Physics) March Meeting, 2006
American Physical Society (Division of Biological Physics) March Meeting 2009

American Chemical Society Meeting, San Francisco, 2000
American Physiological Society Meeting: 1978, 1979, 1983
Argonne National Laboratory Chemical Sciences
Argonne National Laboratory Material Sciences Division
Argonne National Laboratory Mathematics and Computer Sciences Division
Argonne National Laboratory Biology Division
Argonne National Laboratory: Director's Seminar
Association of Chairmen of Departments of Physiology
Australian National University (Canberra)
Banff International Research Station BIRS "Ion Channels- Mathematical Modeling and Analysis" 16frg212, September 2016, Bob Eisenberg, Chun Liu and Huaxiong Huang, organizers
Banff International Research Station BIRS, lead-off speaker at workshop "Ion Transport: Electrodiffusion, Electrohydrodynamics and Homogenization" 16w51, May 2016, Huaxiong Huang and Chun Liu, organizers
Baylor University
Biological Chemists of the Federal Republic of Germany
Biophysical Society, 1991: *in* Symposium on Ion Channels in Intracellular Membranes
Biophysical Society, 1993. Workshop on "From Structure to Permeation in Open Ionic Channels."
Biophysical Society, 2007: *in* Symposium on Modeling as a Tool in Biophysics; Sponsor American Physical Society (Division of Biological Physics)
Biozentrum (Basel, Switzerland): Minicourse on Electrophysiology
Biozentrum (Basel, Switzerland): Selectivity in Channels (Seminar in Structural Biology)
Birkbeck College, London, Institute of Structural and Molecular Biology, Bonnie Wallace, host, May 2016.
Boston University (Department of Mathematics)
Brandeis University (Department of Biochemistry, Host: Chris Miller, 1986; Department of Chemistry, Host: Judy Herzfeld, 2008)
Brigham Young University (Zoology), ~1998
Brigham Young University (Chemistry), 2010
Brigham Young University (Computer Science), 2010
Brigham Young University (Zoology and Neuroscience), 2010
Brigham Young University (Henderson Symposium), 2014
Brookhaven National Laboratory (Department of Physics)
California Institute of Technology (Biology)
California Institute of Technology (Applied Mathematics)
Cambridge University (England) Physiology: Foster Club
Cambridge University (England) Chemistry, *in* the "Lennard Jones Lecture Series"
Cambridge University (England) Pharmacology
Cambridge (England): Schlumberger Lecture, 2002
Cambridge University (England) Centre for Computational Chemistry

Cambridge University (England), Department of Physics, Maxwell Centre, Ulrich Keyser, host, May 2016.
Cambridge University (England), Department of Mathematics, Newton Centre, David Holcman, host, May, 2016.
CCNY, Department of Physics, Mike Lubell Chairman
CECAM: Ionic Transport: from Nanopores to Biological Channels (Organizers Mounir Tarek and Mark Sansom, Lyon (2007)
Centro de Investigacion y de Estudios del Avanzados (Mexico City)
Chicago Heart Association Cardiovascular Research Forum
Chicago Medical School
Chinese Academy of Sciences CAS (Beijing) Institute of Computational Mathematics (Ben-Zhuo Lu, host, 2012)
City of Hope, Duarte, California
K.S. Cole Symposium (FASEB Federation of American Societies of Experimental Biology, 1974)
Colorado State University (Fort Collins: Department of Chemistry)
Columbia University, Department of Chemical Engineering
Conference on Fluctuations, Escape, and Optimal Control Traverse City MI
Conference of N.Y. Academy of Science, 1977
Cornell University Medical School: Department of Physiology
Cornell University: Department of Chemistry
Courant Institute (NYU) Seminar "Mostly Biomathematics" (2004)
Courant Institute (NYU) Joint Seminar with Chun Liu, Yoichiro Mori, "Mostly Biomathematics (2010)
DARPA (Defense Advanced Research Projects Agency)
Many workshops.
Director's Seminar, 2001
DSRC (Defense Sciences Research Council) Workshop on Biosensors
Dominican University (River Forest IL)
Draper Institute (September 2016) Dan Freeman, host.
Duke University Department of Physiology. Hosts Dan Tosteson and Paul Horowicz, 1964.
DuPont Experimental Station, Wilmington DE
European Mathematics Society: Plenary Lecture at AMAM 2003 (Applied Math …)
Participant (not speaker) at EMBO Meeting in honor of retirement of Max Perutz at Kings College, Cambridge, 1980
Emory University, Department of Physiology
Faraday Discussion 160: Ion Specific Hofmeister Effects, Queen's College Oxford September, 2012, Pavel Jungwirth, Organizer
Fields Institute, University of Toronto, Workshop on Transport of Ionic Particles in Biological Environments July, 2014, Organizer: Chun Liu, Maxx Metti . A **three hour tutorial and lecture** with slides are at hyperlinks Part 1a or Part 1b and Part 2a or Part 2b.

Fields Institute Lecture, University of Toronto, November 2014
Fine Structure Society (Rosemont IL 1995)
Florida State University: Inaugural Workshop for Computational Science, 2000
FOCUS 2000, DARPA workshop, Session Leader, Speaker, Plenary Session
Fordham University, Biology and Mathematics Seminar October 2010
Frontiers in Mathematical Biology: NSF-NIH Meeting, 2010 CSCAMM University of Maryland , Invited Speaker
Frontiers in Applied and Computational Mathematics FACM, 2012, NJIT
Free University of Berlin Instituteof Chemistry and Biochemical Modeling
Fudan University, Shanghai, Department of Mathematics, Lectures on Biomathematics, 2011, organizer Chun Liu.
Gordon Conference on Smooth Muscle, 1973
Gordon Conference on Skeletal Muscle, 1980
Gordon Conference on Skeletal Muscle, 1983
Gordon Conference on Skeletal Muscle, 1985
Gordon Conference on Solid State Ionics, 1990
Gordon Conference on Ion Channels, 1998
Gordon Conference on Ion Channels, 2000
Gordon Conference on Water, 2010
Grinnell College, Department of Biology
Harvard University, Cambridge (Biology, Host Howard Berg)
Harvard University, Medical School, Boston, (Neurobiology, Host Stephen Kuffler)
Hebrew University, Jerusalem: Fritz Haber Lecturer in Physical Chemistry
Hebrew University, Jerusalem: Bat Sheva (de Rothschild) Seminar
Hebrew University, Jerusalem: Protein Dynamics and thermodynamics, participant and session chair.
Henderson Symposium (Basic and Applied Statistical Mechanics of Condensed Matter, Brigham Young University, 2004)
HRL (formerly Hughes Research Lab) Malibu: Physics Colloquium, 1999.
HRL (formerly Hughes Research Lab) Malibu: Colloquium, 2005.
ICIAM 6th International Congress on Industrial & Applied Mathematics Zurich 2007, Co-organizer, two minisymposia: Direct and inverse problems in channels and membranes. Organizer Martin Burger, Co-organizer Heinz Engl.
IEEE International Conference on Pattern Recognition (1994), presented by Amir Averbuch and Moshe Israeli
IIT (Illinois Institute of Technology) Department of Biological, Chemical and Physical Science (Hosts: Grant Bunker and Larry Scott)
IIT (Illinois Institute of Technology) Department of Electrical and Computer Engineering (Host: Marco Saraniti).
IIT (Illinois Institute of Technology) Department of Chemical and Biological Engineering (Host: Darsh Wasan)
IIT (Illinois Institute of Technology) Department of Mathematics (Host: Shuwang Li)

Imperial College, London, Department of Chemistry, Alexei Kornyshev, host, May, 2016.
Intel Workshop on Early Disease Detection (Sept 2002)
Institue for Biomedical Sciences, Academia Sinica, Taipei, Taiwan, December 2013, (Host: Ru-Chi Shieh)
Institute for Mathematics and its Applications (IMA), University of Minnesota, Solvation Workshop (December 2008) see link [Talks and PDF] or address http://www.ima.umn.edu/2008-2009/W12.8-12.08/abstracts.html
Institute for Mathematics and its Applications (IMA), Univesity of Minnesota, Mathematics of Biological Charge Transport: Molecules and Beyond Workshop (July 2015) see link Talks and PDF
Institute for Pure and Applied Mathematics, IPAM, UCLA, Ion Channels (2002)
Institute for Pure and Applied Mathematics, IPAM, UCLA, Inverse Problems, Lecture and Workshop (2003)
Institute for Pure and Applied Mathematics, IPAM, Lake Arrowhead UCLA Conference: Inverse Problems Reunion (2005)
Institute for Pure and Applied Mathematics, IPAM, Lake Arrowhead UCLA Conference: Inverse Problems Reunion (2006)
Institute for Theoretical Physics, University of California, Santa Barbara, Conference on Electrostatic Effects in Complex Fluids and Biophysics, 1998
International Conference on Circuit/System Theory, Sydney, Australia (1970)
International Conference on Computational Nanoscience
International Conference on Unsolved Problems of Noise and Fluctuations in physics, biology, and high technology, Bethesda, 2002
International Conference On Biological Oscillations and 9th EGSCO (European Study Group on Cardiovascular Oscillations) Joint Meeting, April 2016.
International Filter Symposium, Santa Monica, CA, 1972
International Workshop on Computational Electronics: IWCE-5, 1997, Notre Dame.
International Workshop on Computational Electronics, IWCE-6, 1998, Osaka
International Workshop on Computational Electronics, IWCE-8, 2001, UIUC
International Workshop on Computational Electronics, IWCE-9, 2003, Roma, Italia
International Workshop on Computational Electronics, IWCE-11, 2006, Vienna, Austria
IUPUI (Indiana University Purdue University Indianapolis), Department of Mathematical Sciences, May 2016, Giovanna Guidoboni and Julia Arciero, hosts.
Jacobs University Bremen Germany
Johns Hopkins (Department of Biology)
Johns Hopkins (Department of Biomedical Engineering)
Kansas University (Mathematics, 2005, 2007)
Kavli Institute of Theoretical Physics, University of California Santa Barbara: Evolutionary Perspectives on Mechanisms of Cellular Organization 2010
Laboratory of Molecular Biology, MRC, Cambridge England, Host Richard Henderson
Lancaster University (Department of Physics, 2011, 2015)
Lancaster University (Department of Biology, 2015)

Lancaster University ('Kickoff Speaker, 2015, EPSRC (Engineering and Physical Sciences Research Council) Grant, PVE McClintock, Principal Investigator)
Lancaster University: Keynote Speaker Conference on Fluctuations and Coherence, 2011. (organizer PVE McClintock) see www.physics.lancs.ac.uk/FluctuationsConference2011/talks.htm
Lawrence Berkeley National Laboratory LBL Lecture to Molecular Foundry, June, 2013
Liblice Conference (5th) on Statistical Mechanics of Liquids, 1998
Los Alamos National Laboratory (Center for Nonlinear Studies)
Loyola University, Department of Physiology, Maywood, Illinois
Loyola University (Chicago), Keynote Speaker, Science Week, 2013
Marquette University: Department of Biology
Marquette University: Department of Mathematics
Marine Biological Laboratory, Woods Hole
Mathematical Biosciences Institute, Ohio State University, Speaker at "Modeling and computation of biomolecular structure and dynamics" April, 2011 MBI 2011, i.e., http://beta.mbi.ohio-state.edu/video/player/?id=549&title=Ions+in+Channels%3A+important+biology+ready+for+mathematical+analysis
Mathematical Biosciences Institute, Ohio State University, Inaugural Speaker Visiting Scholars Program, September 2015
Mathematical Biosciences Institute, Ohio State University, Speaker in workshop: Geometric and Topological Modeling of Biomolecules October 2015
Mathematical Biosciences Institute, Ohio State University, "Wind Up Talk" for Workshop on "Multiple Faces of Biomolecular Electrostatics" October 2015
Mathematical Biosciences Institute, Ohio State University, talk in Workshop "Modeling and Computation of Transmembrane Transport" November, 2015.
Max Planck Institute (Goettingen: Erwin Neher. Am Fessberg series) 2007
Max Planck Institute (Goettingen. MPI for Dynamics and Self-organization. Computational Neuroscience 2009)
Max Planck Institute (Heidelberg: Ken Holmes)
Max Planck Institute (Heidelberg: Bert Sakmann)
Mayo Clinic, Pharmacology, John Blinks.
Mayo Clinic, Physiology, Stuart Taylor.
McMaster University: Department of Physics (Hamilton, Ontario)
McGill University: Department of Biomedical Engineering, Jay Nadeau (March 2010)
Medical College of Virginia
Medical College of Wisconsin
Medical Research Council, Mill Hill, England
Merck, Sharpe, and Dhome
Mesilla Conference on Physical Chemistry (2001), Las Cruces New Mexico
Michigan State University (2011) Quantitative Biology and Mathematics, host Guowei Wei and Michael Garavito
Miller Institute Lecture, October 2012
Miller Institute Interdisciplinary Symposium, June 2013 (participant, not speaker)
MIT Department of Applied Mathematics April 2006 Martin Bazant, host

MIT Bio-Informatics Seminar (with the Whitehead Institute)
MIT McGovern Institute for Brain Research September 2013 (Mark Thomas Harnett, host)
Monash University, Australia: Electrical Engineering
Monash University, Australia: Department of Physiology
NASA Ames: Biomolecular Systems
National Science Foundation (first MOBS Seminar: Modeling of Biological Systems)
NATO Advanced Research Workshop. Ionic Soft Matter, Lviv, Ukraine
National Taiwan University Taipei, Taida Institute for Mathematical Sciences. "Energetic Variational Approaches to Elastic Complex Fluids and Molecular Biology" January, 2010
National Taiwan University Taipei "Workshop on Mathematical Models of Electrolytes Applied to Molecular Biology", January, 2012, December, 2013, Tai-Chia Lin 林太家 Organizer)
New Mexico Institute of Technology and Mining (Socorro)
Dept of Mathematics (host, Bxiang Wang), March 2011
New Mexico Institute of Technology and Mining (Socorro)
Dept of Mathematics (host, Mingji Zhang), March 2016
New York University Medical School (Physiology)
New York University (Biology: Tamar Schlick's Group)
NIH NINCDS
NIH Arthritis Institute
NIH GMS
NISTI-NIGMS Digital Biology Speaker (2003)
NIST Physical and Chemical Properties Division
NJIT (New Jersey Institute of Technology, Newark) Department of Mathematics, 2011
Northern Illinois University (Department of Mathematics, 2013, 2006
Northwestern University: Chicago, Physiology
Northwestern University: Evanston, Applied Mathematics
Northwestern University Evanston Chemistry Colloquium
Northwesern University Evanston Chemistry
George Schatz & Mark Ratner Laboratory (2010)
Northwestern Univ Evanston, Mathematics "Conversations in Mathematics & Biology"
Northwestern University: Evanston, Neurosciences
Northwestern University Evanston, Physics and Engineering Sciences
Northwestern University, Evanston: Monica Olvera de la Cruz, host(ess): Materials Research Science and Engineering Center (MRSEC) July 2012
Notre Dame, Department of Electrical Engineering
Notre Dame, Department of Chemistry and Biochemistry
Novartis Foundation Symposium: Gramicidin and Related Peptides, 1998
Novartis Foundation Meeting: Physical Models of Ion Permeation, 2000
Oak Ridge National Laboratory and University of Tennessee, Knoxville. Summer School on Biophysics: Computational and Theoretical Challenges (2010).

Oregon Health Sciences University (Vollum Institute)
Oxford University (England) Department of Physiology (several times)
Oxford University (England) Department of Biochemistry (2011)
Oxford University Biochemical Society (England)
Oxford University Seminar in Physical and Theoretical Chemistry (England)
Oxford University Seminar in Chemistry (Hagan Bayley)
Oxford University OCIAM Mathematics in Medicine 5th Study Group (October, 2005)
Oxford University OCIAM Mathematics in Medicine: Ion Channels (March, 2006)
Oxford University OCIAM Mathematical modelling of ion channels (September, 2011)
Oxford University OCIAM Lecture in Applied Mathematics, April, 2016, Jon Chapman, host.
PacifiChem (meeting of American Chemical Society, 2000)
PacifiChem (meeting of American Chemical Society, 2005)
Penn(sylvania) State University, Deptartment of Mathematics,
IMA-PIP Workshop on Numerical Simulation of Complex Fluids and MHD
Chun Liu Laboratory Workshop, August 2012
Penn(sylvania) State University, Center for Neural Engineering; Physics, Engineering Science, and Mechanics. Steve Schiff organizer, July 2013)
Penn(sylvania) State University, Deptartment of Mathematics, Special Lecture, July 2014, organizer Tao Huang
Penn(sylvania) State University, Deptartment of Mathematics, CAM Lecture February 2015, organizers Chun Liu and Jinachao Xu
Penn(sylvania) State University, Department of Mathematics, leadoff lecture in "Workshop On Transport And Dynamics In Complex Fluids And Biology", organizers Arkadz Kirshtein and Chun Liu. Abstract available at https://sites.psu.edu/tdcfb16/abstracts/ Slides available with DOI: 10.13140/RG.2.1.2584.8569 at https://www.researchgate.net/publication/306119626_Electricity_is_Different_August_2016_Penn_State_Mathematics and at https://sites.psu.edu/tdcfb16/files/2016/08/PSU-TDCFB16-Eisenberg-1gmxsqg.pdf
Polytechnic University (Brooklyn, NYC) Department of Chemical Engineering (2010)
Pierre & Marie Curie University (UPMC) Paris Department of Physical Chemistry (Pierre Turq, Jean-Pierre. Hansen) 2009
Princeton University Program in Applied Mathematics (October 2009)
Purdue University: Department of Biology (1967)
Purdue University: Department of Electrical Engineering: Solid State Physics, Organizer: Mark Lundstrom
Purdue University Physical Chemistry Seminar Series, 2008, Organizer Dor Ben-Amotz available at http://www.nanohub.org/resources/4726/ [PDF]
Purdue University Computational and Applied Mathematics Seminar, 2014, Host Jie Shen
Purdue University Physical Chemistry Seminar Series, 2014, Organizer Dor Ben-Amotz
Purdue University, Electrical and Computer Engineering, Graduate Seminar , 2014, Organizer: Gerhard Klimeck.

Radon Institute (RICAM) EMS (European Mathematics Society) Linz, Austria (2006) Minicourse (3 days) Lectures on Ion Channels
Radon Institute (RICAM), Linz, Austria, Special Semester on Quantitative Biology (2007) Ionic Channels
Rensselaer Polytechnic Institute Department of Mathematics
Rice University Colloquium in Computational and Applied Mathematics (March 2010)
Rowland Institute (Cambridge MA)
Rush Medical College (Physiology, 1975)
Rush Medical College (Pharmacology, 2008)
Salk Institute (Host: Steven Kuffler)
Salk Institute (Host: C. Stevens)
Sandia National Laboratory (Laura Frink/Grant Heffelfinger)
Sandia National Laboratory Biophysical Discussion (Susan Rempe)
Satellite Meeting (Debrecen) of International Physiological Congress, 1980
Schlumberger Cambridge Research
Scripps Research Institute La Jolla
Shanghai Jiao Tong University (SJTU) "Recent Progresses on Coulomb Many Body Systems" (Xiangjun Xing and Wei Cai, 2012)
Shanghai Jiao Tong University (SJTU) Seminar 2016
Shanghai Jiao Tong University (SJTU) Short Course (8 lectures), 2016 SJTU Soft Matter Summer School 2016 see Summer School , Lectures Day 1, Day 2, Day 3
Simon Fraser University (Vancouver) Department of Physics
SISSA and ICTP Trieste, Italy Theoretical Biophysics and Structural Biology
SISSA and ICTP Trieste, Italy. Challenge: correcting Einstein's mistake
Society of Industrial and Applied Mathematics (SIAM)
- Invited lecture, Conference on Applied Probability in Science & Engineering Society of Industrial and Applied Mathematics
- Invited lecture, symposium on "Ionic Channels in Biological Membranes". Annual meeting, 1993
- Invited lecture, Symposium on Ionic Channels, 2001, Annual meeting
- Invited lecture, Symposium Electrodiffusion: Modeling, Analysis, Simulation, and Applications, 2005, Annual Meeting. New Orleand
- Invited lecture, Co-organizer Symposium Multiscale Modeling of Electrochemical Systems, 2006, Annual Meeting, Boston.
- Invited lecture, Symposium, Multiscale Nonlinear Problems in Biology, 2007, Conference on Dynamical Systems
- Lead-off Lecture, Workshop on Dimensional Reduction

Society of Mathematical Biology (2013) Minisymposium "Modeling Ionic Flows in Biological Cells" Organizers, Carl Gardner and Steven Baer
SPIE Annual Meeting (1994) *in* Symposium "Mathematical Imaging: Wavelet Applications" (presented by Amir Averbuch and Moshe Israeli)
Stanford University (Department of Electrical Engineering)

State University of New York (Albany)
State University of New York (Stony Brook)
Suzhou University (School of Mathematical Sciences) Mathematical Center for Interdisciplinary Research . "Modeling and analysis in molecular biology and electrophysiology" June 1-5 2014. Organizers Chun Liu, Benzhou Lu, Xingye Yue
Suzhou University (School of Mathematical Sciences) Mathematical Center for Interdisciplinary Research . "Modeling and analysis in molecular biology and electrophysiology" June , 2016. Lead-off speaker. Organizers Chun Liu, Xingye Yue, Shenggao Xu
Taft School Centennial Symposium
Technical University of Vienna (Mathematics)
Telluride Science Research Center Symposium on Biological Ion Channels (2003)
Telluride Science Research Center Symposium on Biophysical and Biochemical Properties of Ion Channels in Epithelia (2004)
Telluride Science Research Center Symposium Biological Ion channels: Structure and Function (2005)
Temple University, Philadelphia, Three Lecture Series including First Dean's Distinguished Lecture, Michael Klein Dean (April 2015)
Texas Instrument Corporation (1966)
Thomas Jefferson University: Daniel Baugh Institute
TIDS12 Transport in Disordered Systems 12th Annual Meeting, Marburg, 2007
TMR Meeting on Kinetics, Goteborg Sweden, 2000, Plenary Speaker
Tulane University (1967)
UCLA: Biology Department (1968)
UCLA: Jerry Lewis Muscle Disease Center
UCLA: Physiology Department
UCLA: Molecular Biology Institute
UCLA: Department of Anesthesiology
UCLA School of Engineering, Mechanics and Structures
UCLA Department of Bioengineering
Universidad del Valparaiso (Chile) Symposium in Honor to [sic] the 70th Birthday of Francisco Bezanilla, Centro Interdisciplinario de Neurosciencia de Valparaiso, September 25, 2014.
University of Calgary, Seminar, Centre for Molecular Simulation, Sergei Noskov, host. May 2016.
University College (London): Biophysics
University College (London): Physiology
University of Buffalo (SUNY) Department of Physiology and Biophysics
University of Buffalo (SUNY) Department of Electrical Engineering
University of California (Berkeley) Chemical Engineering, Chakraborty Group
University of California (Berkeley) Mathematics, Craig Evans Student Symposium, Partial Differential Equations (October 2012)

University of California (Berkeley) Colloquium in Physics Department (Marvin Cohen)
University of California (Berkeley) Seminar on Physical Chemistry (David Chandler) October 2012
University of California (Davis) Department of Physiology (1969, Gene Renkin, host)
University of California (Davis) Institute of Theoretical Dynamics, Joel Keizer, host (1998)
University of California (Davis) Department of Pharmacology, Don Bers host (2012)
University of California (Irvine) Miledi Group
University of California (Irvine) Colloquium in Physics
University of California (San Diego) McCammon Group
University of California (San Diego) Department of Mathematics (Bo Li, Host).
University of California (San Francisco, Biochemistry, ~ 1970)
University of California (San Francisco, Biochemistry, 2007)
University of Chicago: Applied Mathematics. Organizer Victor Barcilon
University of Chicago 'Computations in Science Seminars', Organizers, L Kadanoff & Wendy Zhang
University of Chicago: Department of Biophysics. Organizer, George Eisenman
University of Chicago: Department of Physics (Franck Institute), Leo Kadanoff
University of Chicago: Department of Physiology Organizer, Harry Fozzard
University of Chicago: Department of Chemistry Organizer, Graham Fleming
University of Chicago Institute of Molecular Engineering, Matt Tirrell, Oct 2013
University of Colorado (Boulder): Applied Mathematics
University of Colorado (Denver): Physiology
University of Florida Department of Chemistry, Charles Martin's Nanogroup
University of Gröningen, Netherlands (Department of Chemistry)
University of Hawaii (von Bekesy Laboratory)
University of Heidelberg Bioquant-Vorlesung Seminar, 2007
University of Heidelberg: Bioms-Bioquant Lecture *in* the Workshop on Transport, Signaling and Structure Formation in Cellular Systems: Mathematics Meets Experiments
University of Illinois (Chicago): Department of Chemistry
University of Illinois (Chicago): Department of Physics
University of Illinois (Chicago): Department of Bioengineering, 2007, 2009
University of Illinois Medical School (Chicago): Department of Biochemistry
University of Illinois Medical School (Chicago): Department of Ophthalmology
University of Illinois Medical School (Chicago): Department of Physiology
University of Illinois (Champaign-Urbana): Physiology
University of Illinois (Champaign-Urbana): Biological Physics
University of Illinois (Champaign-Urbana): Physics, Beckman Institute
University of Illinois (Champaign-Urbana): Theoretical and Computational Biophysics Group, Klaus Schulten
University of Illinois (Champaign-Urbana): Computational Electronics

University of Iowa, Physiology and Biophysics (Hosts: Kevin Campbell and Chris Ahern, April 2014)
University of Linz, Oesterreich (Austria). Johan Radon Institute of Applied Mathematics.
University of Maryland (Baltimore): Physiology
University of Maryland (Baltimore): Biochemistry
University of Maryland (College Park): Electrical Engineering, Electrophysics Series
University of Maryland (College Park): Institute for Physical Science and Technology
University of Maryland (College Park): CSCAMM
University of Massachusetts (Amherst) Department of Chemistry
University of Miami: Biophysics and Physiology
University of Michigan: Michigan Interdisciplinary Mathematics Meeting.
University of Michigan: Seminar in Applied and Interdisciplinary Mathematics
University of Münster, Westfälischen Wilhelms-Universität Germany, Department of Applied Mathematics
University of New South Wales, Australia
University of Notre Dame (Department of Electrical Engineering)
University of North Carolina (Physiology) Host Gerry Oxford and Barry Palotta
University of North Caroloina (Chapel Hill) Dept of Biochemistry Host Gerhard Meissner.
University of North Carolina (Charlotte) Joint Seminar Mathematics and Bioinformatics
University of Oklahoma, Department of Physiology 1968
University of Pannonia (Veszprém Hungary): Department of Physical Chemistry Dezső Boda, 2009
University of Pennsylvania, Department of Physiology, Department of Chemistry, Department of Biology
University of Rochester (Physiology)
University of Rochester (Neurology)
University of Rochester (Neuromuscular Center)
University of South Carolina Dept of Mathematics and IMI (Interdisciplinary Mathematics Institute), giving a lecture in the Applied and Computational Mathematics Seminar Series Nanoinstitute, February 2015, Qi Qang host.
University of Sydney, Australia
University of Texas (Austin), Physics and Mathematics Seminar (Irene Gamba, host)
University of Texas (Austin), Colloquium in Physics (Harry Swinney, host)
University of Texas (Austin) ICES/Computational Life Sciences and Biology Seminar: "Ionic Selectivity: A Physical Analysis of Vital Chemistry" (Ron Elber, host)
University of Texas (Austin) Center for Nonlinear Dynamics (Harry Swinney, host)
University of Texas (Austin) Center for Nonlinear Dynamics (Mark Raizen, host)
University of Texas (Galveston)
University of Texas (Southwestern: Dallas)
University of Tokyo (Neuroscience)
University of Utah Department of Chemistry
University of Utah Henry Eyring Institute (2014)

University of Vermont
University of Vienna, Department of Mathematics
University of Washington
University of Wisconsin Madison (Electrical Engineering)
University of Wisconsin Madison (Contemporary Biochemistry)
University of Wisconsin Madison (Biochemistry, 2011, Julie Mitchell, host)
University of Wisconsin Milwaukee
USA-Japan Seminar Excitation-Contraction Coupling, Tokyo 1971
Vanderbilt University Colloquium on Physics
Washington University, St. Louis, Physiology
Washington University, St. Louis, Center for Computational Chemistry
Weizmann Institute, Rehovot: Bat Sheva (de Rothschild) Seminar.
Weizmann Institute, Rehovot: Chemistry Department
Western Nerve Net (San Diego)
Westfaelisch Wilhelms University Muenster Applied Mathematics
Westfaelische Wilhelms University Meunster
Multiscale Simulation for Ion Channels (2009)
Workshop on Wavelets: 16th International Conference of the IEEE Engineering in Biology and Medicine Society.
World Congress on Medical Physics and Biomedical Engineering, 1994.
Yale University (Department of Physiology)
Yale University (Section of Neuroscience)
Yale University (Department of Mathematics and Computational Science)
Xiamen University, Institute of Electromagnetics and Acoutstics, Lecture Series, 2013, Qing Liu, organizer.
Yangtze Conference on Fluids and Interfaces
Zhejiang University, Hangzhou. Symposium Department of Mathematics, 2011, organizer, Fang-Hua Li of the Courant Institute, NYU

Symposia Organized

Chairman, Mini-symposium on **The Lens as a Syncytium**, Biophysical Society Meeting, 1980.

Co-Chairman, with Brian Salzberg, **Symposium on Fine Processing in the Fine Processes of the Nervous System**, Biophysical Society Meeting, 1984.

Chairman of Symposium and Luncheon **Calcium Signals in Muscle**, Biophysical Society Meeting, 1985

Chairman of Symposium. **Nerve Impulse: From Conduction to Channels by way of** Conductance at the 100th Anniversary Meeting of the American Physiological Society, 1987.

Chairman of Symposium. Skeletal **Muscle Physiology: an Update** at the 100th Anniversary Meeting of the American Physiological Society, 1987.

Chairman of Minisymposium. **Moving through (Biological) Channels**, Society of Industrial and Applied Mathematics Conference on Applied Probability in Science and Engineering, New Orleans, 1990.

Chairman of Minisymposium. **Ionic Movement through Biological Channels.** Society of Industrial and Applied Mathematics, Annual Meeting. Chicago, 1990.

Organizer of Workshop: **From Structure to Permeation in Open Ionic Channels.** Biophysical Society Annual Meeting, Washington D.C., 1993

Chairman of Symposium: **Ionic Channels: Natural Nanotubes**. American Physical Society Annual Meeting, 2000.

Chairman and Organizer of **Novartis Foundation Meeting**: Physical Models of Ion Permeation, 2000

Chairman and Organizer of **Symposium at International Conference on Computational Nanoscience, 2001:** Nanostructure Simulation from thin oxides to biological ion channels.

Co-organizer of **Yangtze Conference on Fluids and Interfaces** (Chief Organizers Kwong-Yu Chan and D Henderson). Chairman, Ion Channels Session, 2001. see J. Colloid Interface Sci. 2002 246: p.222.

Organizer and Chairman of **Nanostructures: biological ion channels to thin oxides.** Nanotech 2003, San Francisco.

Co-organizer and Chairman (with Dirk Gillespie) of **Physical Models of Ion/Protein Interactions**, American Physical Society (Division of Biological Physics) March, 2003. Austin, TX.

Chairman (Organizer Maria Kurnikova) **Physics of Ion Interactions with Proteins**, March, 2004, American Physical Society, Montreal Quebec Canada.

Member, Organizing Committee, NATO Advanced Research Workshop. **Ionic Soft Matter** Lviv Ukraine, 2004.

Helper to Andrij Trokhymchuk and David Busath, **Festschrift for Doug Henderson**, Brigham Young University, 2004.

Co-organizer, with Heinz Engl, **RICAM Seminar on Ion Channels,** Johan Radon Institute of Applied Mathematics, University of Linz (Austria), 2004.

Organizer and Chair, **Multiscale Analysis in Biology: Computation,** American Physical Society, March, 2005, Los Angeles.

Organizer and Chair: **MultiScale Analysis of Ions in Solutions, Proteins, and Channels:** Analysis, American Physical Society, March, 2005, Los Angeles.

Problem Presenter: **Mathematics in Medicine Study Group**, Mathematics Institute, Oxford University, Sept. 2005, March 2006

Organizer and Chair: **Physical Models of Ion Channels**, American Physical Society, March 2006, Baltimore.

Helper to Chris Breward: Oxford University OCIAM **Mathematics in Medicine**: Ion Channels, March, 2006.

Member, Organizing Committee for **Special Semester on Quantitative Biology analyzed by Mathematical Methods**: RICAM (Radon Institute for Computational and Applied Math); (Oct 2007- Jan 2008: Johannes Kepler Univ of Linz, Austria) http://www.ricam.oeaw.ac.at/ssqbm/

Co-organizer (with Martin Burger, Peter Pohl, Heinz Engl) of Workshop on Ion Channels, Oct 8-12, 2007

Co-organizer, with Martin Bazant of Symposium, **Multiscale Modeling of Electrochemical Systems** SIAM (Society of Industrial and Applied Mathematics), 2006.

Organizer of ARO Sponsored Meeting, **Calibrating Simulations**, at Rush University Medical Center, January 2007.

Facilitator of Annual Reciprocal Symposia between Biophysical Society and Division of Biological Physics of the American Physical Society, commencing 2007. Planned to be the first in a continuing series.

Organizer of Symposium (Sponsored by American Physical Society Division of Biological Physics) **Modeling as a Tool in Biophysics**, at Biophysical Society Annual Meeting, 2007. Planned to be the first in a continuing series.

Co-organizer: **Direct and inverse problems in channels and membranes,** ICIAM 6th International Congress on Industrial & Applied Mathematics Zurich 2007, Organizer Heinz Engl; co-organizer Martin Burger, pair of minisymposia.

Lecturer Short course on **Channel Biophysics**, 10 hours, ICTP and SISSA Theoretical Biophysics and Structural Biology, Trieste, Italy, Organizer Paolo Carloni.

Co-organizer: Symposium on **Inhomogeneous Electrolytes** Northwest and Rocky Mountain Regional Meeting American Chemical Society Co-organizer Douglas Henderson, June 2008.

Organizer and Speaker: Workshop "Biophysics of Membrane Bound Channels" American Physical Society, Division of Biological Physics, March 2009.

Co-organizer: National Taiwan University "Energetic Variational Approaches to Elastic Complex Fluids and Molecular Biology" January, 2010, Organizer Tai-Chia Lin

Co-organizer Banff International Research Station BIRS "Ion Channels- Mathematical Modeling and Analysis" 16frg212, September 2016, Bob Eisenberg, Chun Liu and Huaxiong Huang, organizers.

Equipment and Software Designed

Wide band amplifiers for microelectrode recording (with several collaborators, see publications 3, 9, 11, 16, 22, and 24).

Software for computing and analyzing impedance measurements with wide band amplifiers *(ibid.)*

Axopatch Amplifier for patch clamp recording, with R. Levis, J. Rae, and A. Finkel, sold by Axon Instruments, Burlingame CA, now part of Molecular Devices Sunnyvale CA.

Perfusing Pipettes, a hardware kit available from ALA Scientific, for perfusing patch pipettes.

***PNP* Online http://www.pnponline.org/** Interactive software for running Poisson Nernst Planck theory, with Brice Burgess

Patent Application, PCT/NL2003/000013 Liquid Based Electronic Device (from BioMade, Groningen, Netherlands.) Patent Application was subsequently withdrawn, but it is an interesting idea, nonetheless, in my biased view, PCT/NL2003/000013 Liquid Based Electronic Device (from BioMade, Groningen, Netherlands.) [PDF]

Patent Application, U.S. Patent Application 12/297,179: Mathematical Design of Ion Channel Selectivity via Inverse Problems Technology (with Heinz Engl and Martin Burger, from Rush University) [PDF]

Professional Societies

American Association for Advancement of Science
American Mathematical Society
American Physiological Society
American Physical Society, Fellow
American Society of Cell Biologists
Biophysical Society
Institute of Electrical and Electronic Engineering, Senior Member
Mathematical Association of America
New York Academy of Sciences
Physiological Society, England (Associate Member)
Royal Society of Chemistry (UK)
Society of General Physiologists
Society for Industrial and Applied Mathematics
Society of Neuroscience
Institute for Strategic Studies (London: 1963-1992)

Research Interests

1960's-1980's:

Electrical properties of cells and tissues. The relationship between the structure of biological tissues and the pathways for current flow: measurements of linear electrical properties to determine equivalent circuits of skeletal and cardiac muscle, nerve, the lens of the eye, and epithelia.

The modeling of tissues of complex geometry and the solution—in physically meaningful form—of the differential (or difference) equations which describe such tissues. Thus, models of the three dimensional spread of current in spherical and cylindrical cells; models of the spread of current in the random network of transverse tubules in skeletal muscle; models of current flow in the clefts of cardiac muscle; models of current flow in epithelia; models of current flow in dendritic trees.

The use of mathematics (ranging from singular perturbation theory to numerical simulation) to provide insight into the physical meaning of complex theory.

1960's-1990's:

Excitation-contraction coupling in skeletal and cardiac muscle; particularly, the junction between the tubular system and the sarcoplasmic reticulum and the mechanism of calcium release from the sarcoplasmic reticulum.

The electrical properties of the sarcoplasmic reticulum and its ionic channels as seen in patch clamp measurements from skinned muscle fibers.

1980's – 2000's:

Analysis of ionic channels, experimental and theoretical: properties of single channels in epithelia, particularly "pressure activated" channels. Single channels in sarcoplasmic reticulum of skinned muscle fibers.

Design of patch clamp amplifiers, headstage, holders with "zero excess" noise.

Optimal detection of single channel events using signal detection theory.

Measurement of open channel noise.

Theoretical analysis of ion movement through channels using an hierarchy of models from molecular dynamics to continuum electrostatics.

Simulations of the molecular dynamics of channel proteins.

Stochastic analysis of flux over barriers: first passage times, concentration boundary conditions and ionic fluxes.

PNP model of the open channel. Poisson-Nernst-Planck model of open channels, in which the potential distribution through the channel is calculated not assumed. PH model of the open channel, the Poisson Hydrodynamic model including temperature changes.

Coupling of fluxes, active transport, gating, and gating currents in a permanently open channel of one conformation as predicted by the PNP model in complex geometries and the PH model.

The stochastic generalization of the PNP model.

Simulations of the molecular dynamics of the entry process models of gramicidin.

2000 -2010:

Design and construction of ion channels as useful devices.

Thus, building design tools for understanding current flow in bulk solution, ion channels, and proteins in general.

Computation of macroscopic properties of ionic solutions and channels from higher resolution models, using Langevin-Poisson, Monte Carlo Poisson, or Molecular Dynamics Poisson methods.

Mathematical analysis of macroscopic properties of ionic solutions and channels starting from higher resolution models, using Langevin-Poisson, Monte Carlo Poisson, or Molecular Dynamics Poisson methods.

Simulations and theories of gating and conformational change.

Construction of nonequilibrium statistical mechanics starting from the properties of chaotic trajectories computed with Poisson and molecular dynamics. Statistical mechanics as stochastic processes.

Crowded Charge model of protein function, specifically, ion selectivity and permeation in ion channels.

Variational Principles (built on the energetic variational approach of Chun Liu) applied to ions in channels, ions and water in solutions, cells, and macroscopic tissues, and to vesicles and viruses fusing with membranes.

2010 - … :

Role of Crowded Charge in Enzyme Function. The density of acid and base side chains is so large at active sites that it appears to be a ‘universal’ feature that is a biological adaptation with an unknown function. Searching for that function, I ask a speculative question: *what is the role of the high charge density and crossed conditions of at active sites? Does it significantly constrain solutions of the Schroedinger equation?*

Field theory of ionic solutions. It seems clear that ‘everything’ interacts with everything else in ionic solutions, because of the range of the electric field, and often the effects of the finite size of ions on the shape of the electric field, and on entropy directly. Selfconsistent treatments are needed for such interacting systems in other areas of science and I suspect that the failures of classical theories of electrolytes arise because those classical theories are not selfconsistent. A field theory offers the additional substantial advantages of

incorporating boundary conditions in a natural way. It thus can deal with nonequilibrium conditions arising from spatially nonuniform boundary conditions (e.g., the power supplies that make digital devices or biological cells work). It seems that a selfconsistent field theory of ionic solutions is needed. It is now practicable because of advances in applied mathematics. It should be clearly understood that ionic solutions are usually highly concentrated where they are most important, in and near the electrodes of electrochemical cells, in and near enzymes and enzyme active sites, ion channels, transporters, and binding proteins.

Field theory of chemical reactions. Chemical reactions usually occur in ionic solutions. Chemical reactions have been analyzed classically as if they occur in vacuum, or in ideal ionic solutions, at infinite dilution. It seems that a selfconsistent field theory of chemical reactions is needed. It is now practicable because of advances in applied mathematics. It seems that a selfconsistent field theory of chemical reactions is needed. It is now practicable because of advances in applied mathematics.

Administrative Work

UCLA

Member of Committee for Graduate Students.
First Year Advisor for Graduate Students.
Member of numerous review committees for promotions: received commendation from Vice Chancellor Saxon for work on review committees.
Member of Advisory Committee for the Jerry Lewis Muscular Dystrophy Center.

Rush Medical College

Chairman, Department of Physiology, then Department of Molecular Biophysics and Physiology. First holder of 'The Francis and Catherine Bard Chair of Physiology'

Department has approximately 19 faculty members and approximately 9,000 sq ft of usable research space. All faculty with research space have been well supported by the NIH, thanks to their significant personal productivity. Tenured faculty include (alphabetical order): Lothar Blatter (mitochondria in cardiac muscle), Fred Cohen (viral fusion); Tom DeCoursey (H^+ ion channels); Mike Fill (Ryanodine Receptor); Dirk Gillespie (selectivity); Eduardo Rios (Ca^{++} movement) Tom Shannon (excitation contraction coupling in cardiac muscle); Jingsong Zhou (mitochondrial defects in skeletal muscle disease). Wayne Chen, Visiting Professor, with a laboratory and Postdocs at Rush. Key members in Medical School Teaching: Tom Shannon, and Dirk Gillespie, formerly Joel Michael (nearly retired); in Nursing Teaching Jingsong Zhou and formerly Sue Donaldson and Joe Zbilut (deceased). Jingsong Zhou has been in charge of our seminar series for many years. Elena Dedokova is responsible for the great success of our journal club, initiated by Eduardo Rios. Assistant Professors include Artem Ayuyan, Vladimir Cherny, Elena Dedokova, Griedrius Kanaporis, Rueben Markosyan, Deri Morgan, Josefina Ramos-Franco, and John Tang.

Academic Administration.
Member of College Councils.
Chairman of Promotions and Appointments Committee.
Member, Vice Chair, then Chair of Search Committee for Microbiology Chair.
Vice Chairman of Search Committee for Dean of the Medical College.
Member, Search Committee for Dean of the Graduate College.
Member, Search Committee for Pediatrics Chair.
Member, Search Committee for Microbiology Chair

Teaching

Graduate students:

J. Leung, R. Mathias, E. Engel, R. Levis, R. Milton (with R. Mathias), J. Tang, P. Gates, J. Wang, A. Hainsworth (with R. Levis), P. Dull (summer student), Dirk Gillespie, Amy Del Medico (summer student), Boaz Nadler (in significant part: Zeev Schuss, supervisor); Amit Singer (in significant part: Zeev Schuss, supervisor), Janhavi Giri (Bioengineering, University of Illinois, Chicago), Claudio Berti, David Jiminez-Morales (Jie Liang, supervisor), Allen Flavell (Xiaofan Li, supervisor)

Post-doctoral fellows:

John Howell, Peter Vaughan, Bert Mobley, Art Peskoff, Richard Mathias, Eli Engel, Richard Levis, Richard Milton (with Rick Mathias), Kim Cooper, Peter Gates, Dunapin Chen, John Tang, Danuta Rojewska, Dirk Gillespie,; Trudy van der Straaten (with Umberto Ravaioli), Sheila Wigger-Aboud (with Marco Saraniti), Jim Fonseca, Claudio Berti, David Jimenez-Morales

Community Activity

AVENUE BANK OF OAK PARK: Director, Member, then Chairman of Audit Committee, Executive Committee, and Marketing Committee (1987-1992).

AMERICAN HEART ASSOCIATION OF METROPOLITAN CHICAGO: Member, Board of Governors, Executive Committee, and President's Cabinet (1984-1986). Member Research Council (1989-1990) and Chairman, Committee on Human Experimentation.

TAFT SCHOOL (Connecticut): Speaker at Centennial Symposium, and Seminar/Discussion Group.

PRESIDENT 7320 Condo Association. 1997– 2003; 2007; 2009-2015

TOWN TALK Telluride Science Research Center (part of Pinhead Lecture Series) 2003.

ARMY RESEARCH OFFICE talk to North Carolina Ventures Program for High Schools 2005

LOYOLA UNIVERSITY Chicago. Keynote Speaker, Science Week, 2013.

ROBERT S. EISENBERG

PUBLICATIONS

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(Last update: October 5, 2016)

[Laboratory of Robert S. Eisenberg]

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