FAMU-FSU Engineering

Department of Chemical and Biomedical Engineering

RESEARCH DAY

April 1, 2022

Schedule of Events

9:00 am	Student Oral Presentations, Room 106
10:00 am	Poster Session 1, First-floor atrium
11:00 am	Keynote Presentation, Room 106
12:00 pm	Lunch and Poster Session 1, First-floor atrium
1:00 pm	Poster Session 2, First-floor atrium
2:30 pm	End of Poster Session 2
2:40 pm	Announcement of winners of oral presentation and poster presentation competitions

Time and Location

April 1st, 2022

Aero-propulsion, Mechatronics and Energy (AME) Building

2003 Levy Avenue, Tallahassee, FL 32310

Keynote Presentation

Novel Ligands and Supports for the Affinity Purification of Biologics

Ruben G. Carbonell, Ph.D.
Frank Hawkins Kenan Distinguished Professor
Department of Chemical and Biomolecular Engineering
North Carolina State University, Raleigh, North Carolina

The vision for the future of biopharmaceutical manufacturing calls for the development of flexible facilities and equipment that serve the production needs of an increasingly diverse portfolio of products for the prevention, treatment, and cure of chronic and deadly diseases. These new processes need to feature enhanced productivity, as well as reduced footprints and lower capital and operating costs, to ensure a robust supply chain and worldwide accessibility for these novel biologics. Finally, these new approaches demand the use of renewable raw materials and minimization of water and energy use.

This presentation will focus on the role that affinity purification methods are likely to play in this environment. New platforms and screening processes are being developed for the rapid identification and characterization of a wide variety of new affinity and pseudo-affinity ligands for an increasingly large variety of different targets from a broad range of new product modalities. In addition, there have been significant advances in the type of supports that are available for these affinity ligands, including membranes and monoliths of various types and morphologies. New hybrid and intensified affinity processes are being developed that utilize bind-and-elute, flow-through and continuous and semi-continuous formats. This lecture will review some of the more exciting advances in this area and will provide a perspective on future directions in this field.

Short Biography of Dr. Ruben G. Carbonell

Professor Ruben G. Carbonell joined NC State in 1984, after ten years in the Chemical Engineering Department at the University of California, Davis. He is the Senior Technology Strategist at the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) and has served as director of the William R. Kenan, Jr. Institute for Engineering, Technology & Science at NC State since 1999. Dr. Carbonell was director of the Biomanufacturing Training and Education Center (BTEC) from 2008 to 2017 and Head of the Chemical and Biomolecular Engineering Department from 1995 to 1999. He has published over 260 technical papers in the areas of isolation, purification and detection of biopharmaceuticals, transport processes in multiphase systems and surface and colloid science. Dr. Carbonell has supervised more than 80 MS and PhD students, and is an inventor in over 30 patents, several of which have been licensed. He was elected to the National Academy of Engineering, and the National Academy of Inventors, and he is a Fellow of the American Institute of Chemical Engineers, the Industrial and Engineering Chemistry Division of the American Chemical Society, and the American Association for the Advancement of Science. Dr. Carbonell has won numerous awards, including the O. Max Gardner Award - the highest award given to faculty in the UNC System. He also was elected member of the Slovenian Academy of Science and the Academy of Sciences of the Institute of Bologna. Professor Carbonell received his BS degree in Chemical Engineering from Manhattan College in 1969 and his PhD from Princeton University in 1973.

List of Student Oral Presentations

1. “On Migraine and Sex: Preclinical 23Na & 1H MRI at 21.1 T Displays Sodium & Metabolic Differences in Female Sprague-Dawley Rats undergoing Central Sensitization” by Holder, Samuel W.
2. “Synthesis and Characterization of Lignin-Based polyester with High mechanical properties” by Kim, Sundol

Student Oral Presentation #1

On Migraine and Sex: Preclinical ^{23}Na & ^{1}H MRI at 21.1 T Displays Sodium & Metabolic Differences in Female Sprague-Dawley Rats undergoing Central Sensitization

Samuel W. Holder[1,2], Dayna Richter[1,2], David Hike[1,2], Michael G. Harrington[3] and Samuel C. Grant[1,2]
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The majority of human migraineurs are female; preclinical examination of migraine relies on the male Sprague-Dawley rat model due to the female rat estrus cycle. While this cycle may add variance, concerns of interference with migraine mechanisms may be unwarranted, *e.g.* the Sprague-Dawley estrus cycle does not influence CGRP release in the trigeminal nerve[1]. Previously preclinical MRI at 21.1 T showed that a well-established migraine model, nitroglycerin (NTG)-based central sensitization, results in widespread sodium increases[2] and a sharp thalamic metabolic response within the male Sprague-Dawley model. To elucidate potential sex differences in the response to NTG, ^{23}Na chemical shift imaging (CSI) and localized ^{1}H magnetic resonance spectroscopy (MRS) were performed at 21.1 T in female Sprague-Dawley rats.

Prior to scanning, animals underwent implantation of an intraperitoneal (IP) line for *in situ* NTG delivery. Once baseline values were acquired, the NTG dose was administered IP. Groups examined were female animals injected 2-mg/kg body weight NTG (N=14), 10-mg/kg body weight NTG (N=14) or an equivalent volume of saline (N=14). For 3D FID-based ^{23}Na CSI, Hamming-filtered data were acquired to maximize SNR within the preferred temporal resolution. Acquired image resolution was 1x1x3 mm. Image reconstruction and segmentation were performed in MATLAB 2020b, with a final resolution 0.25x0.25x1 mm. The brainstem, thalamus, cisterna magna, ventricular aqueduct, lateral, 3rd and 4th ventricles were examined. Spectra were acquired using a relaxation-enhanced spin-echo sequence localized to a 4x3x3 mm voxel centered between thalamic lobes, with an effective TE=54 ms and TR=2.5 s. Scans were interdigitated, 10 min CSI followed by 10 min RE-spectroscopy repeated out to 2 h post-injection. Mixed model analyses were performed in JMP Pro 15 with post-hoc Tukey HSD tests. $p < 0.05$.

Both NTG doses (2 and 10 mg/kg) evaluated in females display similar trends in both sodium and metabolic signal, with larger changes at 10 mg/kg. Metabolically, female Sprague-Dawley rats lack the increase in thalamic taurine and glycine seen in males; significant increases in lactate signal are seen across both sexes. With sodium, sex differences are most apparent in the lateral ventricles and thalamus, with females showing sustained significant decreases in sodium signal post-NTG. Female rats also show resilience to the brainstem sodium increases seen in males. As sex differences were most pronounced in regions related to the trigeminal nerve and the ventricular system its possible differences in sodium regulation play a role in the sex distribution of migraine.

1. Moussaoui, S., Duval, P., Lenoir, V., Garret, C. & Kerdelhue, B. CGRP in the trigeminal nucleus, spinal cord and hypothalamus: Effect of gonadal steroids. Neuropeptides 30, 546–550 (1996).
2. Abad, N., Rosenberg, J. T., Hike, D. C., Harrington, M. G. & Grant, S. C. Dynamic sodium imaging at ultra-high field reveals progression in a preclinical migraine model. Pain 159, 2058–2065 (2018).

Student Oral Presentation #2

Synthesis and Characterization of Lignin-Based Polyester with High Mechanical Properties

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Non-degradable petroleum-based plastics waste issue is a global challenge that requires urgent attention due to its harmful impact on humans and the environment. Lignin is an important biomass that can be a raw material to produce functional polymers due to its abundance, low price, sustainability, and high concentration of aromaticity. However, not thoroughly understood lignin modifications and characterizations limit the potential as a new sustainable raw material. The biomass lignin can be integrated with the concept of aliphatic polyesters to produce biomass-based biodegradable polymers. Among various biodegradable polylactides poly(ethylene brassylate) (PEB) is a relatively unexplored polymer with advantages of low cost and sustainable resource, castor oil. In here, we have synthesized a new lignin-containing copolymer, lignin-graft-poly (ethylene brassylate). First, the lignin was chemically modified by sebacic acid to introduce a carboxylic acid functionality onto lignin. Herein, the abundant hydroxyl groups were used for the modification of lignin. Another precursor of the copolymer, poly (ethylene brassylate) was prepared by ring-opening polymerization of ethylene brassylate in the presence of a catalyst, 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD). The condensation polymerization of modified lignin and poly (ethylene brassylate) was occurred by the reaction between 1,5,7-triazabicyclo[4.4.0]dec-5-ene terminus of the poly (ethylene brassylate) and carboxylic acid of modified lignin. A low melting temperature (78 ℃) of the new polymer enables an easy thermal process. Mechanical properties of the new lignin-graft-poly (ethylene brassylate) can be conveniently controlled by changing mass ratios of lignin and poly (ethylene brassylate). The highest modulus is 471.99 MPa, which is 3-fold higher than homo poly (ethylene brassylate).

List of Poster Presentations

Session 1

1. "Interfacial Studies of Monoclonal Antibodies Using Localized 1H NMR Spectroscopy" by Bhagu, Jamini
2. "A Precision Polyanion for High Performance Lithium-Ion Transport in Polymer Blend Electrolytes" by Blatt, Patrick
3. "Modeling Dynamic Swelling of Polymer-Based Artificial Muscles" by Bowen, Shefik
4. "Understanding the Effect of Crosslinkers to The Performance and Stability of Tunable UV and Thermal Curable Poly(arylene ether) for 3D Printing" by Boyer, Nichole
5. "Structural Analyses and Application of Mathematical Models to Cobalt-Containing Compounds" by Burnett, Nicole
6. "Surface Engineering of Auxetic Scaffolds for Neural and Vascular Differentiation from Human Stem Cells" by Chen, Xingchi
7. "Thermally Triggered Phagosomal Rupture for Cytosolic Delivery of Nanoparticles" by Cheng, Wenhao
8. "Synthesis and Characterization of Poly(Xylitol Sebacate)-Based Nanoparticles for Targeted Drug Delivery" by Culpepper, Kadisha
9. "Numerical Analysis of Rupture of Macrophage Phagosomes Induced by Ploy(N-isopropylacrylamide) (PNIPAM) Microparticles" by Fukuda, Masahiro
10. "PFAS Degradation with a Thin-Film Non-Thermal Plasma Gas-Liquid Reactor" by Gallan, Rachel
11. "Towards Rapid 3D Tissue Printing: Rheological Characterization of Cell-Laden Alginate-Gelatin Hydrogels" by Gregory, Tyler
12. "On-Demand Structural Health Monitoring Sensor Manufacturing for NASA Applications" by Hossain, Md Alamgir
13. "Effect of Liquid Conductivity on Reductive and Oxidative Species Formation in a Nanosecond Pulse Discharge Plasma Gas-Liquid Reactor" by Jenks, Lauren
14. "Upscaling Human Mesenchymal Stem Cell Production in a Novel Vertical Wheel Bioreactor Enhances Extracellular Vesicle Secretion and Cargo" by Jeske, Richard
15. "Developing Polymeric Coating Systems for Controlled Extracellular Vesicle Delivery" by Joshi, Sailesti

Session 2

16. "Encapsulation of Phenylacetic Acid in Poly(Glycerol Methacrylate)-b-poly(2-Hyroxypropyl Methacrylate) During Polymerization Induced Self-assembly" by Li, Guanrui
17. "Extracellular Matrix-bound Nanovesicles Secreted by Human Stem Cells" by Liu, Chang
18. "Bone Regeneration Capacity of Extracellular Vesicles Isolated from Bone Marrow-Derived and Adipose-Derived Mesenchymal Stromal/Stem Cells" by Liu, Yuan
19. "Microrheological Evaluation of Pancreatic Ductal Adenocarcinoma Across Races" by Mao, Yating
20. "Minima in the Temperature Gradient of the Crystallization Rates of Polyethylene Brassylate at the Transition Between Two Isomorphic Crystalline Structures" by Marxsen, Stephanie F.
21. "Magnetic-core/Gold-shell Nanoparticles for the Detection of Hydrophobic Chemical Contaminants" by Mills, Anna
22. "Engineering Choroid Plexus Organoid Derived from Human Pluripotent Stem Cells" by Muok, Laureana
23. "Integrin Ligand Dependent Activation of YAP and NFkβ in Intervertebral Disc Cells" by Naha, Ananya
24. "The Effects of Fluid Microstructure on the Kinematics of Achiral μ-Swimmers" by Quashie Jr, David

25. “Effect of Micellar Microstructure on Kinetics Of Shear Banding Flow Formation” by Rassolov, Peter
26. “CSF Flow During Preclinical NTG-Triggered Central Sensitization at 21.1 T” by Richter, Dayna
27. “Effect of Actin Branching on Cellular Mechanotransduction” by Sadeghifar, Amir
28. “Probing Microstructure of Self-Assembled Micellar Solutions via 1D 1H NMR diffusometry” by Scigliani, Alfredo
29. “Rheological Characterization of Bacteria-Breast Cancer Cell-laden Alginate-based Hydrogels” by Scutte, Annie
30. “Fabrication and Wireless Manipulation of Magnetic Erythrocyte-Based Micromotors” by Wang, Qi

Student Poster Presentation #1 (Session 1)

Interfacial Studies of Monoclonal Antibodies Using Localized ^{1}H NMR Spectroscopy

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Introduction: Monoclonal antibodies (mAb) represent an important class of biologic therapeutics that is used to treat a variety of diseases. Despite many advantages, their processing, storage and/or administration remains challenging because of the high flow environment in processing and/or presence of hydrophobic interfaces during administration and storage that may promote mAb aggregation (1). In this work, a modified spatially resolved Point RESolved Spectroscopy (PRESS) sequence is utilized to observe the impact that a hydrophobic interface, particularly the oil-water interface, has on the structure and conformation of mAb.

Materials and Methods: A spatially resolved Relaxation Enhanced Point RESolved Spectroscopy (REPRESS) sequence was used to acquire relaxation enhanced (RE) ^{1}H NMR spectra at 21.1 T (^{1}H Larmor frequency = 900 MHz) at the National High Magnetic Field Laboratory. With or without additional water suppression via a VAPOR scheme, this sequence (REPRESS) imparts both spatial and frequency selectivity on the analysis of localized voxels (minimum dimension of 115 μm). Using localizer MRI scans for placement and verification of REPRESS voxels, the structure of a model mAb was evaluated in the bulk (mAb in sodium phosphate buffer) as well as in incrementally closer voxels (375x1500x1500 μm) that approach a model water-oil interface (with matched magnetic susceptibilities for the interfacial components). Using a model mAb (IgG2a subclass) reactive against maltose binding protein and with a molecular weight of 155 kDa, MR experiments were conducted at different concentrations (0.39 & 0.15 mM) and temperatures (40 & 30 C). Short echo time and diffusion-weighted REPRESS data were acquired from adjacent voxel locations in 375-μm steps, with six voxels in bulk mAb above the interface, one voxel centered at the water-oil interface and two voxels in oil below the interface (Figure 1a).

Results and Discussion: Results indicate that REPRESS spectra of mAb approaching the interface differ dramatically from the bulk mAb. REPRESS mAb spectra in the bulk yield highly resolved line-shapes (FWHM ≈ 30 Hz) and multiple resonances while spectra nearing the interface display significant spectral broadening, indicative of a shortened T_2/T_2^* relaxation that is may be due to conformational alteration of mAb molecular structure and potentially aggregate formation, as seen in Figure 1b. Using diffusion analysis and a self-similarity index, this study provides the first direct evidence of mAb higher order structure changes at water-oil interfaces.

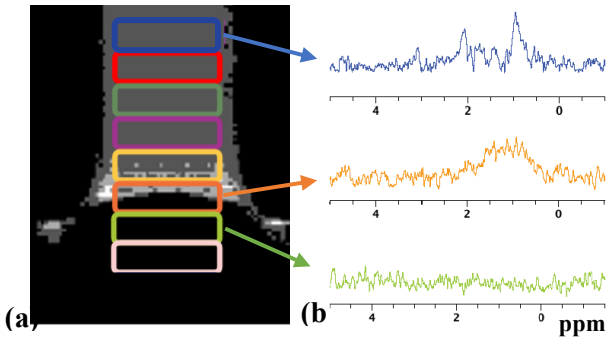

Figure 1 (a) The nine voxels were shifted in the axial direction by 0.375 mm with six voxels placed in the bulk mAb, one centered at the interface and two in the oil. (b) The color of the spectra corresponds to the color of the voxel. The line broadening can be seen between the spectra from the bulk mAb (blue) and the spectra at the interface (orange).

Conclusion: The efficacy of protein biotherapeutics can be impacted by the presence of hydrophobic interfaces Data show significant line broadening at the interface, which should indicate conformational changes in the microstructures of the protein. Further studies will be performed using different mAb systems and surfactants to assess structural alterations of mAb at interfaces.

References: (1) C. Smith et al., "Antibody adsorption on the surface of water studied by neutron reflection," MAbs, vol. 9, no. 3, pp. 466–475, 2017, doi: 10.1080/19420862.2016.1276141.

Student Poster Presentation #2 (Session 1)

A Precision Polyanion for High Performance Lithium-Ion Transport in Polymer Blend Electrolytes

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A novel precision single ion conductor with an *N*-((trifluoromethyl)sulfonyl)phenylsulfonimide lithium salt covalently bound to every fifth carbon of a polyethylene backbone, *p*5PhTFSI-Li, was synthesized via post polymerization modification. The conversion to a trifluoromethanesulfonimide (TFSI) anion from the parent polymer bearing a phenylsulfonate anion was highly efficient (~90%) as determined by ^{19}F-NMR analysis and corroborated through other spectroscopic methods. The bulky and flexible TFSI anion led to a reduced and observable glass transition temperature of ~199 °C and an improved thermal stability up to ~375 °C. Blending of *p*5PhTFSI-Li with poly(ethylene oxide) at various compositions was performed to investigate electrochemical performance and transference numbers with respect to the lithium electrode using a combination of impedance and polarization methods. At 90 °C, this system displayed high conductivity up to 2.00 X 10^{-4} S cm^{-1} and transference numbers were near unity independent of temperature, making this system highly competitive with other polyanion/polyether blend electrolytes. Investigations into the complex miscibility and phase behavior of these blends at various compositions was also probed by a combination of microscopy and differential scanning calorimetry which is discussed.

Student Poster Presentation #3 (Session 1)

Modeling Dynamic Swelling of Polymer-Based Artificial Muscles

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Polymer-based artificial muscles could potentially replace traditional motors and actuators in applications where weight and flexibility are important, such as soft robotics, active prosthetics, and microfluidics. Material chemistry and muscle geometry are important parameters that impact device performance, e.g. strain, strain rate, lifetime, achievable work, and efficiency. Modeling the rate and degree of swelling of polymer fibers is an essential part of developing materials and designing muscles that perform as desired. This study is motivated by the possibility of significant actuation from twisted and coiled polymer fibers that rely on radial swelling to produce reversible work. An analytical thermodynamic expression (based on Flory-Huggins Theory) was combined with a numerical transport model in order to simulate transient swelling of a polymeric network driven by diffusion and migration. The numerical model evaluates the impact of polymer swelling on transport in polymers directly by locally accounting for the length increase of discrete elements due to solvent presence, which cannot be done analytically. The combined model of transient radial swelling of polymer fibers can be used for parametric studies or analysis of experimental data. This study will aid efforts to identify the best material candidates for practical use as artificial muscle fibers and will help evaluate the geometry needed to achieve device requirements.

Student Poster Presentation #4 (Session 1)

Understanding the effect of crosslinkers to the performance and stability of tunable UV and thermal curable poly(arylene ether) for 3D printing

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The goal of this project is to synthesize and characterize poly(arylene ether)s with UV and thermally curable functionalities through the inclusion of 2-(bis(4-hydroxyphenyl)methyl) benzoic acid monomer (phenolphthalin) into the PAE backbone. Chemical cross-linking methods have been widely employed to optimize membrane morphology and improve the physical properties using cross-linkers such as dihalides, diols, dithiols, and dicarboxylic acids under basic or catalytic conditions. The mode of crosslinking is generally initiated through thermal or UV stimuli allowing for a wide range of polymer structures to be prepared. Interestedly, no reports of combining UV/thermal crosslinking sites into a single PAE polymer have been found in the literature. Combining the properties of PAE thermal and UV crosslinkable polymers could result in the formation of membranes with tunable thermal, mechanical, and processing properties controlled by the concentration of the crosslinking site and agent used. Therefore, the purpose of this work is to develop modifiable PAE polymers for efficient processing and manufacturing of versatile material by 3-D printing. PAE of with carboxylic acid active sites along the backbone will be synthesized and these functional sites will be crosslinked to generate various microstructures. Ideally, a synthetic platform to tailor a variety of PAE polymer with optimized properties for 3-D printing can be achieved.

Student Poster Presentation #5 (Session 1)

Structural Analyses and Application of Mathematical Models to Cobalt-Containing Compounds

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This body of work explores the growth and structure of two different cobalt containing compounds that may show interesting quantum spin behaviors: $[(CH_3)_3NH]CoCl_3$ and $BaCo_2(PO_4)_2$. $[(CH_3)_3NH]CoCl_3$ behaves as a one dimensional Ising model and $BaCo_2(PO_4)_2$ behaves in accordance to a honey comb lattice model.

The crystal growth and room temperature single crystal structure of the linear magnetic chain compound $[(CH_3)_3NH]CoCl_3$ is reported, along with low temperature magnetic susceptibility and heat capacity measurements. $[(CH_3)_3NH]CoCl_3$ single crystals were grown using two methods: slow evaporation and seeded growth. The compound crystallizes in an orthorhombic structure with lattice parameters a =7.2716Å b =8.0983Å and c =16.6473Å, consistent with previous literature values[1]. Crystals grown in a supersaturated seeded solution resulted in large crystals. $[(CH_3)_3NH]CoCl_3$ is of interest because it realizes a one-dimensional spin system, which can be proven through heat capacity and magnetic susceptibility measurements. Attempts to grow deuterated crystals for neutron scattering experiments are in progress.

A literature review and experimental analysis on the synthesis of $BaCo_2(PO_4)_2$is also reported. Single crystals of $BaCo_2(PO_4)_2$ were previously grown using hydrothermal methods. Although no single crystals of Barium Cobalt Phosphate have been obtained, several side products resulting from different reactants, pH, and temperatures profiles have been isolated. The main goal, to obtain the single crystal of Barium Cobalt Phosphate to probe the spin interactions has not yet been attained.

Student Poster Presentation #6 (Session 1)

Surface Engineering of Auxetic Scaffolds for Neural and Vascular Differentiation from Human Stem Cells

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The complexity and dynamic microenvironments of the extracellular matrix (ECM) can change the interactions with stem cells which can regulate stem cell fate decisions. Stem cells can sense the biophysical and biochemical properties of their microenvironment (such as biomechanical properties andgrowth factors) and transduce the extracellular signaling to the intracellular nuclei to induce gene transcription. Negative Poisson's Ratio (NPR) (i.e., auxetic) materials have attracted high attention in biomedical applications due to their unique biophysical properties. Poisson's ratio describes the degree of a material that contracts (or expands) transversally when axially strained, and most materials have Poison's ratio of 0.3-0.5. The NPR materials also have high porosity, intendent resistance, and shear resistance, which are attractive properties in neurovascular tissue engineering. Human induced pluripotent stem cells (hiPSCs) have the ability to differentiate into all types of cells. The potential applications of hiPSCs include the investigation of neural and vascular tissue degeneration to treat blood-brain barrier dysfunction. In this study, six different polyurethane auxetic foams with different modulus (700-2700 Pa) and Poisson's ratio (-0.3 to -0.5) were fabricated and characterized to study the hiPSC lineage-specific differentiations. The biocompatibility of the foams was regulated by modifying the surfaces with chitosan and heparin. Chitosan modified foams were shown to promote cell viability. Then, the vascular and neural differentiation of hiPSCs on different foams with distinct elastic modulus and Poisson's ratio were investigated. Heparin modification may cause less endothelial and neural differentiation. In the foam with modulus of 365 ± 50 Pa and Poisson's ratio of –0.196, the neural specific markers were mostly expressed when cultured with the chitosan-modified scaffolds. In addition, endothelial cell-specific markers CD31 and ZO-1 were mostly expressed in the foam with modulus of 1400 Pa and Poisson's ratio of -0.297. This study has significance in understanding biophysical regulation of human pluripotent stem cell fate decisions and in establishing 3-D neurovascular tissue models for drug screening and neurological disease modeling.

Student Poster Presentation #7 (Session 1)

Thermally Triggered Phagosomal Rupture for Cytosolic Delivery of Nanoparticles

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Nanoparticles (NPs) have attracted considerable attention as vehicles for delivering drugs into the cytosol of macrophages. While NPs can be internalized into macrophages through endocytosis, they are typically trapped in the endosomes and are therefore separated from the cytosol by the endosomal membrane, which can act as a diffusion barrier for drug molecules released from the NPs. Here, we report a new method to allow delivery of the nanoparticles into the cytosol in macrophages. The method features the use of poly(N-isopropylacrylamide) (PNIPAM) microparticles as carriers for NPs. PNIPAM is a thermoresponsive polymer with a lower critical solution temperature (LCST) around 32°C in water, meaning that it is soluble in water at a temperature below the 32°C and insoluble at a temperature above it. We found that the microparticles could be internalized into phagosomes in macrophages at 37°C and subsequent exposure of the macrophages to 0°C for 2 minutes led to release of fluorescent NPs into the cytosol of the macrophages. We believe that the phagosomes were ruptured by high osmotic pressure generated by the dissolved PNIPAM at 0°C and the dissolved PNIPAM spread in the cytosol with the NPs being trapped in the dissolved PNIPAM solution. Following a 24-hour incubation at 37°C after the cold shock, the NPs in the cytosol formed micrometer-sized droplets, suggesting that the dissolved PNIPAM re-condensed and the NPs were trapped in the PNIPAM matrix throughout this process. Moreover, the droplets apparently did not reside in any membrane-bound vesicles. In addition, most of the macrophages that contained the ruptured phagosomes were alive as measured by calcein AM and trypan blue assays. Overall, this method allows creation of micrometer-sized, nanoparticle-loaded and membrane-less PNIPAM droplets in the cytosol of the macrophages. It is potentially applicable to a variety of functional nanoparticles and promises to be useful for treating various diseases.

Student Poster Presentation #8 (Session 1)

Synthesis and Characterization of Poly(Xylitol Sebacate)-Based Nanoparticles for Targeted Drug Delivery

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Breast cancer is the most common cause of cancer in women and the second leading cause of cancer deaths. Current treatment of breast cancer involves the use of chemotherapy, radiation and surgery. The cytotoxicity of chemotherapy treatment creates a drive for the development of more target-specific drug delivery to allow for cancer cells only to be treated. The focus of this research is to improve the formation of biodegradable and biocompatible polymeric nanoparticles using a series of polyesters from xylitol and sebacic acid with various monoacids. Preliminary research shows that nanoparticles can be synthesized from poly(xylitol sebacate), but were too large (264nm), with low encapsulation efficiency and drug release. The desired size for nanoparticles for chemotherapeutic use is 100nm to 200nm. Current research investigates the effect of branching on nanoparticle formation, size, encapsulation efficiency, and drug release, via the addition of the monoacids. Future research will investigate the effect of molar ratios using copolymers of these monoacid functionalized polyesters on the same properties.

Student Poster Presentation #9 (Session 1)

Numerical Analysis of Rupture of Macrophage Phagosomes Induced by PNIPAM Microparticles

Masahiro Fukuda*, Wenhao Cheng, Jingjiao Guan
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Phagocytosis performed by macrophages is a cellular process that plays critical roles in immunity and tissue homeostasis. This process is characterized by the internalization of a micrometer-sized object such as a bacterium into a membrane-bound vacuole called phagosome in a macrophage. Rupture of the phagosomal membrane has been associated with various diseases such as bacterial infections and multiple sclerosis. Critical to developing effective therapies for these diseases is to acquire a quantitative understanding of the biophysical properties of the phagosomal membrane of macrophages, which is currently unavailable. The long-term goal of this study is to determine the critical tension required to rupture the membrane of a macrophage phagosome. We are seeking to develop an innovative approach to achieve this goal. The approach relies on the use of microparticles made of non-crosslinked linear ploy(N-isopropylacrylamide) (PNIPAM) as the phagocytic objects. PNIPAM is a polymer that is insoluble in water at a temperature above 32 °C and becomes soluble below 32 °C. We observed PNIPAM microparticles were phagocytosed by macrophages at 37 °C. When exposed to 0 °C for 2 minutes, a phagocytosed PNIPAM microparticle typically disintegrated and spread out in the cytosol of the host macrophage, indicating that the phagosome was ruptured. We hypothesize that the PNIPAM in the phagosome generated a high osmotic pressure at 0 °C, resulting in influx of water into the phagosome and rupture of its membrane. To test the hypothesis numerically, we have used Flory-Huggins solution theory to calculate the osmotic pressure generated by a dissolved PNIPAM microparticle in a phagosome at different temperatures. Furthermore, assuming that the phagosome has a spherical shape, we used Law of Laplace to calculate tension in the phagosomal membrane caused by the osmotic pressure. Our calculation has revealed that the PNIPAM microparticles used in this study can generate high enough surface tension to rupture the phagosomal membrane. This is consistent with our current experimental results and warrants a further investigation by integrating the theory and experiments.

Student Poster Presentation #10 (Session 1)

PFAS Degradation with a Thin-Film Non-Thermal Plasma Gas-Liquid Reactor

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The contamination of groundwater by per- and polyfluorinated substances (PFAS) is a major worldwide environmental problem. Current water treatment methods for dealing with PFAS use the non-degradative methods of activated carbon and reverse osmosis for physical removal from the contaminated water. In the present work we utilize a non-thermal plasma chemical reactor to degrade the following PFAS: 8-carbon (perfluorooctanoic acid – PFOA and perfluorooctanesulfonic acid - PFOS), 6-carbon (perfluoro hexanoic acid - PFHxA) and 10-carbon (perfluoro decanoic acid - PFDA). The non-thermal plasma, a type of ionized gas, is generated by a high voltage electrical discharge in a reactor with flowing gas (argon) and liquid (water). The plasma discharge channel propagates along the interface between the gas and the thin liquid water film where the generated reactive chemical species, including reductive and oxidative species, degrade the PFAS into smaller carbon chain daughter products and mineralization products such as carbon dioxide and fluoride (F-). We have quantified PFAS degradation, mineralization, and daughter product production for different feed concentrations (10 ppb to 1 ppm) in deionized water solutions. Through optimizing of the plasma reactor operating conditions (pulse frequency and pulse width) we have achieved 90-75 percent degradation. Degradation of PFAS in this plasma reactor is insensitive to the solution conditions of pH, conductivity, and added organic matter; however, pulse frequency has a major effect on the degradation of the parent compounds. We have also demonstrated that ground water samples contaminated with PFAS can be treated with this plasma reactor.

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Student Poster Presentation #11 (Session 1)

Towards Rapid 3D Tissue Printing: Rheological Characterization of Cell-Laden Alginate-Gelatin Hydrogels

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The biofabrication of tissue models that closely mimic the tumor microenvironment are necessary for high throughput rapid screening of anticancer drugs. 3D bioprinting of heterogeneous cell-laden hydrogels has shown promise in advancing rapid artificial tissue development. A major bottleneck limiting the rapid production of physiologically relevant tissue models is the current limitations in printing large populations of cells effectively. However, by significantly increasing hydrogel cell-seeding densities, the time required to produce tissues can be effectively reduced. Here, we explore the effects of increasing cell seeding densities on the viscoelastic properties, printability, and viability of two different alginate-gelatin hydrogel compositions. Rheological analysis of hydrogels of varying cell seeding densities reveals an inverse relationship between cell concentration and zero-shear viscosity. We also observe that as cell seeding densities increase, the storage moduli decrease, thus lowering the required printing pressures required for gel extrusion. We also observe that increasing cell concentration can negatively impact the structural properties of the extruded material by increasing line spreading -the amount of line width increase after the bioink leaves the nozzle post-print. We find that hydrogels composed of higher molecular weight alginates and the highest cell-seeding densities (10^7 cells/mL) yield high cell viability (>80%) and structural uniformity after printing. The optimized printing parameters determined for the alginate-gelatin bioinks explored may aid in the future rapid fabrication of functional tissue models for therapeutic screening.

Student Poster Presentation #12 (Session 1)

On-Demand Structural Health Monitoring Sensor Manufacturing for NASA Applications

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Structural healthy monitoring (SHM) is significantly essential for the safety and liability of space exploration. In the past, various sensor techniques, including fiber Bragg grating (FBG) sensor, ultrasonic transducer, pressure transducer, thermometry, and direct current analysis, were used for SHM applications in metal and composites structures each of them had limitations. For instance, those sensors have a multi-step fabrication process with poor sensitivity and low stretchability. Those incompatibilities create a weak link, delamination, partial or complete part failure. Furthermore, limited choices of sensor types and sizes and the complexity of preparing sensor networks to cover large areas are also among the major challenging issues for aerospace industries to widely adopt SHM for real-world engineering applications. However, conductive polymer composites (CPCs)-based SHM-sensors (strain sensors) fabricated by additive manufacturing (AM) technology (also known as 3D printing) is a promising option due to their advantages of the single-step fabrication process, low cost, short fabrication time, and high accuracy. This research aims to study and develop on-demand manufacturing technology of strain sensors by optimizing CPCs inks, the printing process, and post-processing strategies. We will explore Ag-based commercial ink, carbon nanotube-based inks, graphene-based ink, and multiple conductive fillers-based inks sequentially. First, we will optimize the CPCs inks printability via rheological characterization. Then, we will fabricate strain sensors with various geometry by a state of art 3D printer. Finally, we will characterize the printed strain sensors for sensitivity (as known gauge factor), stretchability, and stability.

Student Poster Presentation #13 (Session 1)

Effect Of Liquid Conductivity on Reductive and Oxidative Species Formation in A Nanosecond Pulse Discharge Plasma Gas-Liquid Reactor

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Plasma interacting with liquid water has been investigated for many applications in chemical, environmental, materials, and electrical engineering. The plasma reactor used in this study, utilizes flowing gas and liquid streams whereby a thin liquid film is formed, and the electrical discharge propagates along the interface of this film. The interaction of argon plasma with water molecules (H_2O) leads to the formation of both oxidative species, including hydroxyl radicals (•OH), hydrogen peroxide (H_2O_2), atomic oxygen (O), and reductive species including atomic hydrogen (H), molecular hydrogen (H_2), and aqueous electrons (e^-_{aq}). Previous work has shown that with plasma formed by nanosecond pulsed discharges propagating along the gas-liquid interface the liquid conductivity up to 40 mS/cm did not affect the formation of H_2O_2. In this study, methylene blue (MB) dye is used as chemical probe in the liquid phase. Methylene blue(MB) was measured using UV-vis spectrophotometer at 664nm. Methylene blue(MB), reacts with •OH to form a colorless complex. In this study, we determine the effects of liquid conductivity over a very wide range up to salt water (0.25 mS/cm – 40 mS/cm) on rates of formation of •OH in our gas-liquid plasma reactor. We varied the conductivity of the liquid using potassium chloride (KCl).

Student Poster Presentation #14 (Session 1)

Upscaling Human Mesenchymal Stem Cell Production in a Novel Vertical Wheel Bioreactor Enhances Extracellular Vesicle Secretion and Cargo

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Human mesenchymal stem cells (hMSCs) are mechanically sensitive undergoing phenotypic changes when subjected to shear stress encountered in dynamic bioreactor cultures. However, little is known how shear stress affects the secretion and cargo profiles of hMSC-extracellular vesicles (EVs) including the subset, "exosomes", which contain therapeutic proteins, nucleic acids, and lipids derived from the parent cells. In this study, bone marrow–derived hMSCs were expanded on Synthemax II microcarriers in the PBS mini 0.1L vertical wheel bioreactor system under variable shear stress at 25 rpm, 40 rpm, and 64 rpm. The results show up to a 20-fold increase in cell densities over 8 days of culture. The PBS vertical wheel bioreactor system promotes increased EV secretion by 2.5-fold over traditional 2D culture and upregulates the expression of EV biogenesis and autophagy related genes. Bioreactor culture also promoted upregulation of EV microRNA cargo including miR-10, 19a, 19b, 21, 132, and 377. Cell and EV protein cargo was characterized by proteomics analysis. Functional analysis of bioreactor EVs were shown to enhance cell migration in an *in vitro* wound healing model and alter T cell proliferation. In addition, the scalability of the PBS vertical wheel bioreactor system was demonstrated in the PBS mini 0.5 L bioreactor, showing similar or better hMSC-EV secretion and cargo content compared to the 0.1L bioreactor. This study advances our understanding of bio-manufacturing of stem cell-derived EVs for applications in cell-free therapy towards treating neurological disorders such as ischemic stroke, Alzheimer's disease, and multiple sclerosis.

Student Poster Presentation #15 (Session 1)

Developing Polymeric Coating Systems for Controlled Extracellular Vesicle Delivery

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Extracellular vesicle (EV) based therapies have been shown to be effective in several preclinical tissue repair and regeneration applications(1)(2). However, common EV delivery methods, which include localized, intraperitoneal, intravenous, and subcutaneous injections, inefficiently deliver EVs to the target site and can result in rapid systemic clearance(3). Thus, to enhance EV retention as well as control EV delivery, this project aims to develop biomaterial-based EV delivery systems using several polymeric coatings. Towards this goal, the interactions of EVs with different coatings composed of Collagen 1 (Col 1), Glycol-Chitosan (GC), Hyaluronic acid (HA), Fibronectin (FN), Polydopamine (pDA), and Poly-L-Lysin (PLL), are investigated at different pHs, salt concentrations and PBS concentrations. EV properties are also characterized at different pHs, salt concentrations and PBS concentrations. Preliminary results indicate that the zeta potential of EVs was significantly lower at higher salt concentrations and PBS concentrations; whereas, only slight variations were observed with different pHs. Meanwhile, acidic pH as well as 0.1X PBS resulted in significantly larger EV sizes, but the effect of salt concentration on EV size was less significant. Further studies will examine the loading and release kinetics of EVs on different coatings and the ability of each coating system to promote cellular uptake and cellular differentiation.

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Student Poster Presentation #16 (Session 2)

Encapsulation of phenylacetic acid in poly(glycerol methacrylate)-*b*-poly(2-hyroxypropyl methacrylate) during polymerization induced self-assembly

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Amphiphilic block copolymer nanoparticles (PNPs) can serve as drug carriers for poorly water-soluble drugs. The hydrophilic block behaves as the PNP corona, while the hydrophobic block forms the core. Polymerization induced self-assembly (PISA) is an emerging and efficient method for synthesizing PNPs. For PISA conducted in the presence of a drug, the polymerization, self-assembly, and drug encapsulation occur simultaneously, which simplifies the preparation steps and avoids the use of toxic organic solvents. However, the mechanism of drug encapsulation during PISA is still not well understood. Here, we study how encapsulation during PISA impacts the PNP nanostructure and drug loading ability. In this study, the model polymer is poly(glycerol methacrylate)-*b*-poly(2-hyroxypropyl methacrylate) (PGMA-*b*-PHPMA). The model drug is phenylacetic acid, which has a water solubility of only 15 mg/mL. With increasing concentration of drug, the PNP morphology shifts from spherical micelles to cylindrical micelles to vesicles. At a targeted drug loading of 32 mg/mL, twice the water solubility of phenyl acetic, the encapsulation efficiency reaches a maximum of ~ 75%. Increasing the PHPMA degree of polymerization changes the PNP nanostructure, but it has minimal influence on the encapsulation efficiency.

Student Poster Presentation #17 (Session 2)

Extracellular Matrix-bound Nanovesicles Secreted by Human Stem Cells

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Extracellular vesicles (EVs) including the small size of the subpopulation exosomes (30-150 nm) are membrane bound vesicles that are secreted by all cell types. In particular, EVs secreted by human stem cells show significance in intercellular communications and high potential in therapeutic outcome (e.g., Immunomodulation, angiogenesis, and neuroprotection) in treating neurological disorders such as Alzheimer's disease and ischemic stroke. Most studies have been focusing on biofluid-derived EVs (BEVs), however, in 2016, it was found that extracellular matrix (ECM) in the human tissue contains EVs, which were defined as matrix bound nanovesicles (MBVs). MBVs serve as one of the functional components in ECM, recapitulating part of the regulatory roles and in vivo microenvironment. In this study, BEVs and MBVs were isolated from both bone marrow-derived human mesenchymal stem cells (hMSCs) and induced neural progenitor cortical organoids (iNPCos) derived from human induced pluripotent stem cells. Nanoparticle tracking analysis showed no significant difference between the BEVs and MBVs for the particle size, and their mode sizes were between 100-150 nm. When normalizing particle numbers to cell numbers, hMSCs generated one order of magnitude more BEVs than MBVs, while iNPCos generated one order of magnitude less BEVs than MBVs. When normalizing proteins to particle numbers, MBVs of hMSCs showed high value due to the lower order of magnitude particle numbers than MSCs secreted BEVs, while MBVs of iNPCos showed low value due to the more concentrated particles. Transmission electron microscopy (TEM) images captured the typical cup shape of exosomes for both BEVs and MBVs. Western blot revealed that MBVs lacked some of detectable EV markers such as syntenin-1, while EBVs expressed all the positive markers. miRNA analysis of 2D and 3D MBVs showed that 3D microenvironment enhanced the generation of miR-21, miR-125b, and miR-145. This study has the significance in advancing our understanding of the bio-interface of EVs with the human brain tissue and in the design of cell-free based therapy for treating neurological disorders such as Alzheimer's disease and ischemic stroke.

Student Poster Presentation #18 (Session 2)

Bone Regeneration Capacity of Extracellular Vesicles Isolated from Bone Marrow-Derived and Adipose-Derived Mesenchymal Stromal/Stem Cells

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Displaying trophic and immunomodulatory effects upon transplantation, mesenchymal stromal/stem cells (MSCs) currently represent a critical part of clinical and preclinical bone regeneration research. The therapeutic effects of MSCs have recently been largely attributed to the paracrine effects of the MSC secretome, including soluble factors and extracellular vesicles (EVs). Due to the remarkable advantages of EV-based therapies, replacing or combining MSCs with their secreted EVs has begun to draw attention as a bone regeneration treatment strategy. However, it remains to be determined which MSC source produces EVs with the greatest therapeutic potential. This project will compare the angiogenic, osteogenic, and immunomodulatory potentials and cargo compositions of EVs isolated from the two most common clinical sources of adult MSCs, bone marrow and adipose tissue, across different passage numbers, in order to find the optimal MSC source for clinically translatable EV-derived bone regeneration therapies. Although both MSC sources secreted EVs with similar mean sizes and total protein content, bone marrow MSCs (BMSCs) showed a significantly higher EV yield per cell at passage 2 (P2) than adipose MSCs (ADMSCs). Preliminary tube formation assays employing human umbilical vein endothelial cells (HUVEC) suggested that P2 ADMSC-derived EVs had a higher pro-angiogenesis capability than P2 BMSCs-derived EVs, as indicated by increased numbers of branches. Meanwhile P2 BMSCs-derived EVs showed stronger immunomodulatory effects in RAW264.7 cells than P2 ADMSC-derived EVs, as suggested by preliminary RT-PCR data. Further *in vitro* comparison studies of EV angiogenic, osteogenic, and immunomodulatory capacity will shed light on the optimal MSC-derived EV population for clinical bone regeneration therapies.

Student Poster Presentation #19 (Session 2)

Microrheological Evaluation of Pancreatic Ductal Adenocarcinoma Across Races

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Pancreatic ductal adenocarcinoma (PDAC), the most common form of pancreatic cancer, has become one of the leading causes of death worldwide. By the year 2030, PDAC is expected to be the second leading cause of all cancer-associated deaths. Over 80% of pancreatic cancer patients have unresectable or metastatic malignancies. For resectable cases, the 5-year survival rate remains around 20% after surgery [1]. Multiple risk factors that are associated with the incidence, mortality, and survival rate of pancreatic cancer have been evaluated [2]. Among these factors, race appears to have a significant effect on diseases progression. In general, African American populations have higher rates of incidence and poorer outcomes versus Caucasian and Hispanic populations. While there has been some evidence of biochemical origins of PDAC racial disparities, currently the role of biophysical properties is unknown. Here, we focus on investigating the mechanical origins of racial disparities using microrheological techniques. To investigate the mechanical properties of PDAC across races, pancreatic acinar cells were collected from African American, Caucasian, and Hispanic donors and cultured in Matrigel with fluorescent tracer particles and induced to undergo acinar-ductal metaplasia (ADM), a key step in PDAC formation. Videos of tracer particles within *in vitro* ADM models were recorded for up to five days. The trajectories of embedded fluorescent particles were tracked and used to determine the complex shear modulus, |G*|. Results indicate that the acini into duct-like structure transdifferentiation process occurs the most rapidly in African American samples that also have the highest |G*|. In contrast, the ADM progression and stiffness for Hispanic samples were the lowest. These observations are consistent with pancreatic cancer statistics that show African Americans have the highest incidence and mortality rate, followed by Caucasians and Hispanics [2].

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Student Poster Presentation #20 (Session 2)

Crystallization Rate Minima of Polyethylene Brassylate at Temperatures Transitioning Between Quantized Crystal Thicknesses

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Poly (ethylene tridecanodiate), also known as poly(ethylene brassylate) (PEB), is a short-long aliphatic polyester obtained from a renewable source. Cooled from the melt by differential scanning calorimetry or by fast scanning calorimetry, PEBs in a range of molar mass between 27,000 and 188,000 Dalton display single crystallization exotherms. On heating, PEBs exhibit two major melt-recrystallization events at ~ 40 and ~ 60 ºC prior to their final melting at ~ 70 ºC. WAXD patterns collected *in-situ* during heating rule out any polymorphic transition, but SAXS patterns collected at the isothermal crystallization temperatures below and above the highest melt-recrystallization event (~ 60 °C), indicate a step increase by one repeating unit of the crystal thickness. The overall isothermal crystallization rate displays two minima at the same temperatures where melt-recrystallization was observed on heating. The minima correspond to the transition between 2 – 3 repeats (T_c = 40 °C) and between 3 – 4 (T_c = 60 °C) monomer repeats in the crystal thickness. A minimum also occurs at the same temperature in the isothermal linear growth rates and is accompanied by a minimum in nucleation density. The observed rate minima at the transition between crystals differing by a quantized thickness are equivalent to the behavior of *n*-alkanes and low M_w PEO fractions and are also explained by the manifestation of *self-poisoning*. At T_c approaching a rate minimum from above, PEB stems with non-integer repeats attach temporarily to the integer lateral growing surface halting productive growth until they detach or expand to complete the layer. Hence, for this type of polyester, it is the length of the stem approaching the growing surface rather than stems with a different conformation that drives *self-poisoning*.

Student Poster Presentation #21 (Session 2)

Magnetic-core/Gold-shell Nanoparticles for the Detection of Hydrophobic Chemical Contaminants

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Magnetic-core/gold-shell nanoparticles (MAuNPs) are of interest for enabling rapid and portable detection of trace adulterants in complex media. Gold coating provides biocompatibility and facile functionalization, and a magnetic core affords analyte concentration and controlled deposition onto substrates for surface-enhanced Raman spectroscopy. Iron oxide cores were synthesized and coated with gold by reduction of $HAuCl_4$ by NH_2OH. MAuNPs were grafted with polyethylene glycol (PEG) and/or functionalized with 4-mercaptobenzoic acid (4-MBA) and examined using a variety of microscopic, spectroscopic, magnetometric, and scattering techniques. For MAuNPs grafted with both PEG and 4-MBA, the order in which they were grafted impacted not only the graft density of the individual ligands, but also the overall graft density. Significant Raman signal enhancement of the model analyte, 4-MBA, was observed. This enhancement demonstrates the functionality of MAuNPs in direct detection of trace contaminants. Magnetic deposition rate of MAuNPs in chloroform and water was explored. The presence of 4-MBA slowed the mass deposition rate, and it was postulated that the rate disparity originated from differing NP-substrate surface interactions. These findings emphasize the importance of ligand choice in reference to the medium, target analyte, and substrate material, as well as functionalization procedure in the design of similar sensing platforms.

Student Poster Presentation #22 (Session 2)

Engineering Choroid Plexus Organoid Derived from Human Pluripotent Stem Cells

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The choroid plexus is a complex structure in the human brain that is responsible for the secretion of cerebrospinal fluid (CSF). It also forms the blood-CSF barrier (B-CSF-B), which is similar to the blood brain barrier (BBB). The BBB and the B-CSF-B are two of the three major interfaces that separate extracellular fluids in the central nervous system (CNS) from the changeable environment of blood. The third barrier is the arachnoid barrier. The BBB and the B-CSF-B are able to prevent the entry of most toxic molecules into the human brain. Human induced pluripotent stem cells (hiPSCs) have shown promising results in the formation of BBB organoids and other brain organoids in vitro, however, only one study to date has utilized hiPSCs to generate Choroid Plexus Organoids (CPO). CHIR99021 (CHIR) is a small molecule that is known to activate the canonical Wnt/β-catenin pathway. Studies have shown that Wnt signaling is required for normal choroid plexus development in the mammalian brain. Additionally, it has also been observed that a loss of β-catenin in mice lead to an absence of canonical Wnt signaling which caused a disruption in choroid plexus epithelial development. In this study, the impact of Wnt signaling on choroid plexus organoid derivation from hiPSCs was investigated. The iPSK3 cells were grown in suspension to form 3-D aggregate-like structure. For the first 10 days, the cells only received DMEM/F12-B27 medium every other day. On day 10, and until day 15, BMP4 was added to the culture along with (+/-) CHIR. Then the culture was put on a wave motion shaker to promote the organoid formation. At day 30, the CPO were characterized by immunocytochemistry and flow cytometry for TTR (42-73%) and CLIC6 (20-30%) expression. The gene expression was determined using reverse transcription-polymeric chain reaction. Compared to the –CHIR group, the +CHIR group showed upregulation of CLIC6 (2-fold), PLEC (4-fold), PLTP (2-4 fold), DCN (~7 fold), DLK1 (2-4 fold), and AQP1 (1.4-fold), and down-regulation of TTR (0.1 fold), IGFBP7 (0.8 fold), MSX1 (0.4 fold), and LUM (0.2-0.4 fold). This study has the significance in modeling the human B-CSF-B for the purpose of drug screening and designing drug delivery systems to treat neurological disorders.

Student Poster Presentation #23 (Session 2)

Integrin Ligand Dependent Activation of YAP and NFkβ in Intervertebral Disc Cells

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Intervertebral disc degeneration (IVD) is characterized by the breakdown of one or more discs of the spine leading to the reduction of disc height. This condition is a result of genetic inheritance, aging or faulty mechanical loading of the discs. The inner most cells of the disc are the nucleus pulposus (NP) cells, which lose their phenotypic characteristics with degeneration, driving inflammation and changes in the extracellular matrix (ECM). Two transcription factors that are influenced by these changes are NFkβ and YAP. NFkβ is a multifunctional transcription factor that plays an important role in inflammatory responses, cell proliferation and apoptosis. YAP is a mechanosensitive transcription factor that translocate to the nucleus in response to high stiffness and cell spreading. Previous work has shown that fibronectin activates YAP by increasing F-actin and altering the morphology of the NP cells from circular to more flattened (Setton et al., 2019). To study the influence of fibronectin on inflammatory signaling, NP cells were isolated from fresh bovine caudal discs (Westville Meats, Westville, FL) and expanded on tissue culture plastic. Cells were seeded on glass or PDMS substrates coated with different ECMs fibronectin (FN), collagen (Col) or laminin (LM), blocked with heat denatured BSA to limit non-specific cell-ECM interaction. The cells were fixed at 2hr with 4% PFA and stained with DAPI, Alexa488 Phalloidin, YAP/Alexa568 and p65/Alexa647 antibodies then imaged at 20x. Quantification of cell area and nuclear to cytoplasmic ratio for YAP and p65 was performed in MATLAB. Additionally, cells seeded for 3 days were used for quantification of sGAG with the DMMB assay. On glass FN showed highest YAP and p65 nuclear translocation ($p<0.0001$ and $n=177$-417 cells per group, One-way ANOVA). On soft (2kPa) and stiff (30kPa) PDMS substrates, YAP and p65 were most activated on FN for stiff but showed less of a difference on soft ($p<0.05$ and $p<0.01$ respectively). sGAG production was highest on LM coated surfaces (compared to FN, $p<0.05$). With increasing passage, YAP and cell area increased, consistent with de-differentiation of NP cells. Another finding was that of the amount of proteoglycan produced was increased when cytoskeletal contractility was inhibited with blebbistatin, however the YAP inhibitor verteporfin had a minimal effect. Future experiments will look at changes in extracellular and intracellular forces, and the influence of cytoskeletal inhibition on NP phenotype.

Student Poster Presentation #24 (Session 2)

The Effects of Fluid Microstructure on the Kinematics of Achiral μ-Swimmers

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Natural fluids are often comprised of colloids and polymer molecules that form complex fluid microstructures. These microstructures give rise to time dependent properties, including viscoelasticity, at both macro and microscopic scales. For low Reynolds environments, Stokes law states that the propulsive force, F, of an object is related to the object dimensions, K, fluid viscosity, η, and object velocity, v, ($F = K\eta v$). Hence, as viscosity increases, a submerged object is expected to reduce its velocity when the propulsive force remains constant. However, some motile microorganisms have been observed to increase their propulsion speed in dilute polymer fluids while maintaining a constant propulsive force. In previous work, we explored the effect of increasing polymer concentration on the kinematics of achiral microswimmers which are similar in size to bacteria. Achiral microswimmers are known to achieve propulsion despite its lack of chirality and flexibility due to a nonzero coupling tensor between torque and velocity. In contrast to many biological microswimmers, it was observed that the propulsion speed decreases as a result of increased viscous drag forces. Here, to further explore the effect of fluid microstructure on achiral propulsion, we preformed swimming experiments in polymer fluids of various molecular weight but constant bulk dynamic viscosity. Fluids were characterized using bulk rheology and demonstrated Newtonian behavior between 1-100 s^{-1}. A 5 DOF magnetic field generator was used to induce homogeneous rotating magnetic fields of varying frequencies to actuate three and four magnetic bead-based achiral swimmers. We characterize the achiral swimmers at their step-out frequencies, where the magnetic torque no longer balances the viscous torque. We observe that while increasing viscosity decreases the propulsion velocity, the fluid microstructure governs the rate of decrease. More specifically, at a constant bulk viscosity achiral, swimmers always maintain a higher propulsion velocity in high molecular weight polymer fluids.

Student Poster Presentation #25 (Session 2)

Effect of micellar microstructure on kinetics of shear banding flow formation

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Surfactants and salts in aqueous solutions can self-assemble into micelles of various morphologies; of these, wormlike micelles, or long, flexible, cylindrical assemblies of molecules, can give rise to interesting rheological properties such as viscoelasticity and shear banding. Depending on the surfactants and salts used and the concentrations, wormlike micelles may or may not form branches. Here, we compare a linear with a branched wormlike micellar solution under step shear rate flow (i.e. a fixed shear rate flow applied starting from rest). We study these two solutions using rheometry with particle tracking velocimetry to quantify local velocity, measurements of flow-induced birefringence to probe fluid microstructure, illumination with a laser to visualize shear bands and instabilities in the velocity gradient-vorticity plane, and video recording of fluids prepared with mica flakes to visualize secondary flows and instabilities.

We found that although both fluids have shear stress plateaus in the flow curves, or ranges of shear rate where shear stress remains nearly constant, we only observe the shear banding typically associated with such shear stress plateaus in our linear wormlike micelles. At shear rates just beyond the onset of shear banding (towards the lower shear rate end of the plateau), the shear stress undergoes an overshoot, and then shear bands form as the shear stress decays toward the steady state value. The shear banding then becomes unstable, and the high shear towards the inner cylinder develops chaotic flow. Towards the end of shear banding (the higher shear rate end of the plateau), the instabilities become less prominent, and a stable high shear band forms. Additionally, as the shear bands form, the higher shear rate band towards the inner cylinder is birefringent, indicating micellar alignment in this region; however, the onset of flow instabilities obscures any further meaningful observation of birefringence.

At shear rates just beyond the onset of shear banding, our branched wormlike micelles initially display flow heterogeneity that may be interpreted as transient shear banding; however, as the shear stress goes through the maximum and decays towards the steady state value, the flow heterogeneity fades, and the quasi-steady velocity profile is gently curved with no distinct shear banding interface observable through velocimetry or turbidity visualization. For higher shear rates, instabilities form as the shear stress reaches the quasi-steady state, though there is still no shear banding. These branched wormlike micelles also show strong end effects starting around the same time. At still higher shear rates approaching the end of the shear stress plateau, these end effects quickly grow until they completely fill the gap.

Student Poster Presentation #26 (Session 2)

CSF flow during preclinical NTG-triggered central sensitization at 21.1 T

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Introduction: Increased sodium levels in cerebrospinal fluid (CSF) due to alterations in Na^+/K^+-ATPase activity in the choroid plexus is a potential mechanism of hyperexcitability in disorders such as migraine.[1] CSF flow is influenced by production and transport at the choroid plexus, and as such, flow may be affected by alterations in choroid plexus activity. This study characterizes CSF flow during the progression of acute nitroglycerin (NTG)-triggered central sensitization by mapping CSF flow in the ventricular system of an *in vivo* preclinical rat model using Fourier Velocity Encoding (FVE) MRI.[2]

Methods: Male Sprague Dawley rats were assigned to an NTG group (n=5) or a saline control group (n=5). Once in the scanner (21.1-T, 900-MHz vertical magnet), the animals were administered 10 mg/kg NTG or an equivalent volume of saline. Following the infusion, a 10-min FVE scans were acquired every 20 min out to 2 h post NTG. Whole-brain FVE images were acquired at 0.2 x 0.2 x 0.8 mm^3 using 16 flow encoding steps ranging between ±240 cm/s. Resulting in a flow resolution of 30 cm/s, which covers the range of CSF and arterial flow. Figure 1 is a representing a FVE MRI velocity-related intensity image including the fourth ventricle. Statistical analysis was done using JMP Pro 16 using a mixed model and an AR repeated covariance structure. Statistical significance is reported at $p<0.05$.

Results and Discussion: Extracerebral CSF flow intensities were evaluated in the positive and negative z-direction over the course of 2 hours during NTG-triggered central sensitization. Figure 2 shows some instability of CSF flow in the extracerebral space during NTG-triggered central sensitization maintained over several trials. Figure 2 also shows that the CSF flow in the extracerebral space decreases steadily with time for 2 hours post saline injection. Anesthesia and time in the magnet may result in a dehydration, but the difference between NTG and saline control may mean that there is increased production of CSF. Previous work done by Abad et al. found increased sodium in certain ventricular and ventricular-related regions at time points that pair with these findings of increased CSF flow.[3]

Conclusion: NTG-triggered central sensitization resulted in a CSF flow instability in the extracerebral space, while the saline control showed a sustained decrease in extracerebral CSF flow. This study is aimed at evaluating CSF flow to provide insight on how sodium-containing CSF may fluctuate during a migraine. These findings support the possibility that CSF flow is altered with acutely triggered central sensitization, which may reflect activity at the choroid plexus with respect to CSF production and sodium transport. Such data should inform modeling efforts targeting sodium accumulation driven by CSF flow related to hyper-excitability of neuroanatomical structures such as the brainstem and trigeminal complex implicit in the progression of migraine.

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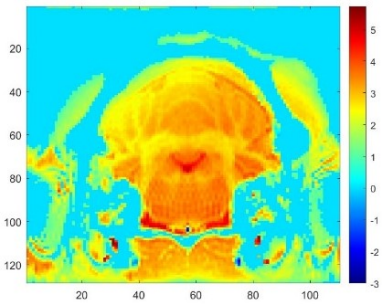

Figure 2:Velocity (cm/s) image acquired using FVE MRI.

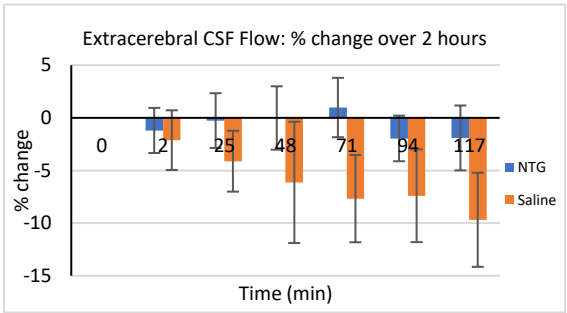

Figure 1: Extracerebral CSF flow percent change with NTG-triggered central sensitization or saline control.

Student Poster Presentation #27 (Session 2)

Effect of Actin Branching on Cellular Mechanotransduction

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The Arp2/3 complex plays a critical role in regulating the actin cytoskeleton and organizing actin filaments into branched networks that are important in cell spreading, protrusion, and migration. However, the role of actin branching in cellular mechanosensing and force transfer to integrin-based adhesions, particularly in 3-D environments, remains unknown. These forces are important for activation of the mechanosensitive transcription factor YAP, a key regulator of mechanotransduction. Stiff environments drive cell spreading and activation of YAP, which translocates to the nucleus. To study the effect of actin branching on this process, we measured cell spreading, YAP nuclear translocation, force on the adhesion adaptor protein Talin (FRET tension sensor), and extracellular matrix forces (traction force microscopy, TFM) in 3T3 cells. Cells seeded on fibronectin coated (10 μg/ml) glass coverslips were inhibited with CK666 (50uM, Arp2/3 inhibitor). Cells were fixed with 4% PFA and stained for F-actin and YAP, or assayed in a live cell imaging chamber for FRET, or on a fluorescent bead coated PDMS substrate for TFM. Our results indicate that cell area decreases with Arp2/3 inhibition ($p<0.001$, $n>250$ cells per group), however, YAP nuclear translocation does not change. A slight decrease in talin force was observed for Arp2/3 inhibited cells. These results indicate that YAP activation can still occur when cell area and focal adhesion forces are reduced, consistent with recent work showing that the nuclear envelope is a key driver of YAP nuclear translocation. Additionally, we generated nanofiber coated coverslips via electrospinning, to test the effects of a fibrous environment on this process. Fibronectin coated PCL fibers show decreased cell area and YAP nuclear translocation. Future work will focus on the role of branching in fibrous environments and the impact of branching on nuclear envelope forces.

Student Poster Presentation #28 (Session 2)

Probing microstructure of self-assembled micellar solutions via 1D ^{1}H NMR diffusometry

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When added with salt in aqueous solutions, surfactants self-assemble to various interesting nano-structures, including spherical, rod-like, vesicles, linear worm-like, and branched networks. A range of micellar solutions with a constant surfactant concentration of 12.5mM of Cetyl trimethyl ammonium bromide (CTAB) and a range of salt concentrations from 6mM to 20mM of 5-methyl salicylic acid (5mS), both dissolved in D_2O, are considered. Our rheological measurements indicate that these micellar solutions exhibit a viscosity peak beyond a critical salt to surfactant concentration ratio. Following rheological characterizations, we investigate the diffusion dynamics in micellar solutions with the help of 1D ^{1}H NMR diffusometry. This technique allows us to probe the type of diffusion the solutions exhibit and correlate them to the expected behavior of a microstructure assembly. This diffusion can either be restricted, with different strengths of restriction (1D or 2D) or non-restricted (3D). With preliminary results of salt free solutions, we were able to identify the chemical shifts of every component (surfactant, salt, solvent) in the solution. The surfactant molecules seem that they can move freely through their environment, but slower than the water molecules diffuse, meaning that their diffusion coefficient is lower and their motion more restricted, as expected. Moving forward to low salt concentrations of 6mM, preliminary results suggest that the solution appears to be restricted to curvilinear (1D) diffusion, which is expected for linear micelles. For this low concentration, literature shows that the micelles are indeed linear. Our current efforts involve testing larger salt concentrations and other surfactant based systems of OTAB/NaOA and CPCl/NaClO3, that show significantly different microstructures.

Student Poster Presentation #29 (Session 2)

Rheological Characterization of Bacteria-Breast Cancer Cell-laden Alginate-based Hydrogels

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Breast cancer is the most frequently diagnosed cancer worldwide and is the second leading cause of cancer-related mortalities in the United States. Mimicking the complex breast tumor microenvironment *in vitro* is critical for next generation drug and treatment development. Several techniques, including 3D fabrication and microfluidics, have been used to develop model systems to better understand the factors contributing to breast cancer progression and metastasis. Yet, despite progress to recreate the complex breast tumor environment, current models fail to explore the effects of microbial organisms on tumor progression, partly due to the original belief that the breast tissue environment is sterile. However, recent investigations have shown that the breast cancer tumor environment harbors many microbial organisms, indicating that prokaryotes play a key role in breast cancer progression. Towards developing *in vitro* breast cancer tissue models that more closely represent *in vivo* tissues, here we investigate the effects of bacteria and cancer cell seeding density on the viscoelastic properties of alginate-based hydrogels for extrusion-based biofabrication. Results indicate that the hydrogels exhibit greater shear-thinning behavior with increasing bacteria and breast cancer cell densities and a monotonic decrease in hydrogel viscosity. Applying the Herschel Bulkley model, we note that hydrogels have decreasing yield stress with increasing cell seeding densities. Understanding the viscoelastic properties of bacteria-cancer cell-laden hydrogel will aid our understanding of bacteria-cancer cell interactions within their extracellular matrix environments and enable the use of *in vitro* biofilm-cancer tissue models for high-throughput therapeutic screening.

Student Poster Presentation #30 (Session 2)

Fabrication and Wireless Manipulation of Magnetic Erythrocyte-Based Micromotors

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A wide range of micromotors, sub-millimeter-sized particles that can be wirelessly manipulated, have been developed over the past 20 years for biomedical applications. An emerging subclass of these systems, termed bio-hybrid micromotors, combines the actuation ability of synthetic particles with the biocompatibility and functionality of living cells and sub-cellular components. Of these bio-hybrid devices, those that combine magnetic particles with erythrocytes hold particular potential for future *in vivo* applications as they can be directly obtained from a patient, modified, and injected into the same donor for active cell therapy. However, current fabrication and control methods are complex and require multiple external control signals for effective manipulation. Alternatively, simplified methods to fabricate magnetic erythrocyte micromotors in conjunction with methods using only magnetic control would serve as an efficient route for employing these devices *in vivo*. Here we report two techniques to fabricate erythrocyte-based magnetic micromotors and demonstrate the ability to control their motion using only a uniform rotating magnetic field. After fabrication, the erythrocyte-based micromotors retain their structure and biological functionality. We also explore swimming and rolling kinematics, specifically velocity, precession angle, and their steerability in aqueous solutions using open-loop control. The observed dynamics may enable the development of future erythrocyte micromotor designs and control strategies for *in vivo* therapeutic applications.

Awardees of Student Presentations

Oral Presentation

1st place	Samuel W. Holder

Poster Presentation

1st place	David Quashie Jr
2nd place	Stephanie F. Marxsen
3rd place	Alfredo Scigliani