Workshop

Micro- and Nanotechnologies for Medicine: Emerging Frontiers and Applications

Harvard–MIT Health Sciences & Technology

Wyss Institute

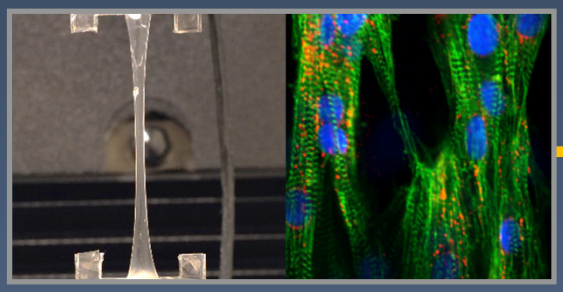
July 28th – August 1st 2014

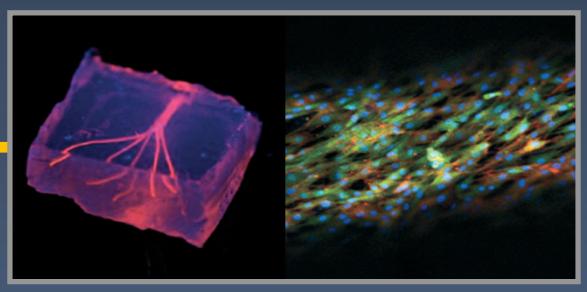
2nd Annual BIOMEMS workshop

65 Landsdowne Street
Cambridge, MA 02139

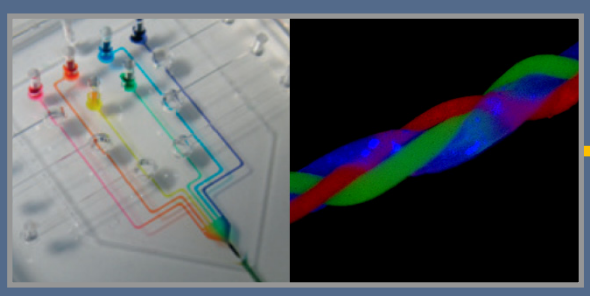
Organizers:

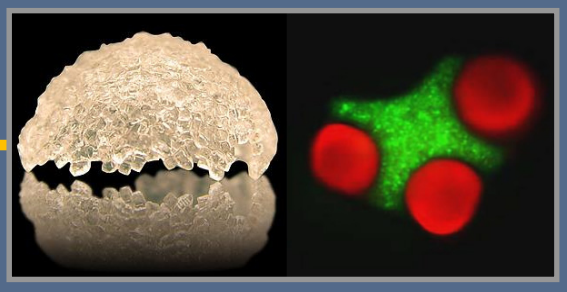
- Ali Khademhosseini, PhD.
- Nasim Annabi, PhD.
- Mehmet Dokmeci, PhD.





Biomaterials Innovation Research Center (BIRC)





Introduction

The advances in micro- and nanotechnologies are expected to open up new possibilities and applications in diagnostics, therapeutic drug delivery and regenerative medicine. In this workshops participants will acquire both the fundamental and advanced knowledge in the field of bioMEMS, biomaterials and tissue engineering. Leading experts will present the latest advances in the development of novel micro- and nanotechnologies and address a range of different challenges that are of importance to biomedicine at the interface of engineering, medicine and biological sciences.

The areas covered during the workshop

1. **Microfluidics**
2. **Biomaterials**
3. **Stem cells**
4. **Drug Delivery**
5. **BioMEMS and Biosensing**
6. **Tissue Engineering**
7. **Nanotechnology**
8. **Professional development/translation to products**

Program schedule

Day 1 (Monday, July 28th, 2014)

Keynote Speaker (Chair: Ali Khademhosseini)
9-10am Robert S. Langer (MIT)

Cardiovascular Tissue Engineering (Chair: Yeh-Chuin Poh)

10-11am Lisa Freed (Draper Laboratory and MIT)
11-12pm Lauren Black (Tufts)
12-1.30pm Lunch

Biomaterials I (Chair: Yu Shrike Zhang)
1.30-2.30pm David Kaplan (Tufts)
2.30-3.30pm Neel Joshi (Harvard University)
3.30-4pm Break
5-6pm Ali Khademhosseini (Harvard Medical School)
6-9pm Networking session

Day 2 (Tuesday, July 29th, 2014)

Tissue Engineering and stem cells (Chair: Nasim Annabi)
8.30-9.30am Jeff Karp (Harvard Medical School)
9.30-10.30am Yeh-Chuin Poh (Harvard Medical School)
10.30-11am Break
11-12pm Rebecca Carrier (Northeastern)
12-1.30pm Lunch

BioMEMS, biosensing, and flexible electronics (Chair: Mehmet Dokmeci)
1.30-2.30pm Fiorenzo Omenetto (Tufts)
2.30-3.30pm Rohit Karnik (MIT)
3.30-4pm Break
4-5pm Edward Boyden (MIT)
5-6pm Jeff Borenstein (Draper Laboratory)

Day 3 (Wednesday, July 30th, 2014)

Drug delivery (Chair: Yeh-Chuin Poh)
8.30-9.30am Shrike Zhang (Harvard Medical School)
9.30-10.30am Mansoor M. Amiji (Northeastern)
10.30-11am Break
11-12pm Nasim Annabi (Harvard Medical School)
12pm-1.30pm Lunch

Microfluidics and Organ-on-a-chip (Chair: Su Ryon Shin)
1.30-2.30pm David A. Weitz (Harvard University)
2.30-3.30pm Daniel Irimia (Harvard University)
3.30-4pm Break
4-5pm Claire Hur (Harvard)
5-6pm Mario Moises Alvarez (Instituto Tecnológico de Monterrey)

Day 4 (Thursday, July 31st, 2014)

Biomaterials II (Chair: Ali Tamayol)
8.30-9.30am Peng Yin (Harvard Univeisty)
9.30-10.30am Hicham Fenniri (Northeastern)
10.30-11am Break
11-12pm Esmaeel Jabbari (South Carolina)
12pm-1.30pm: Lunch

Nanotechnology (Chair: Nasim Annabi)
1.30-2.30pm Heather Clark (Northeastern)
2.30-3.30pm Michael Strano (MIT)
3.30-4pm Break
4-5pm Tom Webster (Northeastern)
5-6pm Qiaobing Xu (Tufts)

Day 5 (Friday, Aug 1st, 2014)

Translational research (Chair: Mehmet Dokmeci)
8.30-9.30am Frederick Schoen (BWH)
9.30-10.30am Art Coury (Northeastern)
10.30-11am Break
11-12pm Chris Loose- David Lucchino(Semprus Biosciences)
12-1.30pm Break

KEYNOTE SPEAKER

Robert S. Langer, Ph.D.
Professor
Department of Chemical Engineering
Massachusetts Institute of Technology

INVITED SPEAKERS

Mario Moisés Álvarez, Ph.D.
Professor
Centro de Biotecnología-FEMSA
Tecnológico de Monterrey in Monterrey México

Mansoor Amiji, Ph.D.
Professor and Chairman
Department of Pharmaceutical Sciences
Northeastern University

Nasim Annabi, Ph.D.
Instructor
Brigham and Women's Hospital
Harvard Medical School

Lauren D. Black , Ph.D.
Assistant Professor
Biomedical Engineering Department
Tufts University

Jeffrey T. Borenstein, Ph.D
Laboratory Technical Staff
Charles Stark
Draper Laboratory

Edward Boyden, Ph.D.
Associate Professor
Biological Engineering MIT Media Lab
Massachusetts Institute of Technology

Rebecca L. Carrier, Ph.D.
Associate Professor, Associate Chair of Research
Department of Chemical Engineering
Northeastern University

Heather A. Clark, Ph.D.
Associate Professor
Department of Pharmaceutical Sciences
Northeastern University

Arthur J. Coury, Ph.D.
Professor
Department of Chemical Engineering
Northeastern University

Hicham Fenniri, Ph.D.
Professor
Department of Chemical Engineering
Northeastern University

Lisa E. Freed, Ph.D.
Draper Laboratory
MIT Affiliated Research Scientist
Massachusetts Institute of Technology

Claire Hur, Ph.D.
Junior fellow
Rowland Institute
Harvard University

Daniel Irimia, MD., Ph.D.
Assistant Professor
Massachusetts General Hospital
Harvard Medical School

Esmaiel Jabbari, Ph.D.
Associate Professor
Chemical and Biomedical Engineering
University of South Carolina

Invited SPEAKERS (continued)

Neel Joshi, Ph.D.
Assistant Professor
Chemical and Bioengineering
Wyss Institute
Harvard University

David Kaplan, Ph.D.
Professor & Chair
Department of Biomedical Engineering,
Tufts University

Rohit Karnik, Ph.D.
Associate Professor
Mechanical Engineering Department
Massachusetts Institute of Technology

Jeffrey M. Karp, Ph.D.
Associate Professor
Brigham and Women's Hospital
Wyss Institute
Harvard Medical School

Ali Khademhosseini, Ph.D.
Associate Professor
Brigham and Women's Hospital
Wyss Institute
Harvard Medical School

Christopher Loose, Ph.D.
Co-founder of Semprus BioSciences
and Executive Director
Center for Biomedical and
Interventional Technology (CBIT)
Yale University

David Lucchino
Co-founder and CEO of Semprus
BioSciences

Fiorenzo G. Omenetto , Ph.D.
Professor
Biomedical Engineering
Tufts University

Yeh-Chuin Poh, Ph.D.
Postdoctoral Fellow
Harvard-MIT Division of Health Sciences and
Technology, Brigham and Women's Hospital,
Harvard Medical School

Frederick J. Schoen, M.D., Ph.D.
Professor and Vice-Chairman
Department of Pathology
Brigham and Women's Hospital
Harvard Medical School

Michael S. Strano, Ph.D.
Professor
Department of Chemical Engineering
Massachusetts Institute of Technology

Thomas J. Webster, Ph.D.
Department Chair and Professor
Department of Chemical Engineering
Northeastern University

David A. Weitz, Ph.D.
Professor
Department of Physics
Harvard University

Qiaobing Xu, Ph.D.
Assistant Professor
Biomedical Engineering Department
Tufts University

Peng Yin, Ph.D.
Assistant Professor
Systems Biology
Wyss Institute
Harvard University

Yu Shrike Zhang, Ph.D.
Postdoctoral Fellow
Brigham and Women's Hospital, Harvard
Medical School

Robert S. Langer

Massachusetts Institute of Technology

Robert S. Langer the David H. Koch Institute Professor (there are 11 Institute Professors at MIT; being an Institute Professor is the highest honor that can be awarded to a faculty member). Dr. Langer has written over 1,250 articles. He also has nearly 1,050 patents worldwide. Dr. Langer's patents have been licensed or sublicensed to over 250 pharmaceutical, chemical, biotechnology and medical device companies. He is the most cited engineer in history.
He served as a member of the United States Food and Drug Administration's SCIENCE Board, the FDA's highest advisory board, from 1995-2002 and as its Chairman from 1999-2002.

Dr. Langer has received over 220 major awards. He is one of 7 individuals to have received both the United States National Medal of Science (2006) and the United States National Medal of Technology and Innovation (2011). He also received the 2002 Charles Stark Draper Prize, considered the equivalent of the Nobel Prize for engineers, the 2008 Millennium Prize, the world's largest technology prize, the 2012 Priestley Medal, the highest award of the American Chemical Society, the 2013 Wolf Prize in Chemistry, the 2014 Breakthrough Prize in Life Sciences and the 2014 Kyoto Prize. He is the also the only engineer to receive the Gairdner Foundation International Award; 82 recipients of this award have subsequently received a Nobel Prize. Among numerous other awards Langer has received are the Dickson Prize for Science (2002), Heinz Award for Technology, Economy and Employment (2003), the Harvey Prize (2003), the John Fritz Award (2003) (given previously to inventors such as Thomas Edison and Orville Wright), the General Motors Kettering Prize for Cancer Research (2004), the Dan David Prize in Materials Science (2005), the Albany Medical Center Prize in Medicine and Biomedical Research (2005), the largest prize in the U.S. for medical research, induction into the National Inventors Hall of Fame (2006), the Max Planck Research Award (2008), the Prince of Asturias Award for Technical and Scientific Research (2008), the Warren Alpert Foundation Prize (2011) and the Terumo International Prize (2012). In 1998, he received the Lemelson-MIT prize, the world's largest prize for invention for being "one of history's most prolific inventors in medicine." In 1989 Dr. Langer was elected to the Institute of Medicine of the National Academy of Sciences, and in 1992 he was elected to both the National Academy of Engineering and to the National Academy of Sciences, and in 2012 he was elected to the National Academy of Inventors.

Mario Moisés Álvarez
Tecnológico de Monterrey, Mexico

Mario Moisés Alvarez is currently a full professor at the Centro de Biotecnología-FEMSA at Tecnológico de Monterrey in Monterrey México. He is also the director of the Biopharmaceutical Engineering Group at the same institution. His areas of research interest include biopharmaceuticals and pharmaceutical engineering, the mixing of liquids, and biomedical engineering.
Prof. Alvarez has completed an industrial postdoctoral stay at the Institute of Pharmaceutical Technology of Bristol-Myers Squibb, USA. He holds a Ph.D. in chemical and biochemical engineering from Rutgers University (2001), a M.Sc. in chemical and biochemical engineering from Rutgers University (2000), a M.Sc. in chemical engineering from Tecnológico de Monterrey (1993), and a B.Sc. in biochemical engineering from Tecnológico de Monterrey (1991).
He is a permanent member of the Mexican Academy of Sciences and a member of the National Research System, within which he has been awarded the highest level of ranking for Mexican researchers (SNI Level III). He is a member of the American Institute of Chemical Engineers (AIChE) and the North American Mixing Forum (NAMF). He has published more than 60 papers in international journals, including Proceedings of the National Academy of Science (one paper), Physical Review Letters (two papers), Lab on a Chip (two papers), PLoS One (three papers), and Biotechnology and Bioengineering (one paper). He has been granted two US patents and one Mexican patent.

Biopharmaceutical and Biomedical Applications of Continuous Flow Micro-reactors: The Production of Monoclonal Antibodies in Continuous Chips and the Anchorage and Proliferation of Cancer Cells in Zein Foams

Abstract: We present proof-of-principle results of a study of the use of continuous flow micro-channel devices for the production of biopharmaceuticals. Recombinant Chinese hamster ovary (CHO) cells, a war horse for the production of biopharmaceuticals, anchor, proliferate, and produce monoclonal antibodies (biosimilar to Infliximab) in continuous flow micro-devices. The geometries of the channels, the flow rates, and the roughness of the channel surfaces significantly influence cell anchorage and proliferation.
In addition, we demonstrate the use of foams made from zein (the main protein of maize) in cell culture applications that are relevant to the production of bio-pharmaceuticals and the culturing of cancer cells. Prostate cancer and breast cancer cells proliferate under continuous flow conditions on the surface of zein foams, forming “tree like” agglomerates that resemble solid tumors. Foams made from plant-derived biomaterials provide an alternative to the use of collagen, gelatin, and other animal-origin materials that are frequently used for biopharmaceutical and tissue engineering applications.

Mansoor Amiji
Northeastern University

Dr. Mansoor Amiji is currently the Distinguished Professor and Chairman of the Department of Pharmaceutical Sciences and Co-Director of Northeastern University Nanomedicine Education and Research Consortium (NERC) at Northeastern University in Boston, MA. NERC oversees a doctoral training program in Nanomedicine Science and Technology that was co-funded by the National Institutes of Health (NIH) and the National Science Foundation (NSF). Dr. Amiji received his BS degree in pharmacy from Northeastern University in 1988 and a PhD in pharmaceutical sciences from Purdue University in 1992. His research is focused on development of biocompatible materials from natural and synthetic polymers, target-specific drug and gene delivery systems for cancer and infectious diseases, and nanotechnology applications for medical diagnosis, imaging, and therapy. His research has received over $17 million in sustained funding from the NIH, NSF, private foundations, and pharmaceutical/biotech industries.

Translational Nano-medicine: Targeted Therapeutic Delivery for Cancer and Inflammatory Diseases

Abstract: The tremendous advances in molecular and personalized medicine also present challenges for translation of innovative experimental approaches into clinically relevant strategies. To overcome some of these challenges, nanotechnology offers interesting solutions for disease prevention, diagnosis, and treatment. For many systemic diseases, overcoming biological barriers and target specific delivery are the key challenges. Additionally, newer generation of molecular therapies, such as gene therapy, oligonucleotides, and RNA interference (RNAi) require robust and highly specific intracellular delivery strategies for effective and clinically meaningful therapeutic outcomes.

In this presentation, I will cover several of our approaches for development of multifunctional engineered nano-systems for targeted therapies in the treatment of cancer and inflammatory diseases. Specific examples will include: (1) overcoming tumor multidrug resistance using targeted polymeric nanoparticle-mediated combination therapy, (2) use of combinatorial-designed engineered nano-systems for RNAi therapy in cancer, (3) genetic modulation of macrophage phenotype to promote anti-inflammatory effect in the treatment of rheumatoid arthritis, and (4) oral RNAi approach for the treatment of inflammatory bowel disease using multi-compartmental nanoparticle-in-microsphere delivery system. In each of the above examples, we focus on challenging medical problems with innovative solutions that use safe materials and scalable fabrication methods in order to facilitate clinical translation and improve patient outcomes.

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Nasim Annabi
Harvard Medical School

Nasim Annabi is an instructor at Brigham and Women's Hospital and Harvard Medical School. She is also affiliated with the Wyss Institute for Biologically Inspired Engineering and the Harvard-MIT Division of Health Sciences and Technology. Her research involves tissue engineering of cardiac and vascular tissues, focusing on the cell and tissue responses to their microenvironment. She has developed advanced biomaterials with controlled physical and biological properties combined with microscale techniques to control tissue microarchitecture. She have synthesized and characterized various 3D cell-laden hydrogels for different tissue engineering applications. She has published 35 peer-reviewed papers in tissue engineering field. In addition, she is the author of 5 book chapters and 2 patents. She has also given over 55 seminars at various conferences and academic institutions.

Microengineering Hydrogels for Tissue Engineering Applications

Abstract: Micro- and nanoscale technologies have been shown to be powerful techniques in addressing the current challenges in tissue engineering. These technologies have allowed for an unprecedented ability to control cell-cell, cell-microenvironment and cell-soluble factors interactions through miniaturized assays for high-throughput cell-based studies. Hydrogels are excellent scaffolding materials in tissue engineering because they generate three dimensional (3D) hydrated environments for cellular support resembling in vivo conditions. Our group has been actively involved in merging of complex 3D hydrogels and micro/nanoscale technologies to precisely control cellular microenvironments and create 3D vascularized tissue constructs. Our work encompasses a wide range of scientific subjects from materials science to biology. In this presentation, I will outline our work in the development of microscale hydrogels to modulate cell-microenvironment interactions for tissue engineering applications. I will also highlight some of the clinical applications of the engineered tissue constructs.

Lauren D. Black
Tufts University

Lauren D. Black III received his BS in Aerospace Engineering from the University of Cincinnati and a MS and PhD in Biomedical Engineering from Boston University. In his thesis work under Dr. Bela Suki, he studied the role of alterations in the structural protein composition of the extracellular matrix in static and dynamic mechanical properties of tissues. He went on to a postdoctoral fellowship in the lab of Dr. Robert Tranquillo at the University of Minnesota, developing new tools to generate and culture engineered cardiac tissues. During his time in Minnesota he was awarded an F32 individual postdoctoral fellowship and a subsequent K99/R00 Pathway to Independence Award from the National Heart, Lung and Blood Institute at the National Institutes of Health. Dr. Black started as an Assistant Professor in the Biomedical Engineering Department at Tufts University in 2010, where he was recently awarded an NSF CAREER Award.

The Extracellular Matrix as a Dynamic Signaling Milieu in Normal and Pathological Cardiac Development

Abstract: The extracellular matrix is no longer viewed as a static support structure, but much of the recent work in studying mechanotransductive effects and other aspects of ECM signaling has been primarily carried out on singular ECM proteins, or on complex ECM derived from healthy adult organs. When trying to develop strategies to repair or regenerate myocardium, it is likely that cues that are present in the developing cardiac ECM are more relevant to promoting regeneration or de novo tissue formation. Moreover, understanding the role of the remodeled ECM of the infarct in cell-signaling to implanted cells is of critical importance. In this presentation I will highlight some of our lab's recent work in understanding the role that extracellular matrix-induced signaling plays in normal and pathological development in the heart and highlight how these findings may be used in tissue engineering and regenerative medicine strategies to repair the heart.

Jeffrey T. Borenstein
Draper Laboratory

Jeffrey T. Borenstein, PhD, is Laboratory Technical Staff at the Charles Stark Draper Laboratory in Cambridge, Massachusetts. Dr. Borenstein is a Principal Investigator for projects involving the application of microsystems technology towards engineered tissue constructs for organ assist devices and organ models for drug efficacy and safety testing, as well as implantable drug delivery systems for hearing loss and other diseases. These programs are funded by DARPA, the National Institutes of Health and several commercial sponsors. Prior to joining Draper Laboratory in 1994, Dr. Borenstein held positions as a research scientist for North American Philips Corporation and Mobil Corporation. Dr. Borenstein has a Ph.D. in Physics from the University at Albany and holds 32 issued patents, as well as over 60 published patent applications and over 80 peer-reviewed journal articles and conference proceedings.

Microfluidic Technologies for Programmable and Implantable Drug Delivery Devices

Abstract: Early applications of microfluidics have focused largely on lab-on-a-chip devices for laboratory research and clinical diagnostics. While these applications are advancing rapidly due to their low cost, ease of use and potential for miniaturization and integration, an equally compelling opportunity for microfluidics technology in medicine will be realized in programmable and implantable drug delivery systems. We will describe our progress in the application of microfluidics technologies toward implantable devices capable of precise,local and extended delivery of compounds for many clinical applications, including relatively inaccessible spaces such as the inner ear. Progress in miniaturization of micropump technologies, power sources and electronic control circuitry will enable fully implantable systems, potentially storing multiple compounds, and capable of programmable, time-sequenced delivery over periods of months or more. While our initial focus is on diseases of the auditory system, these technologies will ultimately afford highly controlled approaches toward treatment of a broad array of ophthalmologic and neurological diseases.

Ed Boyden
Massachusetts Institute of Technology

Ed Boyden is Associate Professor of Biological Engineering and Brain and Cognitive Sciences, at the MIT Media Lab and the MIT McGovern Institute. He leads the Synthetic Neurobiology Group, which develops tools for analyzing and engineering the circuits of the brain. These technologies, created often in interdisciplinary collaborations, include 'optogenetic' tools, which enable the activation and silencing of neural circuit elements with light, 3-D microfabricated neural interfaces that enable control and readout of neural activity, and robotic methods for automatically recording intracellular neural activity and performing single-cell analyses in the living brain. He has launched an award-winning series of classes at MIT that teach principles of neuroengineering, starting with basic principles of how to control and observe neural functions, and culminating with strategies for launching companies in the nascent neurotechnology space. He also co-directs the MIT Center for Neurobiological Engineering, which aims to develop new tools to accelerate neuroscience progress.

Tools for Mapping Brain Computations

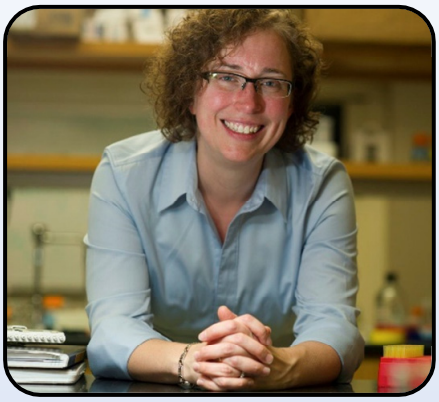
Abstract: The brain is a densely and precisely wired circuit made of heterogeneous cells, which themselves are complex computational devices made of an incredible repertoire of molecules. Our group develops tools for mapping, recording from, controlling, and building brain circuits, in order to reveal how they work, as well as to open up new therapeutic avenues. We have developed genetically-encoded reagents that, when expressed in specific neurons, enable their electrical activities to be precisely driven or silenced in response to millisecond timescale pulses of light. I will give an overview of these optogenetic tools, adapted from natural photosensory and photosynthetic proteins, and discuss new tools we are developing, including molecules that enable multiplexed, noninvasive, and ultraprecise optical neural control, even of endogenous signaling pathways. We are developing, often working in interdisciplinary collaborations, microfabricated hardware to enable complex and distributed neural circuits to be controlled and recorded in a fully 3-D fashion, new kinds of microscopes capable of whole-nervous system neural activity imaging, robots that can automatically record neurons intracellularly and integratively in live brain, and strategies for building 3-D brain circuits in vitro.

Rebecca L. Carrier
Northeastern University

Rebecca Carrier earned a Bachelor's Degree in Chemical Engineering from Rensselaer Polytechnic Institute (RPI) in 1995, and a Doctoral Degree in Chemical Engineering from Massachusetts Institute of Technology in 2000, where she worked in cardiac muscle tissue engineering. After completing her graduate studies, Dr. Carrier worked at Pfizer, Inc., as a Senior Research Scientist in oral controlled release drug delivery for three years. She sought an academic position and joined the Northeastern University (NU) Chemical Engineering Department. The goal of Dr. Carrier's research program is to relate material properties to biological response in drug delivery and regenerative medicine to enable technologies that benefit human health. To advance research efforts, Dr. Carrier has fostered collaboration and worked closely with multiple industrial partners including Pfizer, Merck, Boehringer Ingelheim, and Simulations Plus, Inc., a leader in development of pharmaceutical modeling software. Dr. Carrier received the National Science Foundation CAREER award in 2008 for mechanistic studies and modeling of lipid based drug delivery systems in the GI tract, and NU "Outstanding Teacher" and "Faculty Fellow" Awards in 2011 and 2014 for excellence in teaching and research leadership, respectively.

Biomaterials for Intestinal and Retinal Tissue Engineering

Abstract: Intestine and retina are two generally understudied tissues in regenerative medicine. Accurate in vitro models of intestine would be highly useful for pharmaceutical testing. Intestinal basement membrane possesses distinct structural features (e.g., crypts and villi) motivating study of structurally biomimetic materials. We are analyzing the impact of both approximate and precise biomimetic structure on intestinal cell differentiation. Multiple approaches are being pursued: 1. lithography is being utilized to recreate micro-scale crypt-villus (micro-well – micro-pillar) arrays in a biopolymer membrane, and 2. a novel method employing chemical vapor deposition (CVD) on native tissue is being utilized to recreate multiscale, irregular, complex features in a polymeric membrane. Retinal degenerative diseases, such as macular degeneration and retinitis pigmentosa, currently have no cure; retinal regeneration, aided by retinal progenitor cells (RPCs) delivered with an appropriate biomaterial vehicle, could help restore vision. We are exploring decellularized native tissue for delivery of RPCs to repair degenerated retina.



Heather A. Clark
Northeastern University

Prof. Heather Clark is an associate professor in the Department of Pharmaceutical Science, Northeastern University. Dr. Clark's cutting-edge research focuses on the development of nanosensors to measure concentrations of ions and small molecules at the cellular level. Dr. Clark obtained her degrees in Chemistry from the University of Michigan and then completed postdoctoral training at the Center for Biomedical Imaging Technology at the University of Connecticut Health Center. She has been the recipient of the DARPA Young Faculty Award, the Schumacher Research Award, and recognition in teaching. In addition, her work has been featured in a live CNN interview, the Wall Street Journal, WIRED magazine and MIT Technology Review.

The Nano Clinical Analyzer: Nanosensors for Biological Monitoring

Abstract: The limited available analytical tools for measuring real-time ion and small molecule flux at a cellular level have clarified cell physiology and signaling for a small number of analytes. Modular nanosensors may greatly expand the available library of probes by combining sensing chemistries within the core of a hydrophobic nanoparticle. This tunable analytical platform produces is already capable of measuring sodium, potassium, glucose, histamine, and other bio-analytes in real time. Implementing these probes in biological studies will quantitatively image the biochemical environment of neural cells and monitor physiologically relevant bio-analytes in vivo for chronic illness management. To this end, nanosensors that monitor real-time dynamics of drug concentrations in vivo will be discussed, as well as the extension of these probes to systemic physiological monitoring.

Arthur J. Coury
Northeastern University

Art Coury holds a B.S. degree in chemistry from the University of Delaware (1962), a Ph.D. in organic chemistry (1965) and an M.B.A. (1980) from the University of Minnesota. His industrial career included positions as: Senior Research Chemist at General Mills, Inc. (1965-1976), Director, Polymer Technology and Research Fellow at Medtronic, Inc. (1976-1993), Vice President, Research and Chief Scientific Officer at Focal, Inc. (1993-2000), and Vice President, Biomaterials Research at Genzyme Corporation (2000-June, 2008). His career focus has been polymeric biomaterials for medical products such as implantable electronic devices, hydrogel-based devices and drug delivery systems. He holds over fifty distinct patents and has published and presented widely in his field. Currently he is consultant and full Professor at Northeastern University.

Nanotechnology for Medical Products: Common and Unique Issues in Translation to the Marketplace

Abstract: Although nanotechnology as a known concept has been applied for many years to medical products, it is currently a burgeoning field of research and development. The technology implemented as powders, surfaces, porous structures, suspensions, liposomes, micelles, etc. provides the properties needed for many devices, drugs and combination products in current therapeutic and diagnostic use. Common to other medical products, before implementation as clinical products, nanotechnology-based medical products must meet a rigorous set of safety and efficacy specifications. Test protocols may be run according to established standards for drugs, and for device biomaterials, components and finished products. But, because living tissues behave differently between nano- and larger structures, unique test protocols must be developed for the former. Conceivably, expenses incurred in qualifying new, potentially "disruptive' nanotechnology-based medical products may exceed those of more conventional products. As is often encountered in product development, there materializes the "valley of death" of a promising concept after "proof of principle" and before major resources are designated for application to the required development program. A successful outcome usually requires a strategy based on knowledge of potential resources, leadership in attaining the resources and passionate dedication of staff to executing the development plan. Before committing to such an undertaking, a set of "imperatives" stated in the oral presentation should be considered and "checked off" as potentially feasible. Failure to achieve even one of these imperatives would seriously compromise chances for a commercially successful product. Consideration of bridging the "valley of death" by a hypothetical combination medical product and a case study of a successful vs. unsuccessful medical device in light of the list of "imperatives" comprise an important section of the oral presentation.

Hicham Fenniri
Northeastern University

Dr. Fenniri was educated at the Université Louis Pasteur in Strasbourg, France, receiving his undergraduate degrees in chemistry and biochemistry, and his M.Sc./Ph.D. degrees in supramolecular chemistry. He then joined the Scripps Research Institute in California, USA, where he carried out his postdoctoral training. In 1997 he joined the faculty in the Chemistry Department at Purdue University, where he initiated his independent academic career, and established the Purdue Laboratory for Chemical Nanotechnology. In 2003, He joined the National Research Council and the University of Alberta as a full professor and senior research officer to build and lead the Supramolecular Nanoscale Assembly program. Since 2013, Dr. Fenniri has been a full professor in the Department of Chemical Engineering at Northeastern, Boston, MA.
Dr. Fenniri has achieved international recognition as a leader in the areas of self-assembly, supramolecular chemistry, nanomedicine, and materials sciences. Dr. Fenniri is the recipient of several academic and professional honours and awards, including the Xerox Award (2006–2008), the 3M Faculty Award (2000, 2002), the Cottrell Teacher Scholar Award (2000–2005), and the US National Science Foundation Career Award (1999). Dr. Fenniri has been an invited professor at the Université de Strasbourg and the Collège de France (2010), the National University of Taiwan (2007), the University of Colorado Boulder, USA (2004), and Regensburg University, Germany (2002, 2003).

Engineering Biomedical Function in Supramolecular Nanomaterial

Abstract: Organic synthesis offers tremendous opportunities for the design of small molecules with the ability to spontaneously self-organize into well-defined supramolecular architectures under a defined set of physical conditions. Over the past several years we have developed and utilized a new class of heteropolycyclic molecules to explore hydrogen bonding in water, self-replication in auto-catalytic systems, supramolecular chirality, and the underlying physical phenomena of self-assembly and self-organization processes. With this knowledge in hand, we were able to create and tailor the chemical, physical, and biological properties of tubular nanostructures for applications in biomedical engineering and in the emerging fields nanobiotechnology, and nanomedicine. This lecture is an overview of the design, synthesis, and physical characterization of self-assembled organic nanotubes, and a broad overview of their biomedical applications.

Lisa E. Freed
Draper Laboratory- MIT

Lisa E. Freed is a Senior Member of Technical Staff, Draper Laboratory and an MIT Affiliated Research Scientist at the Institute of Medical Engineering & Sciences, the Harvard-MIT Division of Health Sciences & Technology (HST), and the Langer Lab. She received the S.B. in Life Sciences from MIT, S.M. and Ph.D. in Applied Biological Sciences from MIT, and M.D. from Harvard Medical School in the HST program. She has been a Principal Investigator at MIT since 1993 and at Draper since 2009. Her main research focus is tissue engineering. She has designed and developed biodegradable scaffolds that mimic aspects of tissue mechanical properties, carried out in vitro testing of cell- and tissue responses to biological and physical stimuli, used microtechnologies to engineer functional cartilage and cardiac tissue, and performed in vivo studies of implant efficacy and safety.

Scalable Unit for Building Cardiac Grafts

Abstract: Given the high prevalence of heart attack, heart failure, and congenital heart defects, microtechnologies that enable heart repair can have a huge clinical impact. However, microengineered vasculature has proven challenging to create, especially if the goal is a multi-compartmental tissue with robust conduits that can support fluid flow and mass transport in three dimensions (3D). We envision a scalable unit for building cardiac grafts wherein layers of engineered heart tissue are paired with dedicated engineered vascular networks. The design goal is a modular device which combines tough, slowly degrading elastomers that can provide anisotropic mechanical support with contractile heart cells. This talk will discuss how microtechnologies can be leveraged to fabricate 3D scaffolds capable of guiding heart tissue development, and how microfluidics and microtemplating can be used to enhance survival of heart cells cultured on these scaffolds. Other ideas in the area of microtechnologies for medicine will also be discussed.

SJ. Claire Hur
Harvard University

SJ. Claire Hur is currently a junior fellow at Rowland Institute at Harvard. She received her B.S., M.S. and PhD in Mechanical Engineering from UCLA in 2005, 2007 and 2011, respectively. During her study at UCLA, she has received numerous awards and scholarships, including Edward K. Rice Outstanding Doctoral Student award, HSSEAS academic scholarship, MAE department's Chevron scholarship and UCLA Dean's special fellowship. She has conducted her doctoral work under supervision of professor Di Carlo in Bioengineering department and her PhD thesis focused on development of label-free rare cell purifying inertial microfluidic devices. She co-authored 13 peer-reviewed journals, including three articles featured as journal covers, 32 conference proceedings, 3 US patents, and 2 international patents. She has been selected as one of two junior fellows at Rowland Institute at Harvard in September 2011 with 5 years of research funding for conducting her independent postdoctoral research.

Vortex Generating Inertial Microfluidics: Target Cell Purification and Therapeutic Molecular Delivery

Abstract: There is an increasing demand for techniques allowing intracellular delivery of exogenous substances with minimal toxicity for the purposes of cellular reprogramming studies, development of multigenic disorder therapies, as well as production of industrial and pharmaceutical compounds. The vortex-assisted electroporator uniquely provides the ability to sequentially deliver multiple molecules with different electroporation conditions (i.e., incubation times and electric fields) into identical cell populations by trapping cells in microfluidic vortices as exogenous substances are serially flown over them. The system also provides several novel features, including (i) pre-purification of target cells with a uniform size distribution, (ii) precise and individual molecular dosage control, and (iii) continuous sample agitation for molecular diffusion enhancement and uniform cytosolic molecular distribution. Given these capabilities, the developed electroporation system has practical potential as a versatile tool for cellular reprogramming studies, drug delivery applications, and studies optimizing complex molecular delivery processes.

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Daniel Irimia
Harvard Medical School

Daniel Irimia, MD, PhD is a biomedical engineer, trained as a physician, and pursuing research focused on the role of cell migration in health and disease conditions. At the interface between microscale-technologies and medicine, he is designing novel tools for precision measurements of white blood cell migration, for the early detection of sepsis in burn patients, and for studying the mechanisms of inflammation resolution. He is studying how cancer cells navigate efficiently through micron-scale mazes, to better understand how malignant tumors invade surrounding tissues and form distant metastases. He is also the organizer of the Dicty World Race, a competition for scientists to engineer faster and smarter moving cells. The race was featured on the front page of Wall Street Journal, and is attracting top researchers from US and Europe, mixing fun and serious science.

Microfluidic Assays for Precision Measurements of Cell Migration in Health and Disease

Abstract: While the neutrophil count is one of the most commonly used blood tests to evaluate the risk of infections in patients, it implicitly assumes that all neutrophils are normal and does not account for alterations of their function. To estimate the risk for infections more accurately in patients at risk, we are designing microfluidic devices that measure neutrophil chemotaxis directly from one droplet of blood and in conditions relevant to the neutrophil migration through tissues. By confining the moving neutrophils inside microfluidic channels, we can measure their speed and directionality with higher precision than any other assays. The mechanical confinement also enables us to define specific migratory signatures to typical chemoattractants. By combining mechanical and fluidic features in our devices, we can reverse the direction of moving neutrophils to achieve robust migration away from chemoattractants. Finally, we employ these devices for the early detection of sepsis and to identify interventions that restore normal neutrophil functions after major burn injuries.

Esmaiel Jabbari
University of South Carolina

Esmaiel Jabbari completed his PhD at Purdue University and postdoctoral studies at Monsanto, Rice University, and Mayo Clinic. He is the Director of Biomimetic Materials and Tissue Engineering Laboratory and Associate Professor of Chemical and Biomedical Engineering at the University of South Carolina. He is internationally known for his work on synthesis and processing of biomimetic materials for applications in regenerative medicine and drug delivery. He received the Berton Rahn Award from the AO Foundation in 2012 and the Stephen Milam Award from the Oral and Maxillofacial Surgery Foundation in 2008. He was elected to the College of Fellows of the American Institute for Medical and Biological Engineering (AIMBE) in 2013. He has published >190 books, book chapters, peer-reviewed journal articles, and conference proceedings, and >230 seminars at national and international conferences on biomaterials, tissue engineering, and drug delivery. He has mentored 92 undergraduates and graduate students, post-doctoral researchers, and visiting scholars in last 10 years.

Mutliscale Approach to Skeletal Tissue Regeneration

Abstract: The structural organization of articular cartilage is rooted in the arrangement of mesenchymal stem cells (MSCs) into morphologically distinct zones during embryogenesis with up-regulation of TGF-β, BMP, and IGF signaling pathways. This arrangement is central to the function of cartilage as an articulating surface with uppermost superficial zone providing lubrication, the middle zone resisting deformation, and the calcified zone serving as a mechanically-stable interface for load transmission to the underlying bone. A novel approach to cartilage regeneration is to generate a functional tissue construct that recapitulates the zonal complexity of the articular cartilage with microscale spatial resolution in matrix properties, encapsulated cells, and local distribution of growth factors. I will present experimental results on a multi-zonal approach to cartilage regeneration with microscale gradient in matrix stiffness, cell density, and growth factors.

Current bone grafts are limited by matrix stiffness and non-uniform or incomplete vascularization. In compact bone, osteons that are composed of apatite-nucleated collagen fibrils resist compression while microvessels in the network of Haversian and Volkmann canals uniformly supply nutrients to the embedded cells. A novel approach to regeneration of large metabolically-demanding load-bearing defects is to mimic the nano- and microscale organization of compact bone. I will present experimental results on a multiscale approach to bone regeneration with nanoscale structure for load-bearing and microscale organization for vascularity.

Neel Joshi
Harvard University

Neel Joshi attended Harvey Mudd College before obtaining his Ph.D. in Chemistry at UC Berkeley under the guidance of Matthew Francis. As a graduate student he worked on the development of new bioconjugation methodologies to target native protein residues. He then moved to Boston University to perform postdoctoral research with Mark Grinstaff. There he developed dendrimer-based biomaterials for use in cartilage regeneration applications. He also synthesized contrast agents for the quantitative assessment of cartilage health using computed tomography. Neel is currently an Associate Professor of Bioengineering at Harvard University in the School of Engineering and Applied Sciences in 2010. He also has an appointment as a Core Faculty member at the Wyss Institute of Biologically Inspired Engineering. His research focuses on the development of new biomaterials for biomedical and biotechnological applications based on engineered protein and peptide building blocks.

Building functional materials from proteins: Assembly and dynamism

Abstract: The continual boundary pushing efforts of scientists studying proteins that make up naturally occurring biomaterials provide fertile ground for the creation of smart materials inspired by biology. Combined with the sequence programmability of protein synthetic methodology, this represents a unique opportunity for the rational engineering of materials that can surpass the capabilities of their predecessors. Our group is working with chemical and biosynthetic methods to produce materials that exploit two functional properties that are uniquely suited to proteins – self-assembly and well-defined conformational dynamics. In one example, an engineered peptide sequence was assembled into nanotubes and used as a biocompatible reinforcement agent in the fabrication of a new resorbable composite for biomedical applications. In another example, we have used a domain insertion technique to fuse two protein sequences together and form new type of enzymatic biosensor. Finally, we have developed a novel approach to the fabrication of active surface coatings by leveraging the biosynthetic potential and genetic programmability of bacterial biofilms.

David Kaplan
Tufts University

David Kaplan is the Stern Family Endowed Professor of Engineering at Tufts University. He is Professor & Chair of the Department of Biomedical Engineering and also holds faculty appointments in the School of Medicine, Department of Chemistry and the Department of Chemical and Biological Engineering. His research focus is on biopolymer engineering to understand structure-function relationships, with emphasis on studies related to self-assembly, biomaterials engineering and regenerative medicine. He directs the NIH P41 Center on Tissue Engineering and has published over 600 peer reviewed papers.

Studying Brain Structure and Function – Biomaterial Challenges

Abstract: The brain remains one of the most important yet least understood tissues in our body, due in part to its complexity and to the limitations associated with *in vivo* studies. While simpler tissues have yielded to the emerging tools in the fields of biomaterials design and *in vitro* three dimensional tissue cultures, functional brain-like tissues have not progressed at the same rate. Progress in exploiting biomaterial systems for the study of brain-derived neural cells in complex architectures will be reviewed to illustrate where the science stands with respect to the recapitulation of brain-like structure and function. Key aspects of these systems include tunable protein hydrogels to match mechanical and biological needs, modular 3D compartmentalized architectures to host brain compartments, and electrophysiological functions that emerge from such systems to gain insight.

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Rohit Karnik
Massachusetts Institute of Technology

Rohit Karnik is Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology, where he leads the Microfluidics and Nanofluidics Research Group. His research focuses on the physics of micro- and nanofluidic flows and design of micro- and nanofluidic devices for applications in healthcare, energy systems, and bioseparation and analysis. He obtained his B. Tech. degree from the Indian Institute of Technology at Bombay in 2002, and his PhD from the University of California at Berkeley in 2006 under the guidance of Prof. Arun Majumdar. After postdoctoral work with Prof. Robert Langer at MIT, he joined the Department of Mechanical Engineering at MIT in 2007. Among other honors, he is a recipient of the Institute Silver Medal (IIT Bombay, 2002), NSF Career Award (2010), Keenan Award for Innovation in Undergraduate Education (2011), DOE Early Career Award (2012), and IIT Bombay Young Alumni Achiever Award (2014).

Direct Separation and Analysis of Cells Mediated by Transient Molecular Interactions in Microfluidic Devices

Abstract: Multiple sample-processing steps present a challenge for the development of low-complexity devices for laboratory or point-of-care separation and analysis of cells. In this talk, I will discuss a new approach that can directly separate, enrich, or analyze cells with minimal or no sample processing requirements. We show that transient cell-surface adhesive molecular interactions can exert forces on the cells that can direct the trajectories of cells flowing through microfluidic devices. Such interactions occur in cell rolling, a physiological phenomenon involved in cell trafficking where transient molecular bonds are continuously formed and broken as the cell rolls on a surface under the action of hydrodynamic forces. Using this approach, we demonstrate separation of cells with high purity and efficiency in parallel microchannel devices, and direct separation of neutrophils from blood with ultrahigh enrichment in a neutrophil activation-dependent manner. We extend this approach to controllably contact mesenchymal stem cells with receptor-coated surfaces to quantify cell adhesion behavior by visualization of their trajectories in a “cell adhesion cytometer”, which can track changes in the cell phenotype. The results demonstrate the potential of the emerging technology of using transient cell-surface molecular interactions to directly separate and analyze cells for point-of-care diagnostics, isolation of rare cells, quality control of stem cells, and other applications.

Jeffrey M. Karp
Harvard Medical School

Jeff Karp is an Associate Professor at Brigham and Women's Hospital, Harvard Medical School, and is Principal Faculty at the Harvard Stem Cell Institute and affiliate faculty at MIT through the Harvard-MIT Division of Health Sciences and Technology. His research uses materials and biology to solve medical problems with emphasis on nanoscale/microscale materials and bio-inspiration. He has published more than 100 peer-reviewed papers and book chapters and has given over 130 national and international invited lectures and has 50 issued or pending patents. Several technologies that he has invented are currently being translated into medical products to improve the quality of life of suffering patients. Dr. Karp's work has been recognized by CNN, NPR Science Fridays, Boston Globe, ABC News, MSNBC, Fox News, CBC Quirks and Quarks, CanadaAM, BBC, LA Times, Forbes, National Geographic, Popular Science, the Washington Post, the New York Post, and by Wired Magazine. In 2011 the Boston Business Journal recognized Dr. Karp as a Champion in Healthcare Innovation and in 2013 the Institute for Chemical Engineers (IChemE) awarded one of his technologies at the Most Innovative Product of the Year. MIT's Technology Review Magazine (TR35) also recognized Dr. Karp as being one of the top innovators in the world under the age of 35. He has received the Society for Biomaterials Young Investigator Award and his work has been selected as one of Popular Mechanic's "Top 20 New Biotech Breakthroughs that Will Change Medicine". Dr. Karp was also elected in 2013 to the American Institute for Medical and Biological Engineering's College of Fellows and as a Kavli Fellow. Dr. Karp is also an acclaimed mentor. He was selected as the Outstanding Faculty Undergraduate Mentor among all Faculty at MIT and received the HST McMahon Mentoring award for being the top mentor among all faculty who mentor Harvard-MIT students. To date, 16 trainees from his laboratory have secured faculty positions at institutions throughout the world.

Jackin' up MSCs!

Abstract: This talk will explore technologies that are currently being developed to control cell fate and function following transplantation. Namely, an mRNA transfection strategy using cells for targeted delivery of biologics will be discussed and approaches will be covered to engineer cells with an intracellular depots of phenotype altering agents that can be used for drug delivery or programming cell fate via both intracrine-, paracrine-, and endocrine-like mechanisms

Ali Khademhosseini
Harvard Medical School

Ali Khademhosseini is an Associate Professor at Harvard-MIT Division of Health Sciences and Technology, Brigham and Women's Hospital and Harvard Medical School as well as an Associate Faculty at the Wyss Institute for Biologically Inspired Engineering and a Junior PI at Japan's World Premier International-Advanced Institute for Materials Research at Tohoku University where he directs a satellite laboratory. He has authored over 340 journal papers (H-index = 61, >14100 citations) and 50 book chapters. In addition, he has delivered 250+ invited/keynote lectures. Dr. Khademhosseini's interdisciplinary research has been recognized by over 30 major national and international awards. He has received early career awards from three major engineering discipline societies: electrical (IEEE Engineering in Medicine and Biology Society award and IEEE Nanotechnology award), chemical (Colburn award from the AIChE) and mechanical engineering (Y.C. Fung award from the ASME). He is also a recipient of the Presidential Early Career Award for Scientists and Engineers, the highest honor given by the US government for early career investigators. He received his Ph.D. in bioengineering from MIT (2005), and MASc (2001) and BASc (1999) degrees from University of Toronto both in chemical engineering.
Read more at: http://www.tissueeng.net/

Microengineered hydrogels for stem cell bioengineering and tissue regeneration

Abstract: Micro- and nanoscale technologies are emerging as powerful tools for controlling the interaction between cells and their surroundings for biological studies, tissue engineering, and cell-based screening. In addition, hydrogel biomaterials have been increasingly used in various tissue engineering applications since they provide cells with a hydrated 3D microenvironment that mimics the native extracellular matrix. In our lab we have developed various approaches to merge microscale techniques with hydrogel biomaterials for directing stem cell differentiation and generating complex 3D tissues. In this talk, I will outline our work in controlling the cell-microenvironment interactions by using patterned hydrogels to direct the differentiation of stem cells. In addition, I will describe the fabrication and the use of microscale hydrogels for tissue engineering by using a 'bottom-up' and a 'top-down' approach. Top-down approaches for fabricating complex engineered tissues involve the use of miniaturization techniques to control cell-cell interactions or to recreate biomimetic microvascular networks. Our group has also pioneered bottom-up approaches to generate tissues by the assembly of shape-controlled cell-laden microgels (i.e. tissue building blocks), that resemble functional tissue units. In this approach, microgels were fabricated and induced to self assemble to generate 3D tissue structures with controlled microarchitecture and cell-cell interactions.

Christopher Loose
Semprus Biosciences

David Lucchino
Semprus Biosciences

Dr. Chris Loose serves as Executive Director of Yale University's Center for Biomedical and Interventional Technology (CBIT). He also holds an appointment as Assistant Professor Adjunct of Urology in the Yale School of Medicine. Additionally, Dr. Loose is an Accelerator Executive at the Center for Integration of Medicine and Innovative Technology (CIMIT). Previously, Dr. Loose co-founded Semprus BioSciences with Massachusetts Institute of Technology (MIT) Institute Professor Robert Langer and David Lucchino, and served as Chief Technology Officer until the company was acquired by Teleflex Incorporated in 2012 (TFX: $80M). In Chemical Engineering at MIT, Dr. Loose co-authored the Semprus Biosciences business plan which won entrepreneurial competitions at MIT, Harvard University and Oxford University. Prior to his graduate work, Dr. Loose was a chemical engineer at Merck Research Labs after graduating summa cum laude with a B.S.E in Chemical Engineering from Princeton University.

David Lucchino served as Chief Executive Officer and President of Semprus BioSciences until its acquisition by Teleflex Medical, Inc. (NYSE: TFX). He then served as a Vice President executing the post-M&A integration plan for eighteen months. David co-founded Semprus BioSciences while attending the Massachusetts Institute of Technology. Under his stewardship, Semprus BioSciences grew from two to 50 employees, secured $28.5 million in venture capital financing as well as $8.4 million in federal funding and received regulatory approval from the FDA and European regulators for its first medical device product within five years. David began his career as a technology marketing executive. He earned his MBA as an Alfred P. Sloan Fellow at the Massachusetts Institute of Technology. He also earned a Master of Science degree from Syracuse University and a Bachelor of Arts degree from Denison University. David is a member of the Board of Directors of the Massachusetts Biotechnology Council (Mass Bio), where he serves on the executive committee. He is a Trustee of Mt. Auburn Hospital, a Harvard Medical School facility, Babson College and the Multiple Myeloma Research Foundation.

Managing the Start-Up Transition

Abstract: Successfully building a start-up requires the identification and evaluation of a range of technical and business factors. The critical elements of team formation, first product identification, and business strategy creation will be discussed. Case studies will be drawn from the founding through sale of Semprus BioSciences with Bob Langer. We will review rules of the road for growing and evolving a biomedical start up.

Fiorenzo G. Omenetto
Tufts University

Fiorenzo G. Omenetto is the Frank C. Doble Professor of Engineering, and a Professor of Biomedical Engineering at Tufts University. He also holds an appointment in the Department of Physics. His research interests cover nonlinear optics, nanostructured materials (such as photonic crystals and photonic crystal fibers), nanofabrication, and biopolymer-based technological applications. He has proposed and pioneered the use of silk as a material platform for advanced technology with uses in photonics, optoelectronics and nanotechnology applications, is co-inventor on more than 50 disclosures on the subject, and is actively investigating novel applications that rely on this technology base both for technical and design applications. This material platform has been featured in MIT's Technology Review's magazine as one of the 'top ten technologies likely to change the world.' Prof. Omenetto was formerly a J. Robert Oppenheimer Fellow at Los Alamos National Laboratories, a Guggenheim Fellow, and is a Fellow of the Optical Society of America and of the American Physical Society.

Silk Biomaterials-Multifunctional Outcomes from Natural Building Blocks

Abstract: The use of silk as a material for technological applications has been introduced over the past few years. Silk is now finding new applications as a useful biocompatible material platform with utility in photonics and electronics, ranging from nanoscale optical lattices to metamaterials. We will overview how purified silkworm silk can be reassembled, among other things, in a multitude of high quality, micro- and nanostructured optical and optoelectronic elements largely or entirely composed of this organic, biocompatible and implantable protein matrix truly opening a new silk road that brings together the biological and high-tech worlds.

Yeh-Chuin Poh
Harvard Medical School

Yeh-Chuin Poh received his Ph.D (2013) and M.S. (2009) degrees from the University of Illinois at Urbana-Champaign, and his B.S.E degree (2008) from the University of Michigan, Ann Arbor, all in Mechanical Engineering. His research interest includes cell mechanics, mechanotransduction, nucleolar and cytoskeletal biomechanics, stress induced stem cell differentiation, tissue engineering, and biomaterials. Poh's research seeks to combined biomechanics and biochemistry at the cellular and subcellular levels to understand the fundamentals of cells in response to mechanical stimuli.

In Vitro Organization of Germ Layers from a Single Mouse Embryonic Stem Cell

Abstract: Understanding the mechanism of gastrulation – the early phase in embryonic development where the blastula loses its symmetry and forms organized germ layers (i.e. endoderm, mesoderm, and ectoderm) – has long been a major challenge to the field of developmental biology. A long standing objective in developmental biology is not only to direct the differentiation of ESCs into specific developmental lineages, but also to organize these differentiated lineages into spatially distinct arrangements resembling the physiological gastrulation. In vivo, research on embryo morphogenesis in lower animals has demonstrated the importance of mechanical forces. In vitro, experiments of self-sorting utilize embryoid bodies or pairwise sorting assays where two types of differentiated germ cells are homogeneously mixed. It has not been possible to study the organization of germ layers in mammals in vitro or in vivo. Here we show a method and evidence of a successful germ layer organization in mammalian cells that depends on cellular tension starting from a single embryonic stem cell in an effort to simulate in vivo physiological condition.

Frederick J. Schoen
Harvard Medical School

Schoen is Professor of Pathology and Health Sciences and Technology, Harvard Medical School; Executive Vice-Chairman, Department of Pathology, Brigham and Women's Hospital (BWH); and serves as Director of the BWH Biomedical Research Institute (BRI) Technology Innovation Program (TIP) and BWH Site Miner for both the Center for Integration of Medicine and Innovative Technology (CIMIT) and the Boston Biomedical Innovation Center (B-BIC). Schoen's research contributions have been in the areas of pathologic considerations and iterative and disruptive development of heart valve substitutes and other cardiovascular prostheses, mechanisms of calcification of bioprosthetic tissues, cardiovascular tissue engineering, and heart transplantation. He is author or co-author of nearly 500 manuscripts in journals and books and co-editor of Biomaterials Science: An Introduction to Materials in Medicine (3rd Edition 2012). He is Past-President of the Society For Biomaterials (SFB), the Society for Cardiovascular Pathology (SCVP), and the International Society for Applied Cardiovascular Biology (ISACB); Founding Fellow of the American Institute of Medical and Biological Engineering; and he has received lifetime achievement awards from the Society For Biomaterials (Founders Award, Clemson Award) and the Society for Cardiovascular Pathology. He serves or has served on many national and international academic and governmental advisory committees, grant review committees and editorial boards, and is consultant and scientific advisor to numerous medical device companies and governmental agencies. Schoen received a Ph.D. in Materials Science from Cornell University, an M.D. from the University of Miami School of Medicine, and did a Surgery internship followed by a residency in Anatomic Pathology and fellowship in Thoracic and Cardiovascular Pathology at the University of Florida. He joined BWH as Director of Cardiovascular Pathology in 1980.

Translational Medical Device Development: Principles, Challenges and Differences from Drug Development

Abstract: This presentation will outline the process of developing and implementing medical devices, especially the differences between these processes for drugs and devices and the associated regulatory implications. We will emphasize the importance of clinical need, multidisciplinary convergence, the concept of "value", the assessment of safety and efficacy, new iterative and disruptive developments, the evaluation of medical device failure, and professional development needs and opportunities for the translational medical device investigator.

Michael S. Strano
Massachusetts Institute of Technology

Prof. Michael S. Strano is currently the Charles and Hilda Roddey Professor in the Chemical Engineering Department at the Massachusetts Institute of Technology. He received is B.S from Polytechnic University in Brooklyn, NY and Ph.D. from the University of Delaware both in Chemical Engineering. He was a post doctoral research fellow at Rice University in the departments of Chemistry and Physics under the guidance of Nobel Laureate Richard E. Smalley. From 2003 to 2007, Michael was an Assistant Professor in the Department of Chemical and Biomolecular Engineering at the University of Illinois at Urbana-Champaign before moving to MIT. His research focuses on biomolecule/nanoparticle interactions and the surface chemistry of low dimensional systems, nano-electronics, nanoparticle separations, and applications of vibrational spectroscopy to nanotechnology.

New Concepts in Biosensing using Single Walled Carbon Nanotubes and Graphene

Abstract: Our lab at MIT has been interested in how the 1D and 2D electronic structures of carbon nanotubes and graphene respectively can be utilized to advance new concepts in molecular detection. We introduce CoPhMoRe or corona phase molecular recognition1 as a method of discovering synthetic antibodies, or nanotube-templated recognition sites from a heteropolymer library. We show that certain synthetic heteropolymers, once constrained onto a single-walled carbon nanotube by chemical adsorption, also form a new corona phase that exhibits highly selective recognition for specific molecules. To prove the generality of this phenomenon, we report three examples of heteropolymers–nanotube recognition complexes for riboflavin, L-thyroxine and estradiol. The platform opens new opportunities to create synthetic recognition sites for molecular detection. We have also extended this molecular recognition technique to neurotransmitters, producing the first fluorescent sensor for dopamine. Another area of advancement in biosensor development is the use of near infrared fluorescent carbon nanotube sensors for in-vivo detection2. Here, we show that PEG-ligated d(AAAT)7 DNA wrapped SWNT are selective for nitric oxide, a vasodilator of blood vessels, and can be tail vein injected into mice and localized within the viable mouse liver. We use an SJL mouse model to study liver inflammation in vivo using the spatially and spectrally resolved nIR signature of the localized SWNT sensors. Lastly, we discuss graphene as an interfacial optical biosensor, showing that it possesses two pKa values in alkaline and basic ranges. We use this response to measure dopamine in real time, spatially resolved at the interface with living PC12 cells which efflux dopamine, indicating graphene's promise as an interfacial sensor in biology.

Thomas J. Webster
Northeastern University

Thomas J. Webster's (H index 61 according to Google Scholar) degrees are in chemical engineering from the University of Pittsburgh (B.S., 1995) and in biomedical engineering from Rensselaer Polytechnic Institute (M.S., 1997; Ph.D., 2000). He is currently the Department Chair and Professor of Chemical Engineering at Northeastern University in Boston. His research explores the use of nanotechnology in numerous applications. Specifically, his research addresses the design, synthesis, and evaluation of nanophase materials (that is, materials with fundamental length scales less than 100 nm) as more effective biomedical devices. He has completed extensive studies on the use of nanophase materials to regenerate tissues and has graduated/supervised over 109 visiting faculty, clinical fellows, post-doctoral students, and thesis completing B.S., M.S., and Ph.D. students. To date, his lab group has generated over 9 textbooks, 48 book chapters, 306 invited presentations, at least 403 peer-reviewed literature articles, at least 567 conference presentations, and 32 provisional or full patents. His research is focused on development of biocompatible materials from natural and synthetic polymers, target-specific drug and gene delivery systems for cancer and infectious diseases, and nanotechnology applications for medical diagnosis, imaging, and therapy. His research has received over $17 million in sustained funding from the NIH, NSF, private foundations, and pharmaceutical/biotech industries.

Transitioning from Nano-to Pico-Technology: Toxicity, Infection, and Tissue Growth

Abstract: Inspired from biological systems, nanotechnology (and more recently, picotechnology) is beginning to revolutionize medicine including the improved prevention, diagnosis, and treatment of numerous diseases. This talk will summarize efforts over the past decade that have synthesized novel nanoparticles, nanotubes, and other nanomaterials to improve medicine. Efforts focused on the use of nanomaterials to minimize immune cell interactions, inhibit infection, and increase tissue growth will be especially emphasized. Tissue systems covered will include the nervous system, orthopedics, bladder, cardiovascular, vascular, and the bladder. Materials to be covered will include ceramics, metals, polymers, and composites thereof. Self-assembled nano-chemistries will also be emphasized. Nanomaterial toxicity, which has become a concern, will also be covered. Thus, this talk will:

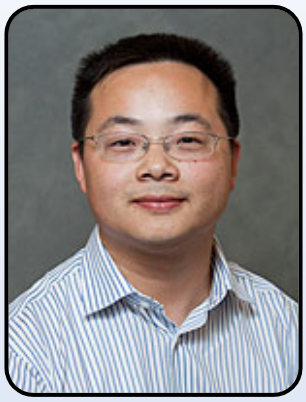
- Summarize recent advances in novel coatings for medical devices
- Emphasize novel properties of nano and pico-technology derived coatings, and
- Identify how such materials can be used to decrease inflammation, infection and improve tissue growth.

David A. Weitz
Harvard University

David Weitz received his PhD in physics from Harvard University and then joined Exxon Research and Engineering Company, where he worked for nearly 18 years. He then became a professor of physics at the University of Pennsylvania and moved to Harvard at the end of the last millennium as professor of physics and applied physics. He leads a group studying soft matter science with a focus on materials science, biophysics and microfluidics. He is director of Harvard's Materials Research Science and Engineering Center, funded by the National Science Foundation. In addition, several start-up companies have come from his group to exploit the technological potential of some of the research.

Drop-based Microfluidics for Single-cell Studies

Abstract: This talk will describe the use of drop-based microfluidics to isolate single cells in drops of picoliters to nanoliters in volume, and to use these as reaction chambers to prepare each cell to investigate its properties. By using genetic barcodes, it is possible to measure large amounts of information through second generation sequencing.



Qiaobing Xu
Tufts University

Dr. Qiaobing Xu is currently an assistant professor in Department of Biomedical Engineering at Tufts University. He also holds adjunction assistant professor position in Department of Chemical and Biological Engineering and School of Medicine at Tufts University. He obtained his B.S. in 1999, and M.Sc. in 2002 both from Department of Chemistry, Jilin University, Changchun, China. He obtained his PhD in chemistry under the guidance of Prof. George Whitesides from Harvard University where he invented "Nanoskiving", a novel technology to fabricate functional nanomaterials. From 2007-2010, he was a Cancer Center for Nanotechnology Excellence postdoctoral fellow with Prof. Robert Langer at MIT, where he worked on developing novel nanomaterials for drug delivery applications. He joined Tufts in September, 2010. His current research interests lie at the intersection of material science engineering, specifically micro/nanoscience, and biomedical application. His work involves using combinatorial method to develop novel materials for the delivery of therapeutic biomacromolecules and using nanotechnology to develop novel biomaterials for tissue engineering. He received Charlton Award from Tufts University School of Medicine in 2012 and named the Pew Scholar for Biomedical Sciences from Pew Charitable Trusts in 2013.

Chemical Modification of Proteins and Their Intracellular Delivery for Cancer Therapy

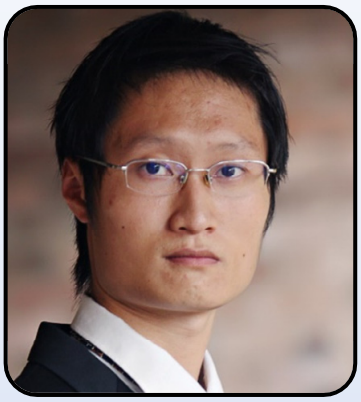
Abstract: Although protein-based drugs have shown success, they have been limited mostly to cytokines, growth factors, enzymes and monoclonal antibodies, all of which function primarily extracellularly. A number of diseases, including genetic diseases and cancers, have the potential to be treated through proteins with an intracellular target. However, proteins alone are not usually able to cross the cell membrane to reach their intracellular targets. Here I will present the development of an effective strategy to deliver therapeutic proteins into cytoplasm for cancer treatment, using a combination of the reversible modification of proteins and cationic lipid-based nanoparticles. The application of such novel delivery system for the inhibition of tumor cell proliferation both in vitro and in vivo will be demonstrated.

Peng Yin
Harvard University

Dr. Yin is an Assistant Professor of Systems Biology at Harvard Medical School and a Core Faculty Member at Wyss Institute for Biologically Inspired Engineering at Harvard University. His research interests lie at the interface of information science, molecular engineering, and biology, his current focus being to engineer information directed self-assembly of nucleic acid (DNA/RNA) structures and devices, and to exploit such systems to do useful molecular work.
Dr. Yin's research has been recognized through several prestigious awards including a 2010 NIH Director's New Innovator Award, a 2011 NSF CAREER Award, a 2011 DARPA Young Faculty Award, a 2011 ONR Young Investigator Program Award, a 2013 NIH Director's Transformative Research Award, a 2013 NSF Expedition in Computing Award, a 2014 ACS Synthetic Biology Young Scientist Award, a 2014 World Economic Forum Young Scientist Award. He is also a finalist for the 2014 Blavatnik National Award for Young Scientists.

Molecular Programming with DNA

Abstract: I will discuss my lab's research on engineering synthetic, nucleic acid-based nanostructures and their applications in biosensing, imaging, nanofabrication, and tissue engineering. We have recently invented a general framework for programming the self-assembly of short synthetic nucleic acid strands into prescribed target shapes or demonstrating their prescribed dynamic behavior. Using short DNA strands, we have demonstrated the modular construction of sophisticated 1D (Science, 321:824, 2008), 2D (Nature, 485:623-626, 2012) and 3D (Science, 338:1177, 2012) structures on the 100-nanometer scale with nanometer precision. Using reconfigurable DNA hairpins, we have demonstrated diverse, dynamic behavior such as catalytic circuits, triggered assembly, and autonomous locomotion (Nature, 451:318, 2008).
By interfacing these synthetic, nucleic acid nanostructures with functional molecules, we are developing diverse applications. In bioimaging, we have engineered geometrically encoded fluorescent barcodes for highly multiplexed single-molecule imaging (Nature Chemistry, 4:832-839, 2012) and dynamic fluorescent probes for highly multiplexed 3D super-resolution cellular imaging (Nature Methods, 11:313, 2014; Science, 334:65, 2014). In biosensing, we have constructed robust and ultraspecific probes for detecting single-base changes in a single-stranded DNA/RNA target (Nature Chemistry, 4:208-214, 2012). In nanofabrication, we have collaboratively developed a versatile framework for producing inorganic materials (e.g. graphene [Nature Communications, 4:1663, 2013], silicon dioxides [JACS, 135:6778, 2013], silver, gold) with arbitrarily prescribed nanometer scale shapes. In tissue engineering, we have developed a general strategy to engineer DNA directed self-assembly of biocompatible hydrogel bricks into complex architectures (Nature Communications, 4:2275, 2013).



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Yu Shrike Zhang was born in Nanjing, Jiangsu, China. He received a B.Eng. in Biomedical Engineering from Southeast University, Nanjing in 2008. He then came to the U.S. to pursue his doctoral training in Biomedical Engineering with Prof. Younan Xia at Washington University in St. Louis and Georgia Institute of Technology/Emory University School of Medicine, where he received his Ph.D. degree in 2013 on the development of inverse opal scaffolds and photoacoustic microscopy for biomedical applications. Currently he is a postdoctoral research fellow in Prof. Ali Khademhosseini's group at Harvard Medical School, Brigham and Women's Hospital, and Harvard-MIT Health Sciences and Technology, focusing on the refinement of organs-on-a-chip platforms. Shrike has co-authored more than 35 peer-reviewed publications spanning across a wide spectrum of areas including biomaterials, regenerative engineering, drug delivery, cancer theranostics, biomedical imaging, and microfluidics. More details can be found on his personal website: http://shrikezhang.weebly.com

Drug and Cell Delivery using Micro- and Nanoparticles

Abstract: Micro- and nanoparticles play critical roles in the field of drug and cell delivery due to their ease of fabrication, versatility in architecture, and potential in multi-functionality. Over the years a variety of particulate carrier systems have been developed to efficiently deliver drugs and therapeutic agents to treat/diagnose cancers as well as to improve tissue regeneration. In this talk, I will start with gold nanocages which possess hollow interiors for highly efficient drug loading, excellent surface accessibility for functionalization of targeting ligands, and tunable optical/photothermal properties for diagnostics and therapeutics (i.e. theranostics). I will then move on to polymeric materials and describe the microfluidic fabrication of microspheres with controllable sizes, structures, and porosity. Stimuli-responsive multi-step release of drugs from hierarchically structured vehicles will be discussed. Finally, I will present a novel approach to produce uniform microbeads with interconnected pores for the delivery of therapeutic cells and modular construction of micro-tissues through self-assembly.

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