VIRTUAL MATERIALS DAY

Design and Fabrication of Tissue Architectures

PROGRAM

Friday, October 23, 2020

Keynote Speaker Jennifer A. Lewis

Harvard University & Wyss Institute

Jianming Yu Professor of Arts and Sciences

Hansjörg Wyss Professor of Biologically Inspired Engineering

John A. Paulson School of Engineering and Applied Sciences

In Vitro Vascularization of Organoid Building Blocks and 3D Tissues

Lecture Abstract: Recent protocols in developmental biology are unlocking the potential for stem cells to undergo differentiation and self-assembly to form "mini-organs", known as organoids. To bridge the gap from organoid building blocks (OBBs) to therapeutic functional tissues, integrative approaches that combine bottom-up organoid assembly with top-down bioprinting are needed. While it is difficult, if not impossible, to imagine how either organoids or bioprinting alone would fully replicate the complex multiscale features required for organ-specific function – their combination may provide an enabling foundation for de novo tissue manufacturing. My talk will begin by describing our recent efforts to generate organoids in vitro with perfusable microvascular networks that support their viability and maturation. Next, I will describe the generation of 3D vascularized organ-specific tissues by assembling OBBs into a living matrix that supports the embedded printing of macro-vessels by a process known as sacrificial writing in functional tissue (SWIFT). Though broadly applicable, I will highlight our recent work on kidney, cerebral, and cardiac tissue engineering.

Speaker Bio: Jennifer A. Lewis is the Jianming Yu Professor of Arts and Sciences, the Wyss Professor for Biologically Inspired Engineering in the Paulson School of Engineering and Applied Sciences, and a core faculty member of the Wyss Institute at Harvard University. Her research focuses on design and fabrication of functional, structural, and biological materials that emulate natural systems. Prior to joining Harvard, Lewis was a faculty member in the Materials Science and Engineering Department at the University of Illinois at Urbana-Champaign, where she served as the Director of the Materials Research Lab. She earned her Sc.D. in Ceramics Science from MIT.

Lewis has received numerous awards, including the National Science Foundation Presidential Faculty Fellow Award, the American Chemical Society Langmuir Lecture Award, the Materials Research Society Medal Award, the American Ceramic Society Sosman and Roy Lecture Awards, and the Lush Science Prize. Her research has enjoyed broad coverage in the popular media. To date, she has co-founded two companies that are commercializing technology from her lab.

Treena Livingston Arinzeh
New Jersey Institute of Technology

Professor
Department of Biomedical Engineering

Functional Biomaterials for Tissue Regeneration

Lecture Abstract: Tissue engineering and regenerative medicine approaches for rebuilding damaged or diseased tissues have shown promise. Stem cells have been sought as an attractive cell source to be used in combination with biomaterials that act as scaffolds to regenerate tissues. Recent discoveries have shown that the properties of the scaffold can influence stem cell self-renewal and/or differentiation, which has had a tremendous impact on identifying strategies for using these cells effectively in the body. This presentation will describe studies examining the influence of biomaterials on stem cell behavior with an emphasis on identifying biomaterial properties and designs that impart appropriate cues to stem cells to affect their behavior both in vitro and in vivo. Recent results using biomimetic materials, specifically piezoelectric polymers and composites that provide electromechanical cues to stem cells and other cell types, will be discussed. Findings demonstrating stem cell differentiation and tissue formation using novel glycosaminoglycan mimetics, which are polysaccharides that also exhibit piezoelectric properties and prolong the bioactivity of growth factors, will be presented. These biomaterials and their potential use for neural and orthopaedic applications also will be discussed.

Speaker Bio: Treena Livingston Arinzeh, PhD is a Professor of Biomedical Engineering at the New Jersey Institute of Technology (NJIT). Dr. Arinzeh received her B.S. from Rutgers University in Mechanical Engineering, her M.S.E. in Biomedical Engineering from Johns Hopkins University, and her Ph.D. in Bioengineering from the University of Pennsylvania. She worked for several years as a project manager at a stem cell technology company, Osiris Therapeutics, Inc. Dr. Arinzeh joined the faculty of NJIT as one of the founding faculty members of the department of Biomedical Engineering and served as interim chairperson and graduate director. Dr. Arinzeh has been recognized with numerous awards, including the National Science Foundation (NSF) CAREER

Award and the Presidential Early Career Award for Scientists and Engineers (PECASE). She is a fellow of the American Institute for Medical and Biological Engineering (AIMBE) and the Biomedical Engineering Society (BMES). She recently served as the chairperson for the National Institutes of Health (NIH) Musculoskeletal Tissue Engineering (MTE) Study Section. She is currently a co-PI and the Director of Diversity of the NSF Science and Technology Center on Engineering Mechanobiology, which is a multi-institutional center with the University of Pennsylvania and Washington University in Saint Louis.

Jason Burdick

University of Pennsylvania

Professor
Department of Bioengineering

Biofabrication Approaches to Organize Engineered Tissues

Lecture Abstract: Biofabrication is described as the production of complex living and non-living biological products from raw materials such as living cells, molecules, extracellular matrices, and biomaterials. This interdisciplinary field has seen rapid technological advances that are important in the fabrication of engineered tissues, particularly with the incorporation of defined structures that drive tissue function. Our group is particularly interested in advancing these technologies towards tissue repair and drug screening. For example, hydrogels that best support cartilage growth are generally quite weak; however, we have engineered composites from the melt-electrowriting of polycaprolactone and cell-instructive hyaluronic acid hydrogels to achieve near-native cartilage tissue properties from embedded mesenchymal stromal cells. As another example towards a disease model of myocardial infarction (MI), we developed a new bioprinting approach to transfer cellular spheroids into self-healing support hydrogels at high resolution, enabling their patterning and fusion into high-cell density microtissues. We bioprinted iPSC-derived cardiac microtissue models with

spatially controlled cardiomyocyte and fibroblast cell ratios to replicate the structural and functional features of scarred cardiac tissue (e.g., reduced contractility, irregular electrical activity) and used them to screen microRNA therapeutics. Such technologies are likely to make a major impact across wide biomedical fields.

Speaker Bio: Jason A. Burdick, PhD is the Robert D. Bent Professor of Bioengineering at the University of Pennsylvania. Dr. Burdick's research involves the development of hydrogels through techniques such as photocrosslinking and self-assembly and their processing using approaches such as electrospinning and 3D printing. The applications of his research range from controlling stem cell differentiation through material cues to fabricating scaffolding for regenerative medicine and tissue repair. Jason currently has over 250 peer-reviewed publications and he is on the editorial boards of Journal of Biomedical Materials Research A, Biofabrication, and Advanced Healthcare Materials, and is an Associate Editor for ACS Biomaterials Science & Engineering. He has been recognized through numerous awards such as a Packard Fellowship in Science and Engineering, an American Heart Association Established Investigator Award, the Clemson Award for Basic Science through the Society for Biomaterials, and the Acta Biomaterialia Silver Medal Award. Lastly, Jason has been elected to the American Institute for Medical and Biological Engineering and the National Academy of Inventors and has founded several companies to translate technology developed in his laboratory.

Mark Grinstaff
Boston University

Distinguished Professor of Translational Research
Department of Biomedical Engineering
Department of Chemistry
Division of Materials Science and Engineering

Biomaterial Based Tissue Augmentation and Preservation Strategies

Lecture Abstract: Disease, injury, and trauma adversely affect tissue function. Strategies to repair such tissues are being investigated across the length scales from molecular to macroscopic. In this lecture, I will share two approaches and our successes. As a case example, I will focus on the repair of articulating tissues and in particular articular cartilage. Specifically, I will describe two polymeric biomaterial-based approaches for the treatment of osteoarthritis (OA). In the first approach, a tissue-supplementing technique is described in which a polymer is polymerized in situ throughout cartilage tissue to form an interpenetrating network. The treatment restores the inferior compressive properties of osteoarthritic cartilage to that of healthy cartilage, preferentially localizing to weaker regions of tissue. The treatment technique also preserves cartilage under harsh articulation conditions. In the second approach, novel hydrophilic polymers lubricate healthy and worn cartilage, provide cushioning, and reside in the joint after intraarticular injection for months. For both approaches, I will discuss the synthesis and characterization of the biomaterials, their performance in ex vivo and in vivo models, and the design requirements. Importantly, the lessons learned in this study are applicable to other dynamic and mechanically functioning tissues such as the muscle, lung, and heart.

Speaker Bio: Mark W. Grinstaff is the Distinguished Professor of Translational Research at Boston University. He is also the Director of BU's Nanotechnology Innovation Center and the Director of the NIH T32 Biomaterials Program. Mark's awards include the ACS Nobel Laureate Signature Award, NSF Career Award, Pew Scholar in the Biomedical Sciences, Camille Dreyfus Teacher-Scholar, Alfred P. Sloan Research Fellowship, the Edward M. Kennedy Award for Health Care Innovation, and the Clemson Award for Applied Research. He is a Fellow of the American Institute of Medical and Biological Engineering, and the Royal Chemical Society, and a Founding Fellow of the National Academy of Inventors. Over the course of his tenure, Grinstaff's groundbreaking research has yielded more than 325 peer-reviewed publications, more than 200 patents and patent applications, and more than 350 oral presentations. He is a co-founder of several companies and his innovative ideas and his efforts have also led to one new FDA approved pharmaceutical (AbraxaneTM) and four medical device products (OcuSeal® and Adherus Surgical Sealants®) that have become the standard of care. His current research activities involve the synthesis of new macromolecules and biomaterials, self-assembly chemistry, imaging contrast agents, drug delivery, and wound repair.

Joerg Lahann

University of Michigan

Wolfgang Pauli Collegiate Professor of Chemical Engineering
Director of the Biointerfaces Institute
Department of Chemical Engineering
Department of Biomedical Engineering
Department of Macromolecular Science and Engineering
Department of Materials Science and Engineering

3D Jet Writing of Tessellated 3D Scaffolds

Lecture Abstract: The need for high-precision microprinting processes that are controllable, scalable, and compatible with different materials persists throughout a range of biomedical fields. Electrospinning techniques offer a range of attractive properties, such as scalability and compatibility with a wide arsenal of polymers, but typically lack precise 3D control. I will discuss the use of 3D jet writing to enable the high-throughput production of precisely engineered 3D structures, including complex, shape-shifting tandem scaffolds. These regularly tessellated scaffold structures induce hydrodynamic shearing and extended deposition of fibrillar networks of extracellular matrix proteins, such as fibronectin. Three-dimensional scaffolds decorated with these engineered extracellular matrices provide a native-like culture system for a wide range of human cells including induced pluripotent stem cells and cardiomyocytes.

Speaker Bio: Prof. Lahann is currently the Wolfgang Pauli Collegiate Professor of Chemical Engineering and the Director of the Biointerfaces Institute. The Biointerfaces Institute is located on 56,000 sq ft of research space in the North Campus Research Complex and is the home to 30 research groups and about 350 researchers. Prior to joining UM, he conducted postgraduate studies under the supervision of Prof. Robert S. Langer at MIT.

Prof. Lahann is a co-author of more than 260 publications including papers and has contributed to 50 patents and patent applications. He has been selected by Technology Review as one of the top 100 young investigators and the recipient of the 2007 Nanoscale Science and Engineering Award, a NSF-CAREER award, and both a single-PI and a team Idea award from the US Department of Defense. In 2011, he was elected as a fellow of the American Institute of Medical and Biological Engineering. Prof. Lahann has mentored 36 graduate students and 30 postdoctoral students. Prof. Lahann serves on leadership committees for the University of Michigan Forbes

Institute for Cancer Discovery, the Rogel Cancer Center, the University of Michigan Materials Institute, and the UM Biosciences Initiative Coordinating Committee.

Shulamit Levenberg
Technion Israel Institute of Technology

Professor
Department of Biomedical Engineering

Fabrication of Functional Vessel Networks for Tissue Regeneration

Lecture Abstract: Fabricating vascularized constructs represents a key challenge in tissue engineering. In vitro pre-vascularization of engineered tissues can be achieved by co-culturing of endothelial cells, support cells and cells specific to the tissue of interest. This approach supports formation of endothelial vessels and promotes endothelial and tissue-specific cell interactions. In addition, we have shown that pre-vascularization of engineered tissue can promote its survival and perfusion upon implantation. Implanted vascular networks can anastomose with host vasculature and form functional blood vessels in vivo. Sufficient vascularization in engineered tissues can be achieved through coordinated application of improved biomaterial systems with proper cell types. We have shown that vessel network maturity levels and morphology are highly regulated by matrix composition. We also explored the effect of mechanical forces on vessels organization and analyzed the vasculogenic dynamics within the constructs. We demonstrated that morphogenesis of 3D vascular networks is highly regulated by tensile forces. Creating complex vascular networks with varying vessel sizes is the next challenge in engineering vascularized tissue constructs. We showed that combination of macro-vessels with self-assembled micro-vessels allows fabrication of multi-scale vascular networks.

Speaker Bio: Professor Shulamit Levenberg is the elected Dean of the Biomedical Engineering Faculty at the Technion. She also serves as the director of the Technion Center for 3D Bioprinting and The Schneur Center for Diabetes Research. Prof

Levenberg earned her PhD at the Weizmann Institute of Science and pursued her post-doctoral research in tissue engineering at MIT, in the lab of Professor Langer. In 2004, she joined the Technion Faculty of Biomedical Engineering where she conducts interdisciplinary research on stem cells, biomaterials and tissue engineering. She spent a sabbatical year (2011-2012) as a visiting professor at the Wyss Institute for Biology Inspired Engineering at Harvard University. Prof Levenberg received the Krill Prize for excellence in scientific research, awarded by the Wolf Foundation, and was named by Scientific American as a "Research Leader" in tissue engineering, for her work on vascularization of engineered tissues, improving survival and perfusion of engineered grafts. She also received the France-Israel Foundation Prize, the Italian Excellence for Israel Prize, the Teva Research Prize and the Juludan Prize. In 2018, she received the Rappaport Prize for Biomedical Sciences and in 2019 received the Bruno prize. Levenberg is a member of the Israel National Counsel for Bioethics and is actively involved in training young scientists.

Jennifer West

Duke University

Fitzpatrick Family University Distinguished Professor of Engineering
Associate Dean for Ph.D. Education
Department of Biomedical Engineering
Department of Mechanical Engineering and Materials Science
Department of Chemistry

Biomimetic Patterning of Materials to Control and Manipulate Tissue Formation

Lecture Abstract: The West Lab has worked extensively in the development of surfaces and 3D scaffold materials that provide a high degree of control over cell adhesion and signaling events. These materials support very low levels of protein adsorption, and thus cell-material interactions are restricted to those intentionally engineered into

the material design. Hydrogel scaffold materials have also been developed that are degraded in response to cellular proteolytic activity. This allows materials to degrade in response to cell activities such as migration rather than continuous hydrolysis as is seen in common polyesters. We have developed patterning technologies in both 2D and 3D to allow spatial control over cell-material interactions. Image-guided laser scanning lithography has allowed us to recapitulate cellular focal adhesion complexes with nanoscale resolution to control and manipulate cytoskeletal architecture of cells seeded on these patterned surfaces. We can prepare highly homogeneous cellular arrays using this technology. Two-photon laser scanning lithography allows 3D micropatterning of covalently immobilized peptides and proteins in hydrogels, again with nanoscale resolution, to guide cell migration and network assembly. This technology allows free-form 3D patterning for material fabrication, immobilization of bioactive factors, or manipulation of mechanical properties. Confocal images from tissues can be used to develop patterning instructions in order to recapitulate complex tissue architectures within scaffold biomaterials.

Speaker Bio: Professor West's research focuses on the development of novel biofunctional materials, with research in regenerative medicine and cancer nanotechnology. Part of her program has developed nanoparticle-based approaches to biophotonics therapeutics and diagnostics. An example of this work is the application of near-infrared absorbing nanoparticles for photothermal tumor ablation. In animal studies, this therapeutic strategy has demonstrated very high efficacy with minimal side effects or damage to surrounding normal tissues. In 2000, Professor West founded Nanospectra Biosciences, Inc. to commercialize the nanoparticle-assisted photothermal ablation technology, now called AuroLase. Professor West has received numerous accolades for her work. In 2017, she was elected to the National Academy of Inventors. In 2016, she was elected to the National Academy of Engineering. In 2015, she received the Society for Biomaterials Clemson Award. In 2014, she was recognized by Thomson Reuters as a Highly Cited Researcher, the top 1% in the field of materials

E-POSTER PRESENTERS
Station Assignments

FLOOR 1
IMAGING (STATIONS 1-3)
3D AND CELL PATTERNING (STATIONS 4-5)

Imaging

Station 1: Jing Guo (Florida International University)
Optical Sensing and Imaging for Engineered Cardiac Tissue

Advised by Jin He

Station 2, Bill Zhao (Boston University)
Computational Tools for Identifying Spatial and Temporal Patterns in Contracting hiPSC-cardiomyocytes

Advised by Emma Lejeune

Station 3, Huate Li (Boston University)
Platform for Dynamically-tunable Isometric and Auxotonic Force Control of Engineered 3D Cardiomyocyte Tissues

Advised by Thomas Bifano

3D Cell Patterning

Station 4, Jeffrey Horowitz & Xiaoyang Zhong (University of Michigan)
Printable Organic Electronic Materials for Attaching Cells

Jeffrey Horowitz advised by Stephen Forrest
Xiaoyang Zhong advised by Joerg Lahann

Station 5, Cecelia Kinane (University of Michigan)
Cardiomyocyte Bundling into Microtubules as Building Blocks to Recapitulate Fibrillar Morphology of Cardiac Tissue

Advised by Max Shtein

FLOOR 2
3D CELL SCAFFOLDS (STATIONS 1-4)

Station 1, Josh Javor (Boston University)
MEMS, Nano, and Magnetic Applications Toward Cardiac Tissue Engineering

Advised by David Bishop

Station 2, M. Cagatay Karakan (Boston University)
A Microfluidic Heart-on-a-Chip with Integrated Transducers

Advised by Kamil Ekinci

Station 3, Yih-Mei Lin (Florida International University)
Mechanobiological Studies on iPSC-Cardiomyocytes-Derived Tissue

Advised by Sharan Ramaswamy

Station 4, Ayse Muniz (University of Michigan)
Engineered Extracellular Matrices for Cardiac Syncytium

Advised by Joerg Lahann

FLOOR 3

TISSUE ENGINEERING (STATIONS 1-7)

Station 1, Katherine Cook (Boston University)
On-Demand Dissolvable Hydrogels for Burn Wound Dressings

Advised by Mark W. Grinstaff

Station 2, Shoshana Das (Boston University)
3D Fibrous Tissue Closure and New ECM Deposition is Modulated by ECM Alignment of Adjacent Tissue

Advised by Christopher Chen

Station 3, Samuel DePalma (University of Michigan)
Compliant and Aligned Fibrous Matrices Promote Cardiac Organization and Function

Advised by Brendon Baker

Station 4, Sedat Dogru (Boston University)
Patient-specific Internalization Rates Mediate TGF-β Delivery in Cartilage Tissue Engineering

Advised by Michael Albro

Station 5, Jourdan Ewoldt (Boston University)
Single Cell and Tissue Level Analysis of Hypertrophic Cardiomyopathy using CRISPR-edited hiPSC Platforms

Advised by Christopher Chen

Station 6, Kazue Orikasa (Florida International University)
Centimeter-Scale Ultra-Soft Material Mechanical Property Testbed

Advised by Arvind Agarwal

Station 7, Jonathan Tabares (Florida International University)
Incorporating Gold Nanorods for 3D Tissue Engineering

Advised by Jin He

SPEAKER INTRODUCTIONS
By BU Graduate Students

Shoshana Das introducing Jennifer Lewis

Christos Michas introducing Treena Arinzeh

Jenny Sun introducing Jason Burdick

Cagatay Karakan introducing Mark Grinstaff

Paria Mir Hashemian introducing Joerg Lahann

Jourdan Ewoldt introducing Shulamit Levenberg

Josh Javor introducing Jennifer West

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