American Physical Society - Ohio Region Section
Northern Ohio Section of the AAPT
SPS -Zone 7

Fall 2015 Meeting

Friday & Saturday, October 16-17

Cleveland State University
Cleveland, Ohio 44115

Physics in Biology and Medicine

Local Co-Organizers: Dr. U. Zurcher
E-mail: u.zurcher@csuohio.edu
Dr. P. Fodor
E-mail: p.fodor@csuohio.edu

Sponsors: **Cleveland State University, College of Science and Health Profession**
John Wiley & Sons, Inc.
TeachSpin, Inc.

Program - Outline

Friday October 16

1:00 - 2:00	Registration (Student Center Atrium)
2:00 - 2:15	Welcome **Dr. M. Bond**, Dean, College of Science and Health Profession - CSU
2:15 - 3:00	**Session A: Invited Papers** Cell density modulates antibiotic efficacy, optimal treatment, and the evolution of resistance in bacteria. **Dr. Kevin Wood**, University of Michigan
3:00 - 3:15	Coffee Break
3:15 - 4:00	Noninvasive Focused Ultrasound Brain Therapy **Dr. Gregory Clement**, Lerner Institute, Cleveland Clinic
4:00 - 6:00	Poster Session & Social Hour
6:00 - 7:30	Banquet: Tickets required
8:00 - 9:00	**Session B: After Dinner Lecture** The physics of life: Molecular machines **Dr. Peter M. Hoffmann**, Wayne State University

Saturday October 17

7:45 - 8:15	Registration and Continental Breakfast (Student Center Atrium)
8:15 - 9:00	**Session C: Invited Paper** Understanding population phenotypic variability through single-cell dynamics **Dr. Hanna Salman**, University of Pittsburgh
9:00 - 9:15	Coffee Break
9:15 - 10:45	**Sessions D1-4: Contributed Papers** Contributed Papers in Parallel Sessions
11:00 - 12:00	**Session E: Invited Paper** Ohio's Learning Standards in Science and the Next Generation Science Standards **Esther Hopkins and Belinda Clark**, OH Department of Education
12:00 - 12:15	Closing Remarks

Invited Speakers

Kevin Wood, Physics Department University of Michigan
Cell density modulates antibiotic efficacy, optimal treatment, and the evolution of resistance in bacteria

Antibiotic efficacy often depends on the starting cell density of the treated bacterial population, a phenomenon known as the inoculum effect. However, the inoculum effect is typically measured in growing populations where the cell density is inherently changing throughout the experiment. Therefore, while the inoculum effect implies that drug efficacy depends on cell density, the explicit density dependence is rarely reported, making it difficult to asses the practical importance of the phenomenon and challenging to incorporate the effect into quantitative strategies for controlling microbial growth. In this work, we leverage customized, computer-automated microbial culture devices to quantitatively measure the cell-density dependence of drug efficacy for a wide range of antibiotics that inhibit growth of E. feacalis, a gram positive bacterial species among the leading causes of nosocomial infections. We then use optimal control theory to demonstrate that accounting for this density-dependence in dynamic dosing strategies can lead to a significant reduction in population size, even for clinically relevant drug concentrations. Finally, we will discuss our ongoing work–both theoretical and experimental– to understand the role of cell density fluctuations in modulating the evolution of drug resistance.

Gregory Clement, Lerner Institute, Cleveland Clinic
Noninvasive focused ultrasound brain therapy

High intensity focused ultrasound (HIFU) is an established medical procedure that focuses acoustic waves into a precise region of the body, killing tissue only in this targeted region while leaving other areas unaffected. Although potential applications in the brain have long been realized, until about 13 years ago it was largely believed that the attenuation and distortion caused by the skull was so severe that transskull therapies were impossible. Contemporary medical physics research, however, has shown that focusing through the intact skull can be achieved. Furthermore, technological advancements have made it practical, owing to the development of high-powered transducer arrays and high-performance computers to calculate the corrections necessary to restore a focus in the brain. Similarly, the ability to target and monitor the deposition of ultrasound energy in the brain has improved dramatically over the past twenty years. Radiological developments including X-ray computed tomography (CT) followed by magnetic resonance imaging (MRI) have made millimeter precision registration with brain structures possible. This progression of improvements has led to the present state of research, where non-invasive transskull focusing technology is commercially available and being clinically investigated worldwide for the treatment of brain tumors, Parkinsons disease, obsessive compulsive disorder (OCD), stroke, and others. Meanwhile, advances continue in the laboratory toward expanding both the number of treatable disorders and the mechanisms of treatment. This talk will highlight the importance of applied physics in developing the technique while providing an example of how academically-based research can directly benefit the clinic.

Peter M. Hoffmann, Physics Department, Wayne State University
The physics of life: Molecular machines

Living beings are based on classical nanoscale systems. These systems have the unique ability to easily transform energy and to assemble themselves into ordered structures. These astonishing feats are only possible because the nanoscale is dominated by thermal motion, and because chemical, electrical, mechanical and thermal energy scales all converge at this length scale. Although living cells have taken advantage of nanoscale physics for billions of years, technology is just beginning to exploit the different rules nanosystems are governed by. This talk will focus on the story of molecular machines, which connect physics to biology and illustrate how life is a game played at the nanoscale. Here, thermal noise meets molecular structure, and chaos becomes order.

Hanna Salman, Physics Department University of Pittsburgh
Understanding population phenotypic variability through single-cell dynamics

Cellular protein content is a major determinant of its phenotype. Therefore, extensive efforts have been dedicated for studying protein variability among cells in a genetically identical cell populations. In an attempt to gain a new insight into the sources of this variability, we have examined the temporal protein fluctuations in a single cell over extended times and compared their statistical properties to those of protein fluctuations measured from population snapshots. Our populations measurements reveal that the fluctuations in a specific type of highly expressed protein measured under broad range of conditions, exhibit a distribution that appears universal: under rescaling by mean and standard deviation, all such distributions collapse onto a single skewed curve. Additionally, the variances of the distributions depend quadratically on their means. To compare these results to single-cell fluctuations, we used recent advancements in microfluidic techniques to track single bacterial cells for many generations while monitoring their size growth, protein expression and division events. Traces of protein copy number obtained from such measurements enabled us to investigate their statistical properties. Our results show that temporal fluctuations in individual traces exhibit the same statistical properties as those observed in populations: 1) Scaled fluctuations around the mean of each trace exhibit the same universal distribution shape found in populations, and 2) The mean and variance of the traces over time obey the same quadratic relation. Further analyses of the temporal features of the protein traces in individual cells reveal that protein content as a function of time can be described as a stochastic process characterized by 3 variables, the exponential rate of protein increase during each cell cycle, the cell-cycle duration and the protein copy-number at the cycle start. This compact description is sufficient to reproduce the universal statistical properties of the protein fluctuations, namely, the protein distribution shape and the quadratic relationship between variance and mean. Finally, based on these findings, we were able to develop a simple model that reproduces the statistical properties of protein fluctuations, and account for their universal nature. Our model demonstrates that a new sort of universal feedback mechanism is necessary to stabilize protein number, and that a single parameter determines the distribution shape and the quadratic variance-to-mean relation. These findings provide important insights that can guide future studies.

Esther Hopkins and Belinda Clark, Ohio Department of Education
Ohio's Learning Standards in Science and the Next Generation Science Standards

New national and state standards in science have been developed in recent years. This presentation will briefly describe the development of these standards, clear up some common misconceptions about the standards, and discuss the implications of the standards for science education in Ohio.