

# Synthesis and Characterization of Novel Hydrogel Coatings for Intrinsically Lubricated Condoms:

## The Condom for the Modern-Day World



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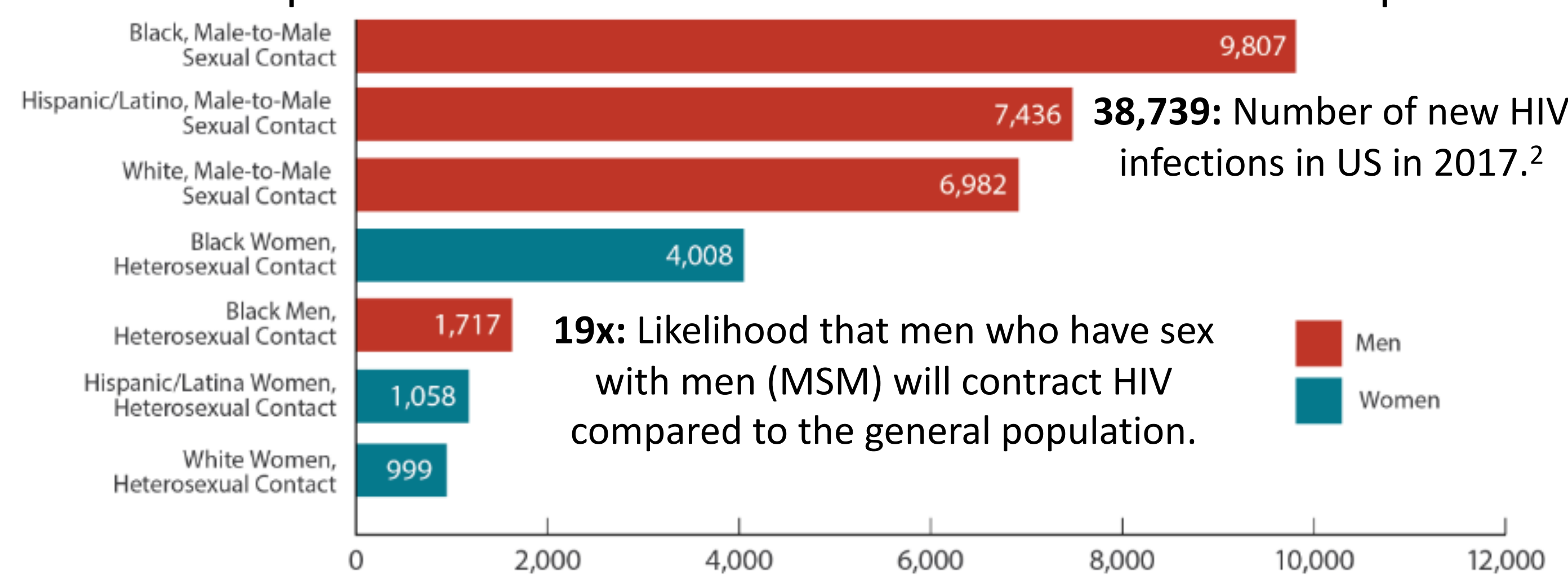
<sup>3</sup>Dept. of Family and Community Health, School of Nursing Application No. 62/847,476

Christian Pohlmann is a Physics major in the College of Arts and Sciences at the University of Pennsylvania whose anticipated graduation year is 2022. His work on this project over the summer of 2020 was funded by PURM.



### Accessing Condom Deficiencies

Consistent condom users are estimated to be 10-20x less likely to become infected with HIV (90-95% reduction). However, realistic estimates put reduction closer to 60-70% due to lack of compliance.<sup>1</sup>



### Project Overview

The synthesis of double network hydrogel coatings and their characterization over physiologically relevant contact pressures, sliding speeds, and temperatures will uncover lubrication mechanisms, which can be used to transform the surface properties of condoms and bolster HIV prevention methods for at-risk populations.

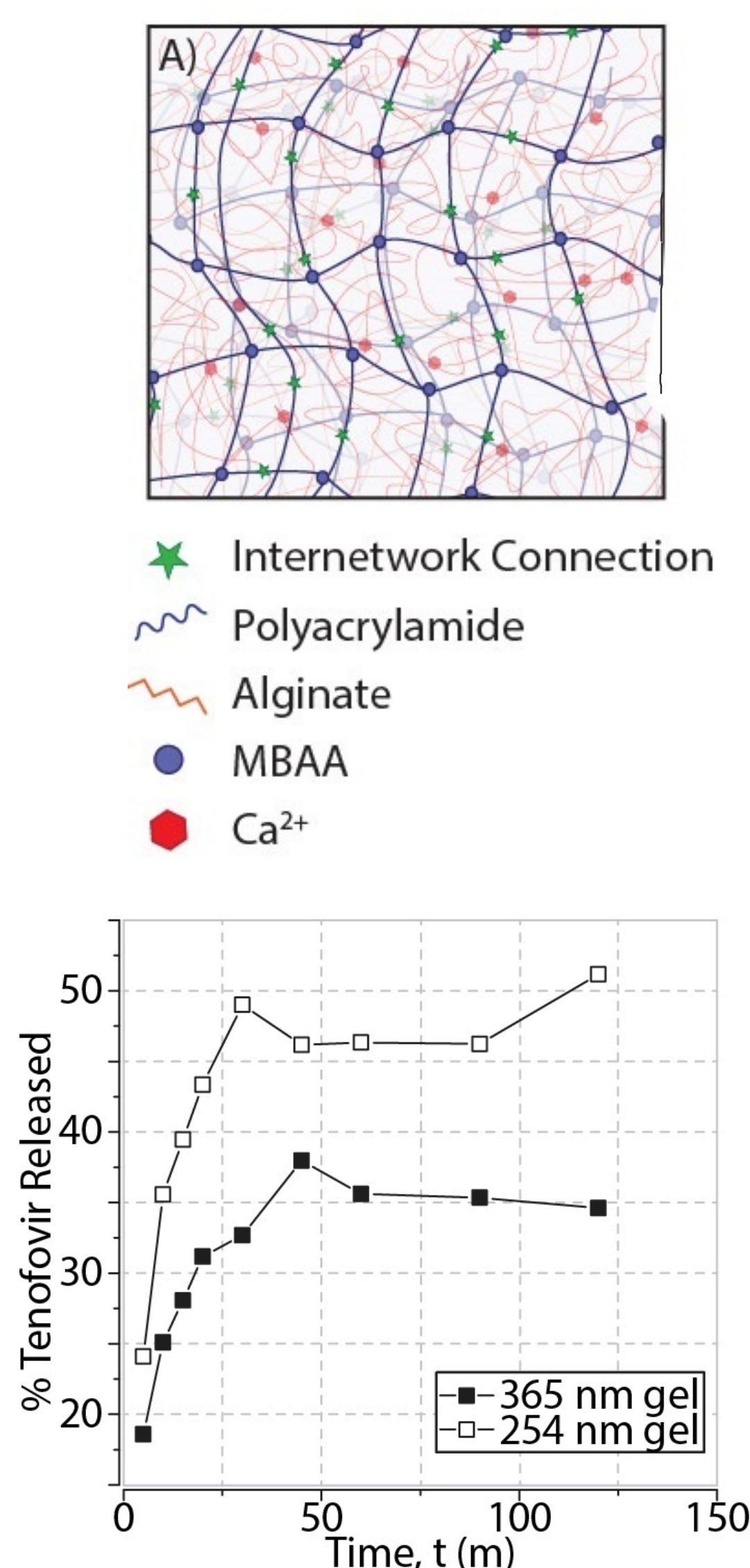
### Double Network Hydrogels

#### Double Network Hydrogels

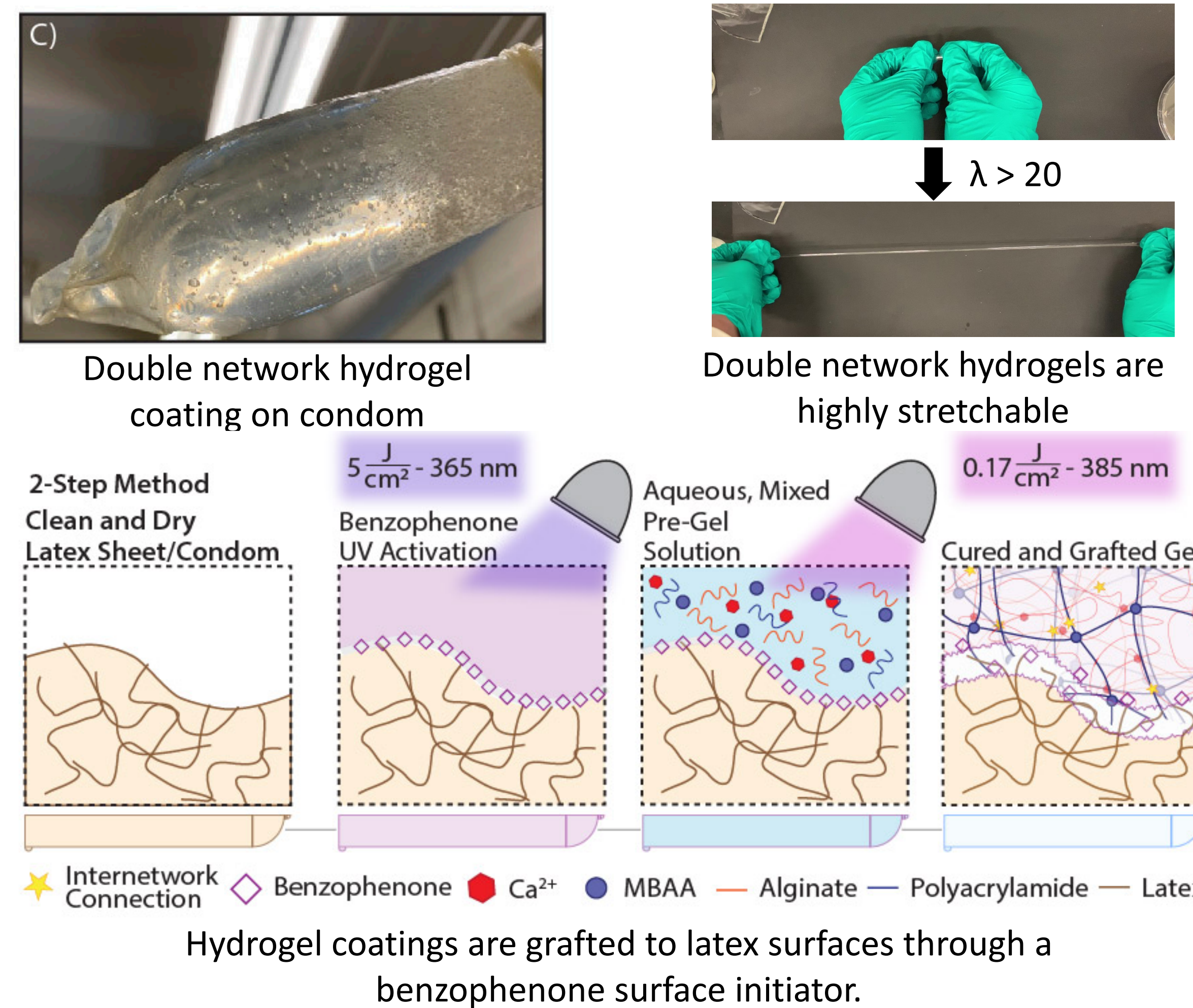
Hydrogels are water-containing rubbery polymer networks. They are intrinsically lubricious and have physical properties that can be fine-tuned to match biological systems, generating wide use in biomedical applications including drug delivery, tissue engineering, contact lenses, and wearable devices

#### Drug-Loading of Double Network Hydrogels

Anti-HIV microbicides are being explored as additions to lubricants to reduce HIV transmission during intercourse. Our hydrogel material can be loaded with such a microbicide as shown in the schematic above. Preliminary results by others on this team, on the left, show that drug loading was successful, as demonstrated by subsequent release in an aqueous environment.

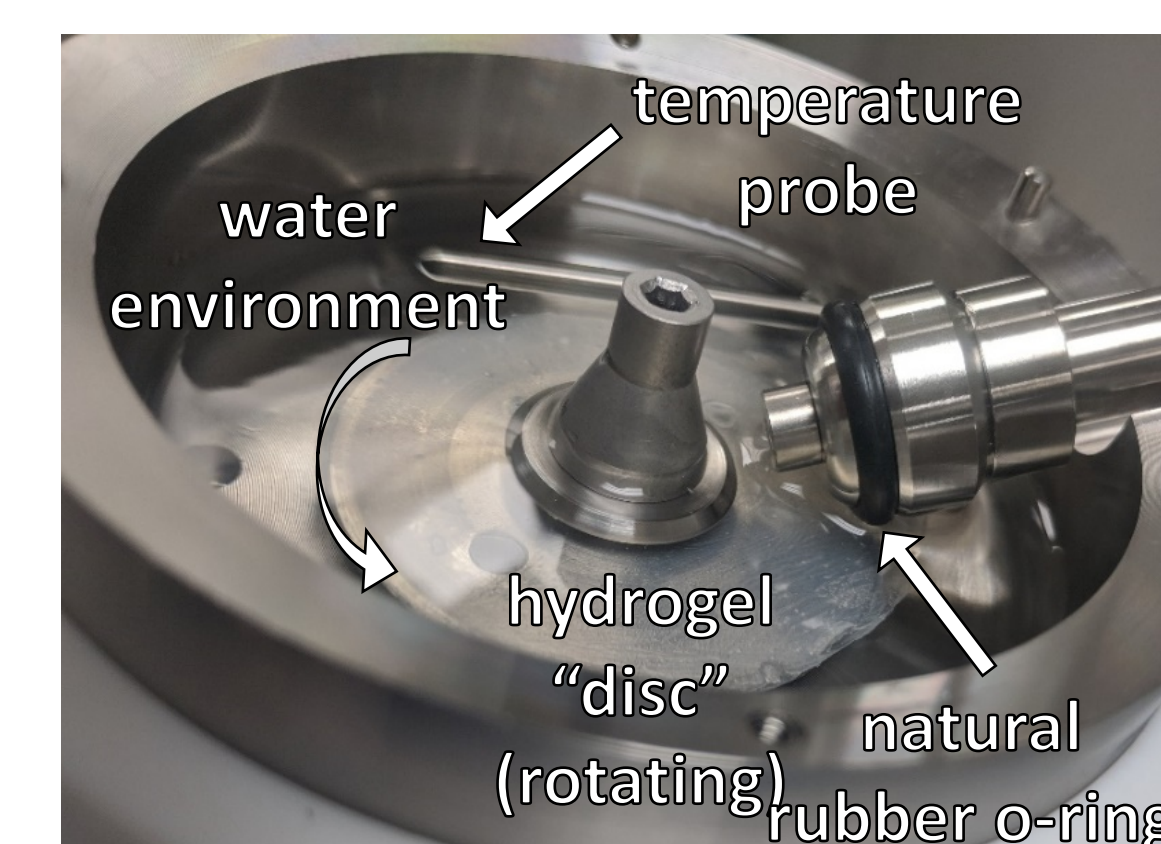
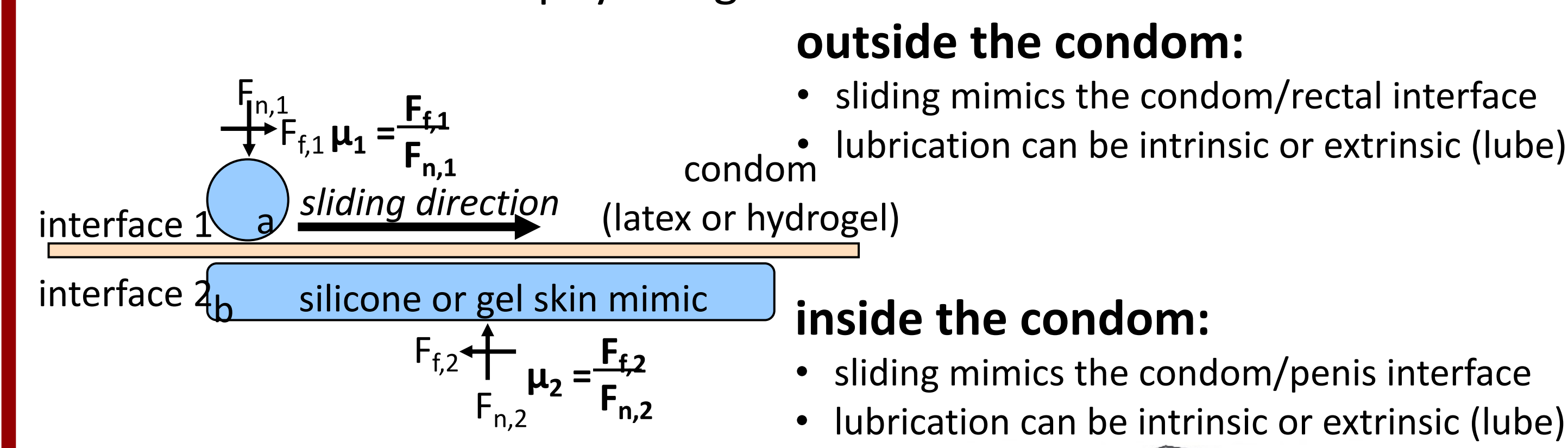


### Double Network Hydrogels with High Interfacial Adhesion



### Tribology at Biological Interfaces

Our goal is to understand the tribology (friction/wear), lubrication mechanisms, and performance limits of double network hydrogels under physiological conditions.

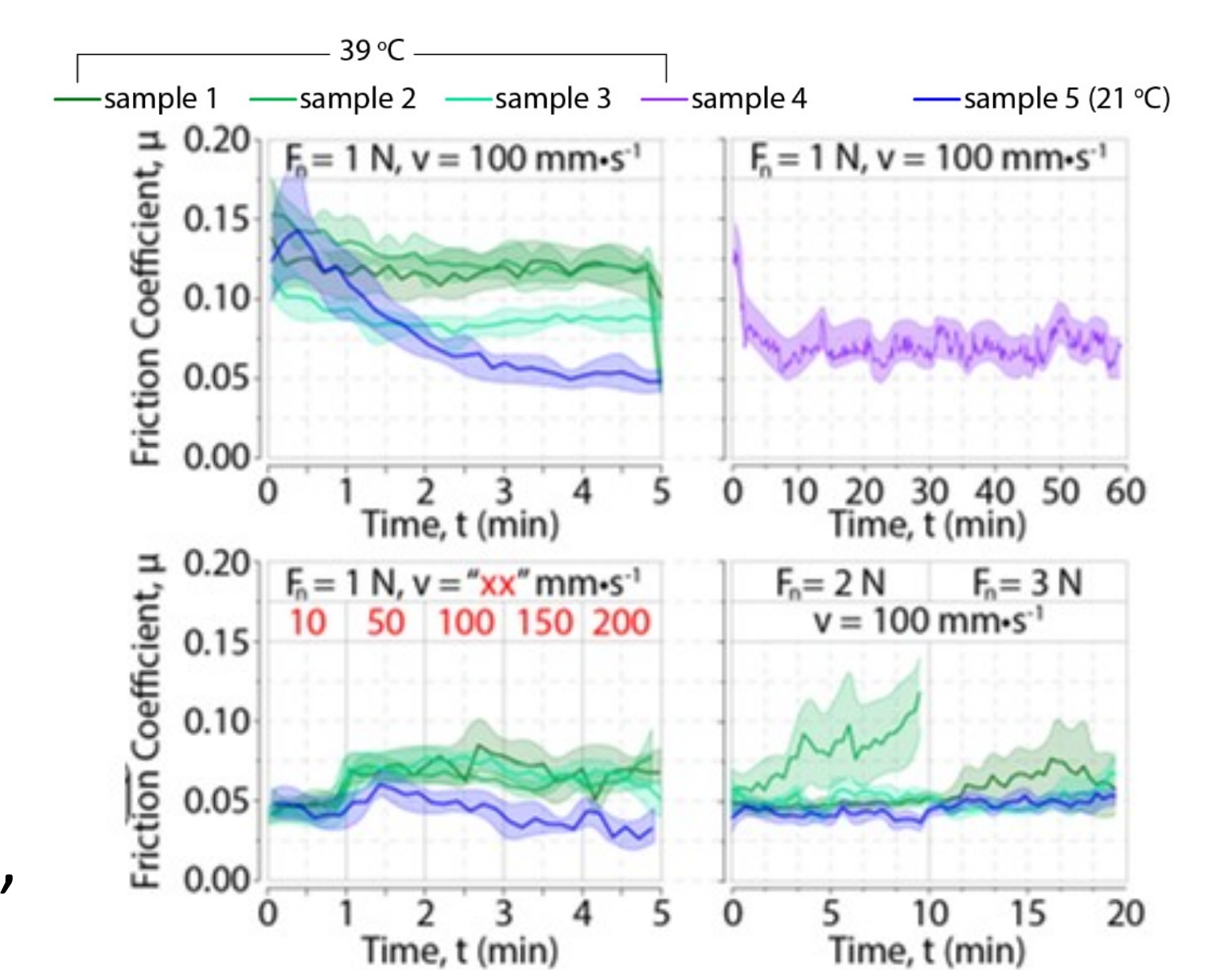


An in-house designed micro-tribometer (by Bennett, A. I.) to probe the mechanical and tribological properties of synthesized hydrogels and condom latex at a fundamental scale.

### Double Network Hydrogel Coatings Exhibit Low Friction Without External Lubricants

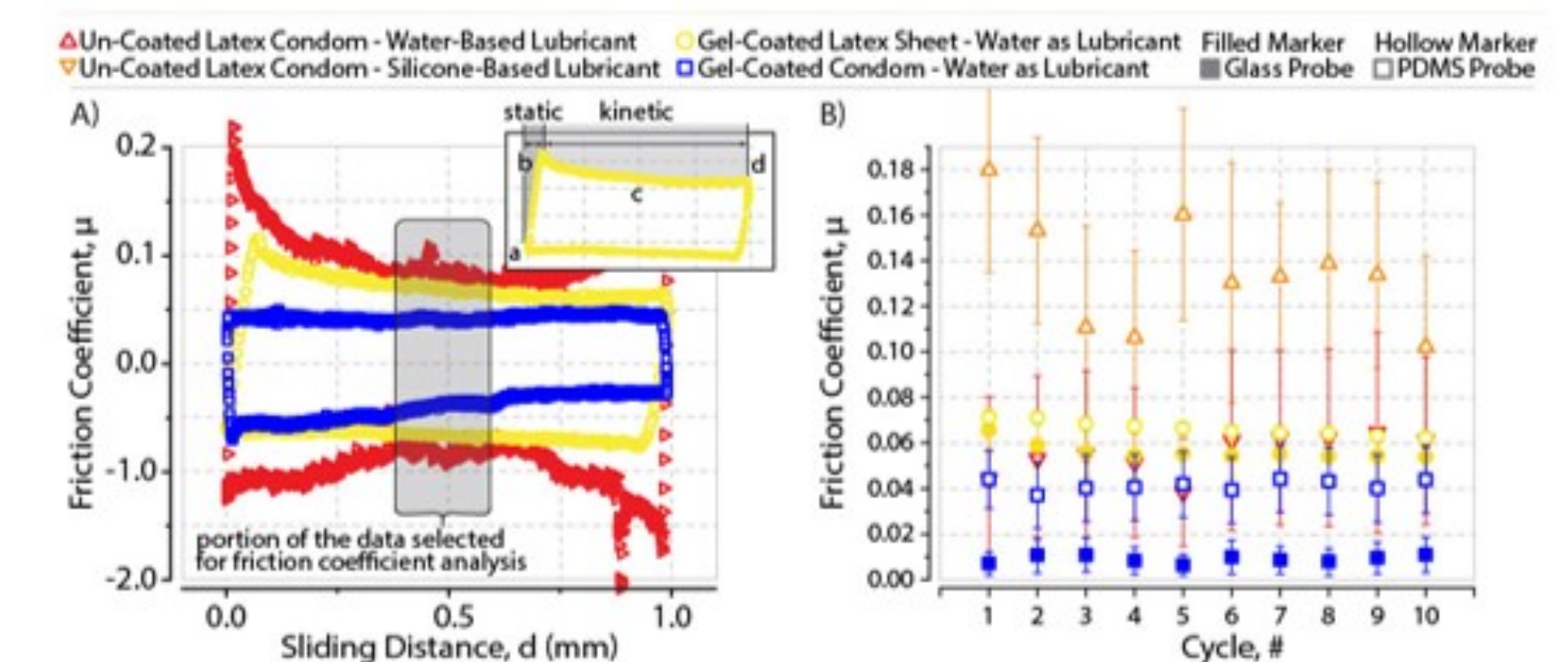
#### MTM Friction

- Load: 1N, 2N, 3N
- Speed: 10mm/s, 50mm/s, 100mm/s, 150mm/s, 200 mm/s
- Duration
- Lubricants
- Temperature



#### $\mu$ Trib Friction

- Speeds: 10 $\mu$ m/s, 100 $\mu$ m/s, 1000  $\mu$ m/s
- Lubricants
- Condoms vs. Thin Gel



After tests on hydrogel-coated samples, we were able to assess their friction coefficients under varying speeds, force loads, and temperature on a macro and micro level.

#### MTM Tests

- Physiologically relevant conditions: 39 °C and 1 N
- Friction ranges from:  $0.07 \pm 0.02 < \mu < 0.11 \pm 0.02$
  - Silicone-based lubricant:  $\mu = 0.06 \pm 0.02$
  - Water-based lubricant:  $\mu = 0.11 \pm 0.02$

Hydrogel coating produced consistent results over 60-minute test

#### $\mu$ Trib Tests

Using a glass probe, the gel coated condom outperformed all other samples with a friction coefficient of  $\mu = 0.015 \pm 0.011$

### Conclusions

We successfully synthesized double network hydrogel coatings designed to be intrinsically lubricious and outperform condoms with commercial lubricants

Under physiological temperatures, contact pressures, and sliding speeds, these hydrogel coatings maintain their lubricious properties and durability

These hydrogels can be loaded with anti-HIV drugs for therapeutic purposes.

### Acknowledgements

My involvement on this project would not have been possible without the support of PURM and the Carpick Research Group. This research was supported by a pilot grant from the Penn Center for AIDS Research (CFAR), an NIH-funded program (P30 AI 045008) and the University Research Foundation of the University of Pennsylvania. We thank Prof. D.L. Burris and Dr. N. Garabedian for assistance with preliminary hydrogel characterization at the University of Delaware.

1. Pinkerson, S. D.; Abramson, P. R. "Effectiveness of Condoms in Preventing HIV Transmission." *Social Science & Medicine* 1997, 44, 1303-1312.  
2. Center of Disease Control. *HIV Data & Trends, U.S. Statistics*. Retrieved from <https://www.hiv.gov/hiv-basics/overview/data-and-trends/statistics> on August 10, 2019