



# Opportunities at the Interface of physics & biology

July 28-20, 2010, Chicago, IL

## SYMPOSIUM SUMMARY

prepared by

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The opportunities for scientific discovery at the interface of the physical and biological sciences have attracted increasing attention over the past decade, evidenced by several insightful and comprehensive reports<sup>1,2,3,4,5</sup> as well as a number of relatively new funding mechanisms (Appendix A). This 2010 symposium, jointly organized by the Burroughs Wellcome Fund, the W.M. Keck Foundation, and the Swartz Foundation, brought together key federal and private non-profit funders interested in exploiting these opportunities (See Appendix B for Agenda). The two day meeting highlighted current puzzles in biology<sup>6</sup> from the perspective of different biological systems, chosen because of their potential to illuminate some common issues that cut across multiple levels of biological organization, and across multiple biological subfields. Cross-cutting themes for the sessions included variability, robustness, and homeostasis; adaptation and evolution; and signals, noise, and control. Speakers were asked to identify the ideas that currently generate significant excitement, as well as the obstacles that hinder pursuit of those questions. This summary highlights the ideas, issues, and solutions that arose during the symposium. It is not intended to be comprehensive, but rather, can form the basis for continued discussions on how to assemble the resources needed to capitalize on these opportunities.

A challenge presented by biological systems is that organisms are continuously rebuilding themselves while remaining functional. Understanding them requires simultaneously measuring system performance or behavior along with the underlying cellular and circuit parameters. Put another way, the challenge is understand the mechanisms and develop a theory of the dynamics occurring in constantly-changing living systems.

One recurring theme was the search for universal principles of network operation, with the recognition that network function is at the heart of biology, whether on the level of cell regulation, nervous systems, Darwinian systems, bacterial quorum sensing, social behavior, or ecosystems.

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<sup>1</sup> Research at the Intersection of the Physical and Life Sciences, Washington DC, The National Academies Press (2010).

<sup>2</sup> Inspired by Biology: From Molecules to Materials to Machines, Washington, DC. The National Academies Press (2008)

<sup>3</sup> A New Biology for the 21<sup>st</sup> Century, Washington, DC. The National Academies Press (2009).

<sup>4</sup> The Role of Theory in Advancing 21<sup>st</sup> Century Biology. Washington, DC. The National Academies Press (2008).

<sup>5</sup> Meeting Summary: Federal Support for Research at the Interface of the Physical, Math, Computational, and Life Sciences. Bridging the Sciences Coalition, 2004. Available at <http://www.biophysics.org/Portals/1/PDFs/Public%20Affairs/summary.pdf>.

<sup>6</sup> There are also opportunities where biological approaches and perspectives may help solve puzzles in physics and engineering- but this was not addressed at this meeting.

**Currently compelling questions include, but are not limited to these:**

- How variable are the parameters in real biological networks, and how do the physiological and behavioral properties of the individual result from the particular parameter configurations?
- How much variability in behavior exists among genetically identical biological systems? In other words, what is the physics of the phenotypic diversity in genotypically identical organisms?
- How is function maintained during constant rebuilding in response to development or environmental change, and how can a full-scale network be monitored in real time as it functions? ? What are the laws governing the network dynamics?
- What is the structural and functional basis of network memory?

**What is needed to address the challenges, both experimental and theoretical, at the interface of physics and biology?**

- Tools for enabling multiscale and multipoint observations on a single system whether that is a neural circuit or an organ system
  - Engineering and biological expertise working in concert to improve/expand current technologies
  - Multimodal instruments including microscopy, spectral analysis and chemical/biochemical measurements
  - Include as many “omics” as possible
- Theory of open, nonlinear systems far from equilibrium
  - Statistical mechanics and dynamic systems theory are good starting points
  - Hardware and software innovations
  - Network analysis

**How do we build an infrastructure to work toward meeting these challenges?**

It boils down to supporting people and projects. For people, this includes shorter term experiences to engage investigators in new fields, as well as formal, multi-year training mechanisms. For projects, this will involve seed funding to test new ideas as well as longer term funding to sustain training programs and fund risky/high impact projects.

- Recruiting scientists to the interface
  - Develop mechanisms to support engagement at any stage of their careers of experts in mathematics, physics, computer science and biology to address life sciences questions, as well as to train biologists in physics and Mathematics. These will be different for graduate students, postdocs, independent early career scientists, mid career and senior scientists.
  - Support visiting scientist programs
- Support specific research projects
  - Support instrument, methods, technology development
  - Provide funds for shared technical experts in engineering and software/informatics that would be available to groups of scientists (Janelia Farm example)
  - Support high risk projects that would have a high impact

**What other processes to facilitate the exchange of ideas are needed?**

- Events: Conferences, workshops, short courses
  - Mathematical/statistical approaches for theorists
  - Instrument/methodology developers
- Social networks
- Ongoing forums

## **APPENDIX A:**

### **FUNDING AGENCIES AND MECHANISMS TARGETED TO THE INTERFACE BETWEEN PHYSICS AND BIOLOGY**

#### **Burroughs Wellcome Fund**

Career Awards at the Scientific Interface

[www.bwfund.org](http://www.bwfund.org)

#### **Howard Hughes Medical Institute**

HHMI-NIBIB Interfaces Initiative for Interdisciplinary Graduate Research Training

[www.hhmi.org](http://www.hhmi.org)

#### **Janelia Farm**

[www.hhmi.org/janelia](http://www.hhmi.org/janelia)

#### **The Kavli Foundation**

[www.kavlifoundation.org](http://www.kavlifoundation.org)

#### **W. M. Keck Foundation**

Medical Research and Science and Engineering Research Awards

[www.wmkeck.org/programs](http://www.wmkeck.org/programs)

#### **Gordon and Betty Moore Foundation**

[www.moore.org/science.aspx](http://www.moore.org/science.aspx)

#### **National Institutes of Health**

**National Cancer Institute**

**National Institute of Biomedical Imaging and Bioengineering**

**National Institute of Mental Health**

**National Institute of Neurological Disorders and Stroke**

See NIH Office of Extramural Research (OER) Extramural Training page:

[grants.nih.gov/training/extramural.htm](http://grants.nih.gov/training/extramural.htm)

Transforming Biomedicine at the Interface of the Life and Physical Sciences (PAR-10-141)

[grants.nih.gov/grants/guide/pa-files/PA-10-141.html](http://grants.nih.gov/grants/guide/pa-files/PA-10-141.html)

New Biomedical Frontiers at the Interface of the Life and Physical Sciences (PAR-10-142)

[grants.nih.gov/grants/guide/pa-files/PA-10-142.html](http://grants.nih.gov/grants/guide/pa-files/PA-10-142.html)

Physical Sciences - Oncology Centers (PS-OCs)

[physics.cancer.gov](http://physics.cancer.gov)

See NIBIB Extramural Training page:

[www.nibib.nih.gov/publicPage.cfm?pageID=1572](http://www.nibib.nih.gov/publicPage.cfm?pageID=1572)

Bioengineering Research Grants (PA-10-009)

[grants.nih.gov/grants/guide/pa-files/PA-10-009.html](http://grants.nih.gov/grants/guide/pa-files/PA-10-009.html)

Bioengineering Nanotechnology Initiative (PA-10-150)

[grants.nih.gov/grants/guide/pa-files/PA-10-150.html](http://grants.nih.gov/grants/guide/pa-files/PA-10-150.html)

Predictive Multiscale Models of the Physiome in Health and Disease (PAR-08-023)

[grants.nih.gov/grants/guide/pa-files/PA-08-023.html](http://grants.nih.gov/grants/guide/pa-files/PA-08-023.html)

BISTI: [www.bisti.nih.gov/funding/index.asp](http://www.bisti.nih.gov/funding/index.asp)

- Collaborative Research in Computational Neuroscience (CRCNS) (R01). A Joint NSF-NIH initiative: NSF-08-514
- Innovations in Biomedical Computational Science and Technology (R01, R21, SBIR, STTR)
- Continued Development and Maintenance of Software (R01) - PAR-08-010
- Predictive Multiscale Models of the Physiome in Health and Disease (R01) - PAR-08-023
- Collaborations with National Centers for Biomedical Computing (R01, R21)
- Data Ontologies for Biomedical Research (R01) - PAR-07-425
- Sharing Data and Tools: Federation using the BIRN and caBIG Infrastructures (R01) - PAR-07-426
- Neuroimaging Informatics Software Enhancement for Improved Interoperability and Dissemination (R03) - PAR-07-417
- Exceptional, Unconventional Research Enabling Knowledge Acceleration (EUREKA) (R01) - RFA-GM-10-009
- Bioengineering Research Partnerships (R01) - PAR-07-352
- Bioengineering Research Grants (R01) - PA-07-279
- Mentored Quantitative Research Development Award (K25) - PA-09-039
- Neuroscience Blueprint Computational Neuroscience Training Program (T90)

### **National Science Foundation**

Physics of Living Systems (PoLS)

[www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=6673&org=NSF&from\\_org=NSF](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=6673&org=NSF&from_org=NSF)

Biomolecular Systems Cluster

[www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=12771&org=NSF&from\\_org=NSF](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12771&org=NSF&from_org=NSF)

Collaborative Research in Computational Neuroscience

[www.nsf.gov/crcns](http://www.nsf.gov/crcns)

Cyber-enabled Discovery and Innovation

[www.nsf.gov/cdi](http://www.nsf.gov/cdi)

Integrative Graduate Education and Research Traineeship

[www.nsf.gov/crssprgm/igert/intro.jsp](http://www.nsf.gov/crssprgm/igert/intro.jsp)

### **Research Corporation for Science Advancement**

Cottrell College Scholars and Scialog on Solar Conversion

[www.rescorp.org](http://www.rescorp.org)

### **Swartz Foundation**

[www.theswartzfoundation.org](http://www.theswartzfoundation.org)

### **U.S. Department of Energy**

Office of Biological and Environmental Research supports fundamental research for developing new methodologies for real-time, high-resolution imaging of dynamic biological processes in living systems including those of interest to DOE (e.g., biofuel plants and microbial communities).

[www.sc.doe.gov/ober/BSSD/radiochem.html](http://www.sc.doe.gov/ober/BSSD/radiochem.html)

## APPENDIX B: Meeting Agenda



# Opportunities at the Interface of physics & biology

July 27-29, 2010

Four Seasons Hotel Chicago  
120 E. Delaware, Chicago, IL 60611  
(312) 280-8800

### Tuesday, July 27, 2010

3:00 pm - 5:00 pm

**Meeting Registration** - State Room (8<sup>th</sup> Floor)

5:30 pm – 7:00 pm

**Welcome Reception** - Season's Restaurant (7<sup>th</sup> Floor)

### Wednesday, July 28, 2010

7:00 am – 8:30 am

**Meeting Registration Continues** – State Room (8<sup>th</sup> Floor)

7:30 am – 8:30 am

**Breakfast** - Delaware Room (7<sup>th</sup> Floor)

8:30 am – 8:45 am

**Welcome and Introductions** – State Room (8<sup>th</sup> Floor)

*John Burris, Burroughs Wellcome Fund,  
Maria Pellegrini, W.M. Keck Foundation and  
Jerry Swartz, Swartz Foundation*

8:45 am – 9:00 am

**Overview of Meeting Goals**

*Nancy Sung (BWF), William Bialek (Princeton University) and  
Eve Marder (Brandeis University)*

9:00 am – 11:50 am

(10:15 am-10:45 am - Break)

**Session 1 Variability, Robustness, and Homeostasis**

**Moderator: William Bialek**

*Aaron Dinner, University of Chicago: Signatures of Regulatory  
Synergies in Intrinsic Biological Noise*

*Mark Goldman, University of California-Davis: Robust  
Memories, Brittle Models: Challenges in Modeling  
Neural Activity in Short-term Memory Networks*

*Ned Wingreen, Princeton University: Why is the Vibrio  
harveyi Quorum Sensing Network So Complicated?*

*Marcelo Magnasco, Rockefeller University: Learning to be  
Critical*

*Eve Marder, Brandeis University:*

*How Good is Good Enough in Neuronal Circuits and  
Behavior?*

11:50 am – 12:30 pm

**Open Discussion**

12:30 pm – 1:30 pm

**Lunch** – Delaware Room (7<sup>th</sup> Floor)

1:30 pm – 3:15 pm

**Session 2 Adaptation and Evolution** – State Room (8<sup>th</sup> Floor)

**Moderator: Eve Marder**

*Ralph Greenspan, UCSD/Kavli Neurosciences Institute:* Does Biology Have Any Principles, Or Is It Just A Lot Of Stuff?

*Hans Hofmann, U. Texas- Austin:* Variations on a Theme: Individual Variation and the Evolution of Social Decision Making

*Michael Desai, Harvard University:* How Do Large Populations Evolve?

*Herb Levine, University of California-San Diego:* Selection for Faster Adaptation

3:15 pm – 3:45 pm

**Open Discussion**

3:45 pm – 4:00 pm

**Break**

4:00 pm – 5:15 pm

**Session 3 Signaling within boundaries** – State Room (8<sup>th</sup> Floor)

**Moderator: William Bialek**

*Boris Schraiman, U. California- Santa Barbara:*

Un-Expected Physics in Biology

*Mary Kennedy, Caltech:* Control of Synaptic Plasticity by Signaling in the Spine

*Thierry Emonet Yale University:* (Spatial Regulation of Biological Function

5:15 pm – 6:00 pm

**Open Discussion**

6:30 pm – 6:45 pm

**Transportation to Field Museum**

7:00 pm – 10:00 pm

**Reception and Dinner at Field Museum**

## **Thursday, July 29, 2010**

8:00 am – 9:00am

**Breakfast** – LaSalle Room (7<sup>th</sup> Floor)

9:00 am – 11:35 pm

(10:15 am-10:45 am - Break)

**Session 4 Signals, noise, and control** – State Room (8<sup>th</sup> Floor)

**Moderator: Eve Marder**

*Fred Rieke, University of Washington:* Seeing in the Dark

*Leslie Osborne, University of Chicago:* Testing Theories of Optimality in Sensory-Motor Behavior

*Emo Todorov, University of Washington:* Optimal Control of Movement

*William Bialek, Princeton University:* How much can we calculate?

11:35 am – 12:30 pm

**Open Discussion**

12:30 pm – 1:30 pm

**Lunch** – LaSalle Room (7<sup>th</sup> Floor)

**1:30 pm – 4:00 pm**

**Session 5: What is needed, and how do we get there?**  
State Room (8<sup>th</sup> Floor)

This session will begin with a summary of the areas of opportunity identified by the talks earlier in the meeting, as a springboard for discussion of what is needed in the areas of training, tools, technology, and research funding. Funders will be asked to share their priorities as well as what they heard that is of interest.

*Confirmed Funders:*

*John Burris, Burroughs Wellcome Fund*  
*Nancy Sung, Burroughs Wellcome Fund*  
*Maria Pellegrini, W.M. Keck Foundation*  
*Jerry Swartz, Swartz Foundation*  
*Hirsch Cohen, Swartz Foundation*  
*Krastan Blagoev, NSF Physics of Living Systems Program*  
*Richard Baird, NIH/NIBIB*  
*Vicki Chandler, Gordon and Betty Moore Foundation*  
*Miyoung Chun, Kavli Foundation*  
*Richard Conroy, NIH/NIBIB*  
*Martha Gilliland, Research Corporation for Science Advancement*  
*Bill Galey, HHMI*  
*Maryrose Franko, HHMI*  
*Dennis Glanzman, NIH/NIMH*  
*Yuan Liu, NIH/NINDS*  
*Kevin Moses, HHMI/Janelia Farm*  
*Larry Nagahara, NIH/NCI Physical Sciences- Oncology Center Program*  
*David Thomassen, DOE*  
*Renee Wegrzyn, DARPA*  
*Kenneth Whang, National Science Foundation*

**4:00 pm**

**Adjourn Meeting**