Compliant mechanisms for manipulation of single-cells and single-celled organisms

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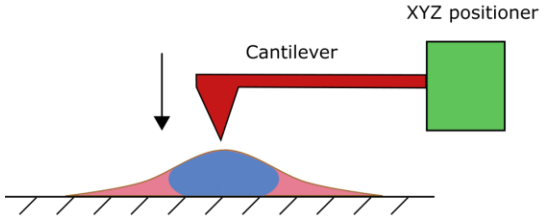
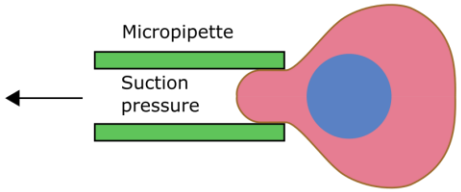
A unified framework for single-cell manipulation

Cell manipulation tools

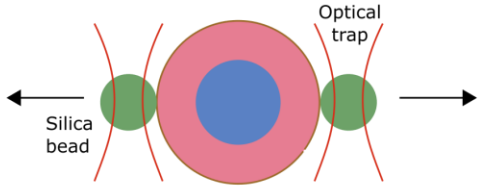
Atomic Force Microscopy



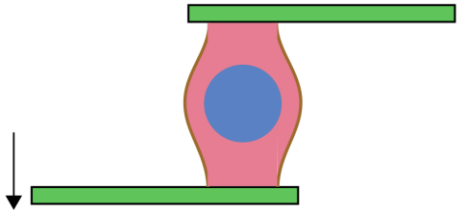
Micropipette Aspiration



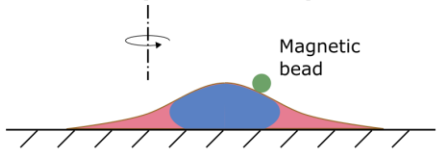
Optical stretcher



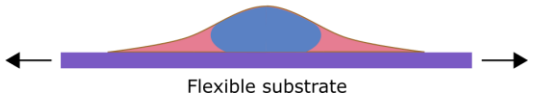
Microplate stretcher

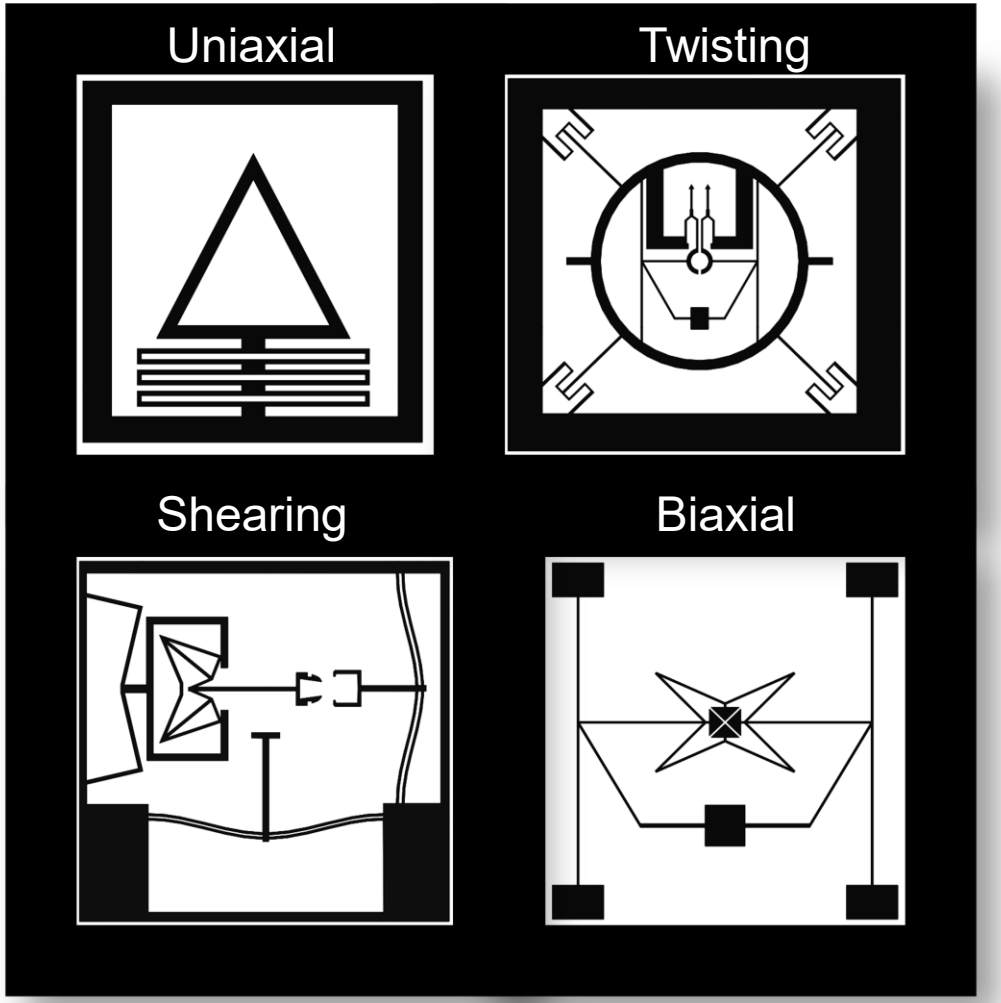


Magnetic twisting cytometry



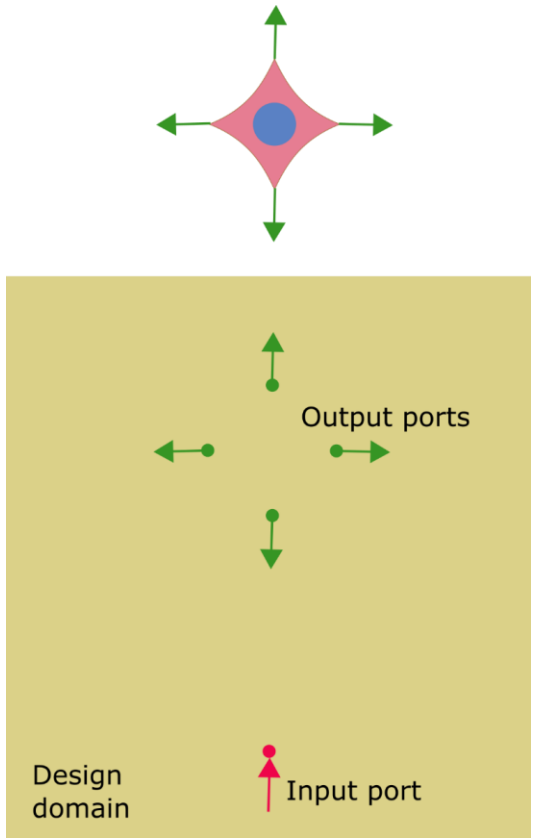
Substrate stretcher



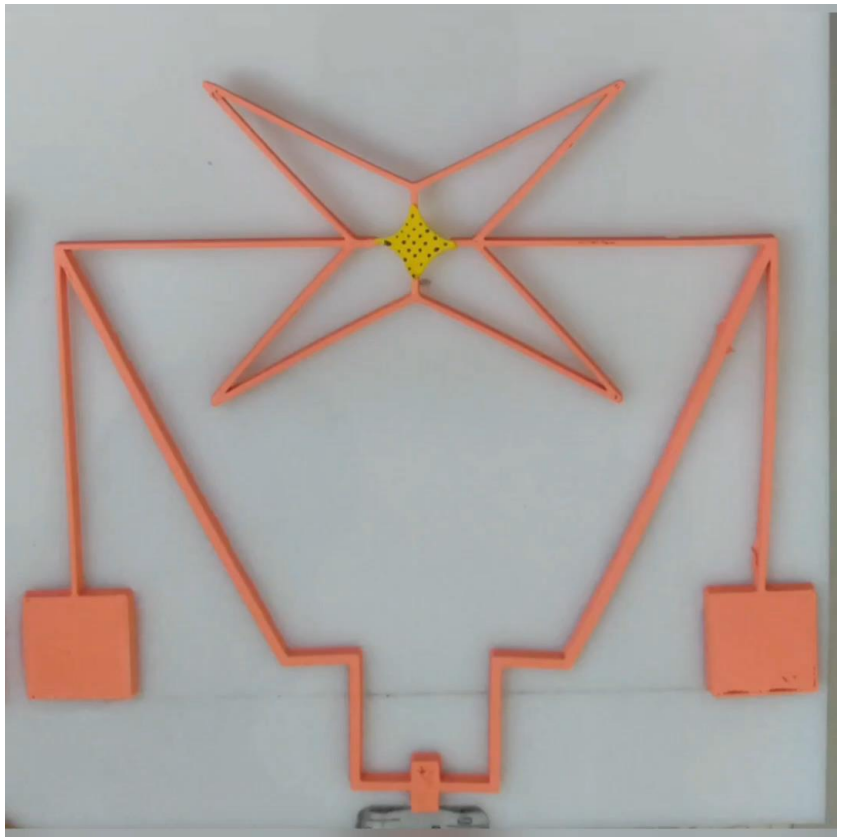


Lab-on-a-chip

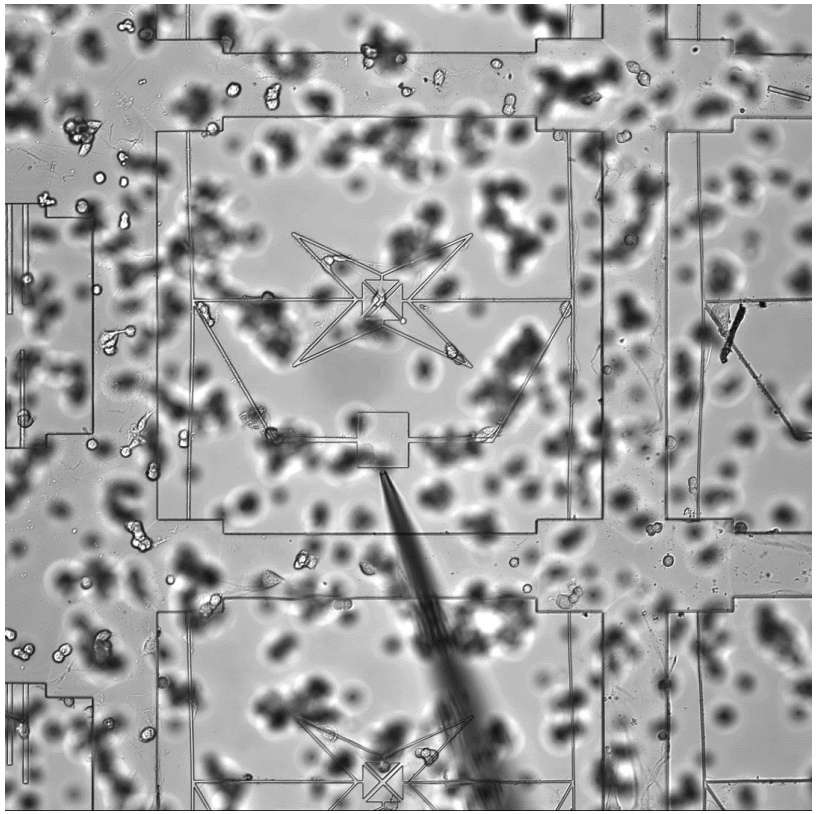
Biaxial stretching – design, fabrication and demonstration



Design problem



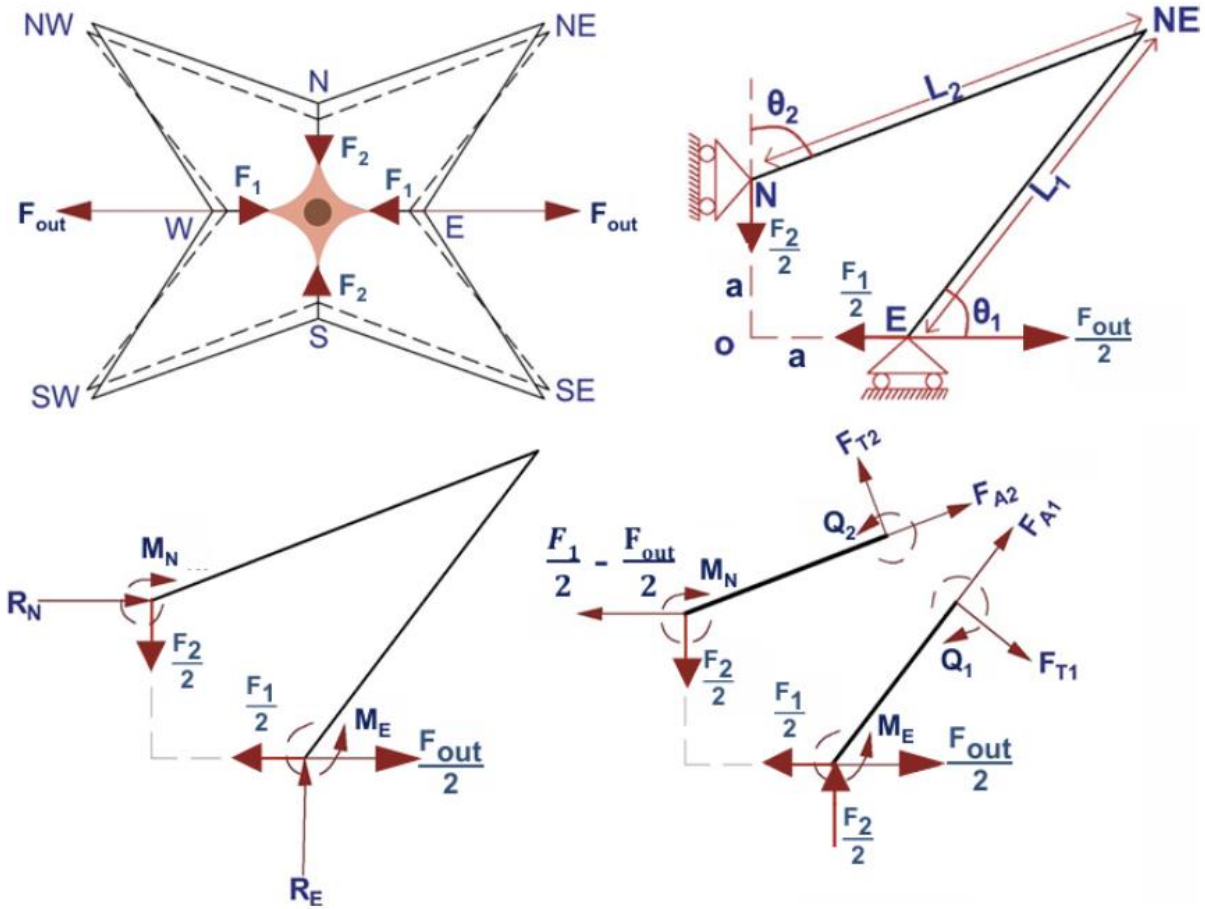
Macro model

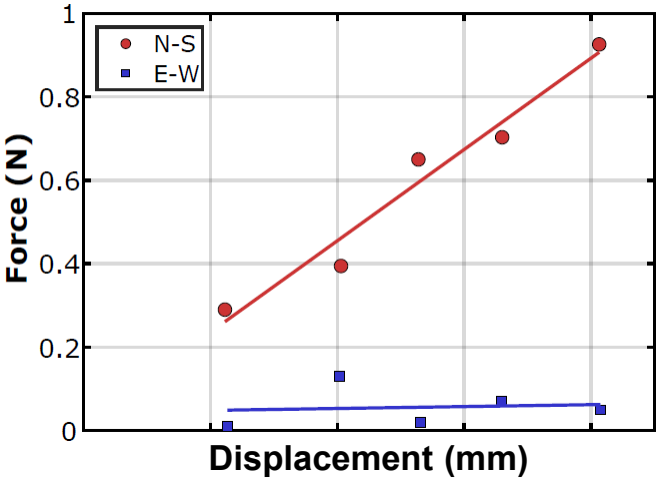


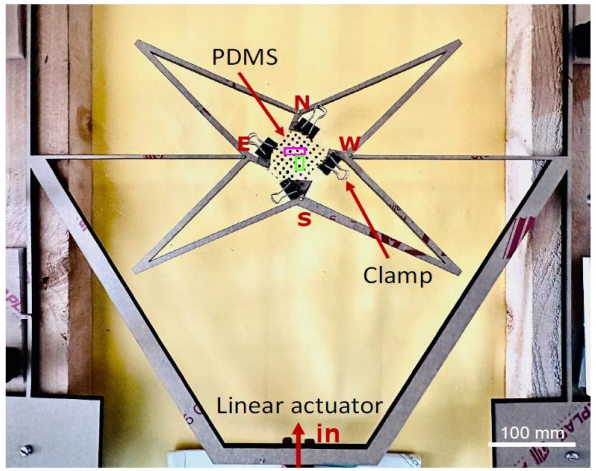
Stretching cells

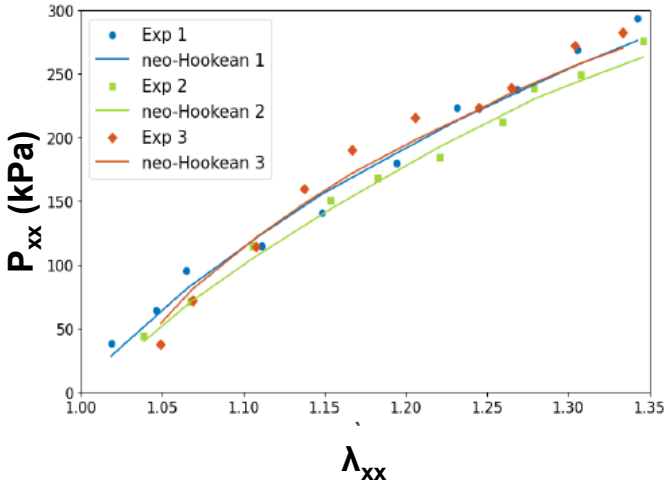
Neeraj et al., *IDETC-CIE* (2021), Himanshu et al., MARSS (2023), Himanshu et al., J. Micro Bio Robotics (2024)

Biaxial stretching – force-displacement relationship







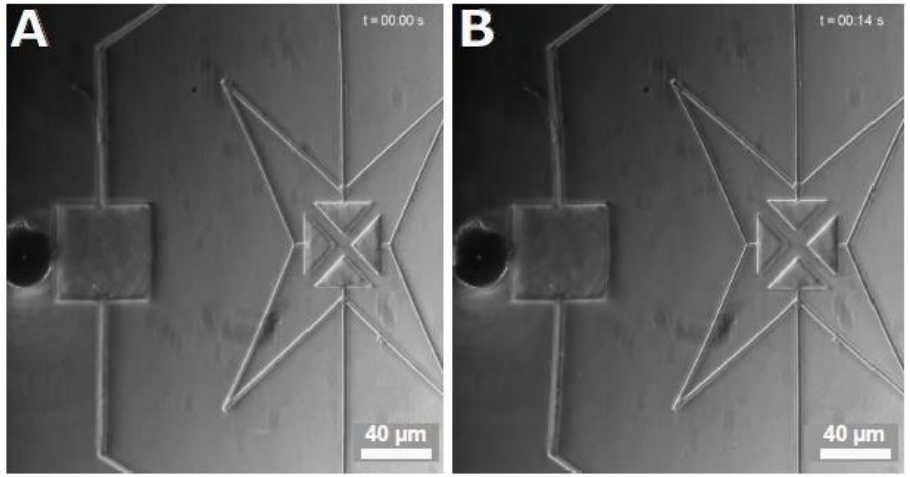


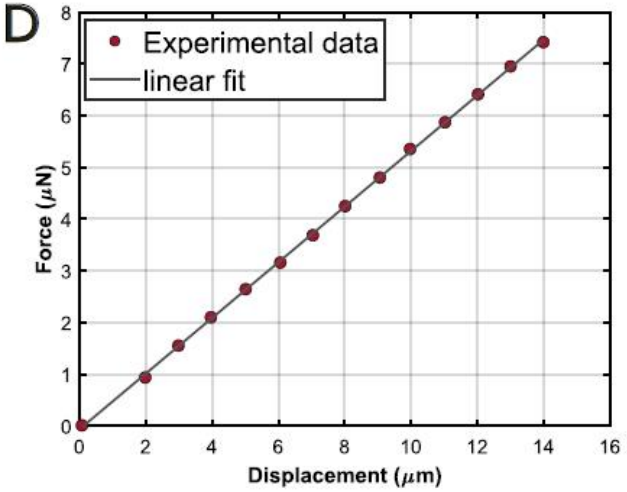
Derive relationship between the cell stretching force and mechanism deformation

Verify relationship at the macroscale

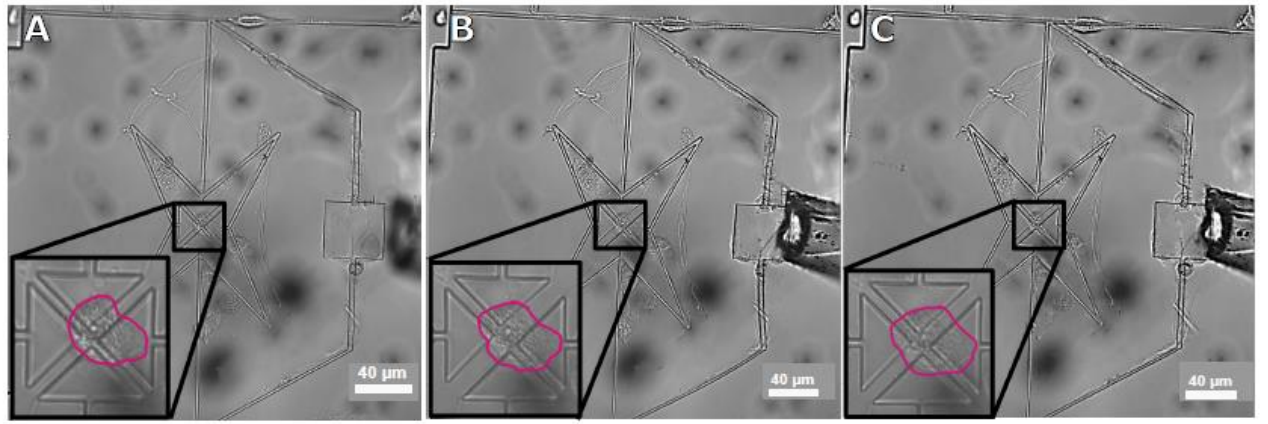
Himanshu et al., J. Micro Bio Robotics (under review)

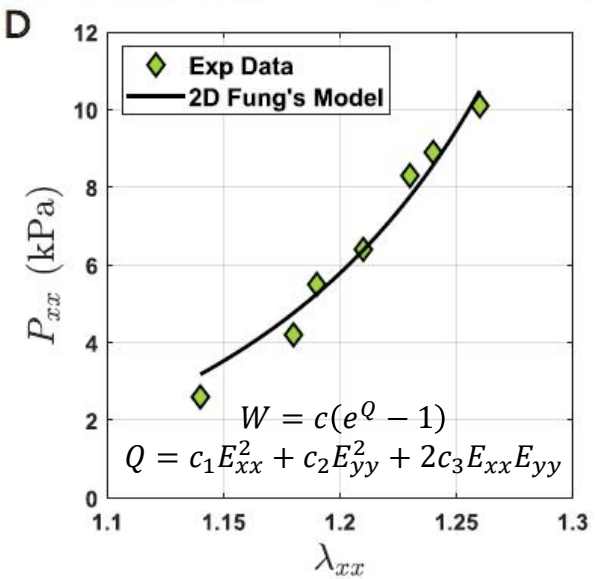
Biaxial stretching – cell anisotropy

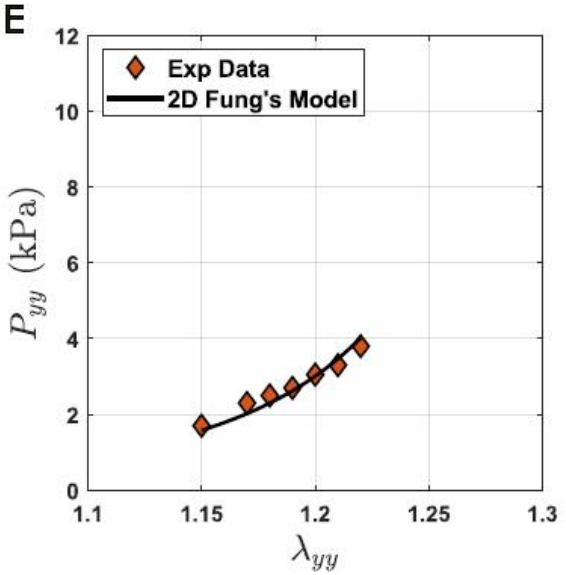




Verify relationship at the microscale







Characterize cellular anisotropy

Himanshu et al., J. Micro Bio Robotics (under review)

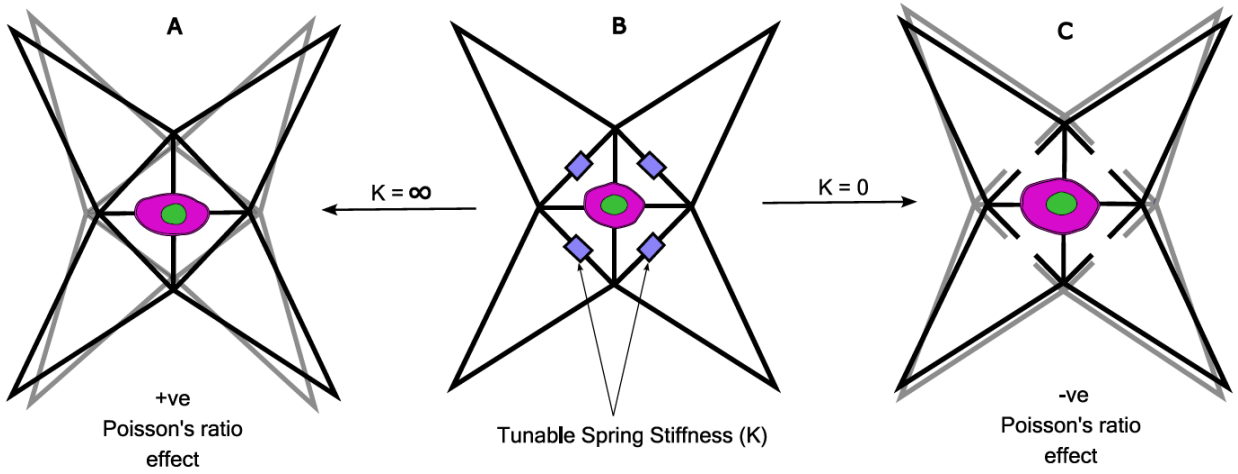
Shearing – design, fabrication and demonstration (macro)

Unpublished work: Redacted

Twisting – design, fabrication and demonstration (macro)

Unpublished work: Redacted

Compliant mechanisms as dynamic cell substrates



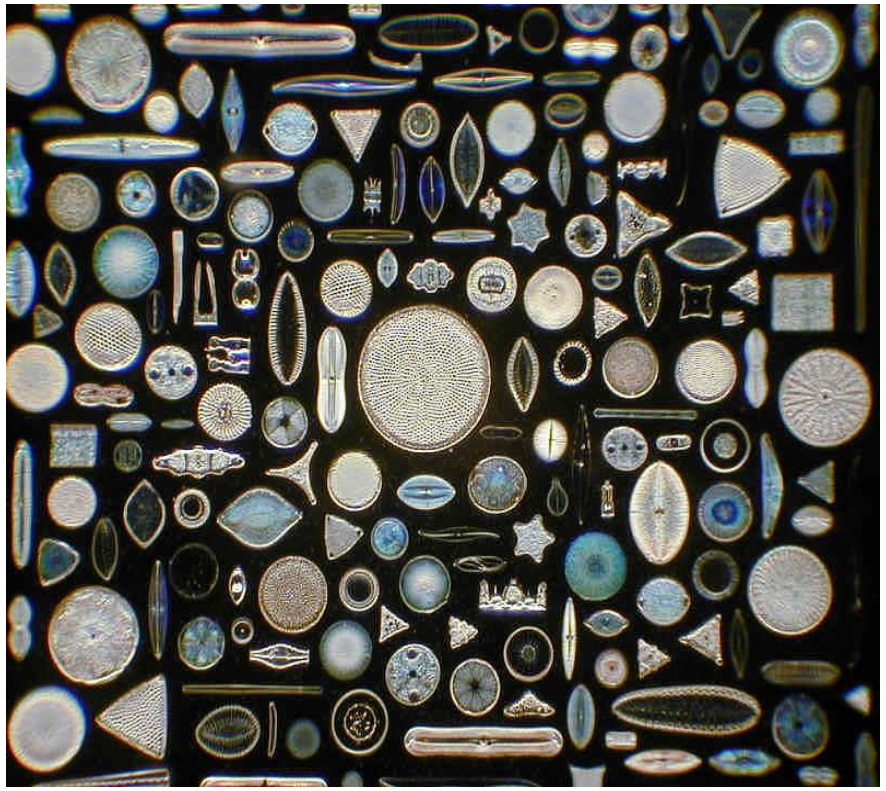
Unpublished work: Redacted

Concept

Design and macroscale prototype

Diatoms

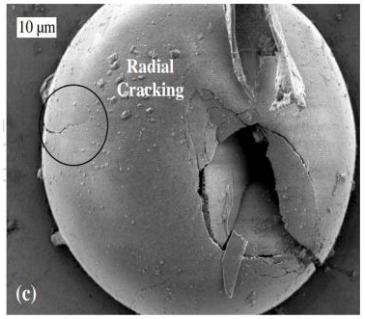
- Diatoms are unicellular algae found in marine and fresh water
- They generate around one-fifth of all oxygen in atmosphere
- The cell wall of the diatoms are made of silica to protect against predators
- Climate change alters the morphology and possibly the mechanical properties of diatom cell walls



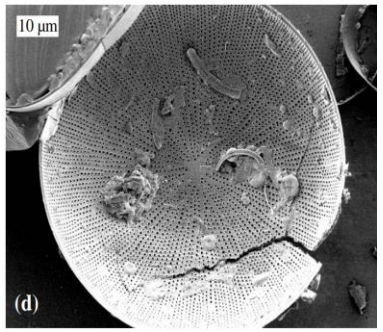
Diatoms

	Cells	Diatoms
Modulus	1-10 kPa	1-2 GPa
Attachment to mechanisms	Adherent	Non-adherent

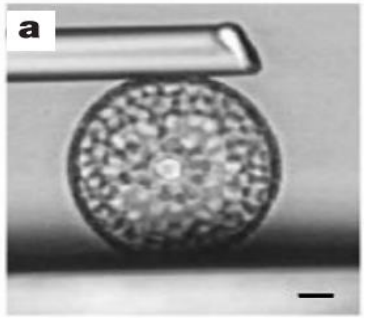
Previous work on mechanical characterization of diatoms



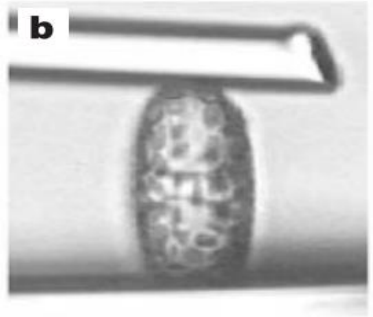
Fracture modes due to nanoindentation/AFM on frustules



Ghatu, Subhash, et al. *J. Nano. Nanotech.* (2005)



Microneedle test on diatoms



Hamm, Christian E., et al. *Nature* (2003)

Shearing diatoms – design, fabrication and demonstration (macroscale)

Unpublished work: Redacted

Conclusion

- Compliant micromechanisms as a generic framework for manipulation of biological micro-specimens
  - Several manipulation modes on a single chip
  - Both active and passive manipulation
  - Across multiple orders of magnitude of elastic moduli

ACKNOWLEDGMENTS

- Mentees
  - Himanshu Marwah (PhD)
  - Ravi Vishwakarma (M.Tech)
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