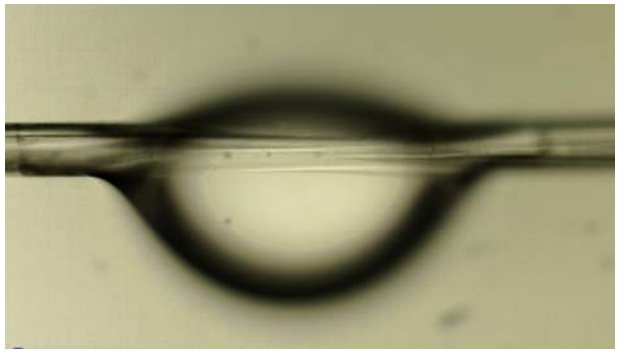
Bioinspired fiber-based micro and nanofluidics. Role of X-ray phase contrast imaging

Kostya Kornev

School of Materials Science and Engineering

Clemson University, SC



Nanofluidic applications of nanofiber yarns and webs

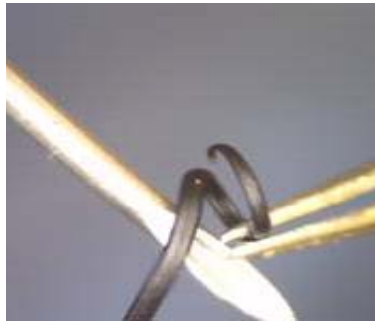
- Fiber-based probes:
  - biofluids from salivary glands, microcapillaries, sweat pores, etc..
  - aerosol droplets 1-10 μm
  - gaseous samples by capillary condensation
- Stimuli-responsive fibers

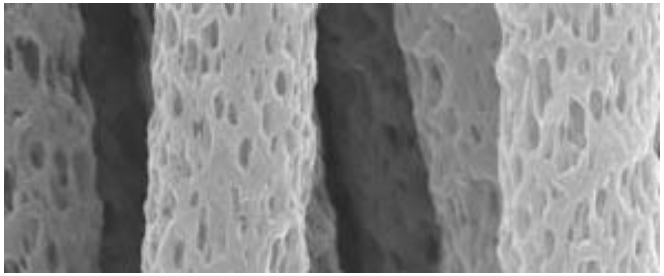
<u>Challenges:</u>

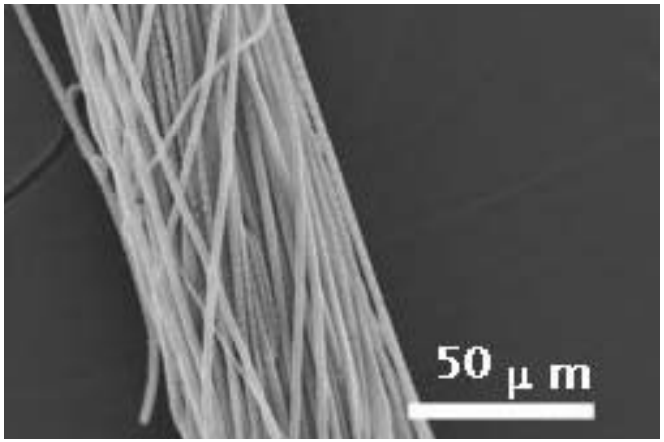
Fibers must be highly

porous,

strong, …

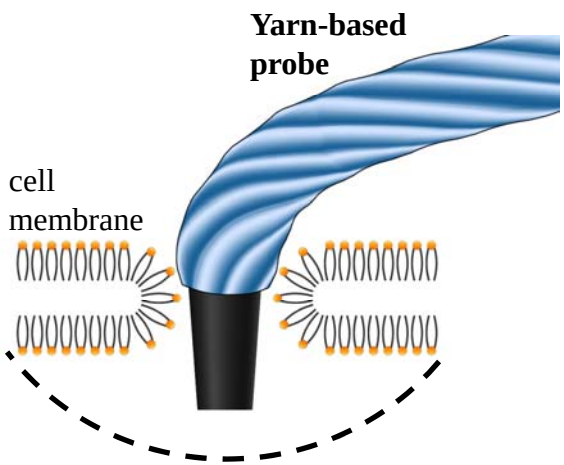


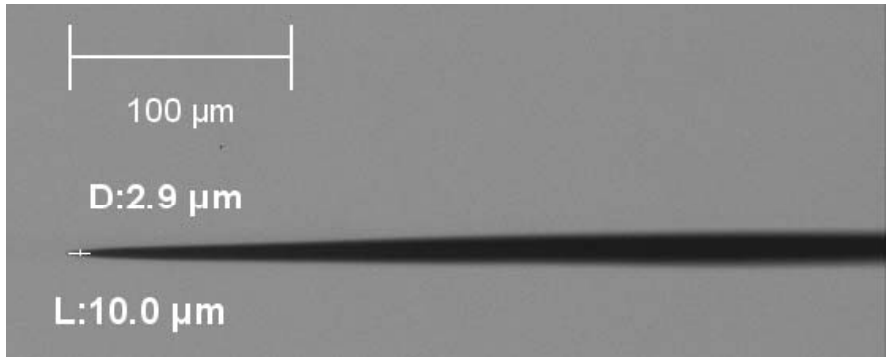


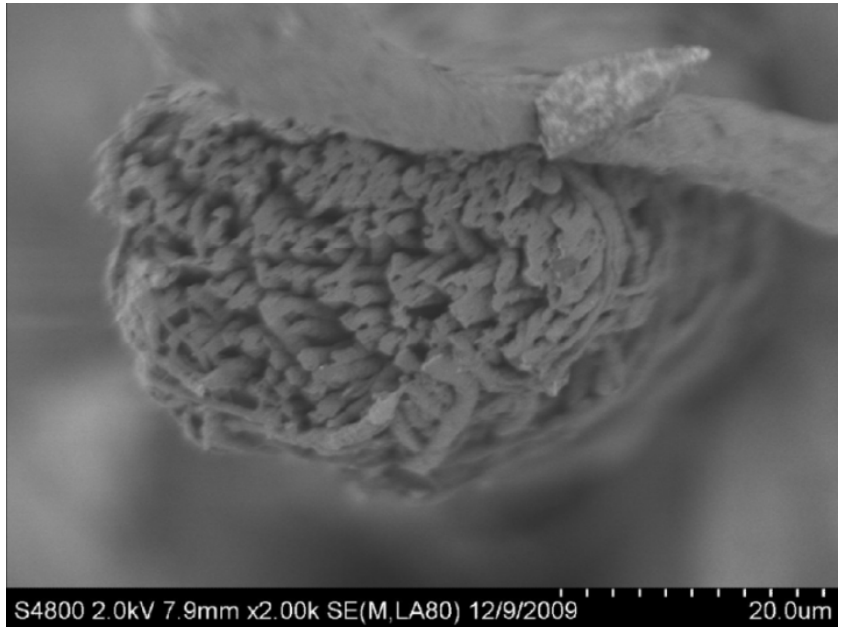


Applications of artificial proboscises

A nanoprobe which will pierce the cells and draw a biofluid from it.

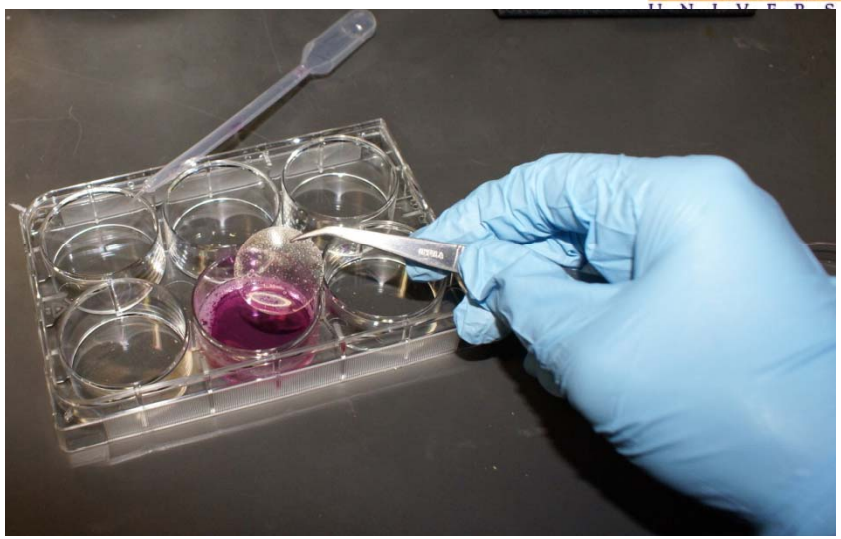


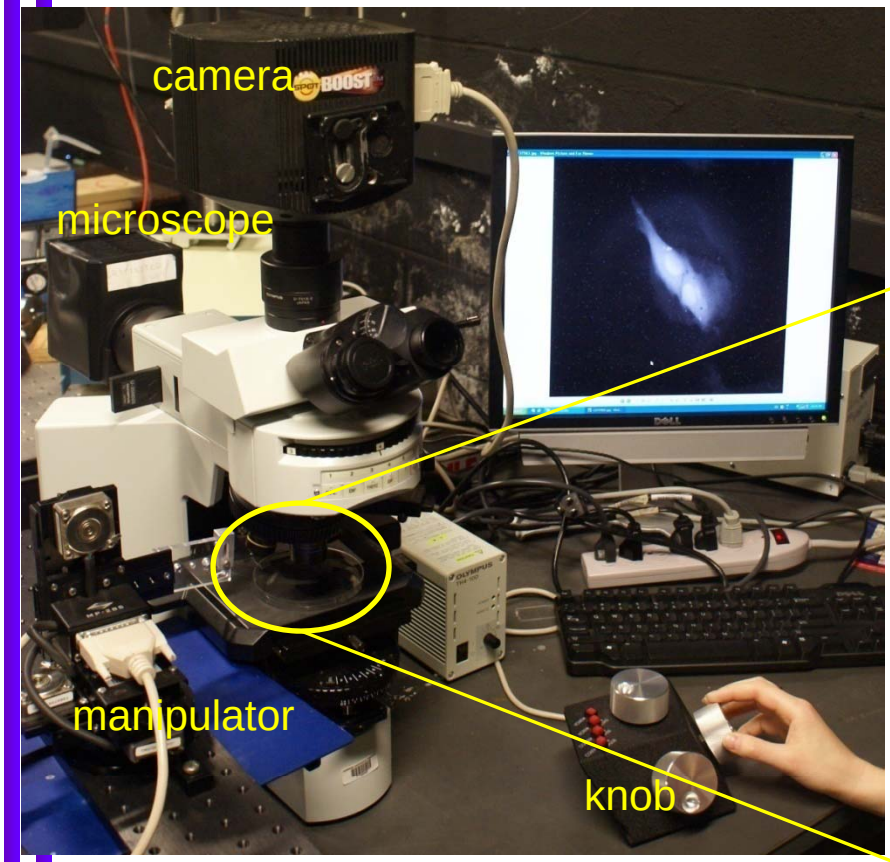


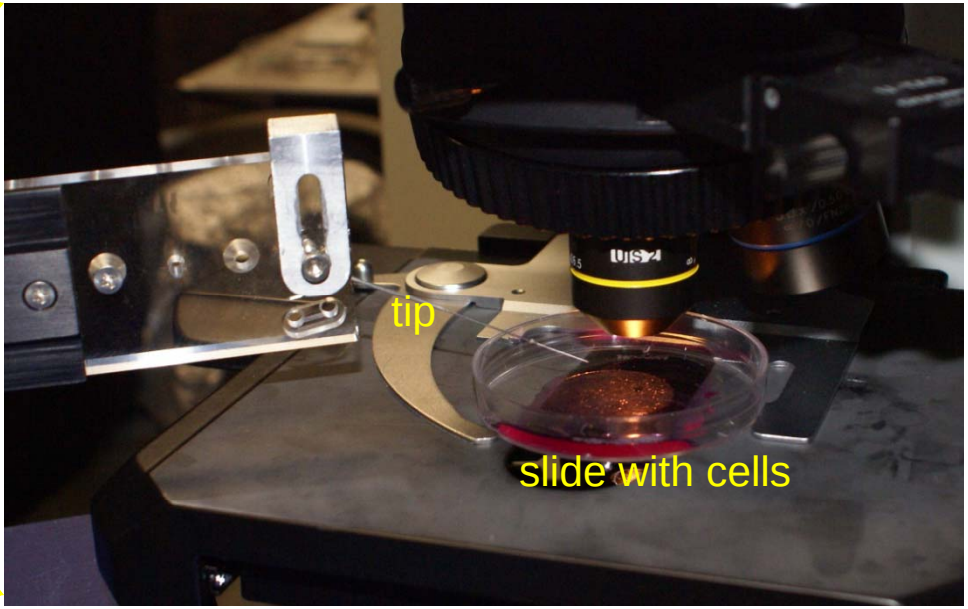


Set up for cells piercing

Medium: Dulbecco's Modified Eagle Medium with 4.5g/L glucose, L-glutamine and sodium pyruvate

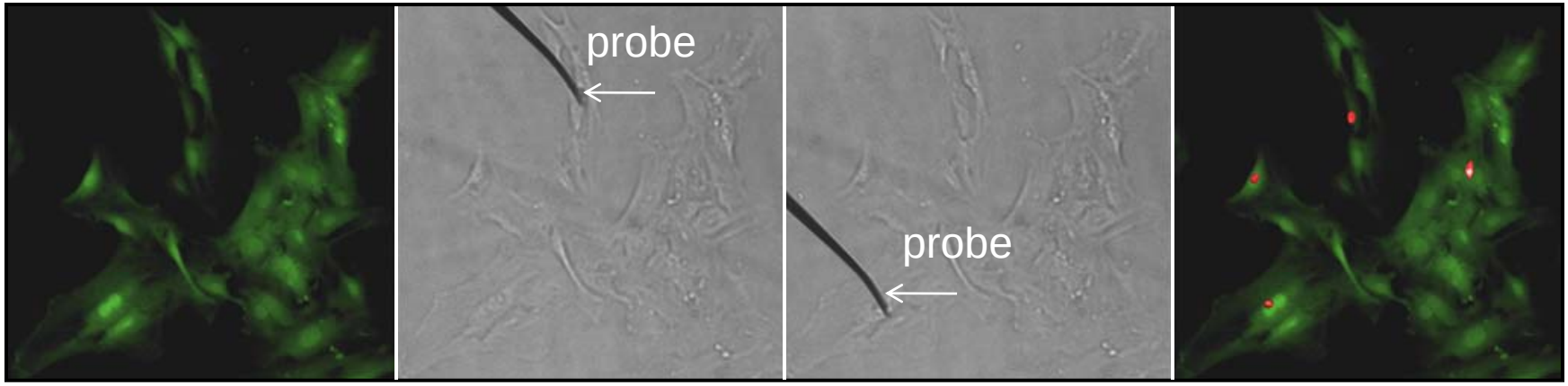




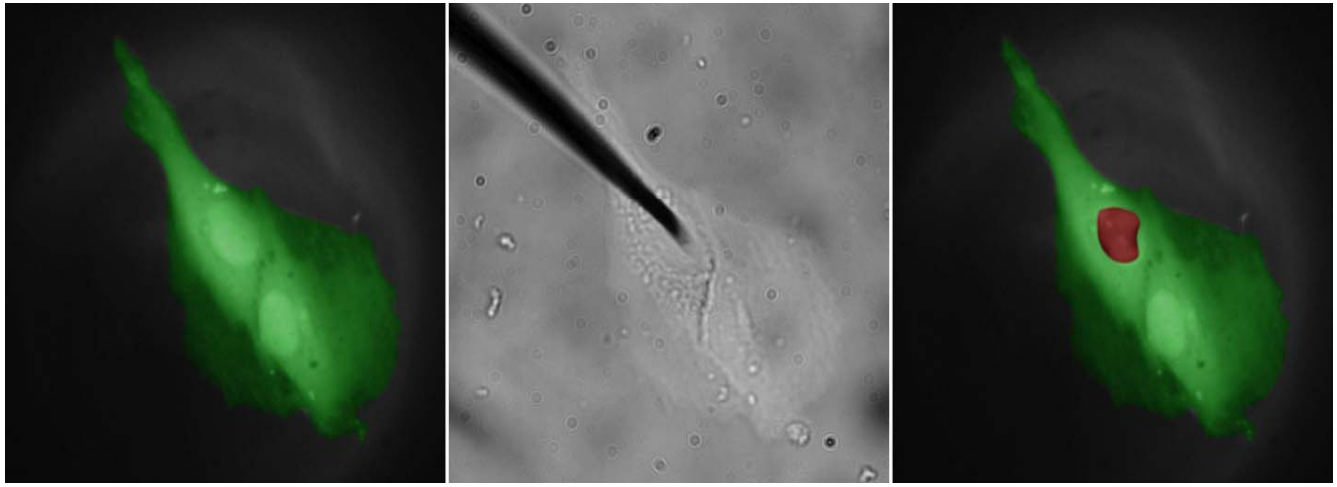


Fluorescence imaging of live-dead cells

Magnification 10



Magnification 50

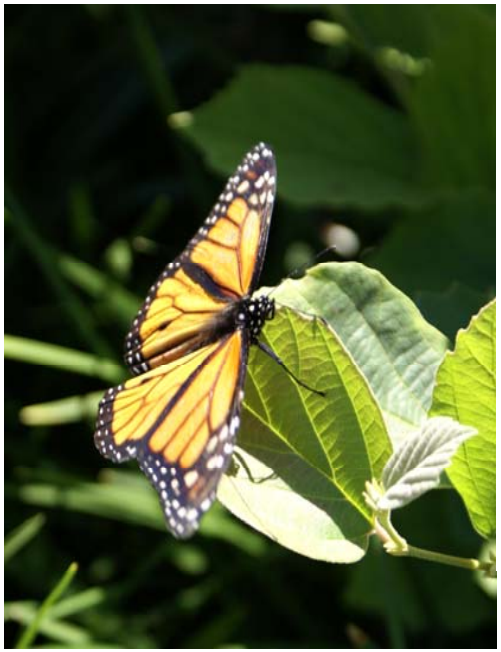


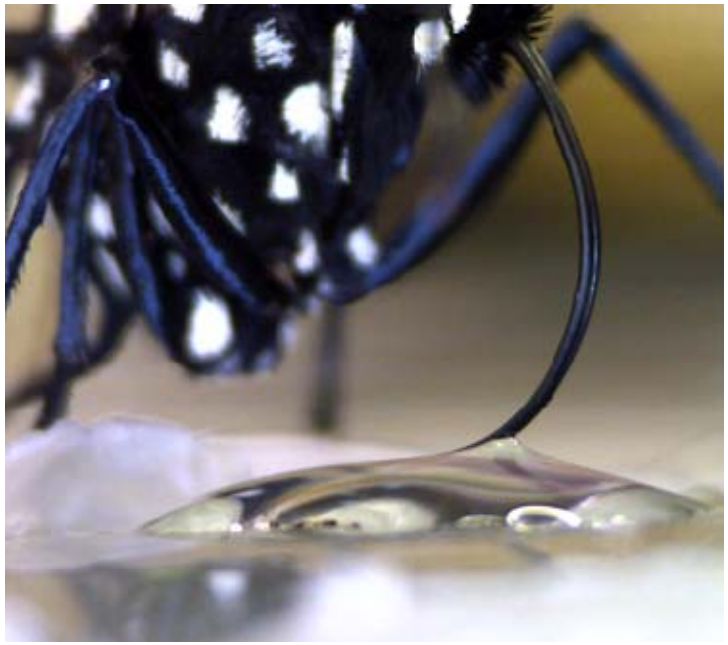
Outline

- Mechanisms of fluid absorption and delivery: lessons from Nature
- Artificial proboscises

What can we learn from Nature?

Courtesy of Dr.P.Adler (1987)



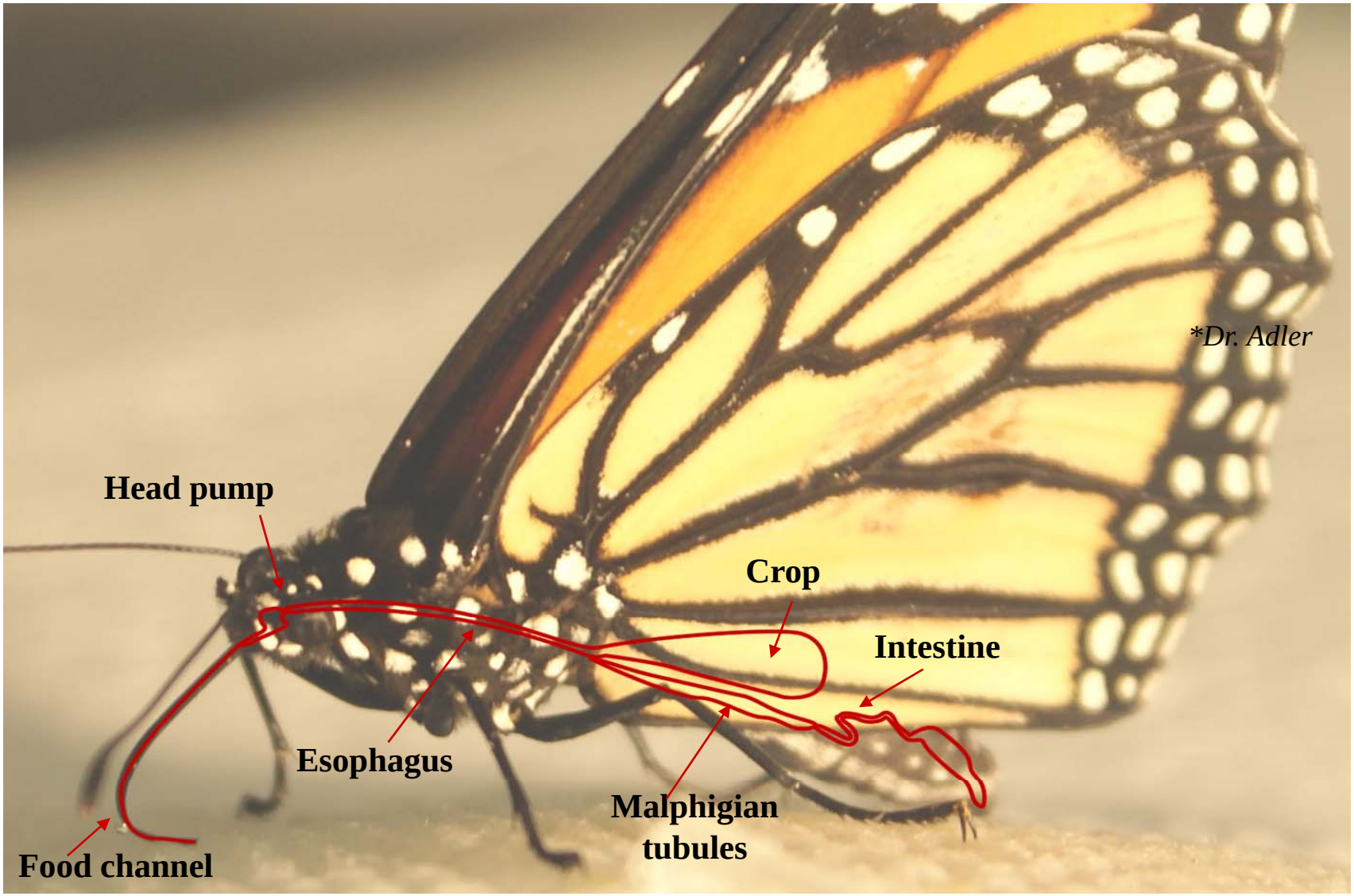


NSF EFRI: Lepidoptera proboscises as prototypes of multifunctional micro and nanofluidic devices

distributed actuation, sensing, superior flexibility, and maneurability + superior suction action +…

Objectives

- Determine the role of dorsal linkage in feeding process



Feeding from porous materials

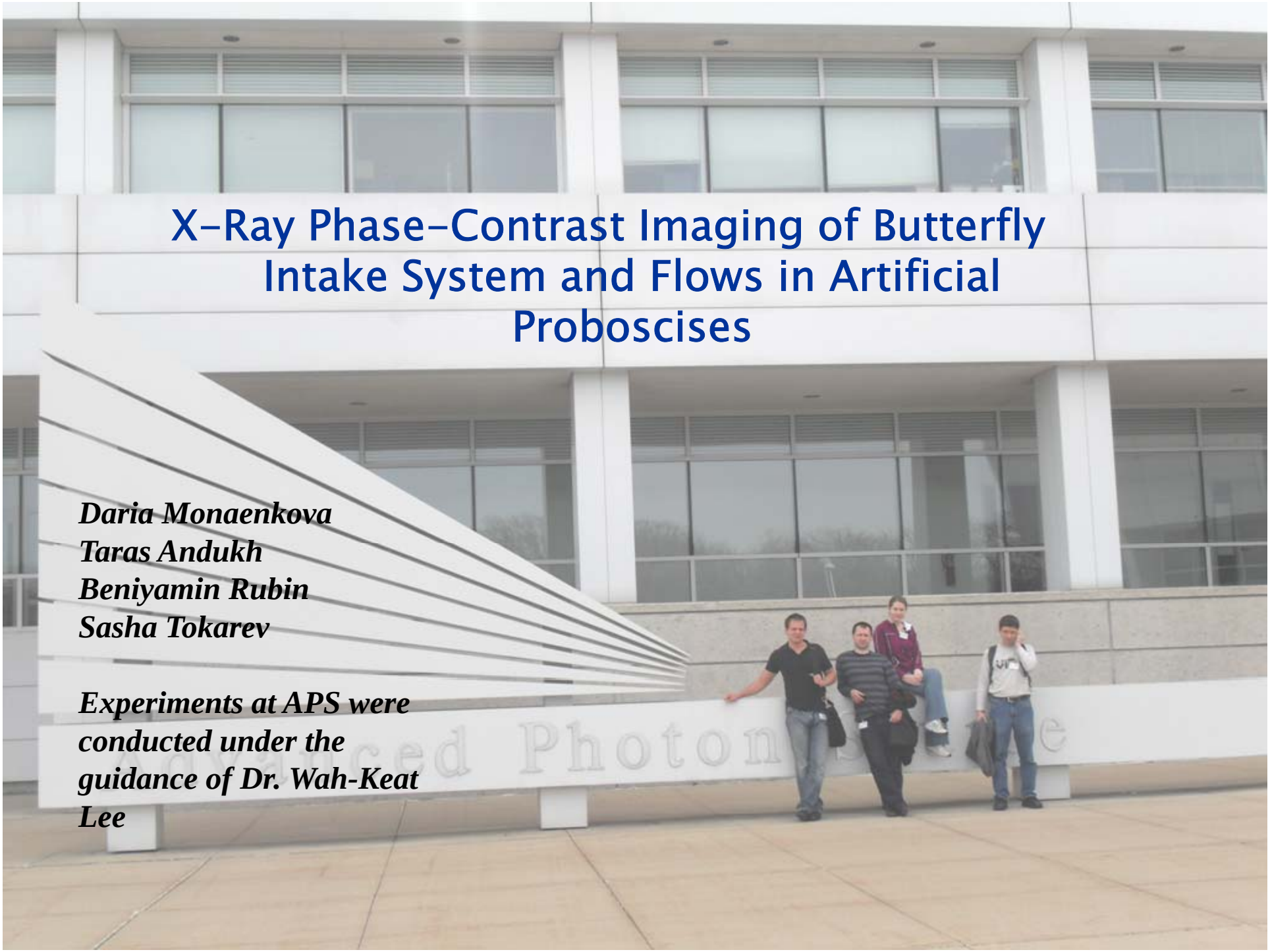
Butterflies and moths are often seen on **porous substrates** like wet soil or dung where they feed to obtain nutrients such as salts and amino acids.

Puddling imitation

X-Ray Phase-Contrast Imaging of Butterfly Intake System and Flows in Artificial Proboscises

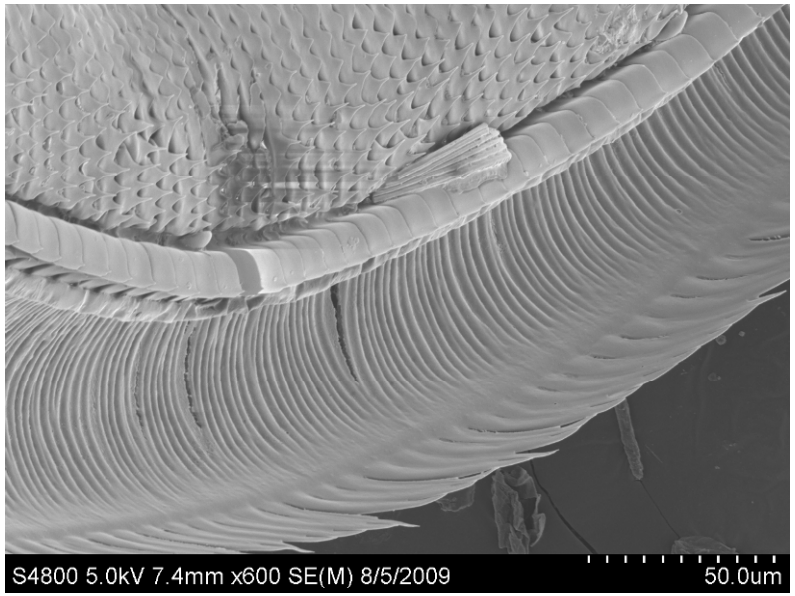
Daria Monaenkova
Taras Andukh
Beniyamin Rubin
Sasha Tokarev

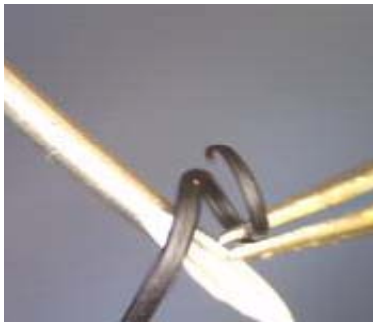
Experiments at APS were conducted under the guidance of Dr. Wah-Keat Lee

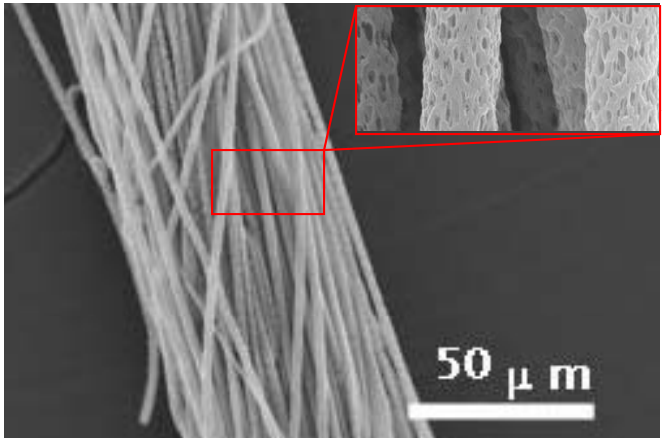


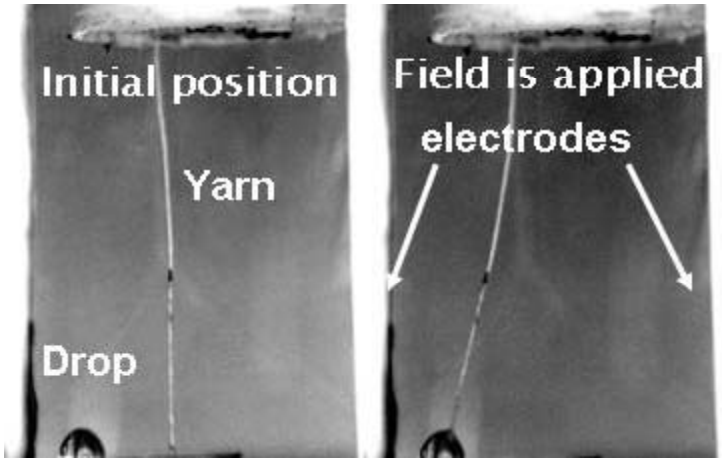
- **Artificial proboscises**

Artificial proboscises









- Stimuli-responsive fibers and yarns

<u>Challenges:</u>

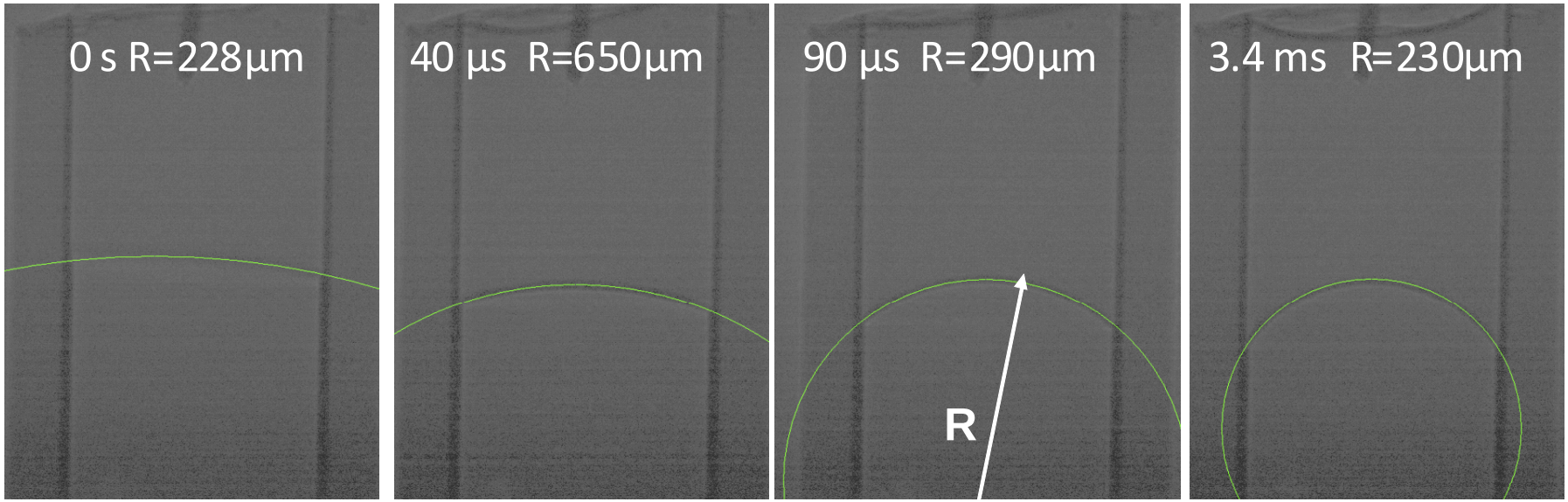
Fibers must be highly

porous,

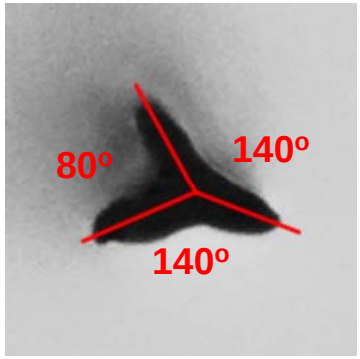
strong,

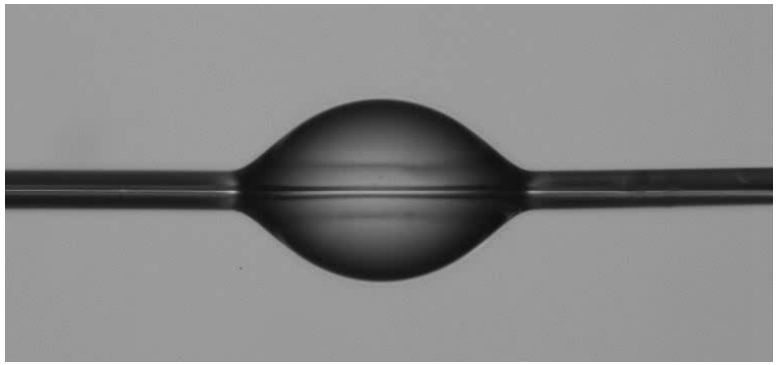
and field reactive

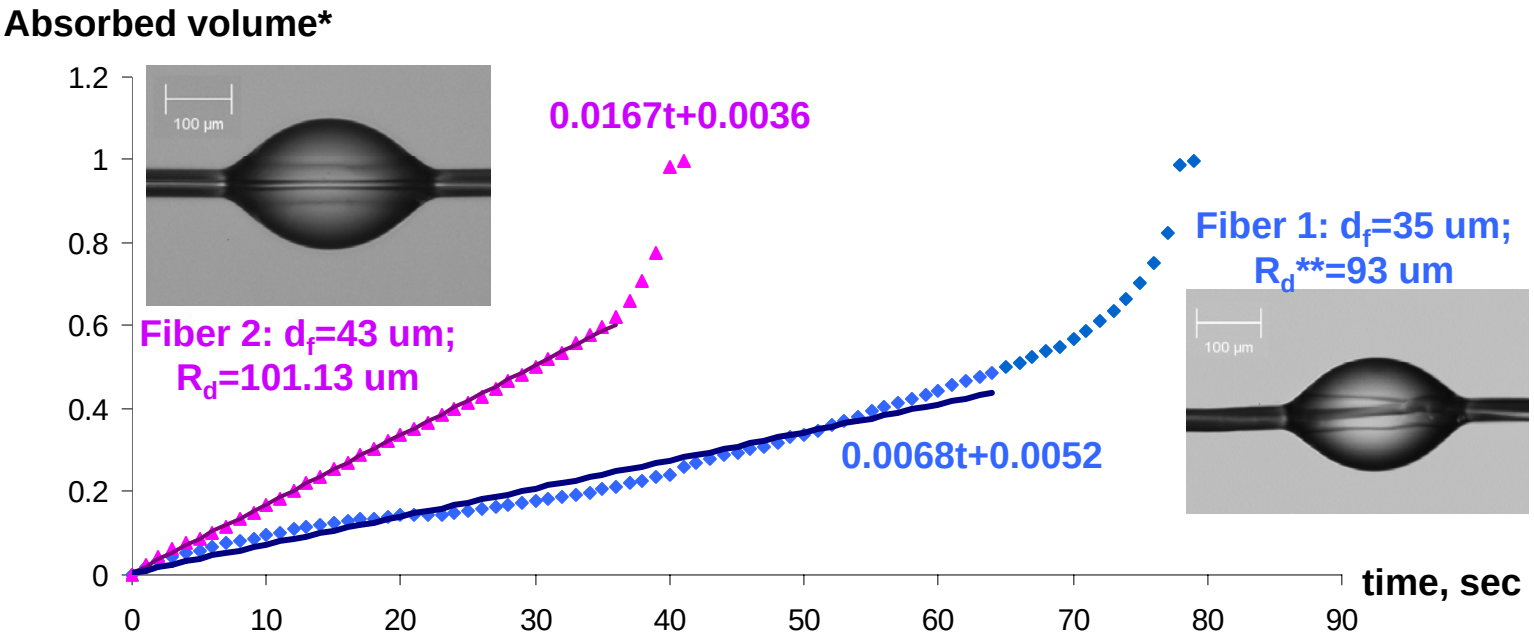
Fast flows or flows in insect's world



Absorption by trilobal fibers: Hexadecane



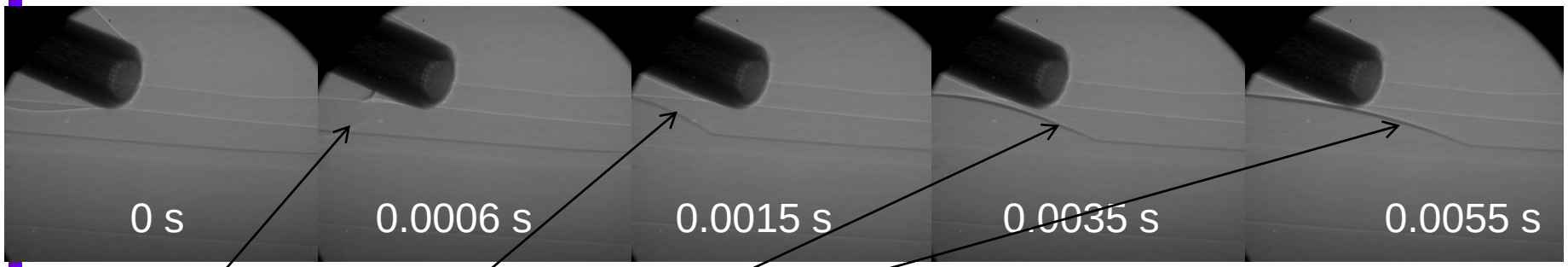




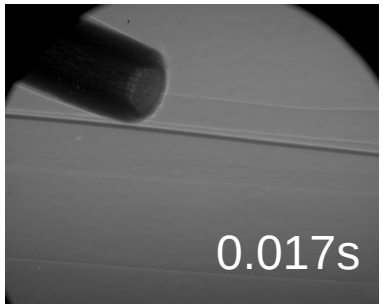
*The values of absorbed volume are normalized by the initial volume of the drop, ** Maximum Radius measured from the center of the yarn

Wicking in shaped fibers: X-ray phase contrast imaging

The droplet is smaller than the fiber size

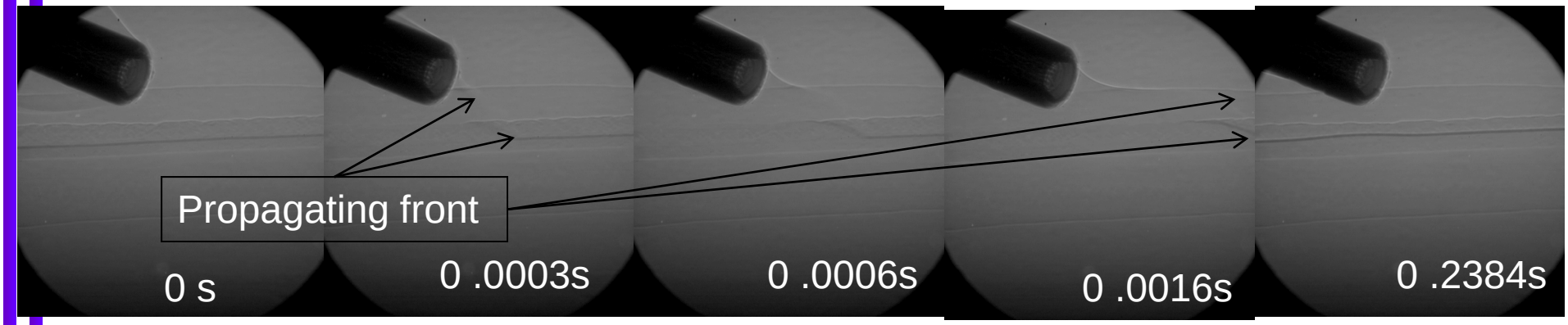


Propagating contact line



Diameter of the fiber is 650µm

Big droplet larger than the fiber diameter



Mimicking the Nature: Fiber based microprobe

Material Science & Engineering
CLEMSON UNIVERSITY

- Fluid probing and delivery using capillary action

Nanometer pores: high suction pressure ⇒

+ strong driving force for absorption, good retention ability
- very slow flow

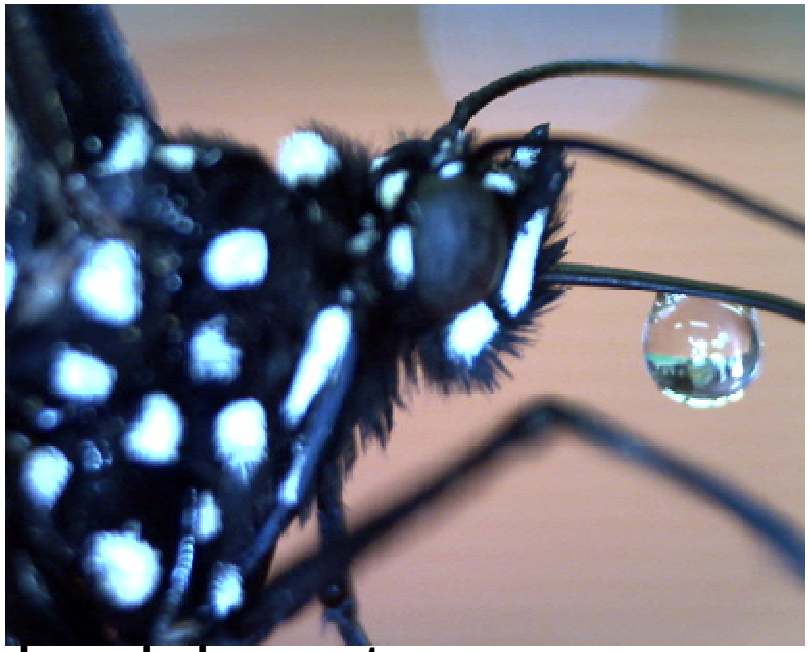
Tens of micrometer pores,

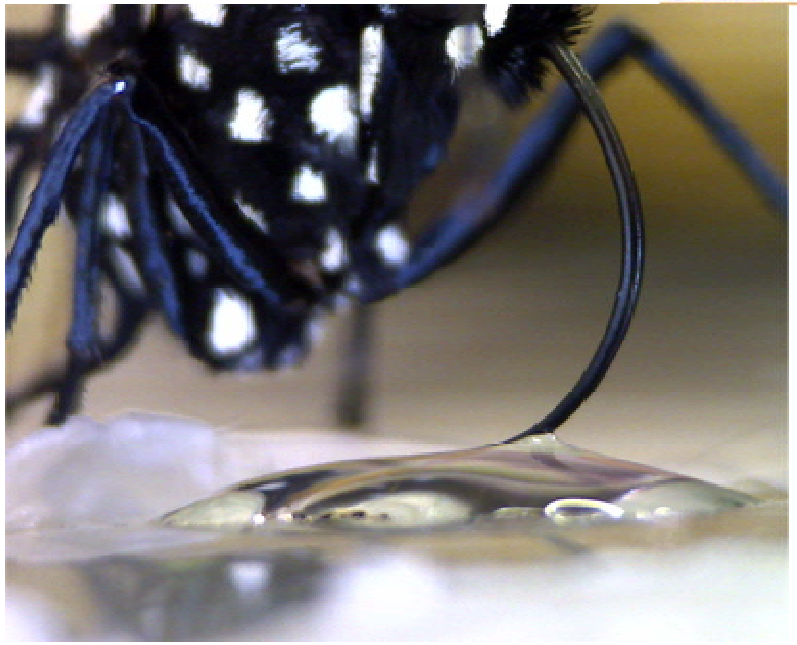
- low retention ability
+ very fast flow

Challenges

- **Visualization of moving menisci and contact lines simultaneously with the feeding droplet (micron and submicron + hundred microseconds resolution)**
- **Visualization of moving menisci and contact lines at the nanometer scale of nanofibers and nanochannels (100 nm – few micrometers)**
- **Fast focus switching**
- **X-ray tomography of hierarchical porous structures and live insects**
- **IMAGING FLOWS IN SINGLE CELLS**

Thank you for your attention!





Acknowledgements:

PhD students: Daria Monaenkova, Taras Andrukh, Sasha Tokarev, Maryana Kovalchuk, Chen-Chih Tsai, Monte Bedford, Vijoya Sa, Yu Gu

HS students: Caleb Clipovitz, Kara Edwards, Campbell Yore, Steven Rea
Post Doc: Dr. Benya Rubin