FACM '19 & NCS11

FRONTIERS IN APPLIED & COMPUTATIONAL MATHEMATICS HELD JOINTLY WITH THE 11TH NORTHEASTERN COMPLEX FLUIDS & SOFT MATTER WORKSHOP

New Jersey Institute of Technology
Newark, New Jersey
May 23 and 24, 2019

Program Guide, Titles, and Abstracts

Hosted by
Department of Mathematical Sciences and
Center for Applied Mathematics and Statistics
http://www.math.njit.edu

NJIT
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ORGANIZING COMMITTEE

FRONTIERS IN APPLIED & COMPUTATIONAL MATHEMATICS
HELD JOINTLY WITH THE 11TH NORTHEASTERN
COMPLEX FLUIDS & SOFT MATTER WORKSHOP
NEWARK, NEW JERSEY
MAY 23 AND 24, 2019

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FRONTIERS IN APPLIED & COMPUTATIONAL MATHEMATICS
HELD JOINTLY WITH THE 11TH NORTHEASTERN
COMPLEX FLUIDS & SOFT MATTER WORKSHOP

MESSAGE FROM THE ORGANIZING COMMITTEE

Welcome to Frontiers in Applied and Computational Mathematics 2019 (FACM '19), this year held together with the 11th Northeastern Complex Fluids and Soft Matter (NCS) Workshop. The FACM conferences are hosted by the Department of Mathematical Sciences (DMS) and the Center for Applied Mathematics and Statistics (CAMS) at the New Jersey Institute of Technology. Hosting the conference is definitely one of the most enjoyable events of our year.

This year the focus is on problems involving particles in fluids, broadly taken, and involving both mathematical and applied aspects. The related fields of research have been very active in the recent years, with significant new development in the fields such as discrete and continuum modeling of particulate systems, application of novel techniques to analysis of interaction networks in particulate systems, as well as developments in various fields focusing on active matter.

The FACM conferences actively seek and support presentations by early-career researchers. These are selected from applications that are submitted by some of the best young applied mathematicians and statisticians. It is a pleasure for us to give the future leaders of the field an opportunity to present their work among more established colleagues.

The FACM conferences are indicative of the central role that the mathematical sciences have at NJIT. This year's joint meeting with NCS illustrates the interdisciplinary nature of the research activities in DMS and CAMS. We hope that you enjoy the meeting and that you return again next year to present your most recent work and to discuss your new ideas, research and achievements.

We take this opportunity to thank the Administrative Staff of the Department of Mathematical Sciences for the enthusiasm and hard work they bring to the event: Wilfred Augustin, Alison Boldero, Pauline Ford, Sarah Lamont, and Michelle Llado-Wrzos.

Finally, we gratefully acknowledge the support by the National Science Foundation Division of Mathematical Sciences (DMS) and Chemical, Bioengineering, Environmental and Transport Systems (CBET) that has allowed us to extend our invitation to many junior mathematicians and scientists who would not have been able to participate otherwise.

FACM '19 Organizing Committee

DMS CHAIR'S MESSAGE

The Department of Mathematical Sciences (DMS), along with the Center for Applied Mathematics and Statistics (CAMS), is very pleased to welcome you to NJIT for our sixteenth conference on the Frontiers in Applied and Computational Mathematics (FACM). We are equally pleased this year to join with the Northeastern Complex Fluids and Soft Matter Workshop (NCS) to address the theme of particles in fluids. This theme deeply touches the research interests of a very significant portion of the DMS faculty. So it is with special anticipation that I look forward to this joint conference.

Last November DMS lost a notable member: Distinguished Professor Emeritus Robert Miura. Robert was of course well-known for his founding contributions to inverse scattering theory. His work in mathematical biology was his primary focus during his time at NJIT and the area where he made his deepest contributions to our department. Robert's lifetime contributions were reviewed and celebrated at FACM 2014.

In addition to welcoming you to our campus, we welcome you to the City of Newark. Newark has a number of perhaps unexpected attractions: the New Jersey Performing Arts Center, the Cathedral Basilica of the Sacred Heart, Branch Brook Park (each April, the site of the Essex County Cherry Blossom Festival featuring over five thousand cherry trees), and the Newark Museum (situated very close to the route between NJIT and the Robert Treat Hotel where many participants will stay). Some will be surprised by the diversity of Newark, which includes one of the largest Portuguese-speaking populations in North America. As in any unfamiliar urban environment, we ask that you exercise due caution as you visit with us but believe that you will find that Newark possesses a special charm worthy of exploration.

The nature of a conference is to bring people together to share ideas and foster collaborations and new directions. Through FACM, we are pleased to include early-career scientists, statisticians, and applied mathematicians in these activities. To see the flourishing careers of so many past participants is immensely gratifying and encourages us to further expand these opportunities. All participants are especially encouraged to attend presentations including posters where early-career participants are presenting and to interact with these rising talents.

Jonathan Luke
Professor and Chair
Department of Mathematical Sciences

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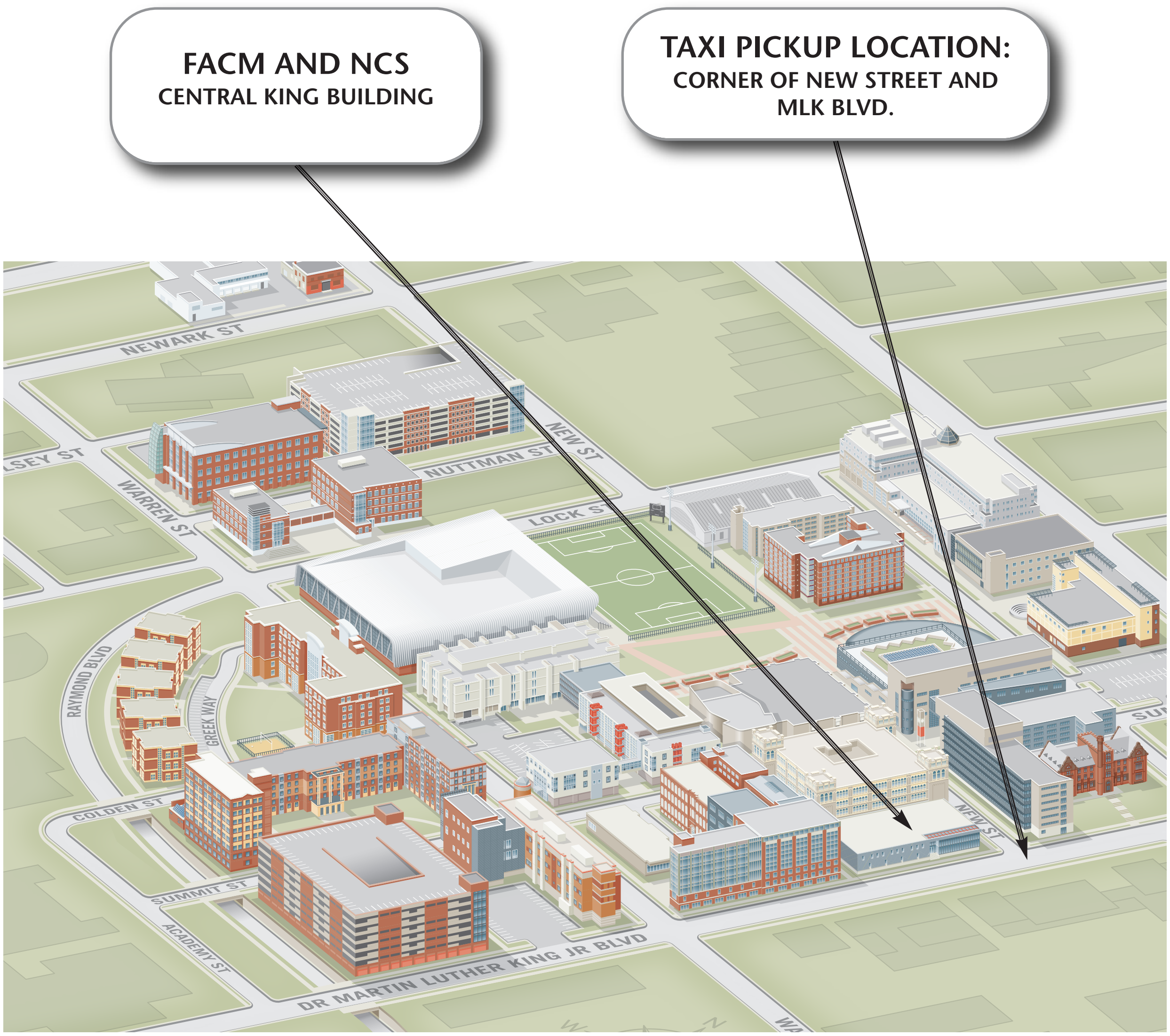
Telephone either one and request pick up at "NJIT campus, corner of New Street and MLK Blvd." This is near the guard station at Parking Lot 7 by Cullimore Hall. If you plan to pay with a credit card instead of cash, tell them when you call because some drivers only accept cash.



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GUEST ACCESS TO THE NJIT NETWORK

MAY 23 – 24, 2019

Welcome to NJIT. Please make use of the wired and wireless connections available in the meeting area. To do so, please follow these three steps:

1. *CONNECT* using either a wireless or wired connection. Addresses are assigned automatically.
   - **Wired:** Most wall plates are active in the meeting area and noted by a RED or YELLOW port on the wall plate.
   - **Wireless:** Connect to the Site ID (SSID) of "NJIT" (all upper case, no quotes), which should appear in your list of available wireless networks.

2. *AUTHENTICATE* by visiting any website: http://www.njit.edu/ for example. When prompted, enter the following authentication credentials:

   User name (UCID): **guest872**

   Password: **version85**

If the "Please enter your UCID and Password" prompt reappears, verify that you have entered the correct UCID and Password, this means you have provided an incorrect username and password combination.

3. *ACCESS* to the NJIT network should now be available. Your guest account will give you access for 12 hours, or until your wireless device goes to sleep. If you have lost connection, open a web browser and repeat step 2.

Please note: these access credentials are only good until midnight of May 24, 2019.

PROGRAM SCHEDULE

THURSDAY, MAY 23

ALL TALKS AND POSTER SESSIONS WILL TAKE PLACE INSIDE THE AGILE STRATEGY LAB
LOCATED IN THE CENTRAL KING BUILDING, ROOM L70.

Time	**Event**
7:30 - 8:15 a.m.	Registration + Coffee/ Pastries Set Up Posters
8:15 - 8:30 a.m.	**Welcoming Remarks** **Lou Kondic,** Organization Committee Chair Department of Mathematical Science
	Introductory Remarks **Jonathan Luke**, Chairperson Department of Mathematical Sciences
8:30 - 9:20 a.m.	**Plenary Lecture I** **Igor Aronson**, Pennsylvania State University *Engineering Spatial-Temporal Organization of Bacterial Suspensions*
10:00 - 10:30 a.m.	Coffee Break
Session I - Granular Matter I	
9:20 - 9:40 a.m.	**Corey O'Hern**, Yale University *Origin of the Jamming Scaling Exponents*
9:40 - 10:00 a.m.	**Luis Pugnaloni**, Universidad Nacional de La Pampa *A First Principle Derivation for the Flow Rate of Discharging Silos*
10:00 - 10:20 a.m.	**Mark Shattuck**, The City College of New York *Deformable Particles*
10:20 - 10:30 a.m.	**Jeremy Cho**, Princeton University *Scaling Law for Cracking in Shrinkable, Granular Packings*
10:30 - 10:40 a.m.	**Sijie Tong**, Princeton University *Mechanical Response of Wrinkled Structures*
10:40 - 11:10 a.m.	Morning Coffee Break
Session II - Granular Matter II	
11:10 - 11:30 a.m.	**Ken Kamrin**, Massachusetts Institute of Technology *Fun With New Methods for Particle Flow Problems*
11:30 - 11:50 a.m.	**Jeffrey Morris**, Levich Institute, The City College of New York *Network Structure and Stress Fluctuations in Shear-Thickening Suspensions*
11:50 - 12:10 p.m.	**Ryan Hurley**, Johns Hopkins University *Measuring Contact- And Particle-Scale Behavior in 3D Granular Materials*
12:10 - 12:30 p.m.	**Jasna Brujic**, New York University *Colloidomer Folding*
12:30 - 12:40 p.m.	**Ryan Kozlowski**, Duke University *Dynamics of a Single-Intruder Driven Through a Granular Medium: Effects of Packing Fraction, Basal Friction, and Interparticle Friction*
12:40 - 12:50 p.m.	**Chao Cheng**, New Jersey Institute of Technology *The Precursors to Stick-Slip Events in Sheared Granular Systems*
12:50 - 2:10 p.m.	Poster Session I and Lunch

PROGRAM SCHEDULE

THURSDAY, MAY 23

Time	Event
	Session III - Active and Soft Matter I
2:10 - 2:30 p.m.	**Jörn Dunkel**, Massachusetts Institute of Technology *Inverse Design of Discrete Mechanical Meta-Materials*
2:30 - 2:50 p.m.	**Miranda Holmes-Cerfon**, New York University *Modeling the Relative Dynamics of DNA-Coated Colloids*
2:50 - 3:10 p.m.	**Alexandra Zidovska**, New York University *Surface Fluctuations and Coalescence of Nucleolar Droplets in the Human Cell Nucleus*
3:10 - 3:30 p.m.	**Leif Ristroph**, Courant Institute, New York University *Blowing Bubbles*
3:30 - 3:50 p.m.	**Wen Yan**, Flatiron Institute, Simons Foundation *Computing Collision Stress in Assemblies of Active Spherocylinders*
3:50 - 4:00 p.m.	**Lucia Carichino**, Worcester Polytechnic Institute *Hydrodynamic and Biochemical Interactions in Sperm Motility*
4:00 - 4:10 p.m.	**Lailai Zhu**, Princeton University *Locomotion Driven by Self-Oscillation via an Electrohydrodynamic Instability*
4:10 - 4:40 p.m.	Afternoon Coffee Break
4:40 - 5:30 p.m.	**Plenary Lecture II** **Michael Shearer**, North Carolina State University *Continuum Equations of Granular Flow*
5:30 - 7:30 p.m.	Cocktail Reception Location: Eberhardt Hall NJIT Campus

PROGRAM SCHEDULE

FRIDAY, MAY 24

ALL TALKS AND POSTER SESSIONS WILL TAKE PLACE INSIDE THE AGILE STRATEGY LAB LOCATED IN THE CENTRAL KING BUILDING, ROOM L70.

Time	Event
7:30 - 8:30 a.m.	Registration + Coffee/ Pastries Set Up Posters
8:30 - 9:20 a.m.	**Plenary Lecture III** **John Brady**, California Institute of Technology *The Dynamics of Active Colloids*
Session IV - Colloidal Suspensions and Surfactants	
9:20 - 9:40 a.m.	**Dan Harris**, Brown University *Diffusion-Induced Aggregation*
9:40 - 10:00 a.m.	**Aditya Khair**, Carnegie Mellon University *Nonlinear Viscoelasticity of a Dilute Suspension of Brownian Spheroids in Oscillatory Shear Flow*
10:00 - 10:20 a.m.	**Shreyas Mandre**, Brown University *Surfactants Driven Out of Equilibrium by a Flow*
10:20 - 10:30 a.m.	**Islam Benouaguef**, New Jersey Institute of Technology *PIV Measurement of Flow Induced on a Salt Waterbody by a Freshwater Source*
10:30 - 10:40 a.m.	**Nicholas Chisholm**, University of Pennsylvania *Hydrodynamics of Microswimmers Trapped at Fluid-Fluid Interfaces*
10:40 - 11:10 a.m.	Morning Coffee Break
11:10 - 12:40 p.m.	Poster Session II
12:40 - 1:40 p.m.	Poster Session II and Lunch
Session V - Active and Soft Matter II	
1:40 - 2:00 p.m.	**Howon Lee**, Rutgers University *4D Printing With Stimuli-Responsive Materials*
2:00 - 2:20 p.m.	**Sujit Datta**, Princeton University *Bacterial Hopping and Trapping in Porous Media*
2:20 - 2:40 p.m.	**Saverio Spagnolie**, University of Wisconsin-Madison *Active Matter Invasion of a Viscous Fluid and a No-Flow Theorem*
2:40 - 2:50 p.m.	**Quentin Brosseau**, Courant Institute, New York University *Microswimmer Design and Rheotaxis in Wall-Bounded Shear Flows*
2:50 - 3:00 p.m.	**Tapomoy Bhattacharjee**, Andlinger Center for Energy and the Environment *Surfing the Wave: How Bacteria Collectively Migrate Through Porous* Media
3:00 - 3:50 p.m.	**Plenary Lecture IV** **Kathleen Stebe**, University of Pennsylvania *Embedded Energy Landscapes in Soft Matter to Direct Colloid Motion*
3:50 - 4:20 p.m.	Afternoon Coffee Break
4:20 - 5:20 p.m.	**Panel Discussion** *Focus on Career Advice for Junior Researchers* Chaired by **Linda J. Cummings**

IGOR ARONSON

Pennsylvania State University

Engineering Spatial-Temporal Organization of Bacterial Suspensions

Suspensions of motile bacteria or synthetic microswimmers, termed active matter, manifest a remarkable propensity for self-organization and formation of large-scale coherent structures. Most active matter research deals with almost homogeneous in space systems and little is known about the dynamics of active matter under strong confinement. I will talk on experimental and theoretical studies on the expansion of highly concentrated bacterial droplets into an ambient bacteria-free fluid. The droplet is formed beneath a rapidly rotating solid macroscopic particle inserted in the suspension [1]. We observed vigorous inability of the droplet reminiscent of a supernova explosion [2]. The phenomenon is explained in terms of continuum first-principle theory based on the swim pressure concept. Furthermore, we investigated self-organization of a concentrated suspension of motile bacteria Bacillus subtilis constrained by two-dimensional (2D) periodic arrays of microscopic vertical pillars [3]. We show that bacteria self-organize into a lattice of hydrodynamically bound vortices with a long-range antiferromagnetic order controlled by the pillars' spacing. Our findings provide insights into the dynamics of active matter under extreme conditions and significantly expand the scope of experimental and analytic tools for the control and manipulation of active systems.

[1] A Sokolov and I.S. Aranson, Rapid expulsion of microswimmers by a vortical flow, Nature Commun 2016, 7, 11114

[2] A Sokolov, LD Rubio, JF Brady, IS Aranson, Instability of expanding bacterial droplets, Nature Commun 2018, 9 (1), 1322

[3] D Nishiguchi, IS Aranson, A Snezhko, A Sokolov, Engineering bacterial vortex lattice via direct laser lithography, Nature Commun 2018, 9 (1), 4486

JOHN BRADY

California Institute of Technology

The Dynamics of Active Colloids

A distinguishing feature of many living systems is their ability to move – to be active. Through their motion living systems are able to self-assemble: birds flock, fish school, bacteria swarm, etc. But such behavior is not limited to living systems. Recent advances in colloid chemistry have led to the development of synthetic, nonliving particles that are able to undergo autonomous motion by converting chemical energy into mechanical motion and work. This intrinsic activity imparts new behaviors to active matter that distinguish it from equilibrium systems. Active matter generates its own internal forces and stresses, which can drive it far from equilibrium, and by so doing active matter can control and direct its own behavior and that of its surroundings. In this talk I will discuss our recent work on active matter composed of Brownian colloidal particles, highlighting some of the interesting phenomena they display such as enhanced diffusion, wave-like propagation, accumulation at boundaries and self-assembly.

MICHAEL SHEARER

North Carolina State University

Continuum Equations of Granular Flow

There are many recent developments in formulating constitutive relations for continuum equations of granular flow. While models of incompressible flow tend to be ill-posed, compressibility can render the equations well-posed, if the dependence of constitutive laws on compressibility satisfies simple constraints. The resulting general theory is referred to as CIDR (Compressible I-dependent Rheology). I present a refinement of CIDR that operates in the inertial regime, where the flow is dense but below the jamming transition. Sample numerical simulations are used to demonstrate the contrasting behavior of models with and without the constraints of CIDR.

KATHLEEN STEBE

University of Pennsylvania

Embedded Energy Landscapes in Soft Matter to Direct Colloid Motion

The ability to dictate the trajectories and docking sites of colloidal objects has far-reaching implications in fields ranging from reconfigurable materials to intelligent systems. We have been developing embed energy landscapes that organize colloidal particles using confined nematic liquid crystals (NLCs) near undulating boundaries. Related concepts have been developed using defect structures within NLCs director fields. However, while these structures can organize colloids within them, they typically trap colloids, preventing reconfiguration. To avoid such trapped states, we design director fields that, in the absence of the colloids, are defect-free, but feature gentle distortions that can be sensed by colloids placed within the domain. This NLC director field gently guides colloid motion. We develop these concepts by placing a boundary of alternating hills and wells with well-defined anchoring in contact with the NLC. This embeds an energy landscape that dictates anisotropic particle orientation, particle paths and defines multi-stable equilibria. These strategies to direct colloid motion can be combined with external fields to afford additional control over reconfigurable systems and in microrobotics applications. The key ingredients for this scheme include a soft matter host in which an energy field can be stored via confinement, and colloids as sources for local distortion of this field. Analogous concepts for other systems are briefly discussed.

ISLAM BENOUAGUEF

New Jersey Institute of Technology

PIV Measurement of Flow Induced on a Salt Waterbody by a Freshwater Source

The presence of the freshwater source point at the interface of a saltwater body induces a solutocapillary flow. This type of flow is driven by the surface tension gradient caused by the solute concentration gradient. At the surface the flow is away from the source point where below the interface the flow is toward the source point. The particle image velocimetry technique is used to obtain experimentally the velocity fields. These results are compared with the analytical solution of a surface tension gradient driven flow in presence of a source.

TAPOMOY BHATTACHARJEE

Andlinger Center for Energy and the Environment

Surfing the Wave: How Bacteria Collectively Migrate Through Porous Media

While chemotaxis—motion in response to a chemical stimulus—is well-studied for bacteria in unstructured environments, most bacteria inhabit heterogeneous porous media such as biological gels and tissues, soils, sediments, and subsurface formations. Here, we study how chemotaxis of E. coli is altered by confinement inside a porous medium. Specifically, by creating multi-cellular communities inside model 3D porous media, we show that the combination of nutrient diffusion and consumption enable bacteria to form traveling waves that "surf" self-generated chemotactic gradients. These waves travel at a rate that is set by the competition between pore-scale confinement and differential metabolism of different nutrient sources. Below a threshold pore size, the individual cells can no longer move through the pore space; nevertheless, we find that communities can still form traveling waves via cell growth and division, by pushing their progeny through the pore space up a chemotactic gradient. Our results help to broaden our understanding of bacterial chemotaxis to more complex environments.

QUENTIN BROSSEAU

Courant Institute, New York University

Microswimmer Design and Rheotaxis in Wall-Bounded Shear Flows

Biological microswimmers in a shear flows often exhibit rheotaxis: a directed movement in response to a background flow near a boundary. We have investigate the rheotactic behavior of motile Janus (Au/Pt) rod-like particles with varying metallic Au/Pt segment length ratios. Numerical models and experiments reveal that the synthetic swimmers switch propulsion modes (pusher/puller) depending on the position of the Au/Pt junction. Our findings suggests new approaches for the sorting and guiding of swimmers based on their flow signature.

JASNA BRUJIC

New York University

Colloidomer Folding

From a broad perspective, the challenge is to understand how different interaction potentials and driving forces can be combined to produce a useful designed structure. Here, we will use biological molecules, particularly lipids and DNA strands, to functionalize emulsions in order to self-assemble arbitrarily designed structure. This versatile system allows us to control the fluidity, specificity, valency, and logical programming of interactions between droplets, which in turn facilitates the assembly of complex structures, including emulsion polymers, loops and clusters with particular geometries. In particular, we will focus on the sequential self-assembly of linear droplet chains, in which we will pre-program the strength and specificity of the interactions along the chain. Secondary structure formation will be revealed by confocal microscopy over time, in response to temperature cycling, this `beads-on-a-string' experimental model is analogous to protein folding on the molecular scale, but provides access to the configurational fluctuations on the droplet scale. Learning the principles of emulsion folding will allow us to design and construct folds that result in complex 3D objects from one-dimensional chains. The droplets can readily be solidified, therefore they offer a route to hands-off manufacturing of objects with inbuilt hierarchies. The long-term goal is to design sequences in order to build unlikely crystalline symmetries, aperiodic crystals, and disordered structures with desirable optical and mechanical properties.

LUCIA CARICHINO

Worcester Polytechnic Institute

Hydrodynamic and Biochemical Interactions in Sperm Motility

Sperm are navigating in a complex three-dimensional (3D) fluid environment in order to achieve fertilization. Sperm trajectories vary form planar to helical depending on species, on external fluid properties and on proximity to walls. Biochemical signaling along the sperm flagellum, such as changes in calcium, regulates sperm trajectories and flagellar beat patterns. We present a fluid-structure interaction model of the sperm flagellum 3D motion in a Newtonian viscous fluid that accounts for (i) spatiotemporal calcium dynamics in the flagellum, (iii) interaction of sperm cells and a planar wall, and (iii) sperm-sperm interactions. The flagellum is modeled as an elastic rod with preferred curvature and twist, using the Kirchhoff rod model. The calcium dynamics, represented as a reaction-diffusion model on the moving flagellum, is coupled to the sperm motility via the flagellum curvature. Model results of 3D emergent waveforms and trajectories are compared to the planar case. In the 3D case, flagelloid curves (paths followed by a fixed point on the flagellum) can be described as hypotrochoids curves, which change shape significantly if calcium coupling or proximity to a wall is considered.

CHAO CHENG

New Jersey Institute of Technology

The Precursors to Stick-Slip Events in Sheared Granular Systems

The stick-slip transition of granular systems is related to earthquakes and avalanches, and therefore understanding the conditions leading to slip events is of general importance. Although stick-slip behavior has been studied extensively, what triggers a slip event still remains unclear. The purpose of our study is to explore the existence of precursors to slip events. For this purpose, we study a sheared system in stick-slip regime via two-dimensional discrete element simulations.

Particular focus is on the evolution of force networks before and during slip events. We will show that some features of force network evolution could be used to gain insight into the occurrence of a slip event.

NICHOLAS CHISHOLM

University of Pennsylvania

Hydrodynamics of Microswimmers Trapped at Fluid-Fluid Interfaces

A fluid interface can strongly influence the behavior of a nearby self-propelled colloid (microswimmer), allowing for boundary guidance or directed assembly. Moreover, such swimmers are often not present alone, and they can interact with other swimmers or material on or near the interface. As a result, such systems may exhibit enhanced transport and collective motion. However, the influence of a fluid interface on these phenomena is not well understood compared to similar phenomena in the bulk. Motivated by this gap in knowledge, we theoretically quantify the flows generated by interfacially trapped microswimmers by developing an appropriate flow singularity model. The Reynolds and capillary numbers are assumed small, in line with many colloidal systems involving an air- or oil-water interface. We consider a "clean" interface where the Marangoni number (Ma) is small as well as an incompressible interface (Ma >> 1), as is often the case if surfactant is present. To identify modes of directed motion, we examine the interactions between a microswimmer and passive "tracer" particles. Here, the trajectory of the swimmer is prescribed to be either rectilinear or circular. Our results will be useful in future work regarding the use of active colloids to direct and enhance transport at interfaces.

JEREMY CHO

Princeton University

Scaling Law for Cracking in Shrinkable, Granular Packings

Despite the ubiquity of materials that shrink and crack into discrete clusters of grains when dried, accurate prediction of cracking length scales remains elusive. Here, we elucidate the previously overlooked role of individual grain shrinkage—a feature common to many materials—in determining crack patterning using both experiments and simulations. By extending the classical Griffith cracking theory, we obtain a universal scaling law that quantifies how cluster size depends on the interplay between grain shrinkage, stiffness, and size—applicable to a diverse array of shrinkable, granular packings.

SUJIT DATTA

Princeton University

Bacterial Hopping and Trapping in Porous Media

Diverse processes rely on bacterial migration in disordered, three-dimensional (3D) porous media. However, how pore-scale confinement alters bacterial motility is unknown due to the opacity of typical 3D media. As a result, models of migration are limited and often employ ad hoc assumptions. Here we reveal that the paradigm of run-and-tumble motility is dramatically altered in a porous medium. By directly visualizing individual E. coli, we find that the cells are intermittently and transiently trapped as they navigate the pore space, exhibiting diffusive behavior at long time scales. The trapping durations and the lengths of "hops" between traps are broadly distributed, reminiscent of transport in diverse other disordered systems; nevertheless, we show that these quantities can together predict the long-time bacterial translational diffusivity. Our work thus provides a revised picture of bacterial motility in complex media and provides new opportunities for mathematical modeling of cellular migration.

JÖRN DUNKEL

Massachusetts Institute of Technology

Inverse Design of Discrete Mechanical Meta-Materials

Metamaterials achieve a wide range of complex functionalities through the synergistic integration of intrinsic material properties and extrinsic geometric structure. A longstanding challenge in acoustic metamaterials design has been the accurate prediction of material structures that realize any desired vibrational spectrum. Our work describes an efficient computational framework for designing discrete network-based phononic metamaterials with predefined spectral properties, including multiple or switchable bandgaps. The algorithm harnesses disorder to achieve the desired phonon spectra in two- and three-dimensional structures.

DANIEL HARRIS

Brown University

Diffusion-Induced Aggregation

An extremely broad and important class of phenomena in nature involves the settling and aggregation of matter under gravitation in fluid systems. In this work we observe and rationalize a new fundamental effective attractive mechanism by which particles suspended within stratification may self-assemble and form large aggregates without need for short-range binding effects (adhesion). This phenomenon arises through a complex interplay involving solute diffusion, impermeable boundaries, and the geometry of the aggregate. Control experiments with two particles isolate the individual dynamics, which are quantitatively predicted through numerical integration of the underlying equations of motion. Ongoing and future work will be discussed. This is joint work with Roberto Camassa, Richard McLaughlin, and students in the Joint Applied Math and Marine Sciences Fluids Lab at UNC Chapel Hill.

MIRANDA HOLMES-CERFON

New York Unive

The Relative Dynamics of DNA-Coated Colloids

A versatile way to makes colloids with programmable interactions is to coat them with strands of sticky single-stranded DNA. The DNA causes particles to stick together, as if they were coated with velcro, but it also creates an effective friction for particles to move relative to each other, much like the force you feel when peeling apart velcro. What is the magnitude of this friction, and how does it depend on the type of relative motion, such as sliding versus rolling? We address this question by coarse-graining a microscopic model of DNA-induced interactions between line segments. We argue that the DNA-induced friction is significant, and could depend in a nontrivial way on the type of relative motion. We speculate that in certain experimental systems DNA-coated colloids could act like gears, and assemble into metastable states that would not be observed in their true equilibrium.

RYAN HURLEY

Johns Hopkins University

Measuring Contact- And Particle-Scale Behavior in 3D Granular Materials

In this talk, I will describe our recent studies of contact- and particle-scale behavior in deforming 3D granular materials. By using X-ray tomography and 3D X-ray diffraction, we have calculated the intra-particle stress tensors, and the inter-particle forces, contact kinematics, and frictional energy dissipation in the bulk of deforming 3D granular materials, including real sand. I will discuss our methodology, show examples of recent work in which we have explored the statistics of a variety of variables describing contact kinematics and kinetics (force, slip, frictional dissipation), and describe efforts to add ultrasound measurements to our experimental setup to investigate vibrational modes and acoustic transmission.

KEN KAMRIN

Massachusetts Institute of Technology

Fun with New Methods for Particle Flow Problems

Dry and fluid-saturated granular media display multiple modeling challenges from a continuum perspective. Foremost is the search for quantitative and robust constitutive models. However, another challenge is to find methods that can implement these theories in non-trivial geometries and to find ways to connect these various approaches together. In this talk we will discuss new modeling approaches for dry and for fluid-saturated granular media and we will exploit a meshless simulation approach to enable full and hybridized simulation.

ADITYA KHAIR

Carnegie Mellon University

Nonlinear Viscoelasticity of a Dilute Suspension of Brownian Spheroids in Oscillatory Shear Flow

The nonlinear viscoelasticity of a dilute suspension of Brownian spheroids under oscillatory shear flow is calculated numerically. This is achieved by determining the long-time periodic particle orientation distribution function via a numerical solution to the Fokker-Planck equation. From an ensemble average of the particle stresslet, the entire stress tensor and relevant birefringence parameters are calculated, over a range of Weissenberg number (Wi) and Deborah number (De). We focus on the nonlinear viscoelastic regime (Wi > 1 and Wi/De > 1) for highly elongated spheroids, where multiple overshoots are observed in the shear stress evolution during an oscillation cycle. The mechanistic origin of these overshoots can be understood from the periodic orientation dynamics (i.e. Jeffery orbits) of a particle under steady shear in the absence of Brownian rotation. We contrast this behavior to recent work (Khair, JFM 2016) on nearly spherical particles in strong, oscillatory shear. Finally, a comparison of our predictions for the birefringence evolution against recent experiments on graphene sheets (Natale et al. PRFluids 2018) is presented.

RYAN KOZLOWSKI

Duke University

Dynamics of a Single-Intruder Driven Through a Granular Medium: Effects of Packing Fraction, Basal Friction, and Interparticle Friction

A key question in granular materials is how a granular medium responds to local perturbations from a driven single-grain intruder as opposed to large intruding rods, sliders, or moving boundaries. Here we experimentally investigate the dynamics of a grain-scale intruder driven by a spring through an annular channel of photoelastic disks. We vary the grain packing fraction, interparticle friction, and basal friction between grains and the table surface; we observe dynamical regimes of either stick-slip or intermittent flow. In the former, the intruder gets stuck when grains form a stable network, the force on the intruder increases due to the driving spring, and the granular structure yields when a certain force threshold is reached, allowing the intruder to slip through the grains until a stable network quickly forms again. In the latter, the intruder flows through the medium with only occasional stick events, reminiscent of clogging-flowing dynamics. For cases with basal friction we observe a smooth transition from intermittent flow to stick-slip as packing fraction increases, and increasing interparticle friction decreases the threshold packing fraction region. Without basal friction, we only observe intermittent flow. Thus the stability provided by friction (and basal friction in particular) strongly controls single-grain intruder dynamics.

HOWON LEE

Rutgers University

4D Printing With Stimuli-Responsive Materials

Soft materials that can actively deform and reconfigure in response to external stimuli have been extensively studied for their profound potential for adaptive material systems. Emerging pathway to create dynamic and adaptive architectures involves additive manufacturing (commonly called 3D printing) of stimuli-responsive materials. This approach has been recently termed 4D printing, with the 4th dimension being the time. In this talk, 3D micro-fabrication of stimuli-responsive soft materials using projection micro-stereolithography (PμSL) will be presented. 4D printing with (i) thermo-responsive hydrogel, (ii) electro-active hydrogel, and (iii) thermo-responsive shape memory polymer will be presented. Applications including soft robotic manipulators, reconfigurable and tunable metamaterials, and bio-medical devices will be presented.

SHREYAS MANDRE

Brown University

Surfactants Driven Out of Equilibrium by a Flow

A surfactant is a chemical compound that adsorbs onto a fluid-fluid interface and reduces its surface tension. A non-uniform distribution of such compounds at the interface causes a Marangoni stress that drives a flow, which in turn transports the surfactant. Estimating in situ the degree to which the adsorbed surfactant is out of equilibrium with the dissolved state is critical but challenging, especially because of the multiple length- and time-scales the surfactant and flow dynamics span. In this presentation, I show that combining asymptotic analysis of the governing mathematical model with experimental flow visualization and velocimetry can furnish a near-complete description of the dynamics.

An epitome of such a system is the axisymmetric flow driven by a steady point source of surfactant on the surface of a deep liquid pool. In this case, the state of the surfactant is difficult to gauge, without which even simple order-of-magnitude scaling theories remain incomplete. I show that by examining three invariant characteristics of the flow, and without knowledge of the surfactant physicochemical parameters, the nature of the surfactant dynamics can be deduced.

JEFF MORRIS

Levich Institute, The City College of New York

Network Structure and Stress Fluctuations in Shear-Thickening Suspensions

Concentrated or "dense" suspensions of solid particles in viscous liquids exhibit extreme rheological behavior, and here we focus on strong shear thickening. This is seen in corn starch dispersions in water, commonly known as "oobleck," but here we consider simulations of hard spheres interacting by hydrodynamics, electrostatic repulsion, and contact friction. The emphasis in this talk will be on the transitional portion of the flow curve, where the viscosity can change discontinuously, and relating this change in behavior to the underlying force network. Visual representations of the network will be presented to elucidate the statistical analysis of various metrics of the network structure.

COREY O'HERN

Yale University

Origin of the Jamming Scaling Exponents

The response of purely repulsive disk and sphere packings to athermal, quasistatic simple shear near jamming onset is highly nonlinear. Previous studies have shown that the ensemble-averaged static shear modulus G is nearly constant at small pressure p, and at a characteristic pressure p^*, G begins to increase as a power-law $G \sim p^{\alpha}$, where $\alpha = 0.5$. Also, p^* decreases with increasing system size, such that $p^* \sim N^{-\beta}$, where $\beta = 1$. Although scaling arguments have rationalized the scaling behavior of p^* and G, there is currently no quantitative theoretical framework that can predict the values of the scaling exponents α and β that control the mechanical properties near jamming onset. Here, we describe numerical simulations of 2D bidisperse disk packings near jamming onset undergoing athermal, quasistatic simple shear at fixed pressure to explain these exponents. We show that α and β can be understood by examining the "geometrical families" of jammed packings, which are intervals of shear or pressure where the packings maintain the same network of interparticle contacts without rearrangements. We present a statistical model based on random switching of the packings from one geometrical family to another to predict the values of the exponents α and β.

LUIS PUGNALONI

Universidad Nacional de La Pampa

A First Principle Derivation for the Flow Rate of Discharging Silos

We present a differential equation for the flow rate of granular materials during the discharge of a silo. This is based on the energy balance in contrast with the traditional derivations based on heuristic postulates, such as the free fall arch. We show that this new equation is consistent with the well known Beverloo rule and provides a theoretical estimate for universal Beverloo prefactor. In the limit of tall silos, we derive from the differential equation an analytic expression for the pressure in the silo under discharging conditions. This agrees with simulation results much better than previous theoretical estimates.

LEIF RISTROPH

Courant Institute, New York University

Blowing Bubbles

Surface tension tends to contract a liquid film and minimize its area, and the resulting shapes are well studied for a film spanning a wire frame and for a free floating bubble. How does blowing on a film take the former into the latter? I'll present lab experiments and numerical simulations into the non-minimal shapes that arise for films in fast flows. Our findings suggest that a bubble may form via two routes, one associated with a loss of equilibrium due to unbalanced pressures and the other with a loss of film stability.

MARK D. SHATTUCK

The City College of New York

Deformable Particles

We introduce a new computational model for deformable particles, appropriate for cells, foams, emulsions, and other soft particulate materials, which adds to the benefits and eliminates deficiencies of existing models. The model combines the ability to model individual soft particles with the shape-energy function of the vertex model, and adds arbitrary particle deformations. We focus on 2D deformable polygons with a shape-energy function that is minimized for area and perimeter and repulsive interparticle forces. We study the onset of jamming, and find that the packing fraction grows with perimeter to arear ratio until reaching the critical value of the underlying Voronoi cells at confluence. We find that deformable packings above and below the critical value are solidlike, which helps explain the solid-to-fluid transition at in the vertex model as a transition from tension- to compression-dominated regimes.

SAVERIO SPAGNOLIE

University of Wisconsin-Madison

Active Matter Invasion of a Viscous Fluid and a No-Flow Theorem

Suspensions of active particles in fluids exhibit incredibly rich behavior, from organization on length scales much longer than the individual particle size to mixing flows and negative viscosities. We will discuss the dynamics of hydrodynamically interacting motile and non-motile stress-generating swimmers or particles as they invade a surrounding viscous fluid, modeled by coupled equations for particle motions and viscous fluid flow. Depending on the nature of their self-propulsion, colonies of swimmers can either exhibit a dramatic splay, or instead a cascade of transverse concentration instabilities, governed at small times by an equation which also describes the Saffman-Taylor instability in a Hele-Shaw cell, or Rayleigh-Taylor instability in two-dimensional flow through a porous medium. Analysis of concentrated distributions of particles matches the results of our full numerical simulations. Along the way we will prove a very surprising "no-flow theorem": particle distributions initially isotropic in orientation lose isotropy immediately but in such a way that results in no fluid flow anywhere and at any time.

SIJIE TONG

Princeton University

Mechanical Response of Wrinkled Structures

Wrinkling instability of compressed stiff thin films bound to soft substrates has been studied for many years and the formation and evolution of wrinkles is well understood. In recent years, the wrinkling instability has been exploited to create structures with tunable drag, wetting, adhesion, and to create a template for wire formation. While these studies successfully demonstrated the proofs of concepts, the quantitative understanding is still lacking, because we don't know how wrinkled surfaces deform in response to interactions with environment. To address this issue we systematically study theoretically and numerically how wrinkled structures respond to infinitesimal surface forces both in the vertical and horizontal directions. We find that the linear response diverges near the onset of the wrinkling instability and then decays away from this critical compression threshold. The mechanical response near the critical compression threshold can be understood exclusively in terms of the dominant characteristic Fourier mode of wrinkles, which is decoupled from other modes. In analogy with the critical phenomena in ferromagnets, we can introduce the critical exponents for the response of the characteristic modes of wrinkles, which are consistent with the Landau theory. However, away from the critical compression threshold, the coupling between different Fourier modes becomes significant and it affects the mechanical response. Our theory can be further used to study the response of wrinkled structures to more complicated distribution of external forces coming from environment, such as the interaction of wrinkle structures with liquid droplets.

WEN YAN

Flatiron Institute, Simons Foundation

Computing Collision Stress in Assemblies of Active Spherocylinders

In this work, we provide a solution to the problem of computing collision stress in particle-tracking simulations. First, a formulation for the collision stress between particles is derived as an extension of the virial stress formula to general-shaped particles with uniform or non-uniform mass density. Second, we describe a collision-resolution algorithm based on geometric constraint minimization which eliminates the stiff pairwise potentials in traditional methods. The method is validated with a comparison to the equation of state of Brownian spherocylinders. Then we demonstrate the application of this method in several emerging problems of soft active matter.

LAILAI ZHU

Princeton University

Locomotion Driven by Self-Oscillation via an Electrohydrodynamic Instability

Some micro-organisms propel themselves by propagating oscillatory bending waves along their slender appendages, flagella and cilia. These structures drive the idea of functional mimicry as part of bio-inspired applications. Standard biomimetic applications commonly require a time-dependent actuation to oscillate the artificial structures. Yet, it remains challenging to actuate them by a steady, uniform stimulus. We hereby conduct a combined theoretical and numerical study and propose a strategy to achieve this goal via an elasto-electro-hydrodynamic instability. We show that a uniform DC electric field can be used to produce self-oscillatory locomotion of a microrobot composed of a dielectric particle and an elastic filament. We anticipate our strategy to be useful in diverse applications mimicking self-oscillatory biological behaviors.

ALEXANDRA ZIDOVSKA

New York University

Surface Fluctuations and Coalescence of Nucleolar Droplets in the Human Cell Nucleus

The nucleolus is a membraneless organelle embedded in chromatin solution inside the cell nucleus. By analyzing surface dynamics and fusion kinetics of human nucleoli in vivo, we find that the nucleolar surface exhibits subtle, but measurable, shape fluctuations and that the radius of the neck connecting two fusing nucleoli grows in time as $r(t) \sim t^{1/2}$. This is consistent with liquid droplets with low surface tension $\sim 10^{-6}$ Nm^{-1} coalescing within an outside fluid of high viscosity $\sim 10^3$ Pas. Our study presents a noninvasive approach of using natural probes and their dynamics to investigate material properties of the cell and its constituents.

POSTERS

DANIEL AMCHIN, Princeton University
Controlling Capillary Fingering Using Pore Size Gradients in Disordered Media

MOHAMED EL HEDI BAHRI, Princeton University
Influence of Thermal Fluctuations on the Mechanical Properties of 2D Anisotropic Materials

RITUPARNA BASAK, New Jersey Institute of Technology
Application of Machine Learning to the Stick-Slip Dynamics of Particulate Media

NAVID BIZMARK, Princeton University
Colloidal Deposition in 3D Porous Media: A Multiscale Visualization

CHRISTOPHER BROWNE, Princeton University
Unstable Polymer Solution Flow in Porous Media

GUANG CHEN, Princeton University
Electrostatics in Semidilute Polyelectrolyte Solutions

JIAHUI CHEN, Southern Methodist University
On Preconditioning the Treecode-Accelerated Boundary Integral (TABI) Poisson Boltzmann Solver

SHENSHENG CHEN, Binghamton University
The Influence of Polymer Conformation on Nanoparticle Assembly in Composite Materials

ZHENGYI CHEN, New York University
Diffusion Effects on Filtration Process

ABDALLAH DADDI MOUSSA IDER, Heinrich-Heine-Universitaet Duesseldorf
Penetration of a Model Membrane by a Self-Propelled Active Particle

SUCHANDRA DAS, advised by Dr. Pushpendra Singh, New Jersey Institute of Technology
Experimental Studies of Electrorheological Fluids

CHRISTOPHER DOBRZANSKI, New Jersey Institute of Technology
Compressibility of Confined Fluids via Molecular Simulation and Equation of State Modeling

YONG DOU, Columbia University
Autonomous Navigation of Colloidal Robots via Shapeshifting

SOHEIL ESMAEILZADEH, UPRI-B Group, Stanford University
Immersed Boundary Method Coupled with Level Sets for Direct Numerical Simulation of Pore Scale Multiphase Flow at Low Capillary Numbers

LARRY GALLOWAY, University of Pennsylvania
Dynamics and Structure of Sheared Colloids

BINAN GU, New Jersey Institute of Technology
Modeling Connectivity and Asymmetry in Membrane Filters

XIAOYI HU, Stony Brook University
From Droplets to Waves: Periodic Interfacial Instability Patterns in Highly Viscous Microflow

CHRISTOPH KAMMER, University of Pennsylvania
Particle Rearrangements and Rheology of 2D Dense Suspensions Under Shear Deformation

JAEUK KIM, Princeton University
New Tessellation-Based Procedure to Design Perfectly Hyperuniform Disordered Dispersions

BORIS KHUSID, New Jersey Institute of Technology
Crystallization of Hard-Sphere Colloids at Large Particle Volume Fractions

NICKOLAS KINTOS, Saint Peter's University
Examining the Effects of Similar Rhythmic Output Elicited by Different Neural Circuits Using a Computational Model

DYLAN KOVACEVICH, Rutgers University
Effect of Substrate Geometry on Electrosprayed Thickness-Limited Coating

CHRIS KUBIK, New Jersey Institute of Technology
Stress Wave Propagation in Granular Columns

LIN LEI, Rutgers University
Obtaining Thickness-Limited Electrospray Deposition for 3D Coating

QIAN LEI, New Jersey Institute of Technology
Electric-Field-Driven Structuring in Dilute Suspensions of Positively and Negatively Polarized Particles

SHUAIJUN LI, The City College of New York
Motion of a Spherical Soft Body in a Cylindrical Channel

SHIYUE LIU, New York University
Diffusion Effects on Filtration Process

NANCY LU, Princeton University
Controlling Capillary Fingering Using Pore Size Gradients in Disordered Media

TIANXING MA, Rutgers University
Thermocapillary Dewetting Based Dynamic Spatial Light Modulator

SHENG MAO, Princeton University
Mechanical Principles of Biofilm Morphodynamics

TIMOTHY MIDDLEMAS, Princeton University
Hyperuniformity Properties of Barlow Packings

MEHDI MOLAEI, University of Pennsylvania
Displacement Fields Around Thermally Forced and Active Colloids at Interfaces

HERVE NGANGUIA, Indiana University of Pennsylvania
Effects of Peclet Number on the Electro-Deformation of Viscous Prolate Drops

THANH DANH NGUYEN, New Jersey Institute of Technology
Image-Based Mass Transport Simulation Shows How to Optimize Tissue Engineering Scaffold Architecture for Optimal Oxygen and Nutrient Transport

RANJIANGSHANG RAN, University of Pennsylvania
Mixing of Active Suspensions in a 2D Time-Periodic Flow

CONNOR ROBERTSON, New Jersey Institute of Technology
Aligning Self-Propelling Particles in Non-Trivial Domains

PEJMAN SANAEI, Courant Institute, New York University
Stable Flight of Meteoroids

SIDDHARTHA SARKAR, Princeton University
Buckling of Thermalized Cylindrical Shells

YIXUAN SUN, New Jersey Institute of Technology
Modeling and Design Optimization of Pleated Membrane Filter

BRYAN TORRES MALDONADO, University of Pennsylvania
Sedimentation of Passive Particles in the Presence of Swimming Microorganisms

HUIZE XUE, New Jersey Institute of Technology
Thermophoresis of Colloidal Particles

TIANYI YAO, University of Pennsylvania
Directed Micro Assembly via Capillary Curvature Attraction Using a Magnetic Micro-Robot at Oil/Water Interface

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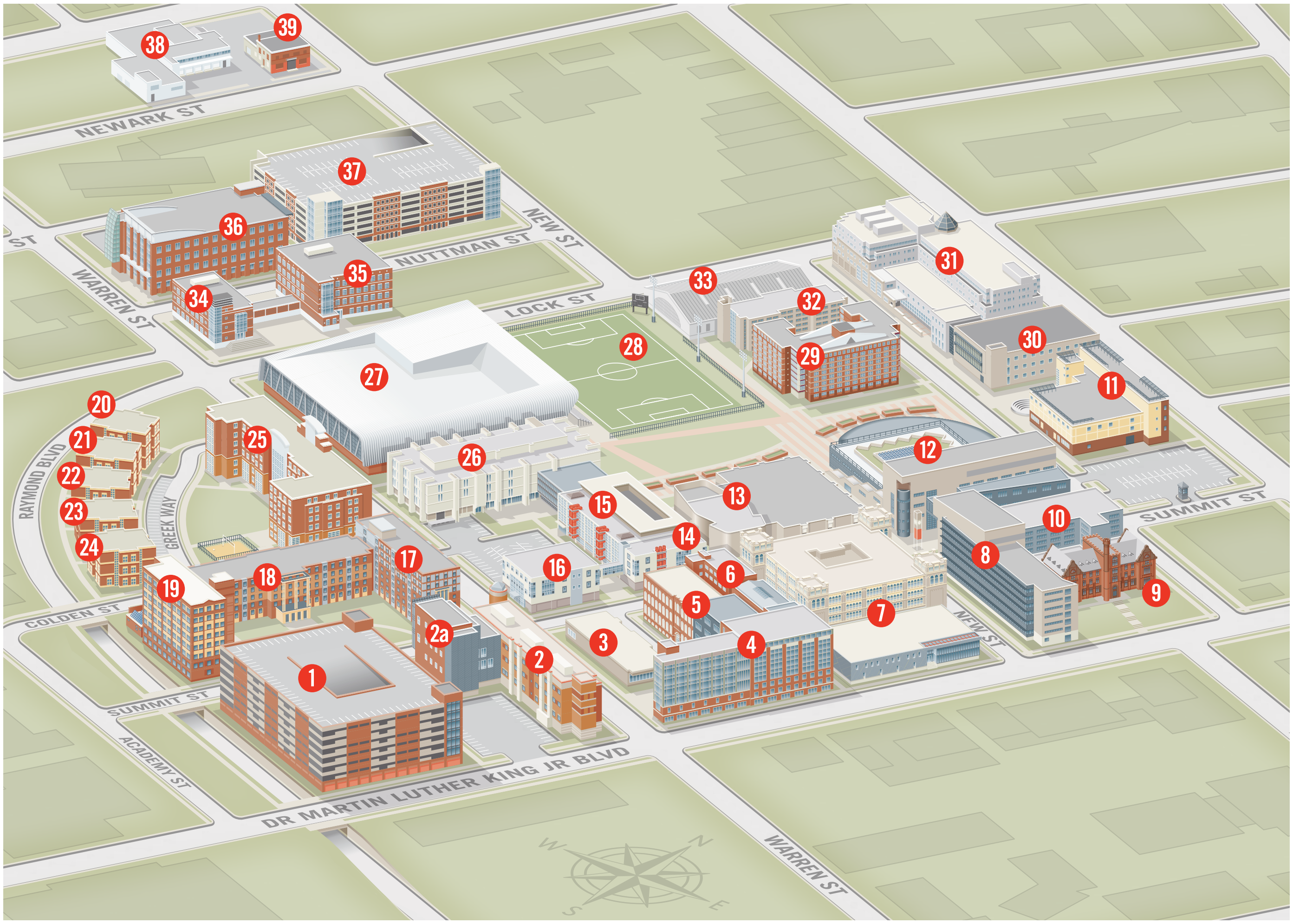
NJIT CAMPUS MAP



1 Parking Deck & Student Mall

2 York Center

2A Life Sciences & Engineering Center

3 Specht Building

4 Weston Hall

5 Colton Hall

6 Campbell Hall

7 Central King Building

8 Fenster hall

9 Eberhardt Hall

10 Cullimore Hall

11 Central Avenue Building

12 Campus Center

13 Kupfrian Hall

14 Microelectronics Center

15 Faculty Memorial Hall

16 Electrical & Computer Engineering Center

17 Laurel Residence Hall Extension

18 Laurel Residence Hall

19 Oak Residence Hall

20 Greek Way 05-07

21 Greek Way 09-11

22 Greek Way 13-15

23 Greek Way 17-19

24 Greek Way 21-23

25 Dorman Honors Residence Hall

26 Tiernan Hall

27 Wellness & Events Center

28 Athletic Field

29 Cypress Residence Hall

30 Mechanical Engineering Center

31 Guttenberg Information Technology Center

32 Redwood Residence Hall

33 Naimoli Family Athletic Center

34 Council for Higher Education in Newark Building

35 Enterprise Development Center 2

36 Enterprise Development Center 3

37 Science & Technology Park Garage

38 Facilities Services Building

NOTES

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