103rd New England Complex Fluids Workshop
UMass Amherst,
Integrated Sciences Building, RM 135
June 6th, 2025

Agenda

Time	Activity	Duration
9:00-9:30	**Registration & Breakfast**	30 min
9:30 – 10:10	**Benjamin Machta (Yale)**	40 min
10:10 – 11:10	**Sound Bite Session 1** (19 talks)	60 min
11:10 – 11:25	**Coffee Break**	15 min
11:25 – 12:05	**Wenlin Zhang (Dartmouth)**	40 min
12:05 – 1:05	**Lunch**	1 hour
1:05 – 1:45	**Colm Kelleher (Syracuse)**	40 min
1:45 – 2:45	**Sound Bite Session 2** (18 talks)	60 min
2:45 – 3:00	**Coffee Break**	15 min
3:00 – 3:40	**Laurel Kroo (MIT/UMass Amherst)**	40 min
3:40 – 4:30	**Poster Session**	50 min

Invited Talks

Title: Proteins undergo prewetting transitions onto membranes and chromosomes.

Speaker: Ben Machta, Department of Physics, Yale University
Work with Mason Rouches, Yousef Bagheri and Sarah Veatch

Abstract – Many macromolecular components in cells have a thermodynamic propensity to phase separate into coexisting liquid phases, sometimes termed condensates. In a few cases these condensates present as roughly spherical three-dimensional droplets even within cells. But often, while components will form three dimensional droplets when isolated at high concentrations, in the cellular context they are present at far lower concentration, and the domains that they form are localized to other structures, like the plasma membrane. Here I will argue that many of these domains are likely generalized *prewet* phases, stable only due to interactions with biological surfaces that contain their own transitions. Classical prewetting occurs when bulk mixtures tuned near to phase coexistence undergo thermodynamic surface transitions at a suitable surface even though they are outside of true bulk coexistence. But for classical surfaces the regime of prewetting is very narrow. Here I will focus on prewetting to the plasma membrane, a two-dimension fluid which has its own propensity to phase separate into coexisting two-dimensional liquids, with many cell types sitting near a critical point of this transition. With a combination of theory, simulation and experiment I will show that the fluid nature of the membrane along with its own propensity to phase separate vastly enlarges the prewetting regime. I will also show in simulation and theory that a similar transition can occur when proteins prone to condensation interact with a long one-dimensional polymer like a chromosome, itself prone to a thermodynamic collapse transition. I will argue that many condensates seen in biology may actually be examples of generalized prewetting onto biological surfaces and transitions.

Title: Predicting structures and dynamics of semicrystalline polymer near different interfaces

Speaker: Wenlin Zhang, Department of Chemistry, Dartmouth College

Abstract: Interfaces are ubiquitous in polymeric materials, either formed spontaneously or induced by processing conditions. Understanding the molecular behaviors of polymer chains near different interfaces is critical to optimizing their performance in various applications. Indeed, powerful polymer theories have been developed for amorphous polymer samples, such as molten blends and solutions. Still, the interfacial behaviors of semicrystalline polymers are less clear when they are partially crystallized.

To reveal the interfacial behaviors of semicrystalline chains near different interfaces, we employ atomistic and coarse-grained simulations. We first study how semicrystalline

polyethylene (PE) crystallizes near the polymer-air interface using atomistic simulations of polymer thin films. We show that the enhanced segmental dynamics near the free surface enhance crystal nucleation and promote the formation of semicrystalline surfaces in PE films. The semicrystalline surfaces can induce fast secondary crystal nucleation in layer-by-layer deposition of multi-layer films.

We also use coarse-grained simulations to show how semicrystalline polymers crystallize near phase-separated blend interfaces, which approximate the interfaces in recycled polyolefins. The inhomogeneous interfaces, together with entanglements within, impede polymer crystallization by limiting lamellar thickening. Adding block copolymer compatibilizers further hinders polymer crystallization near the interfaces. However, sufficiently long block copolymers can bridge crystallites in different polymer domains and act as stress-transmitters across the blend interfaces.

Finally, we use atomistic simulations to show that high-density PE nanoplastic particles are semicrystalline in water. Using umbrella sampling, we show that the semicrystalline

morphologies impose negligible effects on the interactions between the nanoparticles and the polar outer surfaces of model lipid membranes. However, when the particles penetrate the outer surfaces of lipid membranes, semicrystalline morphology prevents the particles from fusing with the alkyl tails of the lipids.

Title: Liquid crystal physics in the spindle microtubule network

Speaker: Colm P Kelleher, Department of Physics, Syracuse University

Abstract: While we have a complete, or nearly complete, "parts list" of the hundreds of proteins and other biomolecules that make up the metazoan spindle, we lack a framework for predicting how these diverse molecules self-organize into cell-scale structures capable of producing forces and transmitting them to chromosomes over cellular length scales, up to tens of microns. I will present data and analysis that suggests that many aspects of the large-scale structure and dynamics of mitotic and meiotic spindles can be understood by using concepts and experimental tools from condensed matter physics and soft matter physics. In particular, liquid-crystal-physics-based models explain observations of spindle shape and the pattern of microtubule orientation in the spindle interior. Liquid crystal models also naturally explain our observations of long-range forces, acting in the direction perpendicular to the spindle long axis, that act to separate metaphase chromosomes from one another.

Title: Transient and periodic exponential shear flows: Rheometric techniques for measuring the transient planar extensional viscosity of complex fluids and soft solids

Speaker: Laurel A. Kroo, Polymer Science and Engineering, UMass, Amherst

Abstract:

Doshi & Dealy (JOR, 1987) showed that a time-varying exponential shear strain of the form $\gamma(t) = 2\,sinh(\alpha t)$ matches the kinematic stretch (and rate of stretching) of a continuum material element in steady planar extension (Kwan & Shaqfeh, 2001), emulating an extensional deformation but using a shear protocol. In complex fluids, both normal and shear stresses develop in response to these large strains, which can be measured simultaneously with a strain-controlled torsional rheometer. These stresses, $N_1(t)$ and $\sigma_{yx}(t)$ can be combined to compute a total principal stress, $\Delta\sigma(t) = \sqrt{(4{\sigma_{yx}}^2 + {N_1}^2)}$, along the vector of principal stretch. We develop a material function for the transient extensional viscosity, ${\eta_{ES}}^+ = \Delta\sigma \,/\, RF(t)$, where RF(t) is the effective rate of deformation. We propose a method for computing RF(t) that is essential when the strain and stress tensors fail to be co-linear. This correction is crucial at intermediate Weissenberg number ($0.1 < Wi < 1$) and can be constructed using accessible information from the measured stress ratio, without optical imaging. We show that this material function closely replicates the planar extensional response in fluids over a range of Wi and strain amplitudes.

Next, we introduce a periodic version based on Composite Harmonic-Exponential Waveforms (CHEW), to study evolution of extensional properties over sequential cycles of stretch (analogous to cyclic tensile fatigue in solids). In polymeric solutions, we observe extensional thickening at Hencky strains > 4, indicative of coil-stretch transition. In more complex multiphase materials, we observe progressive evolution in the tensile properties over repeated cycles of extensional deformation. These results highlight a promising new method for the study of structural mutation during cyclical stretching of complex fluids.

Sound Bites

Section 1: 10:10 – 11:10

1. Abdi, Masoud; Irene Andreu, Ryan Poling-Skutvik
university of Rhode island
Anomalous aggregation kinetics of polymer-grafted nanoparticles
Polymer-grafted nanoparticles (PGNPs) represent a unique class of hybrid nanomaterials that exhibit distinct phase behavior due to the interplay between polymer conformation and solvent quality. In this study, we investigate the anomalous aggregation kinetics of gold PGNPs with polystyrene grafts of varying molecular weights suspended in a thermal solvent exhibiting upper critical solution temperature (UCST) behavior, cyclohexane. Using dynamic light scattering (DLS), we identify a two-step thermal response in which the polymer corona collapses before aggregation occurs upon cooling. Aggregation rates follow a power-law growth in hydrodynamic size, which is characterized by an exponent $\alpha \approx 1/3$. The aggregation rate is significantly lower than the $\alpha \approx 0.55$ typical of diffusion-limited aggregation in hard-sphere colloids, indicating the formation of denser aggregates. We attribute this suppressed rate to a combination of long-range polymer-polymer interactions and the viscoelastic nature of the grafted layer, which facilitates rearrangement and compaction within growing clusters. Moreover, we observed a sharp step change in the aggregation exponent at the binodal temperature, which allows us to define the UCST with high precision. This behavior is consistent across molecular weights, which confirms that solvent-polymer interactions predominantly govern aggregation dynamics. Our findings provide new insights into phase transitions in PGNP systems and suggest pathways to engineer self-assembly and stability of nanostructures through polymer design.

Keywords: Polymer-grafted nanoparticles, gold nanoparticles (aunps), temperature-dependent behavior, aggregation-dispersion

2. Akomolafe, Oluwafemi; Shuang Zhou
University of Massachusetts Amherst
Living cholesteric liquid crystals
We introduce a novel class of active matter termed living cholesteric liquid crystals, created by integrating living bacteria with chiral nematic liquid crystals. Our findings uncover remarkable dynamic behaviors such as bacterial motility in uniform and defect-free twist regions, spatial distributions within chiral nematic cells, interactions across two different twist domains and defect lines, and collective bacterial dynamics near disclination lines. This research highlights an innovative framework for manipulating and controlling the dynamics of soft active matter in three-dimensional environments, opening new avenues for advanced biosensing and biomedical technologies.

Keywords: Bacteria, liquid crystals, cholesteric liquid crystals

3. Amirsadri, David; Masoud Abdi, Ryan Poling-Skutvik
University of Rhode Island
Polymer-grafted nanoparticles with bidispersed polymers
Polymer-grafted nanoparticles (PGNPs) consist of polymers covalently bonded to inorganic nanoparticle cores. Applying a polymer layer to the surfaces of these nanoparticles effectively tailors their aggregation and dispersion properties within solvents. One technique to customize the properties of grafted nanoparticles involves adjusting the ratio of polymer molecular weights attached to a nanoparticle's surface, creating a bidisperse graft. By using a combination of polymers with lower and higher molecular weights for grafting, one can influence graft density through chain interactions, sterics, and screening effects, leading to unique physical characteristics. Our approach explores the influence of bidisperse polymer grafts on aggregation kinetics in thermal solvents. Gold nanospheres with diameters of 30 nm are functionalized with a 20:1 molar ratio of low (5.3 kDa) and high (233 kDa) molecular weight thiolated polystyrene (SH-PS). We

conducted a temperature ramp to examine aggregation and dispersion behaviors. For this molar ratio, aggregation occurred at a low temperature, approximately 23°C. Future experiments will focus on evaluating aggregation within this temperature range to investigate the impact of different ratios of polymer molecular weight grafts on aggregation and dispersion behavior and assessing the effect of bidisperse grafts on core-core attractions and self-assembly behavior compared to monomodal systems. Additionally, we will seek to investigate the effect of temperature variations on the absorbance of UV light by the PGNPs, with the long-term goal of eliciting sustained structural oscillations in the system and introducing further control of nanoscale self-assembly.

Keywords: Polymer-grafted nanoparticles

4. Balogun, Opeoluwa; Kun-Ta Wu
Worcester Polytechnic Institute
Characterizing the role of motor dimerization in activation energy of microtubule-kinesin system
Kinesin motor proteins drive intracellular transport by stepping along microtubules to carry cargo such as organelles, mRNA, and viruses. This stepping process requires the motor to overcome an energy barrier, known as activation energy, which governs the temperature sensitivity of stepping rates and intracellular transport efficiency. While activation energy is a key parameter in motor function, it varies with motor constructs. For example, recent studies have shown that in 2D gliding assay, the activation energy can be twice as high as in a 3D active fluid system, if motors function as monomers in gliding assay, but as dimers in 3D active fluid. This difference raises a fundamental question: How does motor dimerization influence the activation energy of kinesin-driven active systems? To address this question, I propose to redesign the 3D active fluid system so that monomeric motors alone can sustain microtubule motion, effectively eliminating dimerization effect. Then, I will measure the activation energy in this modified system and determine whether it decreases to match that of the 2D gliding assay. The observation of such a decrease in activation energy will demonstrate that dimerization is the primary factor governing the observed differences between these systems. This research will contribute to designing synthetic motor systems with tunable properties that can inform the development of temperature-resistant drugs or strategies to combat pathogenic bacteria/virus that survive in high-temperature environments.

Keywords: Active fluids, motor dimerization

5. Bissitt, Simon; Arshad Kudrolli, Sohum Kapadia
Clark University Physics
Dynamic entanglement and aggregation of california blackworms
Lumbriculus Variegatus or more commonly known as california blackworms exhibit many locomotive features that can inspire the development of soft robots. When grouped together in bunches, these worms can also exhibit fluid-like behaviors as result from the entanglement between the worms. Our goal is to study how these occur and discuss how we can model these situations. The presentation will include a brief overview of our goals as well as our current intuitions/experimental analysis techniques.

Keywords: Collective behavior, active matter, aggregation, entanglement,

6. Biswas, Bipul; Prasanna More, Hima Nagamanasa Kandula
Department of Physics, University of Massachusetts, Amherst, USA
Emergent softening and stiffening dictate transport of active filaments
Active semiflexible filaments are crucial for biophysical processes, yet insights into their single-filament behavior have predominantly relied on theory and simulations, owing to the scarcity of controllable synthetic systems. Here, we present an experimental platform of active semiflexible filaments composed of dielectric colloidal particles, activated by an alternating electric field that induces contractile or extensile electrohydrodynamic (EHD) flows. Our experiments reveal that contractile flow-generating filaments undergo softening, significantly expanding the range of accessible conformations, whereas extensile ones exhibit active stiffening. By independently tuning filament elasticity and activity, we demonstrate that the

competition between elastic restoring forces and emergent hydrodynamic interactions along the filament governs conformational dynamics. Crucially, we discover that the timescale of conformational dynamics directly governs transport behavior: enhanced fluctuations promote diffusion while stiffening facilitates directed propulsion of nonlinear filaments. Together, our direct visualization studies elucidate the links between inherent filament properties, microscopic activity, and emergent transport while establishing a versatile experimental platform of synthetic filamentous active matter.

Keywords: Active matter, colloidal filaments, directed motion

7. Braun, William; Shima Parsa
RIT
Onset and growth of miscible viscous finger instabilities in a radial hele-shaw cell
The viscous fingering instability, which occurs when a fluid displaces another fluid of higher viscosity in a narrow gap, is not entirely understood for the miscible case. We study this problem by imaging the displacement of a glycerin solution with water in a radial Hele-Shaw cell. Processing these images allows us to track local interfacial velocities, pattern area, and average radii of the moving interface. Average radii and pattern area are used to extract a shape parameter. These quantities are then used to empirically model average interfacial speed.

Keywords: Viscous finger, miscible, instability, pattern formation

8. Cheng, Sizhe; Devadyouti Das, Mykhaylo Barchuk, Raveen Armstrong, Michele Klingbeil, Becca Thomases, Shuang Zhou
Umass Amherst
Trypanosoma swims like an active corkscrew
Trypanosoma Brucei is a unicellular eukaryotic parasite that causes sleeping sickness in cattle and humans, impairing the economy and public health of sub-Sahara Africa. During its life cycle, Trypanosoma navigates through complex and distinct environments, ranging from the narrow gut of tsetse flies to the crowded blood vessels of mammals. Despite some modifications at different stages, their general morphology and swimming motion are conserved: a tapered slender body performs corkscrew-like motion led by the thin, anterior end, driven by a single flagellum embedded along the cell membrane. Such swimming traits are shared by many other unicellular parasites that cause tropical diseases, or even insect-infecting parasites, such as Crithidia Fasciculata. However, due to its rapid motion and complex body deformation, conventional optical microscopy is not fast enough to fully reveal the dynamics in 3D, leaving the exact swimming mechanism in debate. In this talk, I will show our recent experimental and simulation results which unveil surprising features of their swimming behavior. We attach fluorescent particles to different body parts of swimming Trypanosoma and obtain their instantaneous 3D locations by comparing their defocused images with pre-established libraries. The particle trajectories indicate that TB exhibits a unique local motion consisting of three distinct components: unidirectional rotation, azimuthal oscillation, and bending. The amplitudes of both the azimuthal oscillation and bending are large at the leading tip and decrease at the body part. The phase difference between azimuthal oscillation and bending remains at pi/2 throughout, resulting in a clockwise rotation of the flagella (viewing from behind) and propagation of a right-handed helical wave from the thin anterior to the thick posterior end. The body, although having a right-handed helical shape, undergoes a counterclockwise rotation. These results contradict previous findings, but were confirmed by our numerical simulation using regularized Stokeslet method. The unusual dynamics are explained by conservation of angular momentum and local activation modes of the attached flagellum complex. The exact biomechanical mechanism of flagellum activation remains unknown at this stage.

Keywords: Trypanosoma brucei, cell deformation and motility, 3d dynamics

9. Das, Devadyouti; Bipul Biswas, Manasa Kandula, Shuang Zhou
Umass Amherst
Enhanced transport and conformational variation of colloidal chains in bacterial baths

Non-equilibrium dynamics of semi-flexible filaments in an active bath is of fundamental importance to both physics and biology. We experimentally studied the dynamics of colloidal polymer chains in dense suspensions of the motile bacteria Bacillus subtilis as a model system. By controlling the concentration and the activity of the bacterial suspension we observe a variety of conformations adopted by the colloidal chains which we quantitatively describe by the shape parameters radius of gyration and acylindricity. We observe enhanced diffusion of the centers of mass of the colloidal chains on short time scales. We use mean curvature to characterize the bending of the chains and report its dependence on the mean velocity of the bacterial bath. We attribute the deformation and transportation characteristics of the chain to the coherent structures of the bacterial bath.

Keywords: Active bacterial bath, semi-flexible polymer,

10. **Dawadi, Amit; Michael Berhanu, Martin Chaigne, Jerome Jovet and Arshad Kudrolli**
Clark university, Worcester, MA ,USA
Self-propulsion of floating ice blocks in saline water
We study the self-propulsion of asymmetric ice blocks floating at the water surface as they absorb heat from the surrounding water and melt. The melting process cools the water around the ice block, which descends under gravity due to its higher density in fresh water, flowing along the longest inclined surface of the block. The momentum carried by this descending flow propels the ice block in the opposite direction with a speed that depends on the length and inclination angle of the inclined surface, as well as the bath temperature. We further study the propulsion of similar ice blocks in saline water baths as a function of salinity and observe the same direction of motion as in freshwater even as the meltwater rises rather than descends in the bathwater.

Keywords: Self-propulsion, melting, buoyancy driven currents

11. **Dinsmore, Anthony; Mingzhu Cui**
UMass Amherst Department of Physics
Interface curvature changes contact-angle hysteresis
Droplets that partially wet solid surfaces exhibit hysteresis in their contact angle. The values of the minimum (receding) and maximum (advancing) angles are empirically well-defined and thought to be unique for a given set of materials. We will discuss several experiments that contradict this standard picture. We have measured the contact angles of air, water, and PDMS-coated glass for several different shapes. We find that the steady-state receding and advancing angles can change systematically with the shape of the interface, even when the same materials are used. In particular, anisotropic shapes of either the fluid interface or solid surface shift the steady-state advancing or receding angle by up to 20 degrees. We will focus on PDMS-coated glass rods inserted into an initially planar air-water interface. Even when the contact line is uniformly advancing or receding, the contact angle varies around the contact line. We will summarize experimental data and propose a qualitative explanation. The results contradict the standard picture of wetting hysteresis. The results might point the way to materials that more effectively trap water droplets or shed droplets for self-cleaning or water-harvesting applications.

Keywords: Wetting, contact angle, hysteresis

12. **Gonzalez, Jason; Shima Parsa**
Rochester Institute of Technology
Jamming of emulsions in 3d porous media
We assess the impact of focal plane deviations on the detection of granular particles in 2D images by analyzing modulation transfer functions (MTFs) as a function of particle height in a fixed imaging system. Additionally, we develop a particle tracking algorithm for deformable droplets at variable packing fractions. The flow of emulsions through a porous medium is recorded, and particle segmentation is performed using a watershed algorithm. These measurements are crucial for understanding the emergence of dense clusters within a three-dimensional Cartesian space. We observe MTF variations up to 200μm from the

~~focal plane, with the MTF width parameter, ?, varying by up to an order of magnitude in cycles per micron. While the watershed algorithm effectively detects undeformed and radially symmetric droplets, improvements are needed to accurately identify non-radial or deformed particles. This research will provide the platform required to resolve the spatiotemporal dynamics of soft granular flow.~~

~~Keywords: Jamming, porous media, modulation transfer function, particle identification, emulsion~~

13. Huang, Tara; Evon S. Petek, Reika Katsumata
University of Massachusetts Amherst
Nanoconfinement effects on intermolecular forces observed via dewetting
Despite wettability is a macroscopic manifestation of molecular-level forces, such as van der Waals (vdW) forces, the impact of nanoconfinement on material properties in reduced film thickness remains unexplored in predicting film stability. In this work, we investigate how nanoconfinement influences intermolecular interactions using a model trilayer system composed of a thick polystyrene (PS) base, a poly(methyl methacrylate) (PMMA) middle layer with tunable thickness (15-95 nm), and a 10 nm top PS film. We find that the dewetting behavior of the top PS layer is highly sensitive to middle PMMA thickness, deviating from classical vdW-based predictions that assume bulk material properties. By incorporating nanoconfinement-induced changes in PMMA refractive index into the calculation of the Hamaker constant, we present a modified theoretical framework that successfully captures the observed behavior. This study links dewetting behavior and material property change as a function of underlayer thickness, providing direct evidence that nanoconfinement in soft matter systems significantly influences long-range intermolecular interactions. We show that film stability can be tuned solely by adjusting underlying layer thickness, while preserving both chemistry and thickness of top functional film. This finding carries broad implications for thin-film technologies across scientific and engineering disciplines by enabling performance-targeted interface design.

Keywords: Nanoconfinement effects; intermolecular forces; dewetting; multilayer polymer films, long-range interactions

14. Jeon, Geunwoong; Hao Wan, Maria M. Santore, Gregory M. Grason
UMass Amherst
Flexible solid domains in fluid-solid composite vesicles; roles of solid elastic moduli
Nanometrically thin 2D solid domains in fluid-solid composite vesicles strongly resist to Gaussian curvature thanks to the non-zero shear modulus that is coupled to the out-of-plane deflection. While the solid domains tend to expel the Gaussin curvature, since the total Gaussian curvature over the vesicle surface is fixed by topology, the fluid membranes that are constituting the rest of the surface have to take more curvature repelled from the solid domains. Although this different elasticity of solid domains induce completely different morphological structures compared to the fluid vesicles, experimental measurement/control of the elastic moduli are limited, and resulting morpholgical behavior is poorly understood. Here we theoretically parametrize elastic moduli that are responsible for morphological behavior of fluid-solid composite vesicles based on the plate elastic theory, and systematically study the elasticity driven equilibirum morphology by conducting finite element method using the computational software Surface Evolver. We find the ratio of bending-to-stretching moduli controls the strength of Gaussian curvature expulsion from the solid domains, and the ratio of solid bending-to-fluid bending moduli control the flatness of the solid domains. We investigate the phase diagram in the 4D parameter space of the two elastic moduli ratios described above as well as the two mechanical parameters, solid area fraction, and degree of inflation. We remark how the earlier studies on homogeneous fluid vesicles and fluid vesicles with planar inclusions are asymptotically understood from our findings on fluid-solid composite vesicles.

Keywords: Membrane, solid elasticity

15. Joseph, Joe Biju; Jonathan P. Rothstein
UMass Amherst

Wake interactions of marangoni-propelled surfers
When the surface tension of a fluid is altered locally, for example using alcohol or surfactant, a surface tension gradient is created. This gradient drives a flow known as Marangoni flow, which can be harnessed to propel small objects. This is observed in nature, where insects such as beetles and water striders utilize Marangoni propulsion as an ultrafast escape response to predators, or even to catch prey using their surfactant wakes. In our work, we mimic this mechanism using small, engineered *surfers* partially coated with surfactants. These surfers move autonomously through Marangoni propulsion. Our study investigates how the surfactant wakes can influence and hinder motion of subsequent surfers. By understanding this chemical interference, we can learn not only how to design more reliable micro-robots, but also gain insight into how biological systems manage such interactions in the wild.

Keywords: Marangoni flow, surface tension, fluid mechanics, surfactant, alcohol

~~**16. Kaynak, Murat; Murat Kaynak, Mehmet D. Aşık, Elif E. Inan, Maksymilian Prondzynski, Hamzeh Ghasemzadeh, Amir Poorghani, Yashasvi Tharani, Daryush D. Mehta, William T. Pu, Orhun K. Muratoglu, Martin L. Yarmush, Alexander Alexeev, O. Berk Usta**~~
~~*Massachusetts General Hospital & Harvard Medical School*~~
~~**Mechanical phenotyping of tissues**~~
~~Changes in the mechanical properties of tissues are powerful indicators of disease states and drug-induced injuries. Although differential mechanical phenotyping has emerged as a valuable tool for non-invasive disease diagnostics, it remains particularly underutilized for drug safety and efficacy screening in preclinical studies. This stems primarily from the absence of mechanical phenotyping methods that are compatible with modern 3D organoid models and simultaneously provide high throughput for screening applications. Here, we present the Centrifugal Mechanical Testing (CeMeT) platform, which enables rapid, robust mechanical phenotyping of 3D organoids. Utilizing centrifugal mechanical principles and high-speed imaging, this platform achieves high accuracy and precision and can assess a wide range of tissue stiffness. We demonstrate that the CeMeT platform distinguishes mechanical properties among various hydrogel bead formulations and hiPSC-derived cardiac organoids, successfully detecting pathological changes with high sensitivity. Through experiments on organoids treated with drugs like pergolide and Cytochalasin-D, we establish that changes in organoid mechanical phenotypes can serve as reliable indicators of drug-induced tissue injuries in vitro. These findings position the CeMeT platform as a potentially transformative tool for early-stage drug safety assessment through mechanical phenotyping, with immediate applications extending to fundamental disease pathology research and drug efficacy testing using organoid models.~~

~~Keywords: Mechanical phenotyping, drug testing, biomechanics~~

17. Kim, Chungman; Jaewon Shim, Sangmin An, Manhee Lee, David. A. Weitz, Wonho Jhe
Tufts University
Molecular layering in polymeric fluids at solid interfaces
This study investigates molecular layering in polymeric fluids at solid interfaces. We observed that the molecularly layered structure exhibits polymer length dependence. On strongly attractive PDMS-MICA surfaces, longer polymers form more layered structures, but entanglements disturb this structure. On weakly attractive HOPG substrates, there was no change in layering depending on polymer length. Quantitative analysis revealed that the bottommost layer is formed through polymer-surface interaction, which depends on the polymer length and substrate. The layering above the bottommost layer is formed by polymer-polymer interaction. This research provides insights into molecular layering in polymeric fluids at solid interfaces.

Keywords: Polymers, atomic force microscopy, rheology, soft matter, viscoelasticity, complex modulus

18. Mathew, Rejoy; Michael Wang,Gregory M. Grason
UMass Amherst
Engineering self-limiting structures from warped jigsaw particles assemblies at finite temperature

In geometrically frustrated self-assembling systems, locally preferred inter-subunit arrangements are incompatible with uniform global order, giving rise to an accumulating frustration energy that grows super-extensively with assembly size. When this energetic cost surpasses the cohesive drive to assemble, a thermodynamic self-limitation emerges, stabilizing assemblies of finite, characteristic size at equilibrium. However, in physical realizations, it is possible for this super-extensive frustration energy to be screened by weak or defective bonds, resulting in equilibrium unlimited structures. Here, we study a numerical model of 2D Warped Jigsaw (WJ) particles using molecular dynamics simulations to determine the design principles—such as particle design, shape frustration, temperature, and concentration—under which suitable interparticle binding can suppress the defect-riddled bulk state and stabilize a finite-temperature, self-limiting ribbons of WJ particles

Keywords: Self-assembly,self-limiting assembly, geometric frustration

19. **Greenvall, Ben; Gregory M Grason**
UMass Amherst

Self-locking and spontaneous detangling in coiled filaments

Assemblies of entangled filaments are ubiquitous in nature and engineering, ranging from polymer melts to intertwined organisms to macroscale structural materials. In entangled matter, the assembly morphology and mechanics are emergent, deriving from both single filament properties and inter-filament coupling. Systematically connecting the subunit shape to the resulting collective behavior remains a daunting yet attractive challenge, which would allow researchers to “engineer’” assembly functionality, such as when the material may flow vs. jam (e.g. curved liquid crystal elastomers, Abdelrahman et al. Nat. Mater. (2024)), or when it may spontaneously disassemble and “unlink” (e.g. entangled “blobs” of worms, Patil et al. Science, (2023)). Motivated in general by this broad, largely unexplored design space of filamentous assemblies, and more specifically by recent experiments on self-coiling mesoscale filaments (Barber, et. al., Nat. Comm. 2023), we use continuum elasticity theory, geometric packing models, and particle-based simulation to investigate the morphological and mechanical space of helical bundles constructed of a variety of subunit shapes, which allows us to connect the component properties to the assembly response. Here, we focus on assemblies where the bundle and subunit structure are incompatible; due to packing, the preferred mechanical state of the individual cannot be realized within the assembly. We show that both the mismatch between target and realizable geometry, as well as the assembly size (length and number of filaments) influences the structural response to elastic misfit, which in some cases promotes stronger self-locking internal stresses or alternatively drives bundles to spontaneously detangle. While focused on helical bundles, we anticipate that these results shed light on design parameters for engineering and aid understanding of complex structure and mechanics in self-linking assemblies more broadly.

Keywords: Elasticity, geometry of materials, packing, filamentous materials

Section 2: 1:45 – 2:45

0. Basu, Arkaprabha; David Weitz
Harvard University
The role of phase separation in vimentin assembly
Abstract: Vimentin is a type III intermediate filament involved in a spectrum of cellular processes. Here we show that vimentin is capable of forming liquid phase separated droplets which act as precursors to vimentin intermediate filaments during their assembly. These droplets wet actin stress fibers. Moreover, the stress fibers act as a nucleation site where vimentin can condense into droplets at a lower concentration than what is required for their bulk phase separation.

Keywords: vimentin, liquid liquid phase separation, cytoskeleton, wetting

1. Mellor, Matthew; Claire Senger, Thomas P. Russell, Todd Emrick, Reika Katsumata
University of Massachusetts Amherst
Polymer nanobandage for patterned healing and doping of graphene defects
Graphene, a single layer of a hexagonal 2-dimensional (2D) array of carbon atoms, is a promising material due to its high electrical conductivity and mechanical strength. Its uses in modern electronic devices, however, are limited due to defects that arise during preparation and post-synthesis processing. Current approaches for healing and doping graphene include thermal annealing and ion implantation, which are time and energy consuming and can cause additional damage to the lattice, respectively. As a fast and efficient solution, the “nanobandage” technique employs rapid thermal annealing (RTA) where a polymer coating placed on graphene is quickly degraded and removed to drive heteroatom dopants into the graphene. To attain the spatial control over doping necessary for constructing device circuit junctions, we aim to utilize the nanobandage method after random copolymer photolithography to achieve patterned doping of graphene. Here, we use a boron pinacol ester homopolymer (PBPin) to observe its efficacy in doping graphene through the RTA approach. We observe an increase in amorphous carbon after PBPin nanobandage treatment as well as increased strain in the graphene lattice, and future work will utilize x-ray photoelectron spectroscopy (XPS) to confirm doping. This work is significant in working towards improved efficiency and scalability of nanoelectronics that can potentially be used in a variety of applications, such as flexible sensors and energy storage and transport.

Keywords: Graphene, rapid thermal annealing, random copolymers, patterned doping

~~**2. Nejad, Mehrana; L. Mahadevan**~~
~~*Harvard*~~
~~**Geometry and dynamics of living films**~~
~~Many living systems—such as epithelial cells and bacterial films at the microscale—exist within thin fluid layers. Theories of active nematics have been successful in describing the instabilities that arise in these systems when confined either to two-dimensional space or to a fully three-dimensional environment. I construct a theoretical frame work that describes the orientation field, thickness, and shape of an active nematic film embedded in 3 dimensions. I show how introducing a finite thickness modifies the well-known active nematic instabilities and leads to new ones associated with centreline deformations and thickness variations, in both flat and curved geometries.~~

~~Keywords: Living films~~

3. Nikkhah, Ali; Viet Sang Doan, Sangwoo Shin
University of Buffalo
Coupling chemotaxis and diffusiophoresis to improve bacterial navigation in microfluidic systemd
Bacterial chemotaxis is a behavior in which motile cells navigate toward food sources or away from toxins, playing a crucial role in their survival. We explore how the synergistic effects of chemotaxis, salt taxis, and

diffusiophoresis can influence bacterial swimming toward chemical stimuli in complex environments. Using microfluidic systems, we investigate the motility of Pseudomonas putida and Escherichia coli under chemoattractant and salt gradients. Our findings show that diffusiophoresis improves bacterias straightness, run speed, and directional persistence, resulting in more effective navigation towards the target chemical. This technique may provide a powerful tool for guiding bacterial transport in applications such as bioremediation and bioaugmentation.

Keywords: Bacteria, chemotaxis, diffusiophoresis

4. Nikoumanesh, Elnaz; Ryan Poling-Skutvik
University of Rhode Island
Guiding printable gel design through thixotropy
Soft materials are characterized by an intricate interplay of structure, dynamics, and rheological properties, which makes it challenging to accurately predict their response to shear stress. In our previous study, we developed a rheological protocol called serial creep divergence that fully characterizes the time-dependent evolution of material structure and properties. This protocol allows us to unambiguously quantify the yield stress in this class of soft materials. We find that gels exhibiting thixotropic hysteresis can fully recover their yield stress over time, while non-thixotropic gels possess time-independent yielding metrics. We hypothesize that these time-dependent properties can form the basis for new printability metrics in direct-ink writing applications. To test this hypothesis, we investigate the ability of printed filaments to span gaps under different shear rate conditions. By linking these printing properties to the restructuring kinetics of the material, we aim to create a clear connection between the flow properties of the gels and their printability. This connection will provide practical guidelines for designing printable soft materials and improving their performance in additive manufacturing.

Keywords: Thixotropy, direct-ink writing, printability metrics, restructuring kinetics

5. Packard, Sydney; Randy Paffenroth, Ph.D.; Elizabeth J. Stewart, Ph.D
Worcester Polytechnic Institute
Machine learning prediction of biofilm removal from surfaces using biocolloidal characteristics of bacterial clusters released from biofilms
Monitoring techniques to assess the success of biofilm disruption in hard-to-reach areas, such as within the human body or upstream processes, are prohibitively invasive and expensive. Bacterial cells released downstream of naturally dispersed or artificially disrupted biofilms can be more readily obtained for analysis than in situ biofilms and therefore provide a promising marker for evaluating biofilm disruption. I use confocal scanning laser microscopy coupled with image analysis techniques common to colloidal science to quantify the biocolloidal characteristics of bacterial cells released from disrupted biofilms. We find that the ~9,100 individual clusters released from biofilms collapse into 5 distinct groups, with varying percentages of each biofilm treatment condition represented across the 5 classes. The characteristics of these released cellular cluster populations can then be used to predict level of biofilm removal upstream.

Keywords: Machine learning, biocolloids, biopolymers, bacterial clusters, biofilms

6. Poe, Beatrice Lunsford; Zeyang Mou, Rui Zhang, Shuang Zhou
UMass Amherst
Dynamics of sedimenting particles in nematic liquid crystals
We investigate the rheological behavior of the lyotropic chromonic liquid crystal sunset yellow (SSY) in the nematic phase by moving a microparticle and directly measuring the force acting on it using optical tweezers. The liquid crystal shows distinct behavior when the particle is manipulated parallel vs perpendicular to imposed director alignment. When dragged parallel to the director, SSY behaves near identically to a Newtonian fluid, however, motion perpendicular to the director elicits a viscoelastic response. This anisotropic behavior is studied through pulling active microrheology, and direct observation of the director distortion under crossed polarizers as the particle is moved. The nature of director distortions is further

explored using simulations. We find that the director orients itself differently depending on the size, velocity, and direction of motion of the particle.

Keywords: Liquid crystals, rheology, optical tweezers, sedimentation

7. Poling-Skutvik, Ryan; Daniel Keane, Elnaz Nikoumanesh, Simon Rogers
University of Rhode Island
A universal relationship between linear and nonlinear responses in soft materials
Yielding is a phenomenon in which a material transitions from elastic deformation to viscous dissipation when subjected to large deformations. This transition has been described and studied for over a century, but it remains elusive to predict in soft materials. Instead, rheologists characterize this transition empirically using a variety of protocols, the most common of which is large amplitude oscillatory shear. During this protocol, a material subjected to a sinusoidal strain (or stress) at a constant frequency with progressively larger amplitudes and the viscoelastic moduli are quantified by the proportional response in stress (or strain). The onset of nonlinearity in this response is often characterized by a peak in the loss modulus G", which precedes the crossover from a primarily elastic regime to a primarily viscous response. In this work, we show that the height of this peak can be fully predicted by tan(?) in the linear response. Additionally, the position of this peak is predicted by a combination of this linear viscoelasticity and flow stress. These relationships hold across material chemistry and structure and orders of magnitude in material elasticity. Our work therefore demonstrates that the same fundamental physics controlling the viscoelastic response under linear deformations is preserved across the yield transition. Furthermore, the direct relationship between the G" peak and linear material properties indicates that the G" peak is not an independent metric by which to classify the yield transition.

Keywords: Yielding, rheology

8. Sayyari, Mohammad Javad; Joshua Bostwick
Department of Mechanical Engineering, Clemson University, Clemson, SC 29634, USA
Dynamic deformation of buoyant granular rafts by solid indenters
Granular rafts are capable of resisting larger deformations than clean liquid interfaces owing to particle-particle interactions. This is seen through enhanced cavity formation and suppression of the crown splash during impact of a solid projectile onto a buoyant granular layer, which we quantify in this experimental study. For low inertia impact, the impactor can become entrained in the granular layer or pass through leaving a stable cusp-like shape in the granular layer. For high inertia events, a hole is formed in the granular raft, which we systematically investigate showing the hole is self-healing whenever $(A_0)^{0.5}/l_c<1.3$, where A_0 and l_c are the initial hole area and the capillary length scale, respectively. Such studies are important in applications such as designing polar ocean detectors in ice-mélange, as well as the aerosolization of microplastics in the ocean.

Keywords: Granular rafts, cavity, crown splash, water entry

9. Shahabuddin, Muntasir; Andrew Teixeira
Worcester Polytechnic Institute
Breaking electrochemical performance-viscosity tradeoffs in flowable suspension electrodes by leveraging electrode capacitance
Flowable suspension electrodes offer a uniquely flexible platform for electrochemistry by enabling continuous heterogeneous reactions in flow. However, because they employ electronically conductive particles suspended in an ionically conductive liquid, their ability to support high-rate current draw is kneecapped by their reliance on particle-particle contact to conduct charge. Increasing particle loading to improve conductivity reduces flowability of the suspension and ultimately leads to excessive pressure drop in practical systems. Suspension electrode design has been constrained by this tradeoff between electrochemical performance and energy loss to maintain flow. We re-explore the value of conductivity to the end of high rate electrochemical performance, and find that leveraging mixtures of highly conductive

and highly capacitive carbon powders creates a differential charge buffer that mediates charge draw in low conductivity environments, allowing higher charge draw at low carbon loadings. We find a decrease in viscosity and an increase in electrochemical performance in select mixtures — breaking this tradeoff — and discuss suspension design criteria leading to this concomitant improvement in both metrics.

Keywords: Electrochemical engineering, dense suspensions

10. Smith, Spencer; Kevin Mitchell
Mount Holyoke College
Optimal mixing in constrained active nematic flows
In active matter systems, energy consumed at the small scale by individual agents gives rise to emergent flows at large scales. For 2D active nematic microtubule systems these flows are largely characterized by the dynamics of mobile defects in the nematic director field. As these defects wind about each other, their trajectories trace out braids, and the topological properties of these braids encode the most important global features of the flow. In bulk flow, defect motion is chaotic, however recent work has shown that confining the active nematic systems - via boundary geometry or the surface topology - leads to periodic defect braiding. Furthermore, the braids that result from confinement are special and appear to maximize a measure of mixing - topological entropy. Using recent advances in braid theory, we compare newly discovered maximal mixing braids to the emergent trajectories of active nematic defects found in experiments and simulations.

Keywords: Active nematics, mixing

11. Sullivan, Kyle; Thomas Videbaek, Madhurima Roy, Benjamin Rogers, Mark Stevens, Gregory Grason
UMass Amherst
Frustrated self-stacking assembly of non-euclidean shell colloids
When geometrically frustrated particles self-assemble local inter-subunit shape misfits can propagate to large scale strain gradients that give rise to finitely sized, self-limiting structures in equilibrium. Recently, a model of deformable, cylindrically curved, colloidal shells investigated the roles of bending and inter-particle bond stretching energies within one-dimensional particle stacks and established a transition from self-limiting to unlimited assembly behavior that depends on the range of attraction and particle geometry. However, shape deformations of shells with curvature in two directions (Gaussian curvature) often involve stretching which incurs elastic penalties that are typically much greater than bending. Here, we propose a model of elastic, doubly curved, shallow shells and investigate the roles of Gaussian curvature and stretching energy in curvature-frustrated shell stacks and the consequences for self-limiting behavior and size selection. Through a combination of continuum elastic theory and coarse-grained simulations we identify key particle variables that control when stretching dominates over bending and uncover the regimes of self-limiting behavior for saddle, spherical and cylindrically shaped particles. These predictions provide critical design criteria for experimental realizations of self-limiting frustrated particle systems including controlled assemblies of polymeric microshells or curved DNA origami nanoparticles.

Keywords: Self-assembly, soft colloids, geometric frustration

12. Sundara Rajan, Kashyap; Jonathan P. Rothstein
UMass Amherst
Flow induced crystallization of polymers
Flow induced crystallization (FIC) in semicrystalline polymers has profound implications in the polymer processing industry. This study systematically examines how crystallization can be affected by the imposed flow rate and strain, using a variety of techniques such as shear and extensional rheology, differential scanning calorimetry (DSC) and small angle X-ray scattering (SAXS). These techniques show the evolution of different crystal structures and how crystal growth and morphology are affected by the imposed flow.

Keywords: Crystallization, rheology, x-ray scattering

13. Taghon, Meredith; Katharine E. Jensen
Williams College
The start of sticking: adhesive contact initiation with silicone gels
Adhesive contact initiation of compliant interfaces is an important process in many applications, including common pressure sensitive adhesives and biolocomotion. The mechanics of soft contact initiation rely on a complex physical interplay between viscous, elastic, and capillary forces as well as the structure of the gel elastic network. In this work, we measure the dynamic interactions between a rigid glass microsphere and a compliant silicone gel during the nascent stage of adhesive contact. Our instrumental design draws inspiration from traditional JKR theory as well as interferometry techniques. We present the initial results from this instrument developed to capture high-speed measurements of the gel deformation profile as adhesive contact is established. The high sensitivity of these measurements at both short length and time scales poises our work to elucidate the fundamental physics governing the dynamic behavior of soft gel materials.

Keywords: Adhesion, silicone gels, linnik interferometer, contact initiation, soft surface mechanics

14. Venkateswaran, Barath; Trevor J. Jones, Grace Kresge, Joel Marthelot, Etienne Jambon-Puillet, and P.-T. Brun
Princeton University
Stacked rayleigh-taylor instabilities grow drops into soft stalactitelike structures
The interplay between thin film hydrodynamics and solidification produces formidably intricate geophysical structures, such as stalactites and icicles, whose shape is a testimony to their long growth. In simpler settings, liquid films can also produce regular patterns. When coated on the underside of a flat plate, these films are unstable and yield lattices of drops following the Rayleigh-Taylor instability. While this interfacial instability is well-studied in Newtonian fluids, much less is known about what happens when the thin film solidifies. Here, we coat the underside of a surface with liquid elastomer, allowing the film to destabilize and flow while it cures into an elastic solid. Once the first coating yields an array of solid droplets, this iterative coat-flow-cure process is repeated and gives rise to corrugated slender structures, which we name “flexicles” for their resemblance to icicles. We study the subtle combination of chaos and order that confers our flexicles their structure, shape, arrangement, and, ultimately, deformability.

Keywords: Pattern formation, elastomers, rayleigh-taylor instability

15. Villariny Rosado, Faviola; Sarah Perry, Fikile Brushett, John Vergados
UMass Amherst
Exploring the electrochemical properties of polyelectrolyte complexes
Polyelectrolyte complexes (PECs) have garnered interest due to their wide applications and unique processing requirements, using salt and water as solvent to plasticize and modify their properties. These “saloplastic” polymers can be used in various applications for encapsulation and enzymatic catalysis, membranes, and hydrogels. Due to their characteristic charged backbone, polyelectrolyte polymers hold promise in the energy storage field as we shift to sustainable and environmentally friendly alternatives in supercapacitors and batteries. Additionally, PECs have been leveraged in electrochemical applications as binding agents, where they have been shown to increase ionic and electronic conductivity [1]. PECs have also been used as performance enhancing dopants during the preparation of semiconducting polymer films due to their ability to transport charge along the backbone [2]. Despite these examples, very little is known about the fundamental ways that PECs affect electrochemical reactions, particularly because of the high concentrations of both polyelectrolyte and salt species present in the material. We are leveraging the canonical PEC system of poly(styrene sulfonate)/poly(diallyldimethylammonium) (PSS/PDADMA) in aqueous salts, such as LiBr, to characterize physicochemical and electrochemical properties for better understanding of how PECs impact thermodynamic, kinetic, and transport processes within homogeneous

solutions. References: (1) Pace, G.; Zele, A.; Nguyen, P.; Clément, R. J.; Segalman, R. A. Mixed Ion–Electron-Conducting Polymer Complexes as High-Rate Battery Binders. Chem. Mater. 2023, 35 (19), 8101–8111. https://doi.org/10.1021/acs.chemmater.3c01587. (2) Le et al, ACS Macro Lett, V10, 2021.

Keywords: Polyelectrolyte complexes, electrochemistry

16. Yue, Haicen; Amir Shee, Ritwik Bandyopadhyay
University of Vermont, Physics Department
Shaping solid-to-fluid transition with active dopants
Activity of particles can shift the fluid-to-glass transition to higher packing fractions than passive ones, effectively fluidizing otherwise solid-like systems. However, the role of a (small) fraction of active dopants in fluidizing the dense systems is still unclear. In this work, we numerically investigate the shear rheology of mixtures of active and passive Brownian particles, with varying fractions of active components. We show that active energy given by dopant fraction multiplied by propulsion speed squared sets the threshold. Surprisingly, we find that a small active dopant fraction, far below fifty percent, triggers fluidization with comparable efficiency to fully active systems. These results reveal how minimal active doping can modulate the fluid-to-glass rheology in soft materials, providing a strategy for fine-tuning their mechanical properties with small amounts of active dopants.

Keywords: Solid-to-fluid transition, active matter

17. Zeng, Xianci; Xianci Zeng, Idris Tohidian, Rohan Chaudhari, Jonathan Zajac, Praveen Muralikrishnan, Caryn L. Heldt, Sapna Sarupria, and Sarah L. Perry
University of Massachusetts Amherst
Understanding the role of excipients in the stability of biological macromolecules
The cold chain is currently a well-established but expensive technology used for the storage and transportation of vaccines and medicines, ensuring they remain at the low temperatures needed to maintain efficacy. To reduce dependence on the cold chain, we investigated the performance of various excipients in enhancing the thermal stability of biologics, including proteins and viruses. Specifically, we used hydrophobic exposure temperature (HET) to accurately capture the transition between the folded and unfolded states of proteins, utilizing a dynamic equilibrium heating system. We characterized the HETs of various model proteins, in the presence of different concentrations of sugars, sugar alcohols, and amino acids. Our data showed that disaccharides generally outperformed sugar alcohols in increasing the HETs of proteins, while lysine and glutamate were stabilizing regardless of protein net charge. Interestingly, arginine was destabilizing across all proteins. Our goal is to understand how the molecular features of excipients and how they interact with water affect stability, and to use studies of proteins to predict formulations for viruses with the goal of developing a design rule for selecting excipients to enhance the thermal stability of biologics in general. Funding for this work is supported by NSF DMREF Collaborative Projects: 2118788, 2118693, and 2118638.

Keywords: Hydrophobic exposure temperature; stability