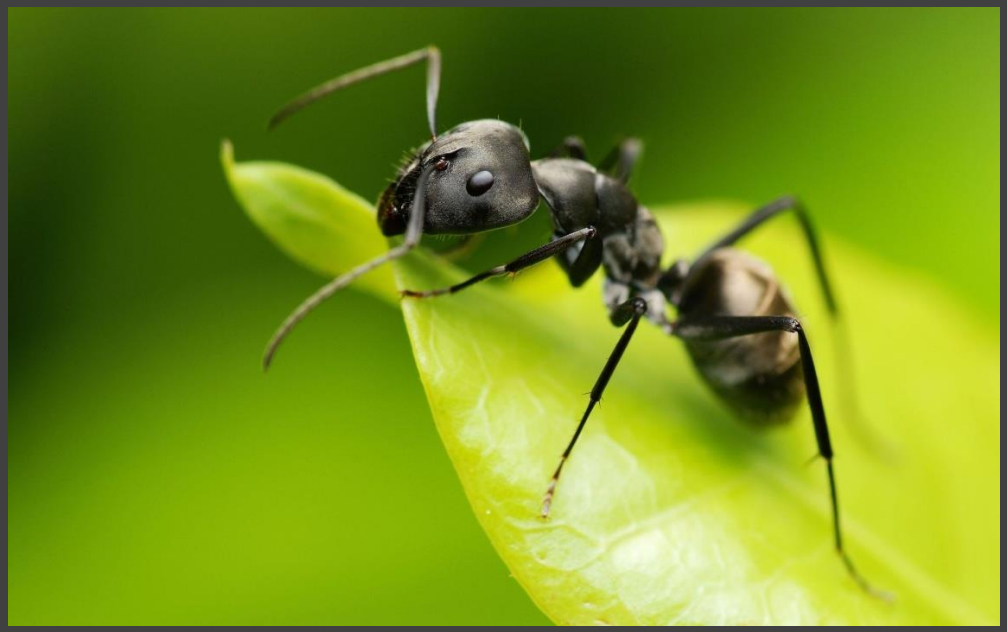
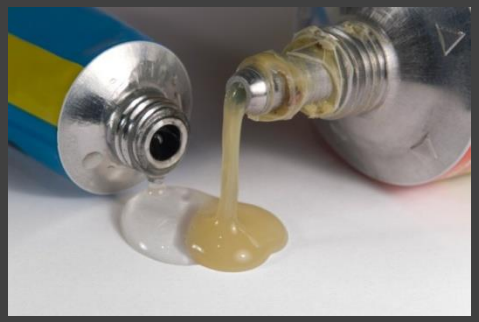
Wet and Dry Biological Adhesives in Complex Environments: Learning from Ants and Geckos



Alyssa Y. Stark

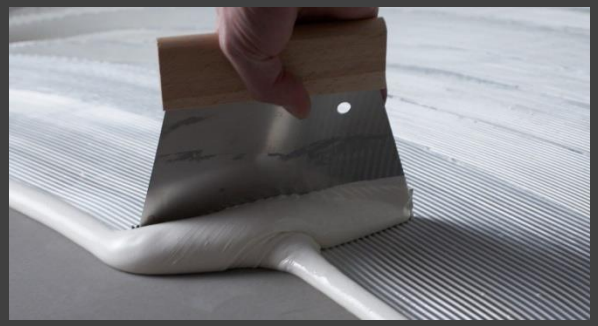
University of Louisville

Adhesives



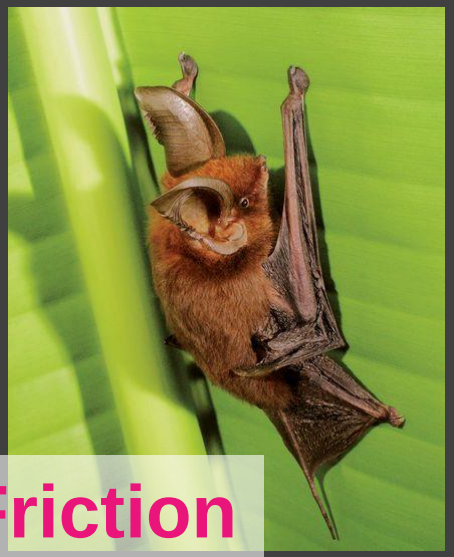
Limitations:

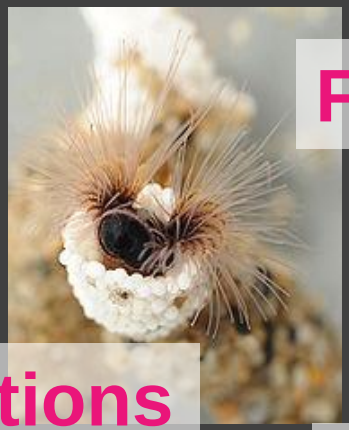
- Surface roughness
- Surface energy
- Contamination
- Temperature
- Humidity
- Curing
- Moisture / Oil



Biological Adhesives

Biological Adhesives





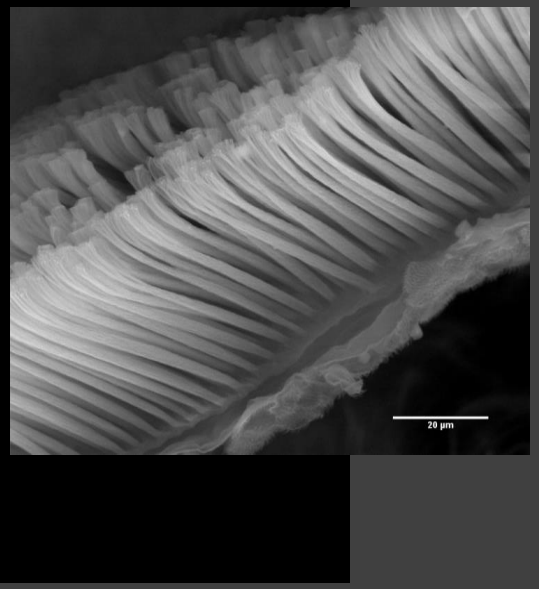
Environment

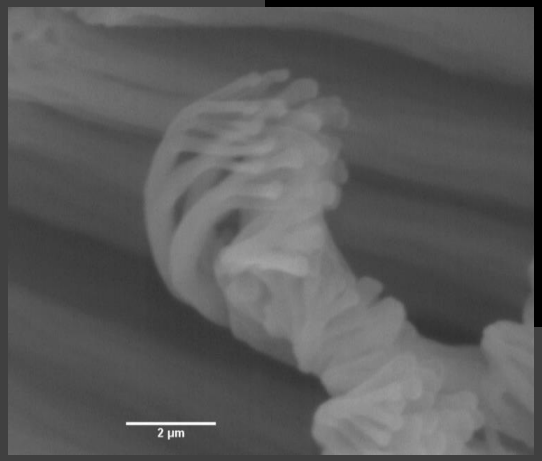
>1,400 species

One of the most diverse groups of terrestrial vertebrates

Gecko Adhesive System

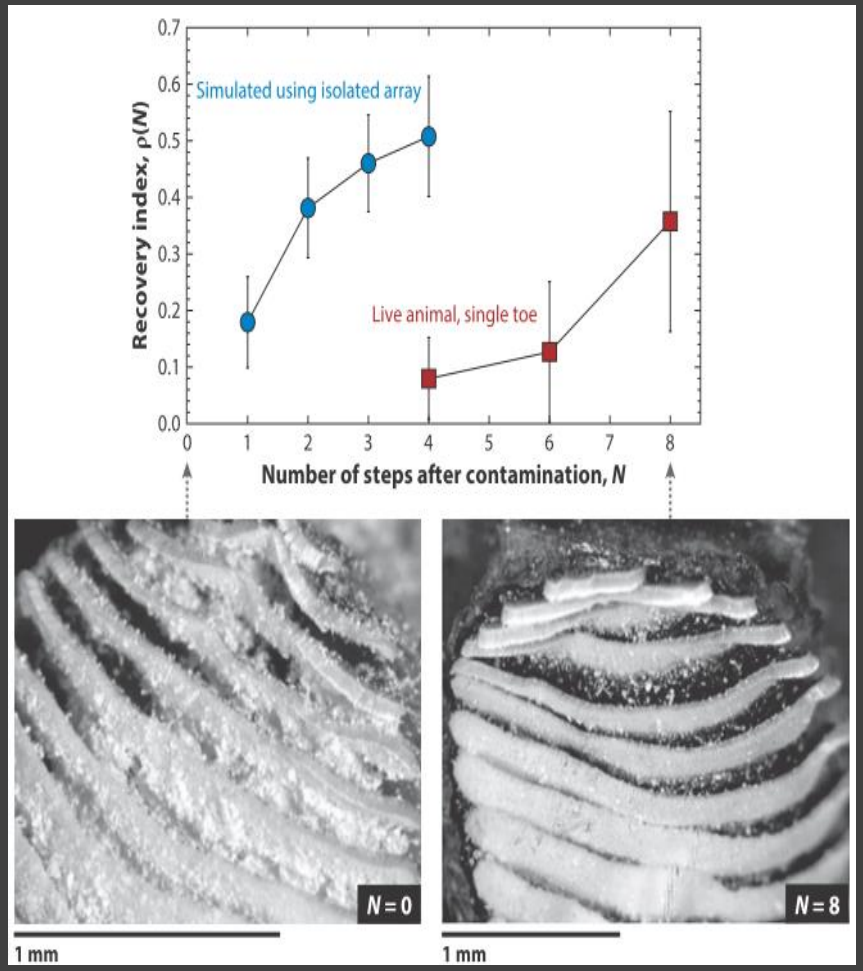
- Morphology
  - Toe Pad
  - Setal mats
  - Branched Setae
  - Flattened Spatula
- Mechanism
  - van der Waals Forces



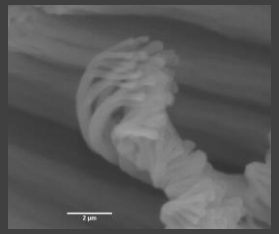


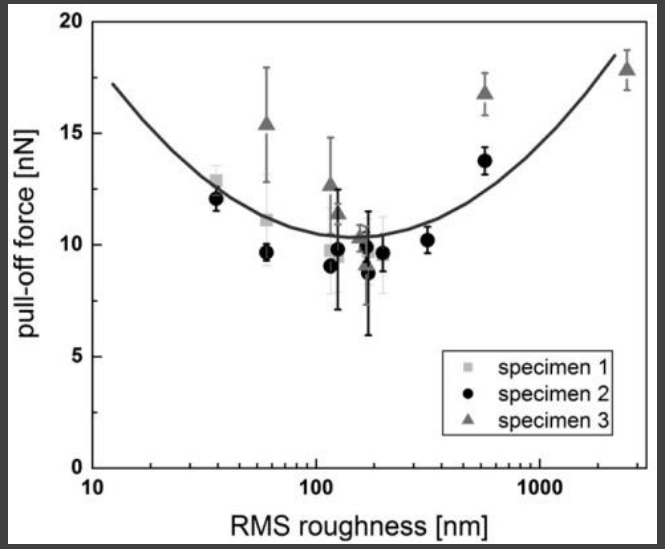
Surface Roughness and Contamination

Huber *et al*., 2007

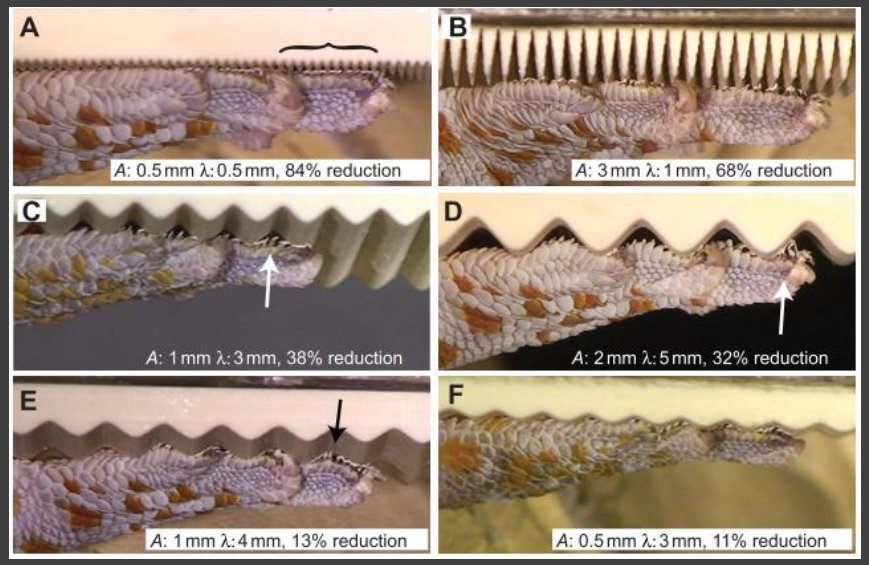


Autumn, Niewiarowski and Puthoff, 2014

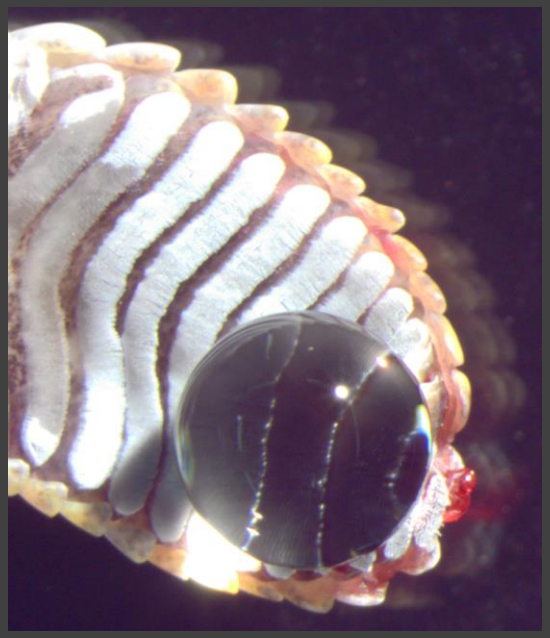




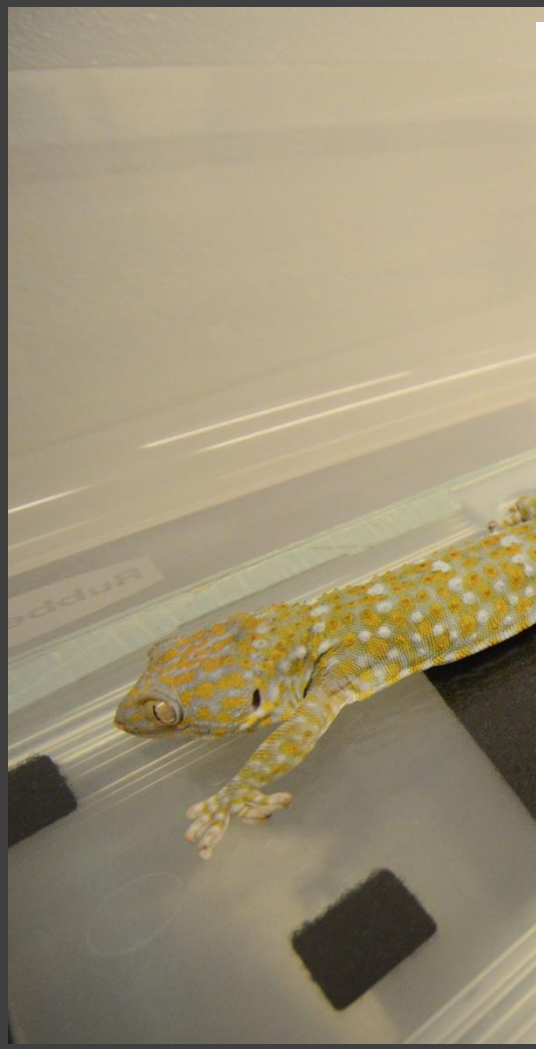
Gillies *et al*., 2014

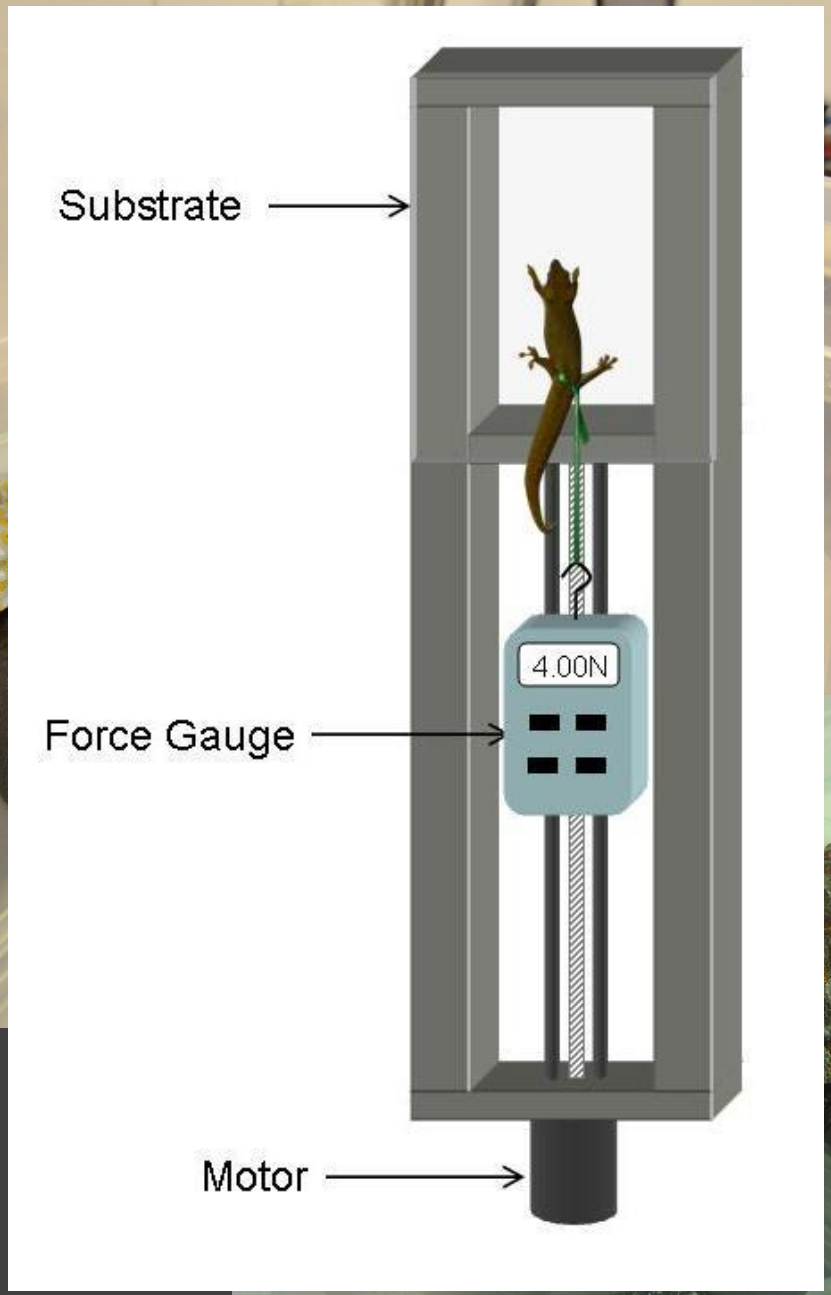


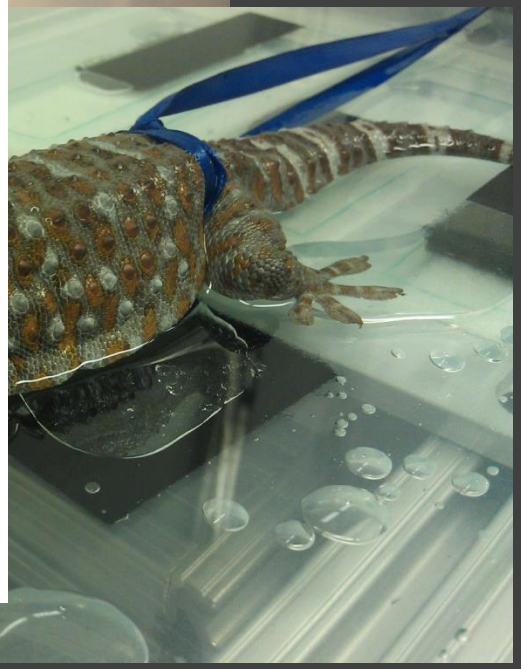
Wet Substrates



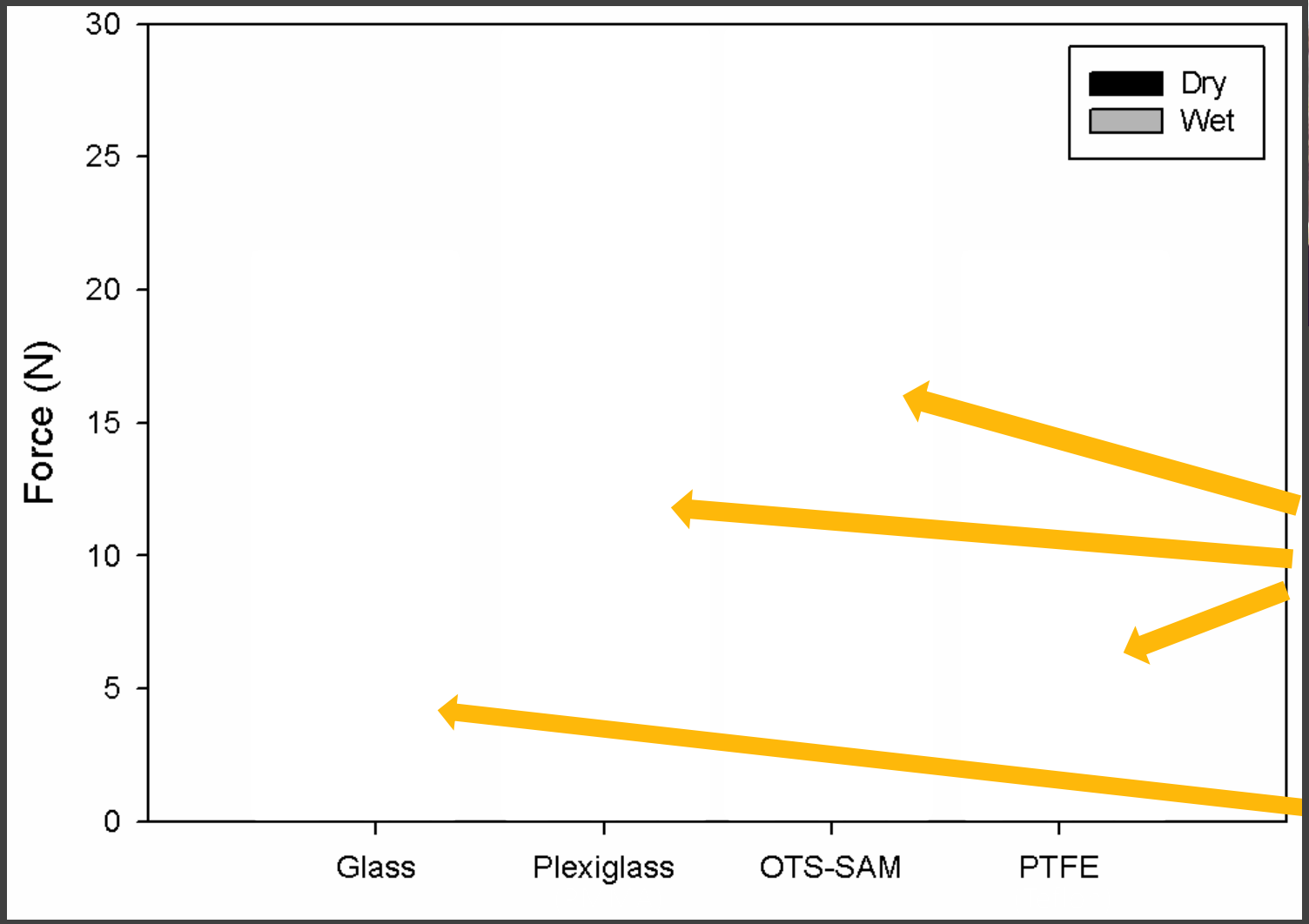
Stark *et al*., *2012*

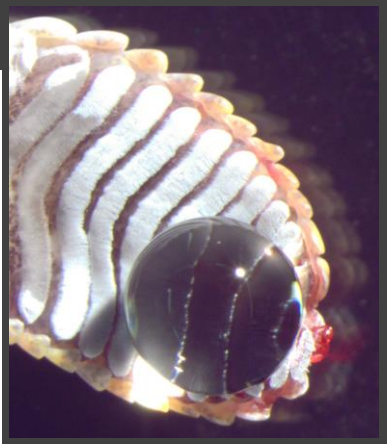






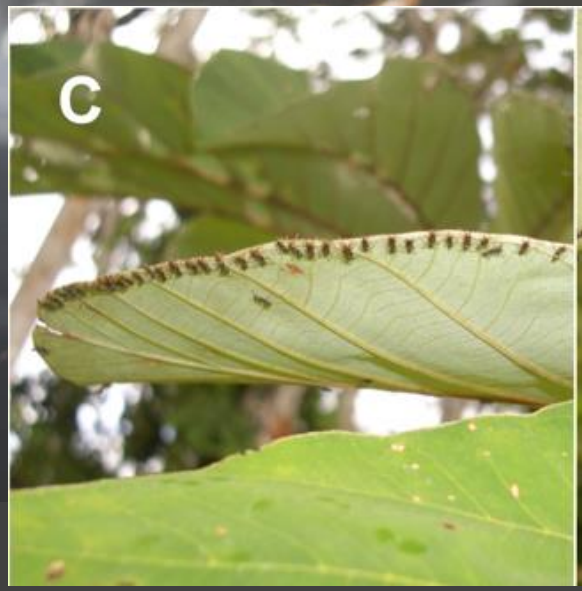
Niewiarowski *et al*., *2008*

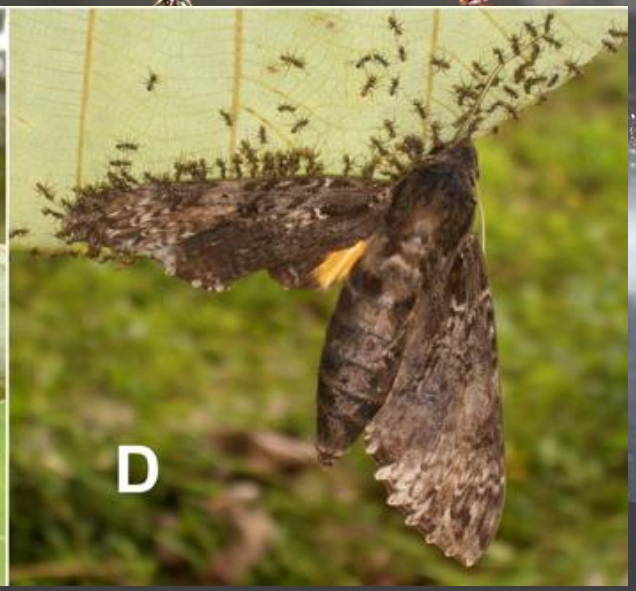




Hydrophilic → **Hydrophobic**

Stark *et al.*, *2013*



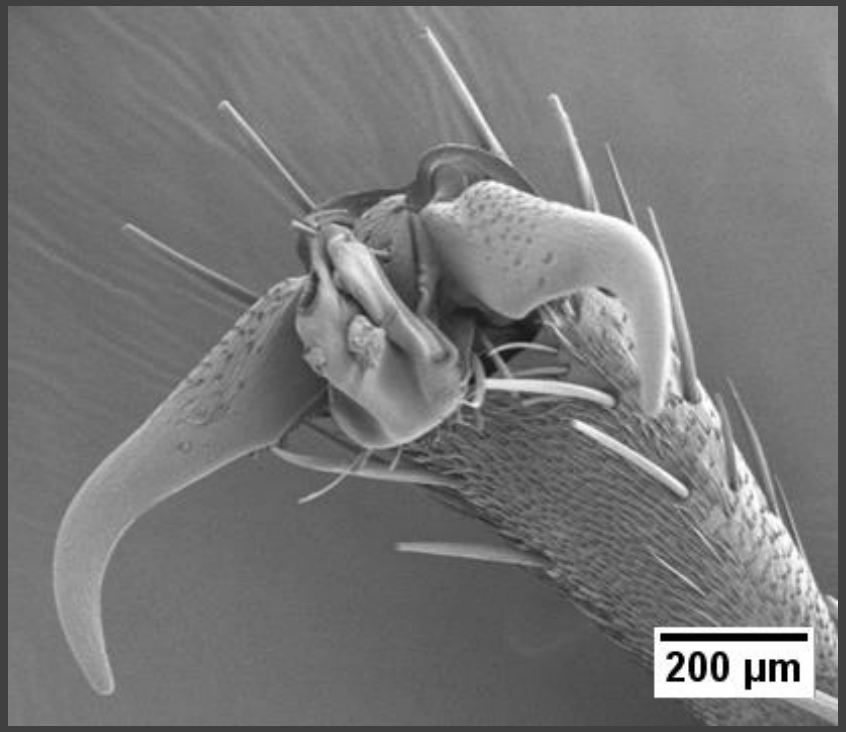


>20,000 species

25% terrestrial animal biomass

Ant Adhesive System

- Morphology
  - Claws
  - Tarsal Pad
  - Adhesive Secretion

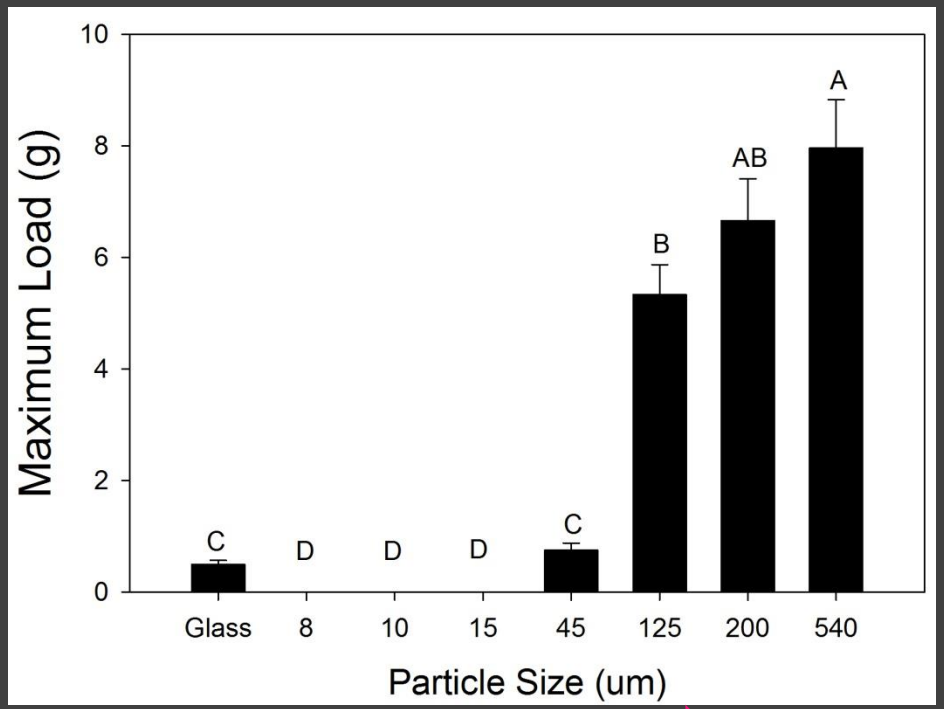


- Mechanisms
  - Mechanical Interlocking
  - Some Friction
  - “Capillary” Adhesion

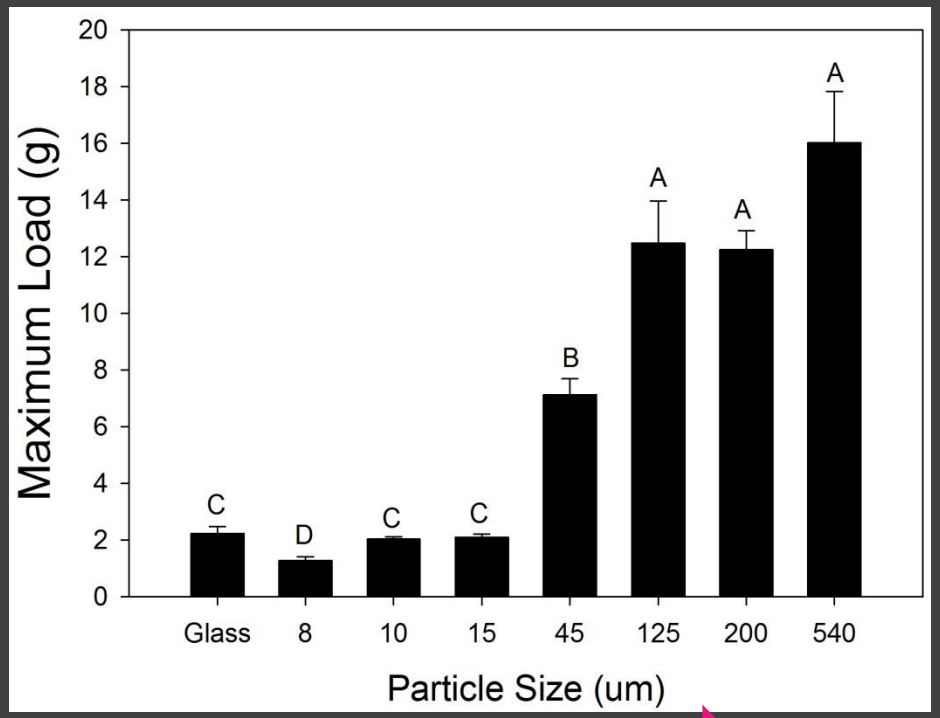
Tropical Rainforest Canopy

Surface Roughness

Normal Adhesion

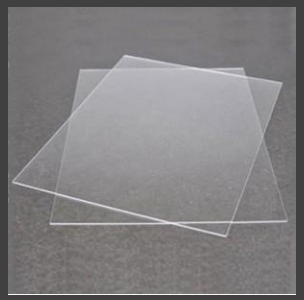


Shear Adhesion

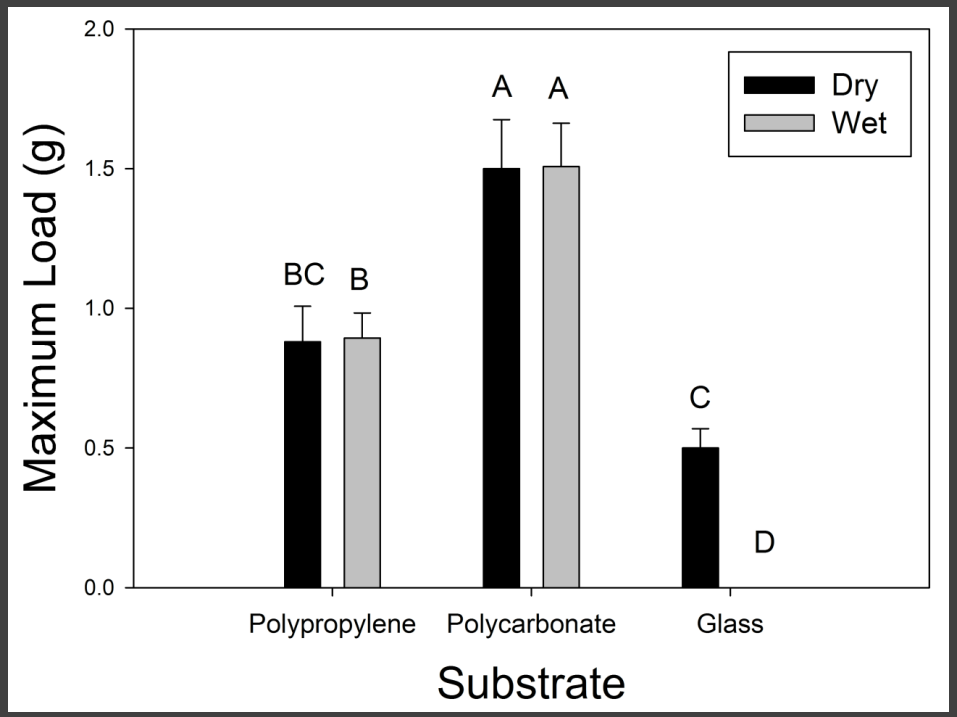


Stark and Yanoviak[a], *in prep*

Wet Substrates

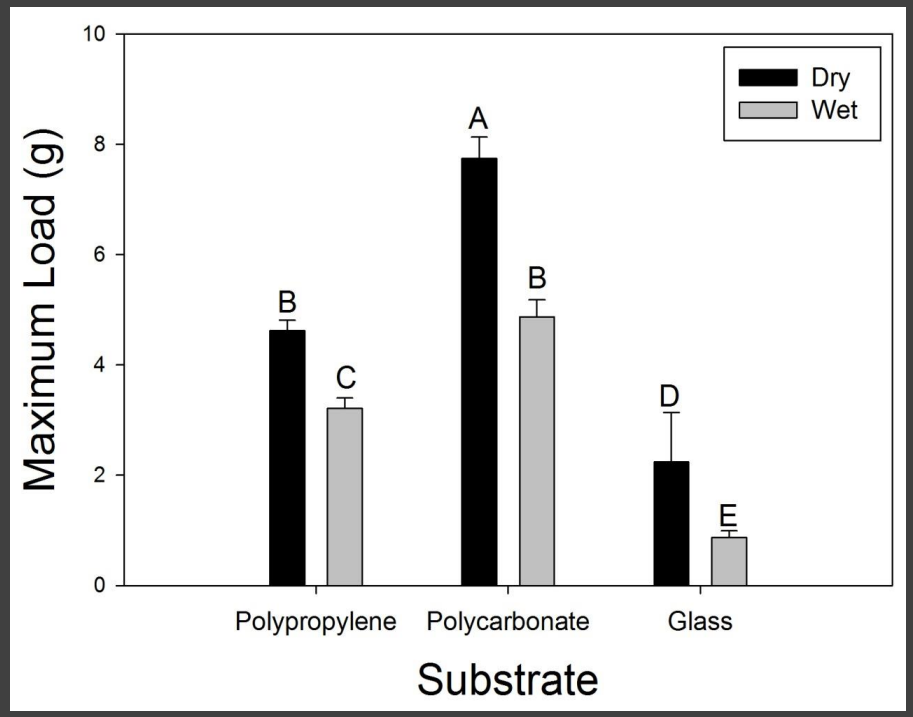


Normal Adhesion



Hydrophobic → Hydrophilic

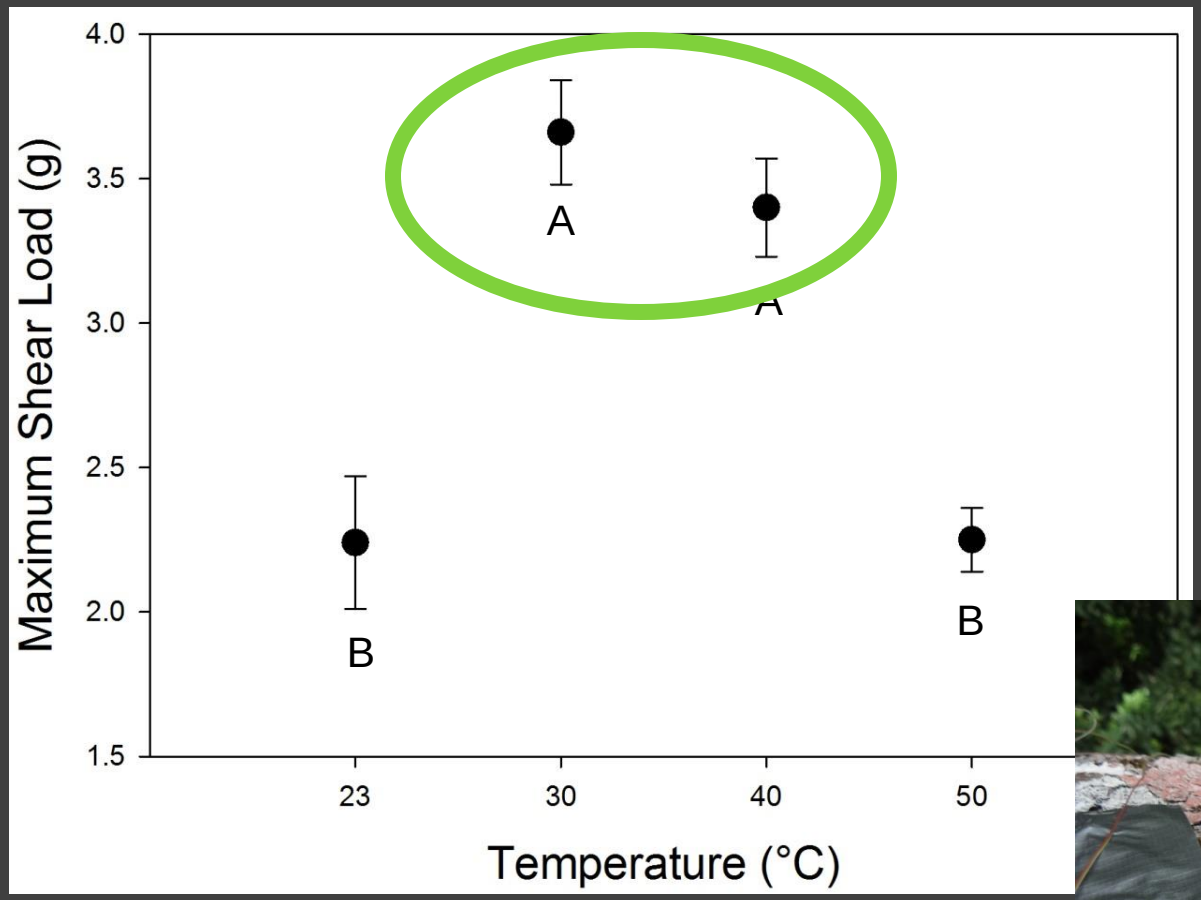
Shear Adhesion



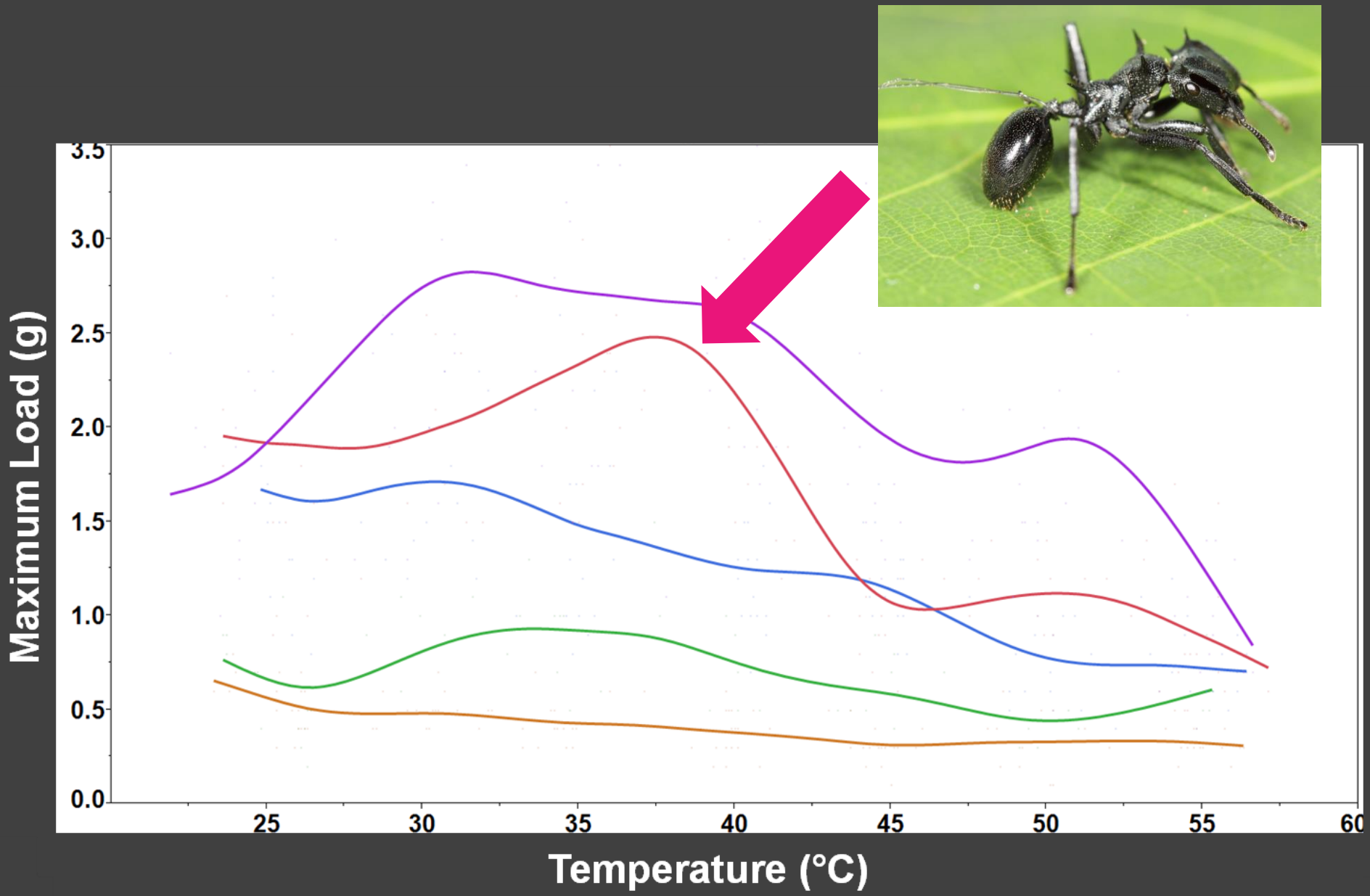
Hydrophobic → Hydrophilic

Stark and Yanoviak[b], *in prep*

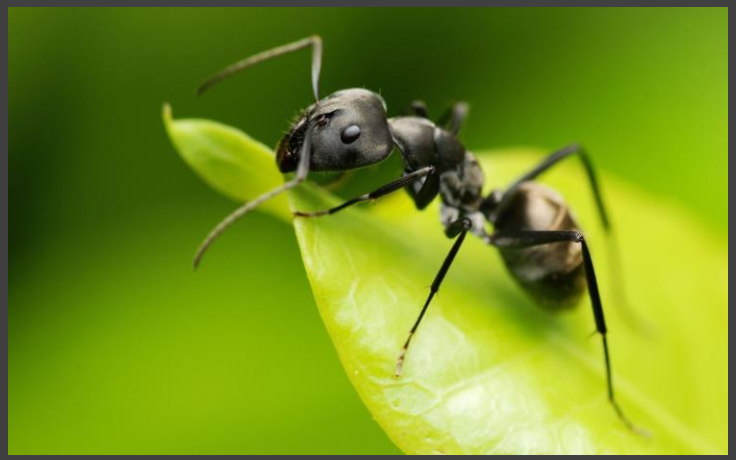
Surface Temperature

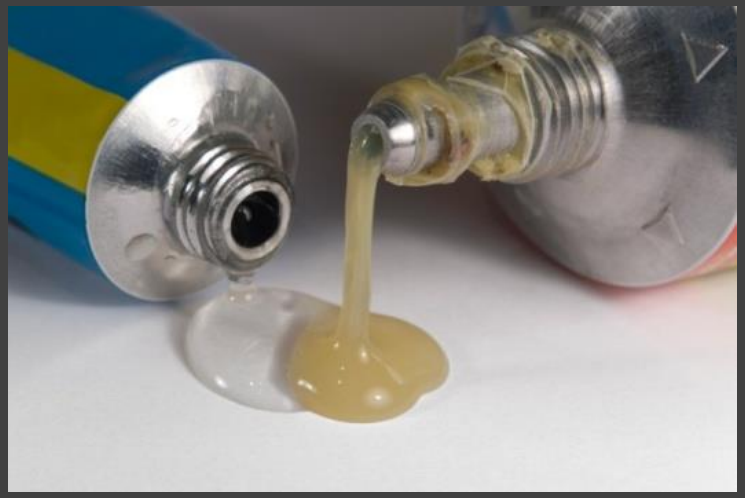


Stark, Arstingstall and Yanoviak, *in prep*

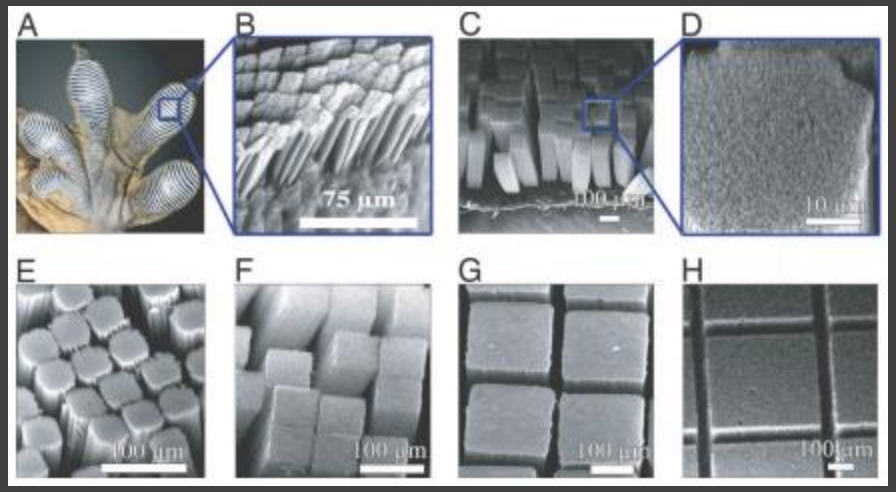


Stark, Arstingstall and Yanoviak, *in prep*



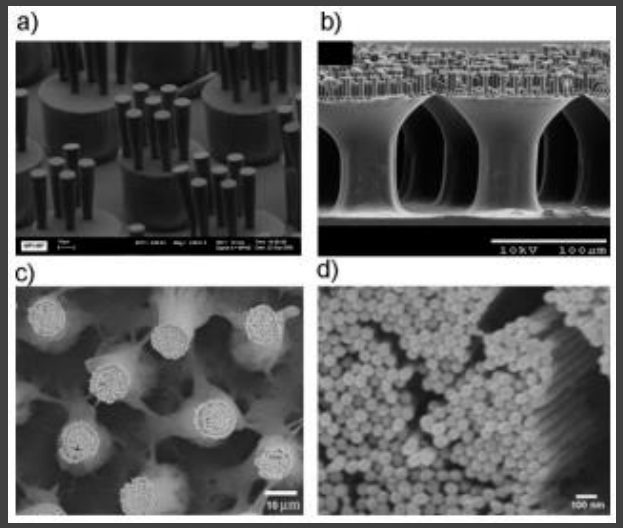


Bio-inspired Gecko Adhesives

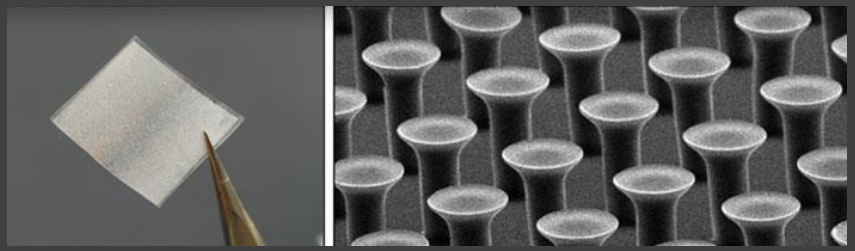


Ge et al., 2007

GeckSkin™

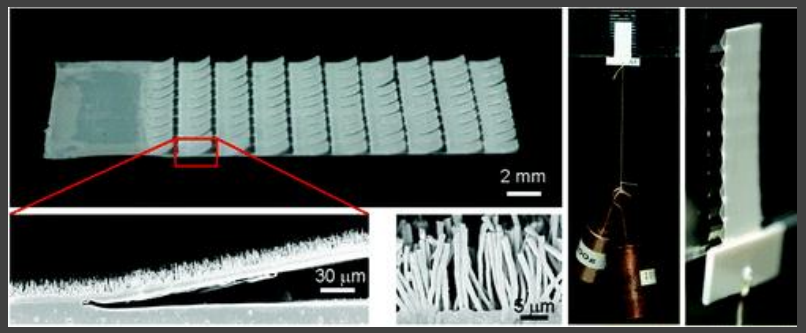


Boesel et al., 2010



nanoGriptech

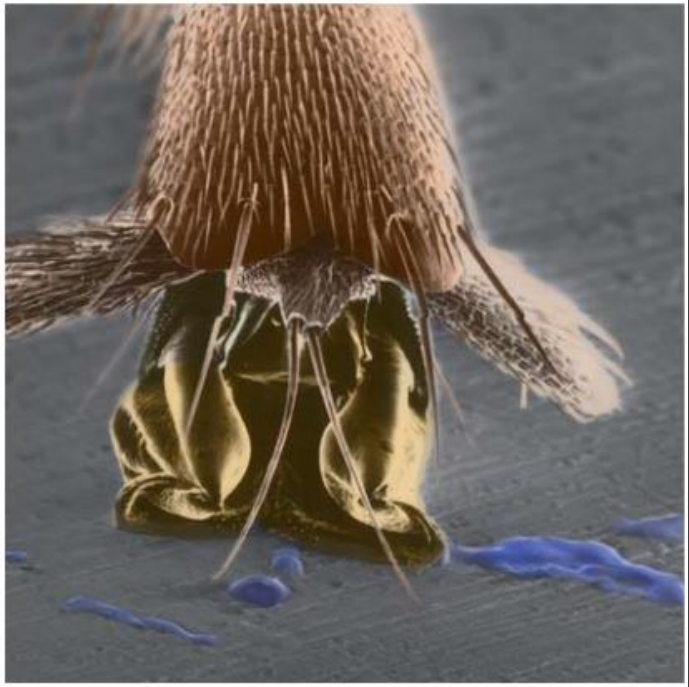
nanoGriptech
GECKO-INSPIRED ADHESIVES

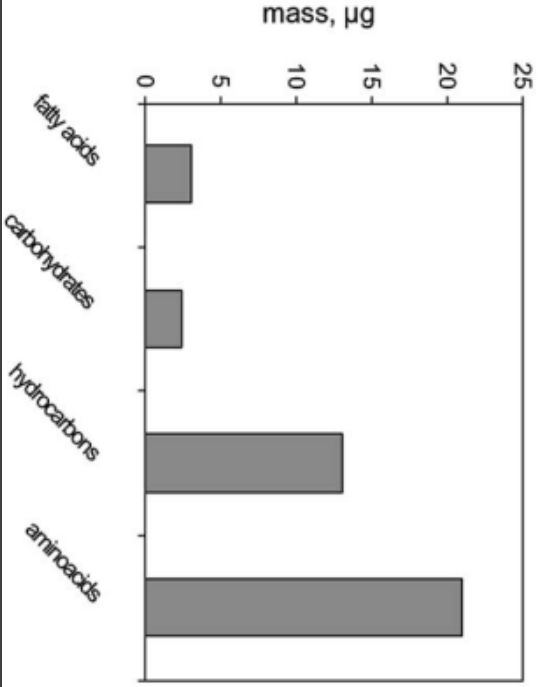


Lee et al., 2009

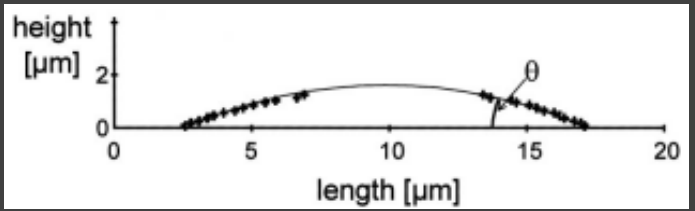
Bartlett et al., 2012

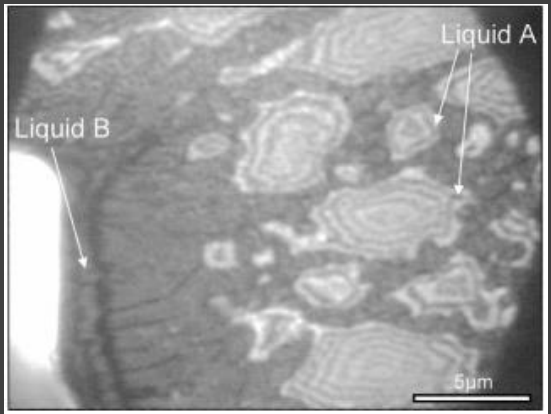
Ant-inspired Synthetics





Votsch et al., 2002





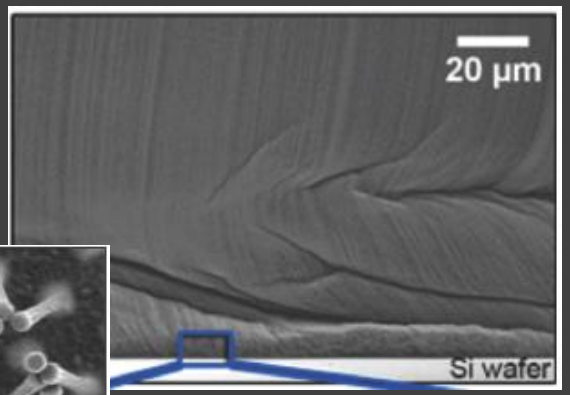
Federle et al., 2002; Dirks and Federle, 2011

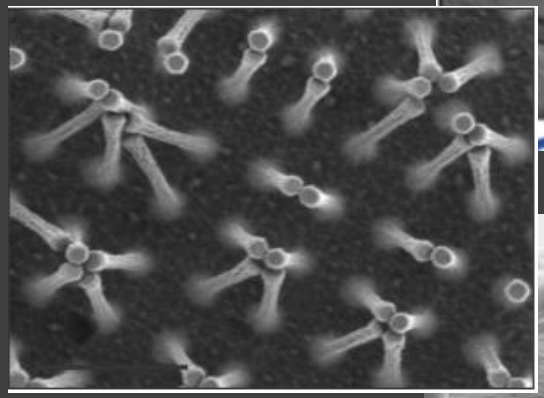
Bio-inspired Adhesives

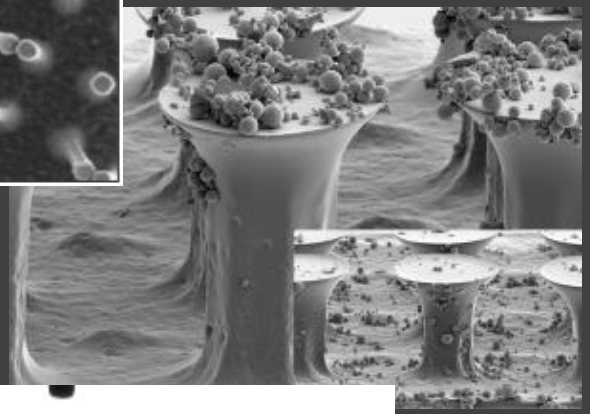
Limitations:

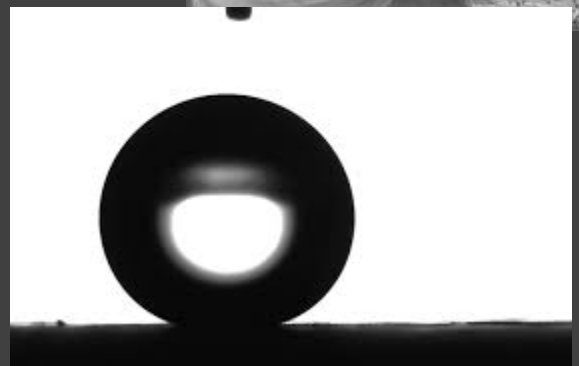
- Buckling
- Damage
- Self-adhesion
- Contamination
- Moisture / Oil
- Surface Roughness
- Surface Energy
- Adhesive Chemistry
- Temperature & Humidity

WHY?









Biological Adhesives

Acknowledgements

University of Akron

Peter Niewiarowski
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Jocelyn Ohlemacher
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Benjamin "Max" Adams
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Roberta Ethington, St. Matthews Elementary School
Egbert G. Leigh Jr., STRI

Grant DEB-1252614 to SPY

The staff at the Smithsonian Tropical Research Institute, Panama (STRI)

Questions?

COMMENT

GENOMICS African American ancestry-seekers deserve good data **p.279**

INTERDISCIPLINARITY A manual for forging great collaborations **p.280**

POLICY Experts raise alarm about peer review of Japanese whaling **p.283**

OBITUARY Nobel winner Alfred Goodman Gilman, discoverer of G-proteins **p.284**

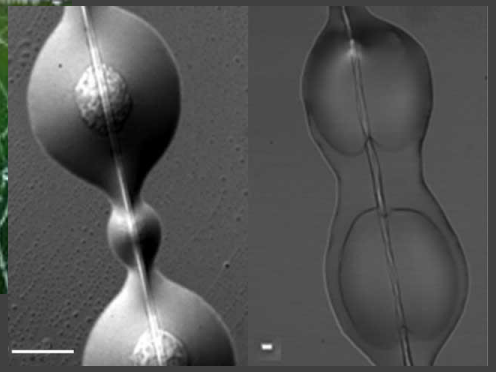
PAUL D STEWART/NATUREPL.COM

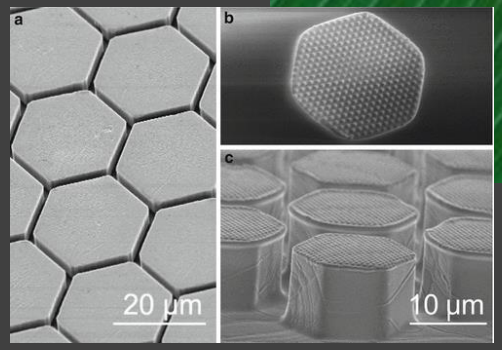
Studying the feet of a variety of gecko species would help scientists to design of a richer variety of dry adhesives.

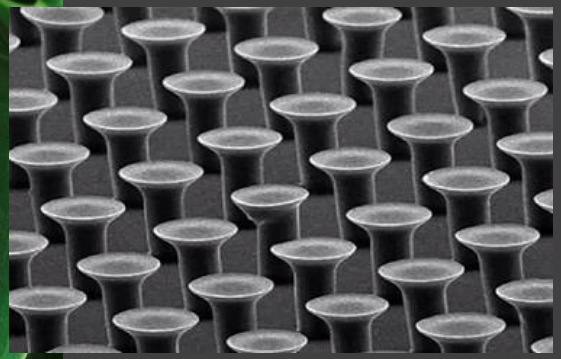
Bring biologists into biomimetics

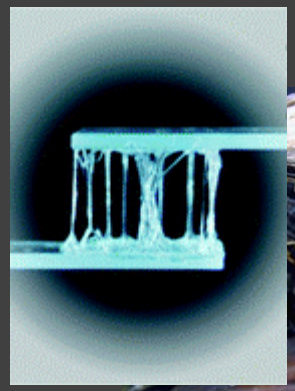
Engineers, chemists and others taking inspiration from biological systems for human applications must team up with biologists, writes **Emilie Snell-Rood**.

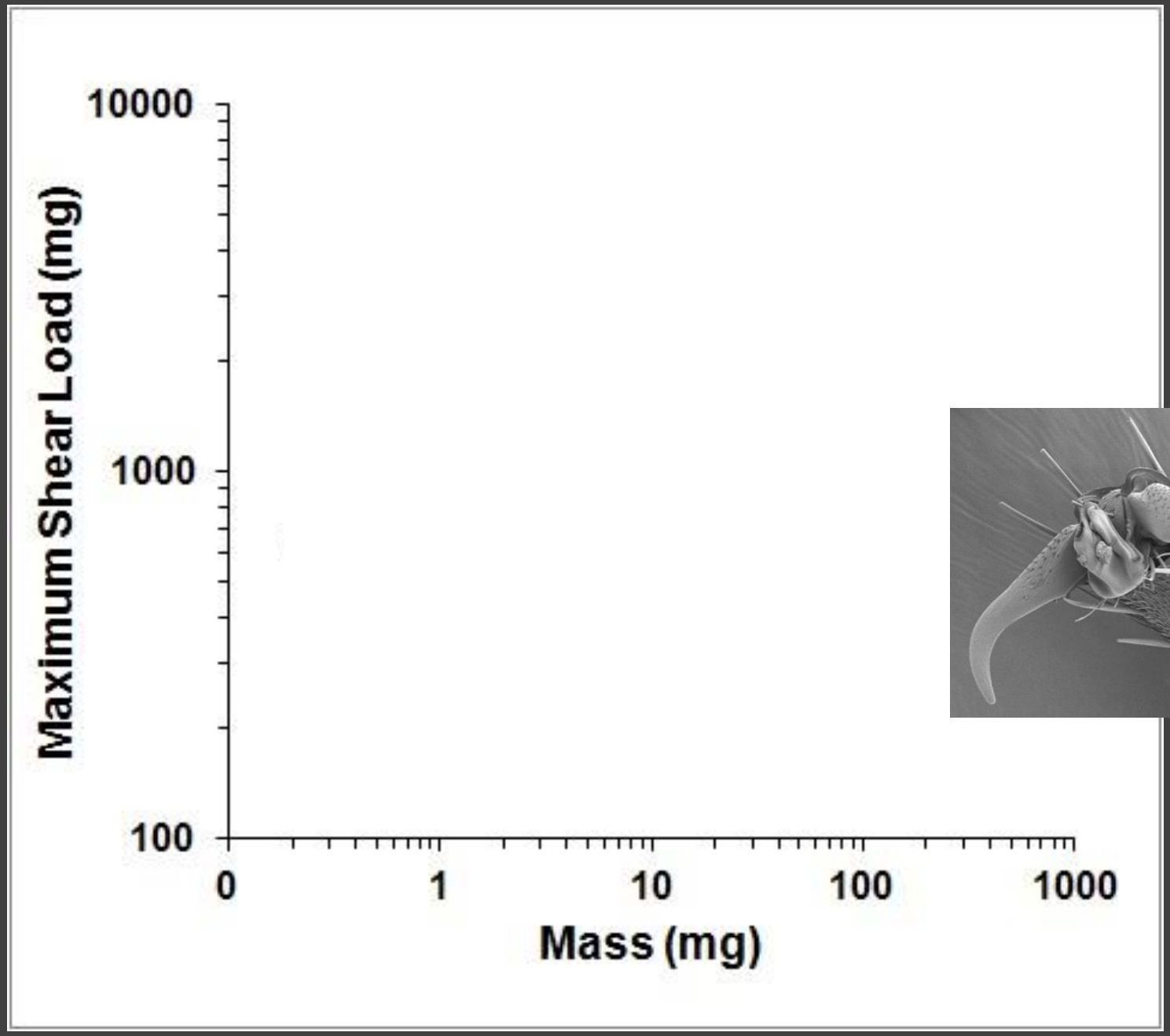
Bio-inspired Adhesives





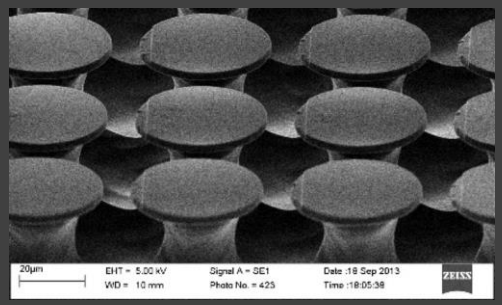


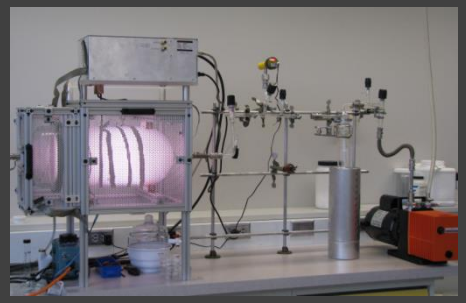




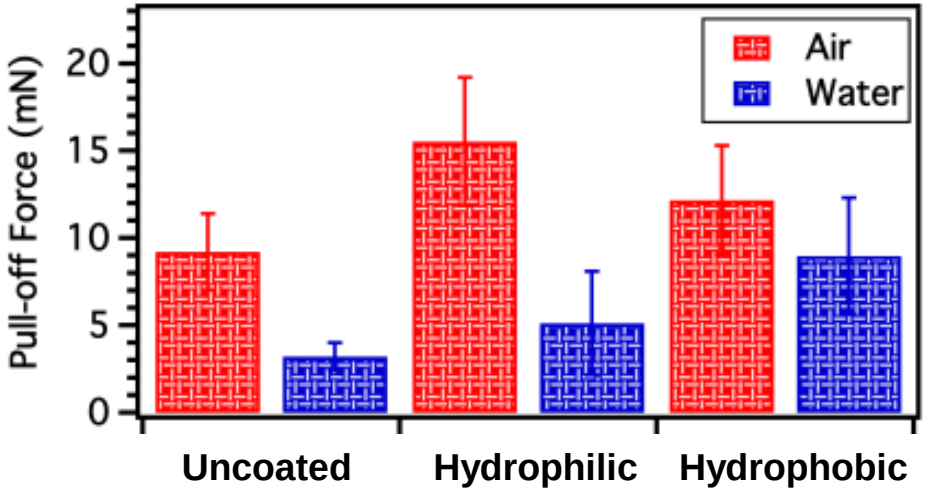
Stark et al., *in prep*

Adhesion in Air and Water

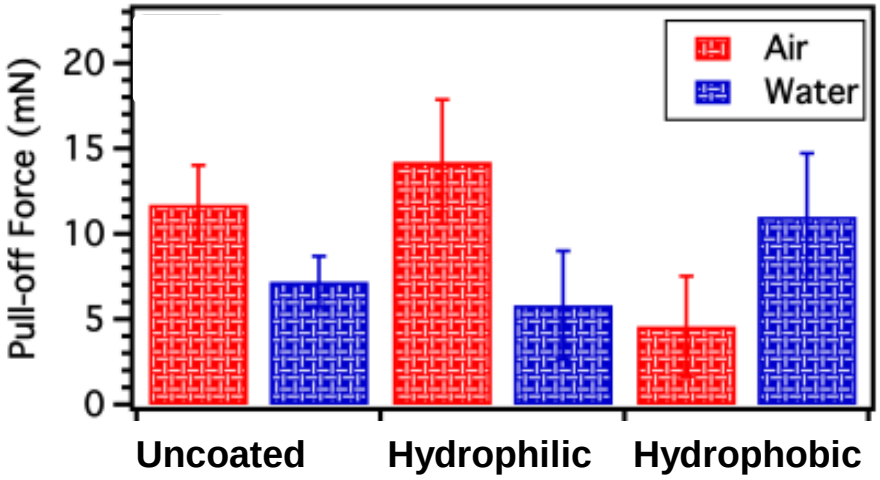




Hydrophilic Substrate

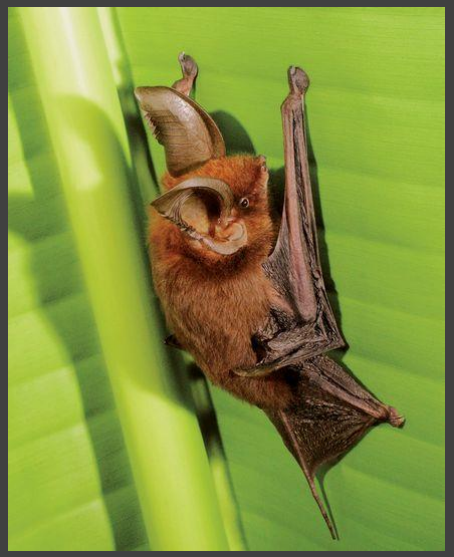


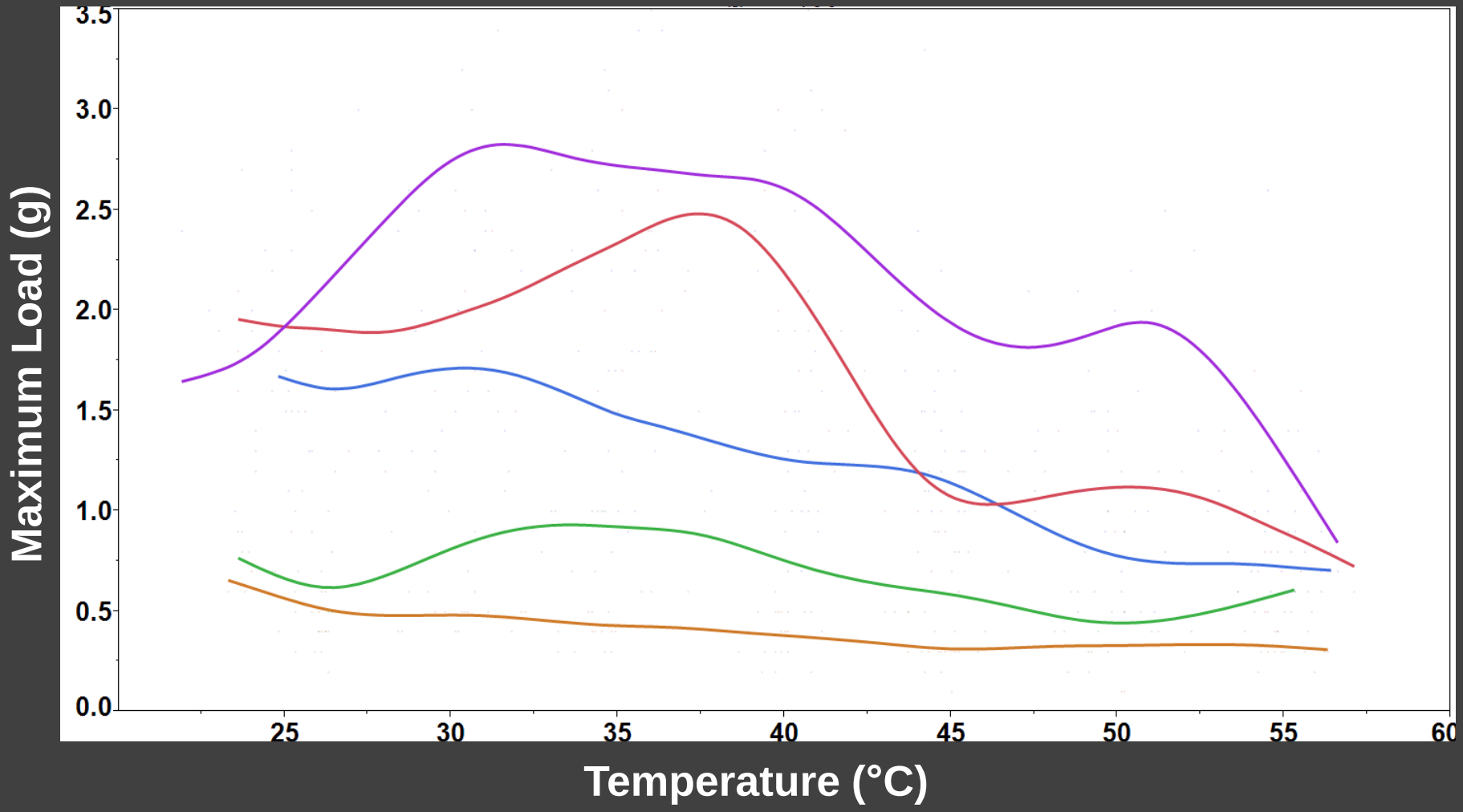
Hydrophobic Substrate



Singla et al., *in prep*

Biological Adhesives

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Temperature (°C)