Interface between Engineering and Biology and its Impact on the Human Condition

Regional National Academy of Engineering Meeting, March 13, 2003
1-5:30 pm, Walker-Ames Room, Kane Hall, University of Washington, Seattle

Bruce Finlayson and Ed Lazowska, Co-chairs

The National Academy of Engineering holds several Regional Conferences each year, on topics of interest to the host institution. Because of the biological focus at the University of Washington, we have decided to concentrate on engineering and scientific developments in the medical field. The program begins with a talk by Dr. Richard Klausner, Director of Global Health at the Bill & Melinda Gates Foundation. He will give an overview of the need for appropriate medical care in developing countries. Dr. Chris Elias, of Path Corporation, Seattle, will then describe the efforts of Path to create medical technology for that same use. Professor Paul Yager will describe his laboratories efforts to combine medical testing on a small scale with information technology to improve (and make cheaper) medical care in advanced countries. Dr. Robert Bea, University of California, Berkeley, will discuss unintended consequences, since engineering projects have the potential to do more than their creators envisaged. Finally, several scientific endeavors will illustrate the future possibilities for improvement in health: Astronaut Bonnie Dunbar, on biological research in space, Buddy Ratner, UW, on how to grow heart muscle, and Mary Lidstrom and Deirdre Meldrum on how to obtain and use genetic information by examining single cells. Thus, the Regional meeting will provide a broad perspective of the needs, some examples of current engineering application, and a preview of prospects for the future.

Introduction to the National Academy of Engineering
Dr. William A. Wulf, President

Dr. Richard D. Klausner, M.D.
Executive Director, Global Health, Bill & Melinda Gates Foundation

Dr. Klausner will describe the need for improved medical care in developing countries and the efforts of the Bill and Melinda Gates Foundation to contribute to the solution of that problem.

Program for Appropriate Technology in Health (PATH)
Dr. Christopher J. Elias, M.D., M.P.H., President of PATH

Life saving health technologies are introduced nearly every day. However, because of cost as well as design and cultural considerations, many of these devices are not accessible or are not appropriate for people living in developing countries, nor do they typically address the major causes of morbidity and mortality in remote countries of the world. At PATH we combine a multi-disciplinary approach to the development, testing, and transfer of technologies to improve the safety and effectiveness of vaccine delivery, medical waste disposal, barrier method contraception, and various other devices aimed primarily at improving maternal and child health. Our staff bring the necessary perspective of the field, business, clinical, medical, design, engineering, fabrication, and public health, to meet the needs of the end user within the economic, health and political context in which they live.

Microfluidics and Engineering a New Doctor-Patient Interface
Professor Paul Yager, (UW, Bioengineering)

A major goal of our department and the Yager laboratory is to allow decentralization of medical diagnostics by making the technology less expensive while maintaining sensitivity and reliability, ultimately bringing sophisticated medical testing to the home. Our primary approach has been development of microfluidic devices and systems for chemical and biochemical analysis of body fluids, which contain a wide range of proteins and larger particles at concentrations not under experimental control. The key idea has been to exploit transport of matter across flow lines in pressure-driven flow; the driving force for transfer between streams has included concentration gradients, gravitation and electric fields.

Unintended consequences
Professor Robert Bea, Department of Civil & Environmental Engineering, University of California, Berkeley

Dr. Bea will discuss risk analysis and its importance to prevent unintended consequences that make technology less useful than it should be.

Biomedical Research in Space
Dr. Bonnie J. Dunbar, PhD, NAE
NASA Johnson Space Center, Assistant Director (University Research and Affairs)

To Tissue Engineer Heart Muscle

Professor Buddy D. Ratner[1], Margaret Allen[2], John Angello[1], Paul Bornstein[1], Kip Hauch[1], Stephen D Hauschka[1], Allan S. Hoffman[1], Charles Murry[1], Joan Sanders[1], Patrick Stayton[1], Robert Vernon[2], Kim Woodhouse[3],
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A challenging goal of this program is to tissue engineer (or regenerate) heart muscle that might be useful for in vivo reparative surgery. The unique muscle cells populating the heart, cardiomyocytes, have lost the ability to replicate. The heart muscle itself is highly vascularized. Muscle tissue is also aligned, organized with a mechanically appropriate extracellular matrix and innervated. Surgical considerations must be addressed. An interdisciplinary team funded through the NIH Bioengineering Research Partnership (BRP) program is exploring the feasibility of engineering heart muscle by addressing many of these challenges in a coordinated research effort. Individual investigator projects, coordinated through a strategic plan, are studying: (1) unique porous gels to stimulate angiogenesis, (2) three-dimensional muscle structures generated on 3-D scaffold arrays (3) the release of drugs, growth factors, angiogenic factors etc (4) a gene transfer system to improve the infarct bed for surgical transplantation (5 to investigate the conversion of embryonic myocardiocytes to conductive Purkinje fiber cells (6) the optimized culture conditions for production of functional basement membrane by myocytes in scaffolds, (7) the development of a bioengineered microvessel capable of sprouting capillaries with a supportive outer wall for the microvessel. (8) development of a perfusion system for oxygenating tissue during in vitro growth.

Flying with Animals: Interfacing Computer Electronics and Biology

Professors Thomas L. Daniel (UW, Biology) and Chris Diorio (UW, CSE)

Neurons and neuronal networks decide, remember, modulate, and control an animal's every sensation, thought, movement, and act. A key goal of neurobiology is understanding how neurons and neuronal networks control behavior. To study the neural substrates of behavior, we must correlate neuronal signaling and control with environmental stimuli, ideally in animals that are free to interact with their sensory world. In this talk we will describe our efforts to build implantable computers that link the electronic signaling of nerve tissue directly with the electronic signaling of digital circuitry, to allow us to probe the dynamical control of behavior in freely behaving animals.

LIFE-ON-A-CHIP

Professors Mary Lidstrom and Deirdre Meldrum, Co-Directors, Microscale Life Sciences Center, University of Washington

The availability of genome sequences for both prokaryotes and eukaryotes is laying the foundation for a revolution that will ultimately transform biology from a largely descriptive and reductionist discipline into a fundamentally predictive science. The growing ability to analyze whole biological systems based on genomic information is creating snapshots of cells at the transcriptional and translational level, which are providing preliminary insights into cellular complexity. However, to understand complex molecular outcomes such as cell proliferation, differentiation, apoptosis, and pathogenesis, it will be necessary to determine how the parts are integrated in time and space to form complex, dynamic cellular functions, and how cellular interactions create higher-order functions. Such analyses require the simultaneous measurement of many variables in real-time, and due to heterogeneity in cellular populations, these analyses need to be carried out for individual cells.

A new Center of Excellence in Genomic Science, the Microscale Life Sciences Center, funded by the National Institutes of Health, National Human Genome Research Institute, has been formed to design and build fully integrated and automated microsystems for the interrogation of individual cells. This core technology will then be converted into modules designed for specific applications, which will push the limits of detection to the minimum, in some cases, to single molecule levels. This enabling technology will be directed towards specific research problems in two main areas: 1) automated detection of rare cells in cell populations, and 2) real-time analysis of metabolism in individual cells. The integrated biologically-active microsystems we develop will push the limits of detection, tackle the module-to-module interconnect problem that is ubiquitous in all integrated microsystems, emphasize overall systems integration, and enable the production of comprehensive data sets. Ultimately, these microsystems will have far-reaching applications for both basic and applied research in broad areas of biomedical systems biology including understanding how cells become infected with HIV or Salmonella bacteria, how proteins act as regulatory switches to turn cell functions on and off, using genetic methods for early diagnosis of esophageal cancer, and understanding genetic changes in aging.