Self-assembled surface reservoirs for ultra-stretchable membranes

Elasto-capillarity for hybrid mechanical properties

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Self-assembled **fiber** reservoirs

Fiber reservoirs?

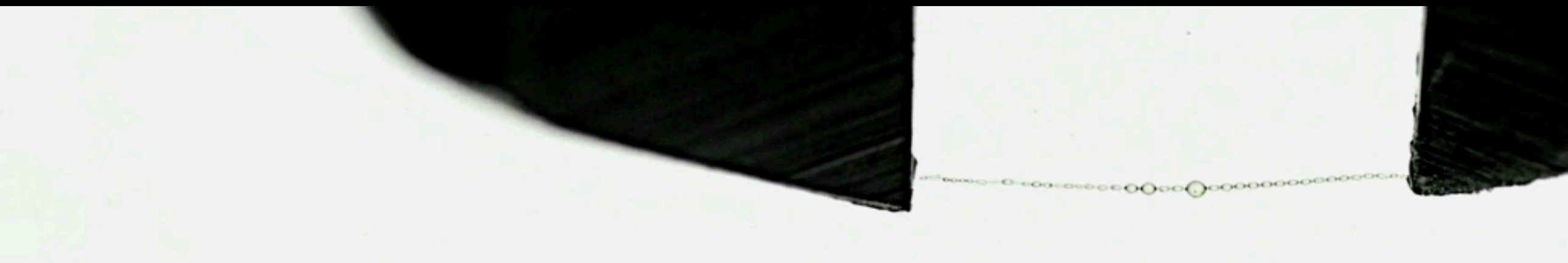
Biological inspiration

Nephila
golden orb weaver

Interesting properties
of its capture silk

Nephila capture silk

Its highly compressible property



H. Elettro *et al.*
PNAS - 2016

Nephila spider capture silk **thread** coated with small water **droplets**.
Throughout the **compression**, the fiber **does not sag**,
it remains under **tension**.

Video credit: Hervé Elettro

Nephila capture silk

A closer look inside the droplets

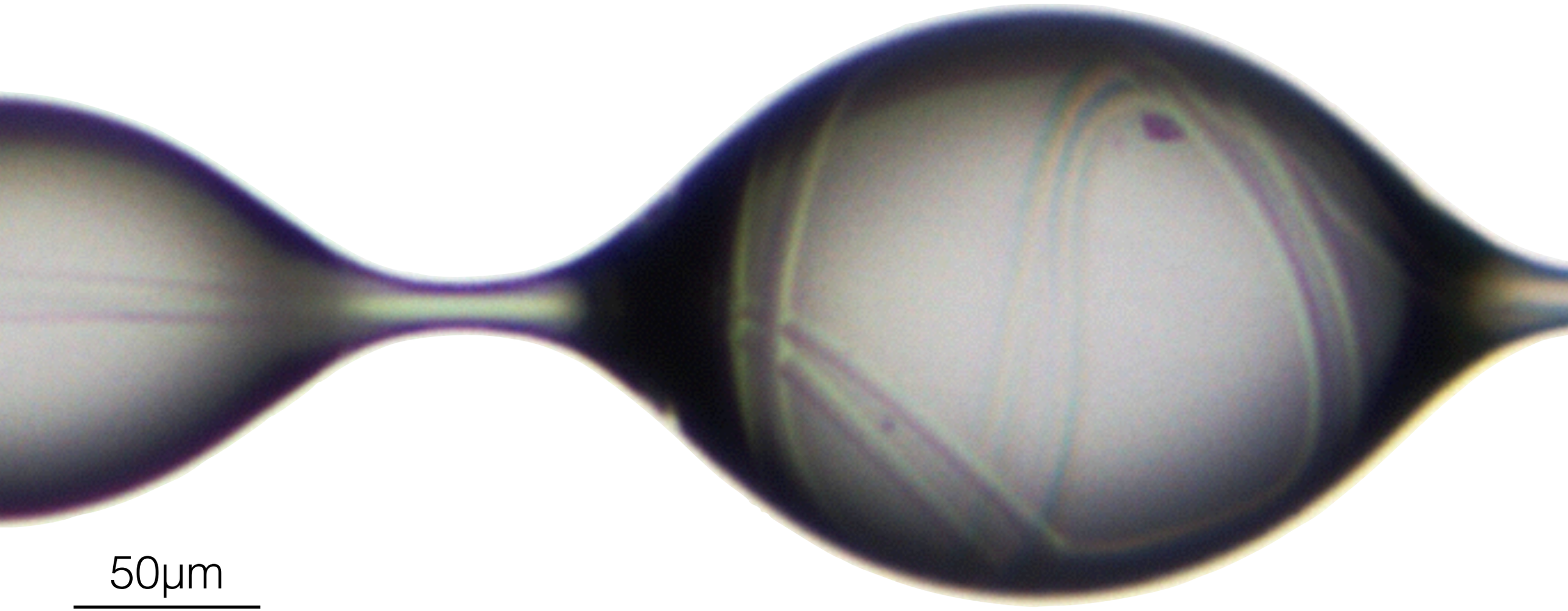
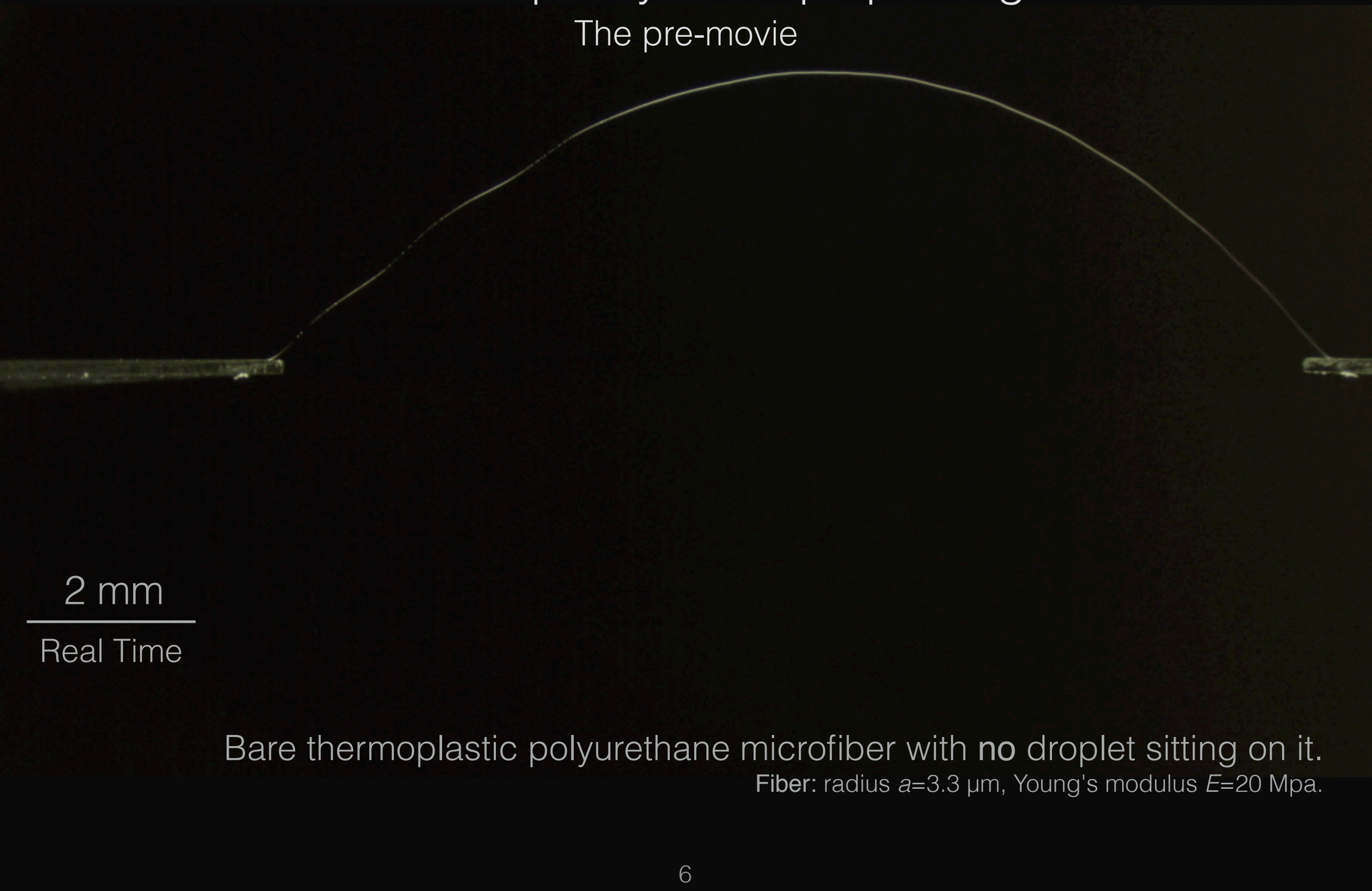


Photo: H. Elettro

During the **compression**,
the thread **spools** inside the water **droplets**.

Elastocapillary in-drop spooling

The pre-movie

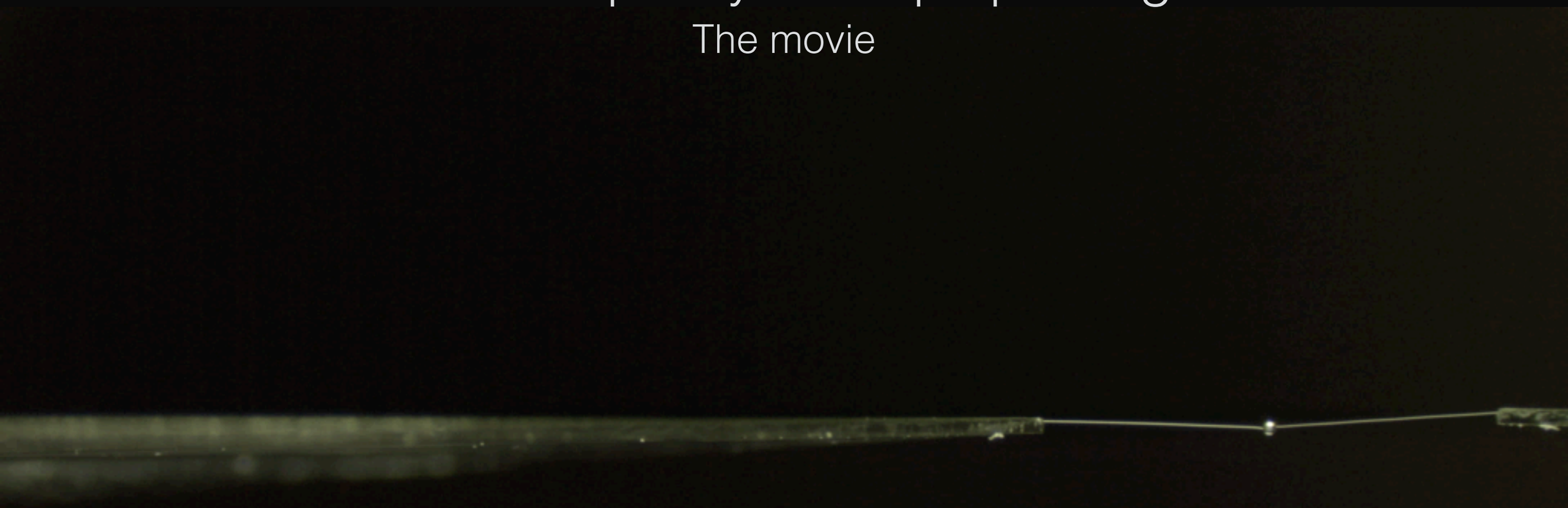


Bare thermoplastic polyurethane microfiber with **no** droplet sitting on it.

Fiber: radius *a*=3.3 μm, Young's modulus *E*=20 Mpa.

Elastocapillary in-drop spooling

The movie



2 mm

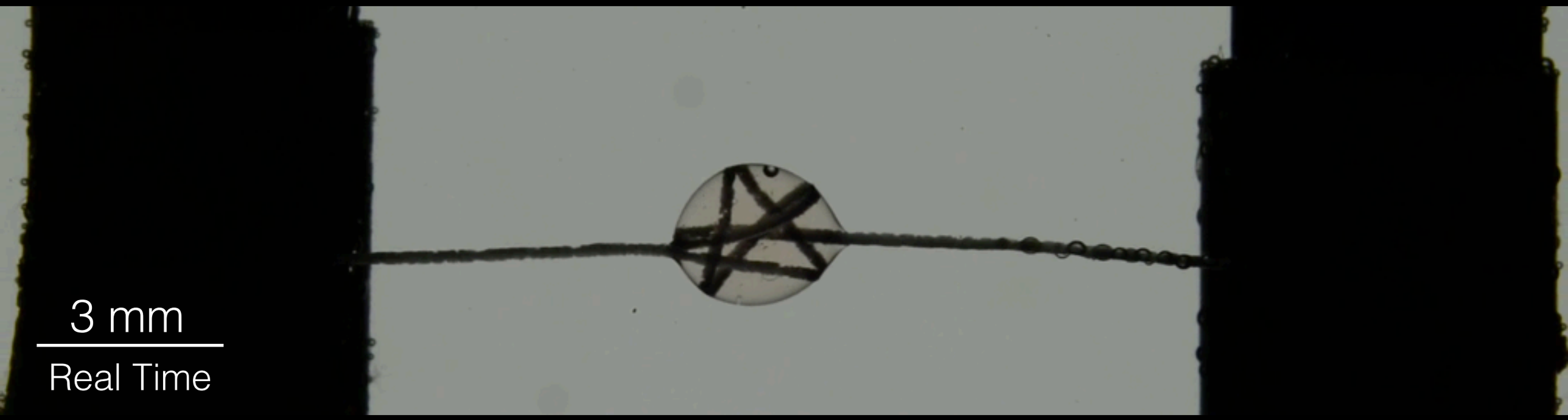
Real Time

Silicone oil **droplets** on said thermoplastic polyurethane **microfiber.**
An artificial ultra **compressible/extensible** device.

Fiber: radius a=3.3 µm, Young's modulus E=20 Mpa.
Final droplet : radius R=106 µm, γ=21 mN/m.

Elastocapillary in-drop spooling

The immersed movie



Silicone oil **droplet** on a RTV (silicone polymer) fiber.
The system is **immersed** in a water bath.

Fiber: radius $a \approx 35$ µm, Young's modulus E≈1 Mpa.
Droplet : radius $R = 1.5$ mm, $\Delta\gamma \approx 40$ mN/m.

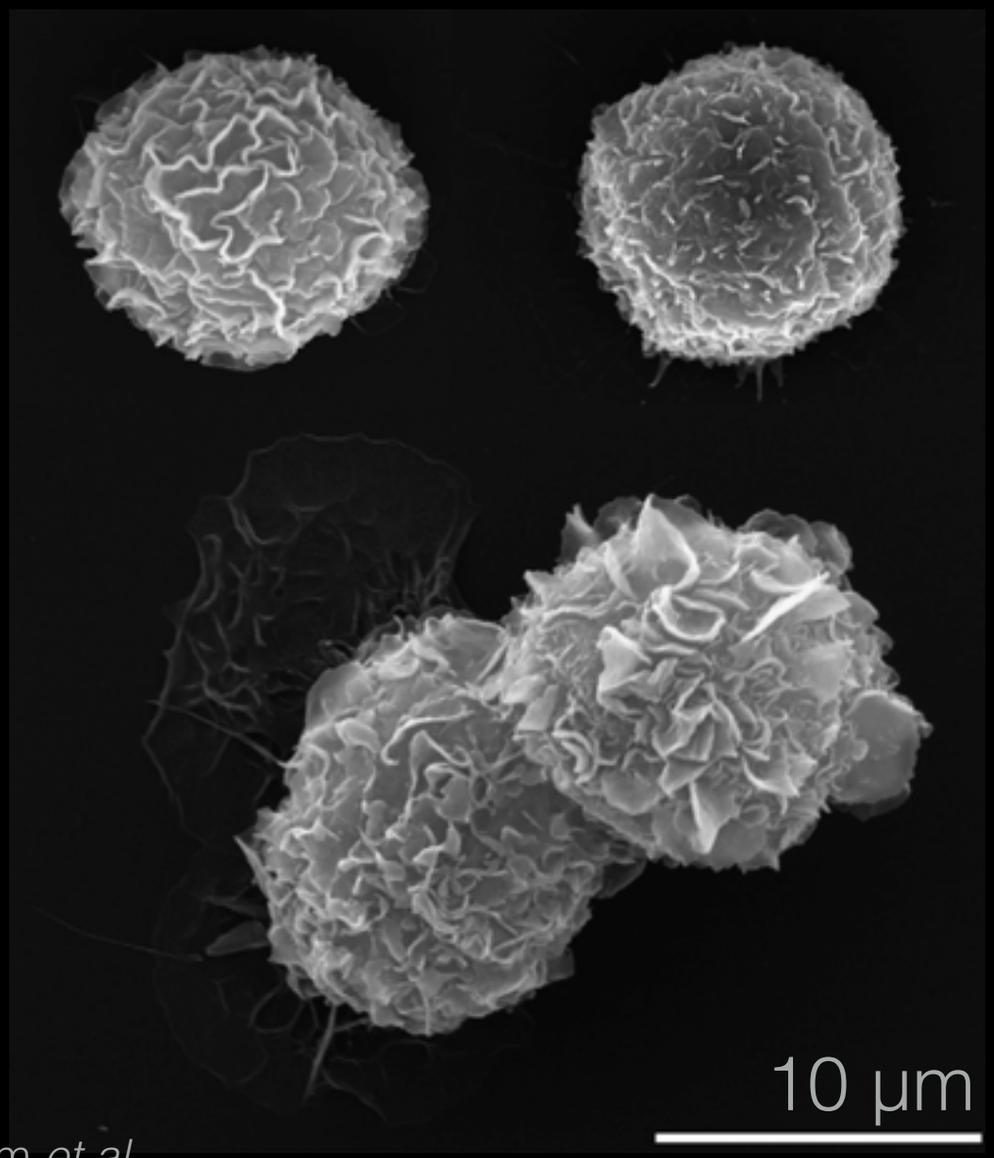
H. Elettro *et al.* PNAS (2016)

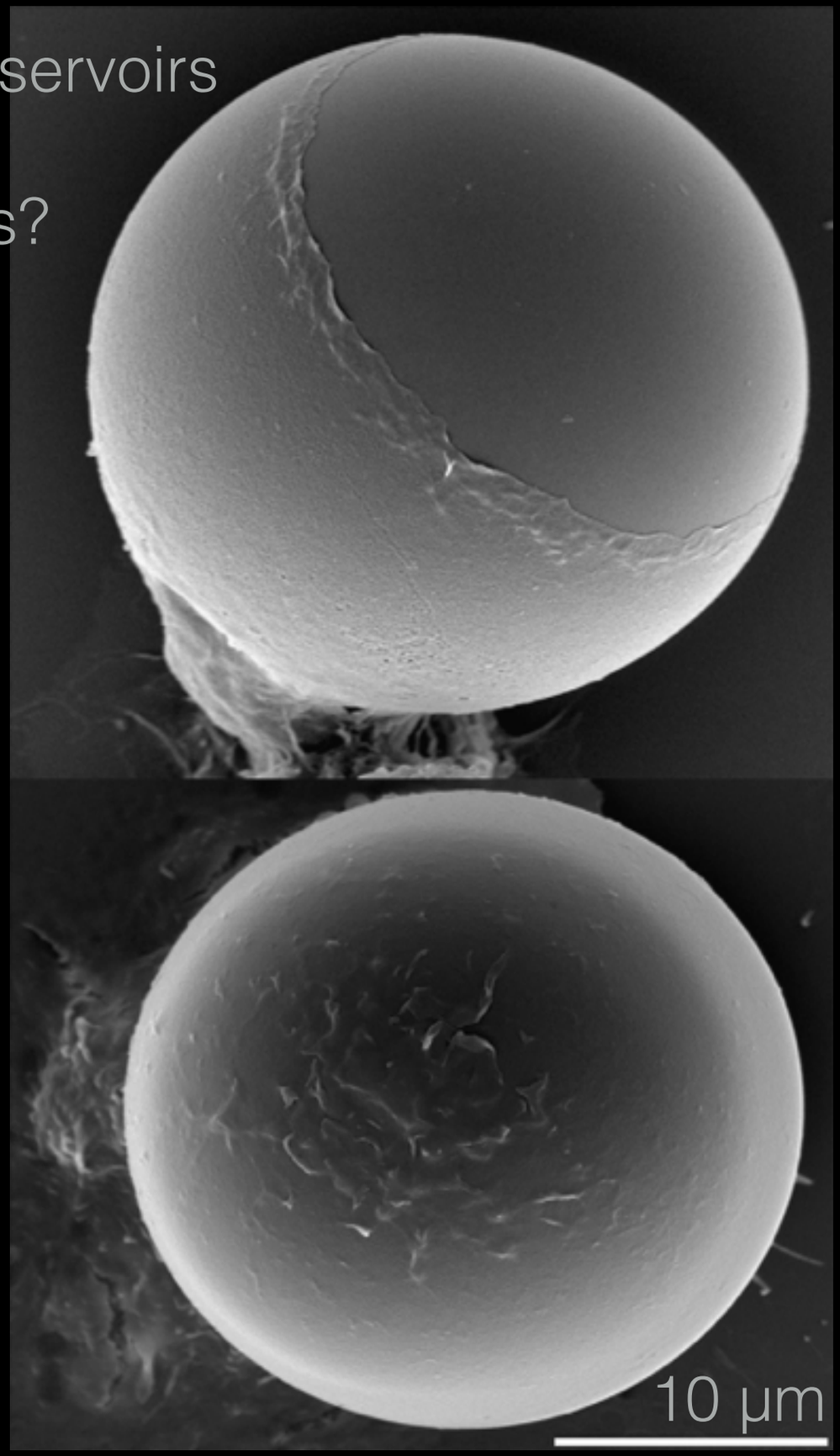
RD. Schulman *et al.* **Soft Matter** (2017)

P. Grandgeorge *et al.* **Adv. in Col. and Interfaces** (2017 in press)

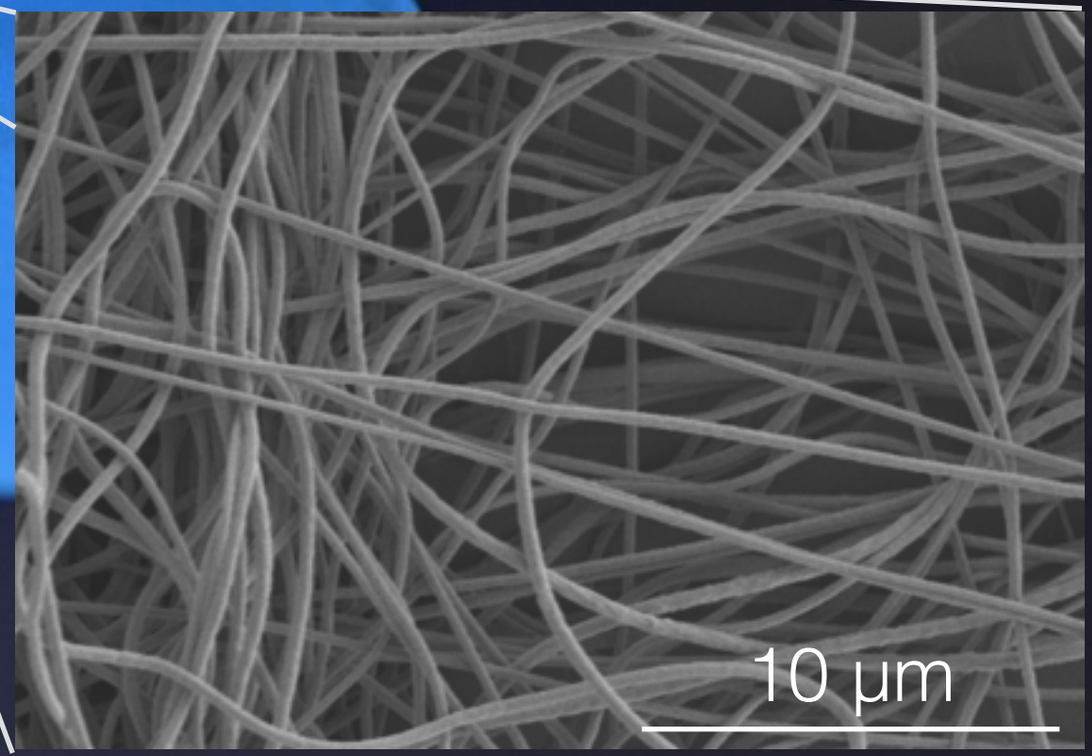
Can we extend the **1D fiber** reservoirs to **2D membrane** reservoirs?

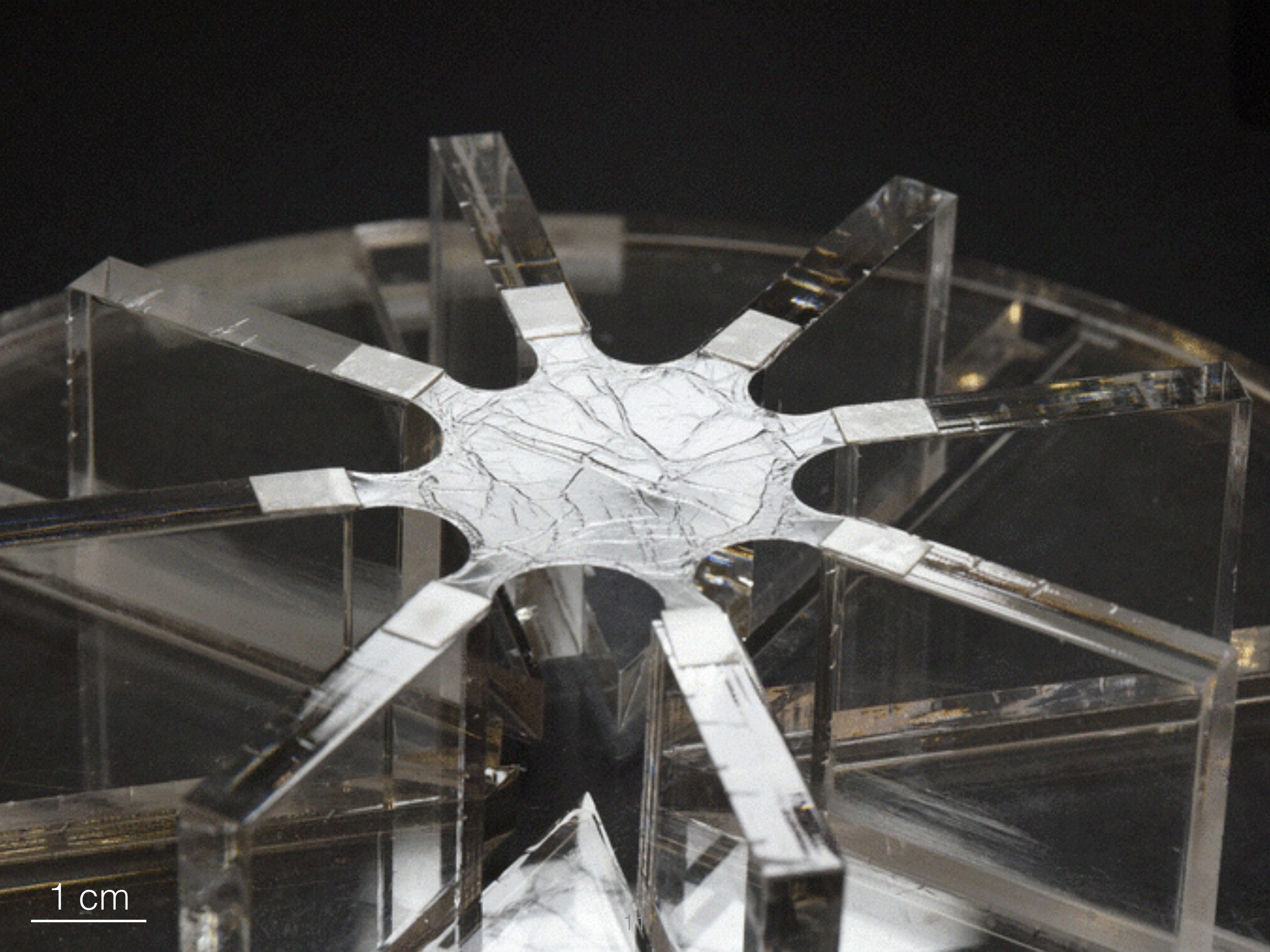
Surface reservoirs in **macrophages** (J774 cell)





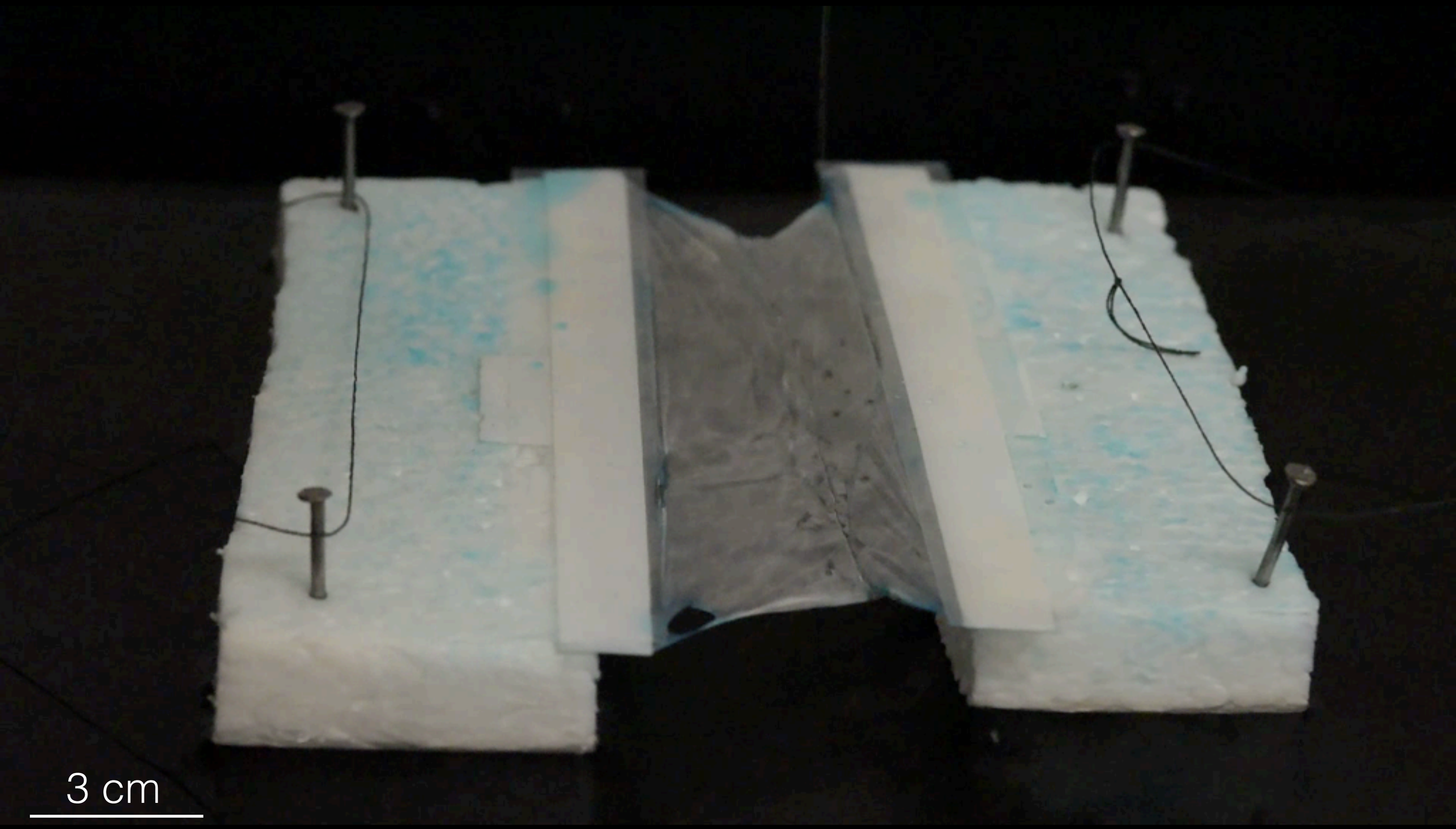
Lam *et al.*
Biophysical journal (2009)


10 µm


1 cm

What are the **forces** at stake?

Forces ?



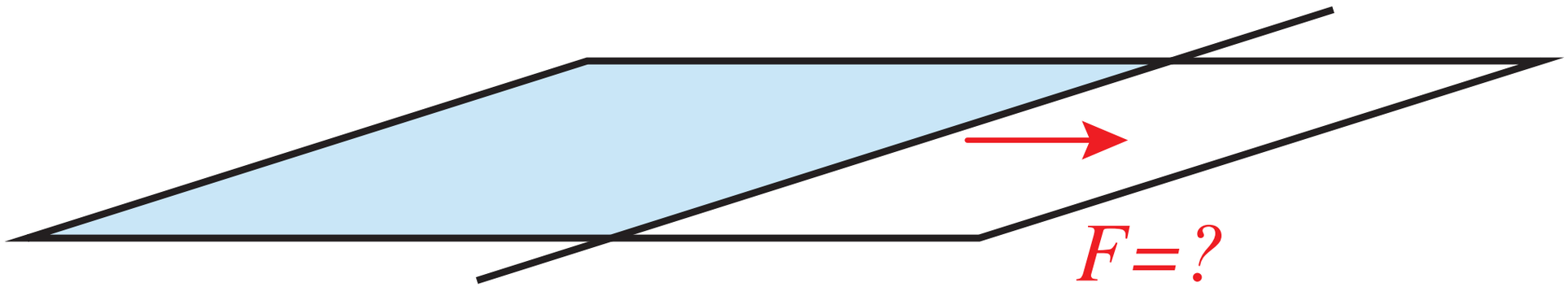
Closer view

0.5 cm

Real Time

Liquid soapy film

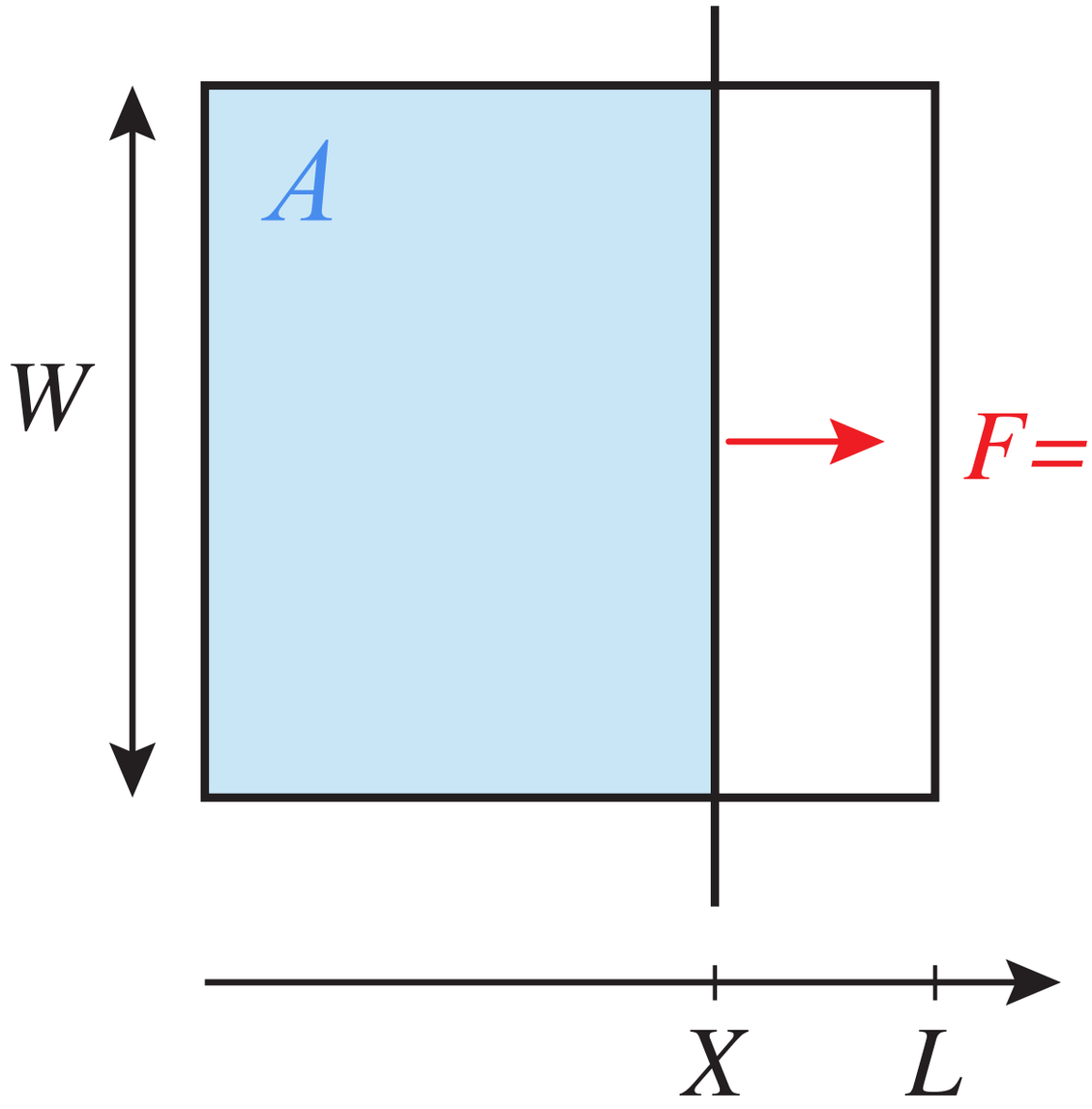
The archetypical liquid object



Liquid film on a frame

Liquid soapy film

A simple model



$$F = \frac{\partial E}{\partial X}$$

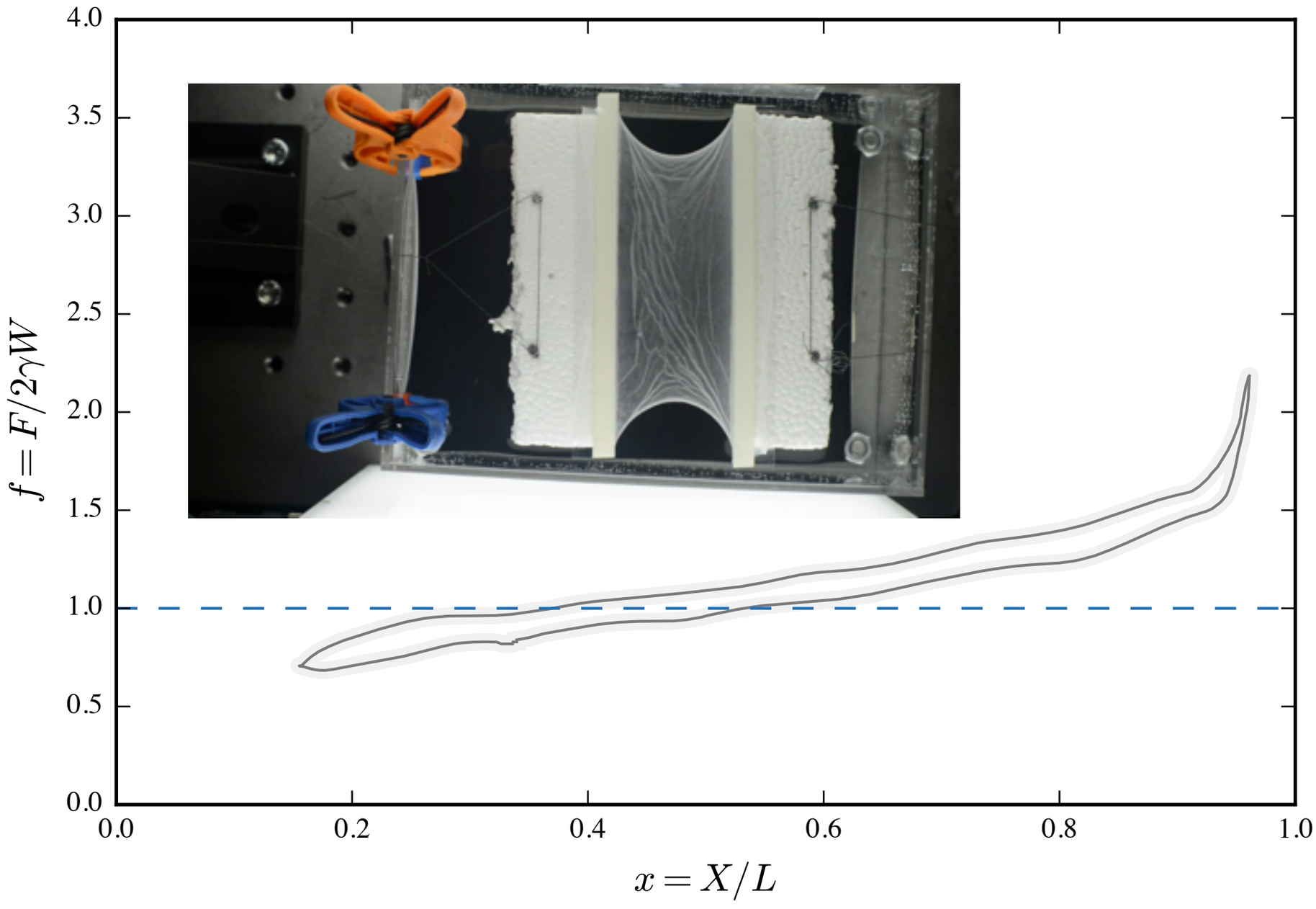
$$E = 2\gamma A$$

$$A = W X$$

$$F = 2W\gamma$$

Liquid soapy film

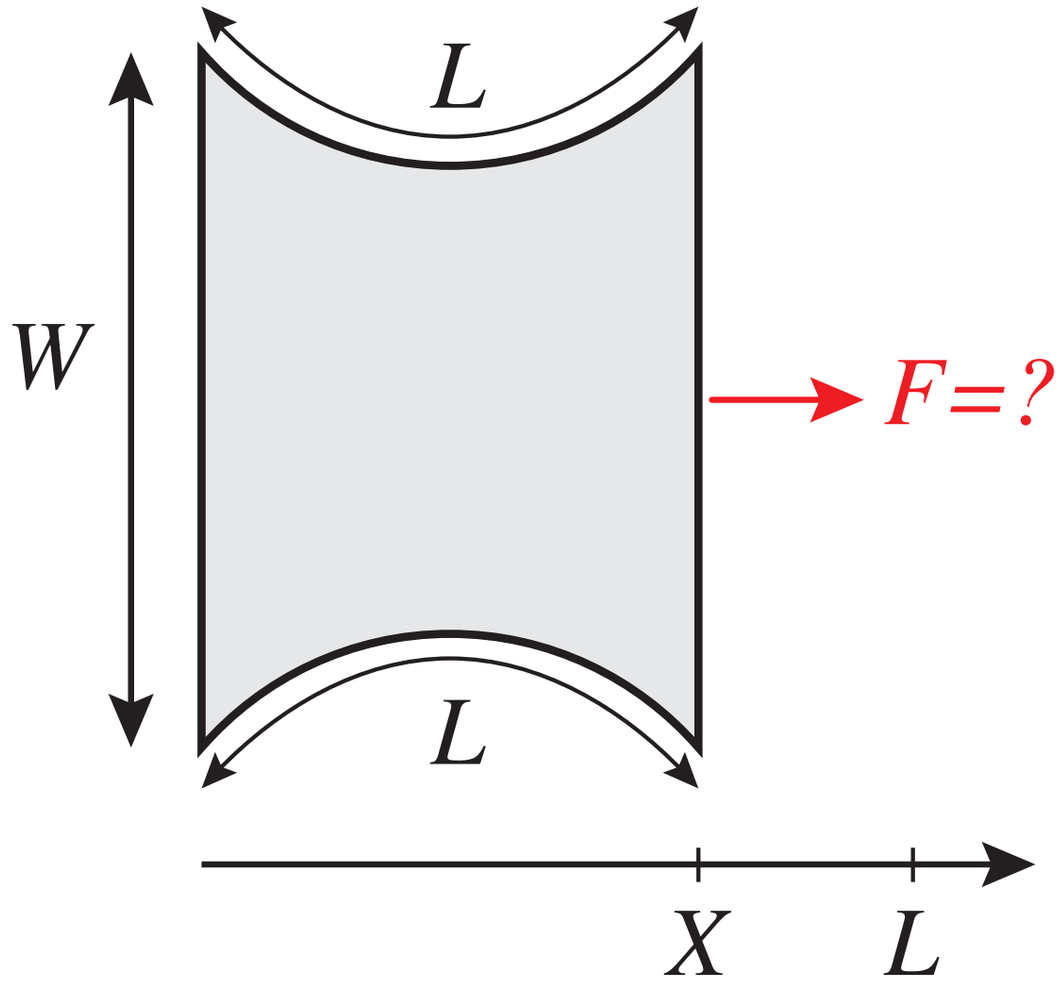
A simple model



Youtube: Soap Film Loops

Liquid-solid : iso-perimetric constraint

Shapes and forces



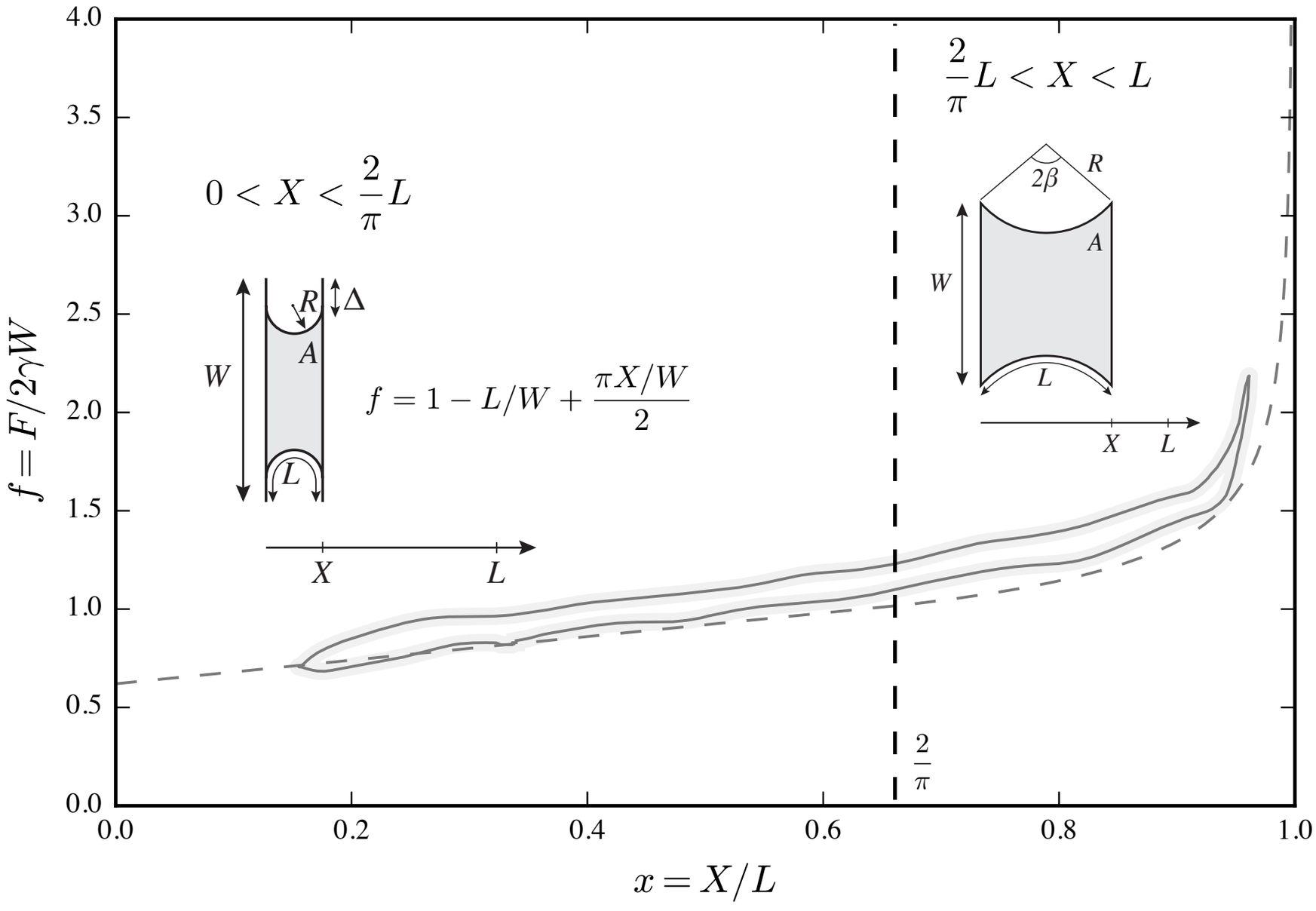
$$F = \frac{\partial E}{\partial X}$$

$$E = 2\gamma A$$

L is fixed

Liquid-solid : iso-perimetric constraint

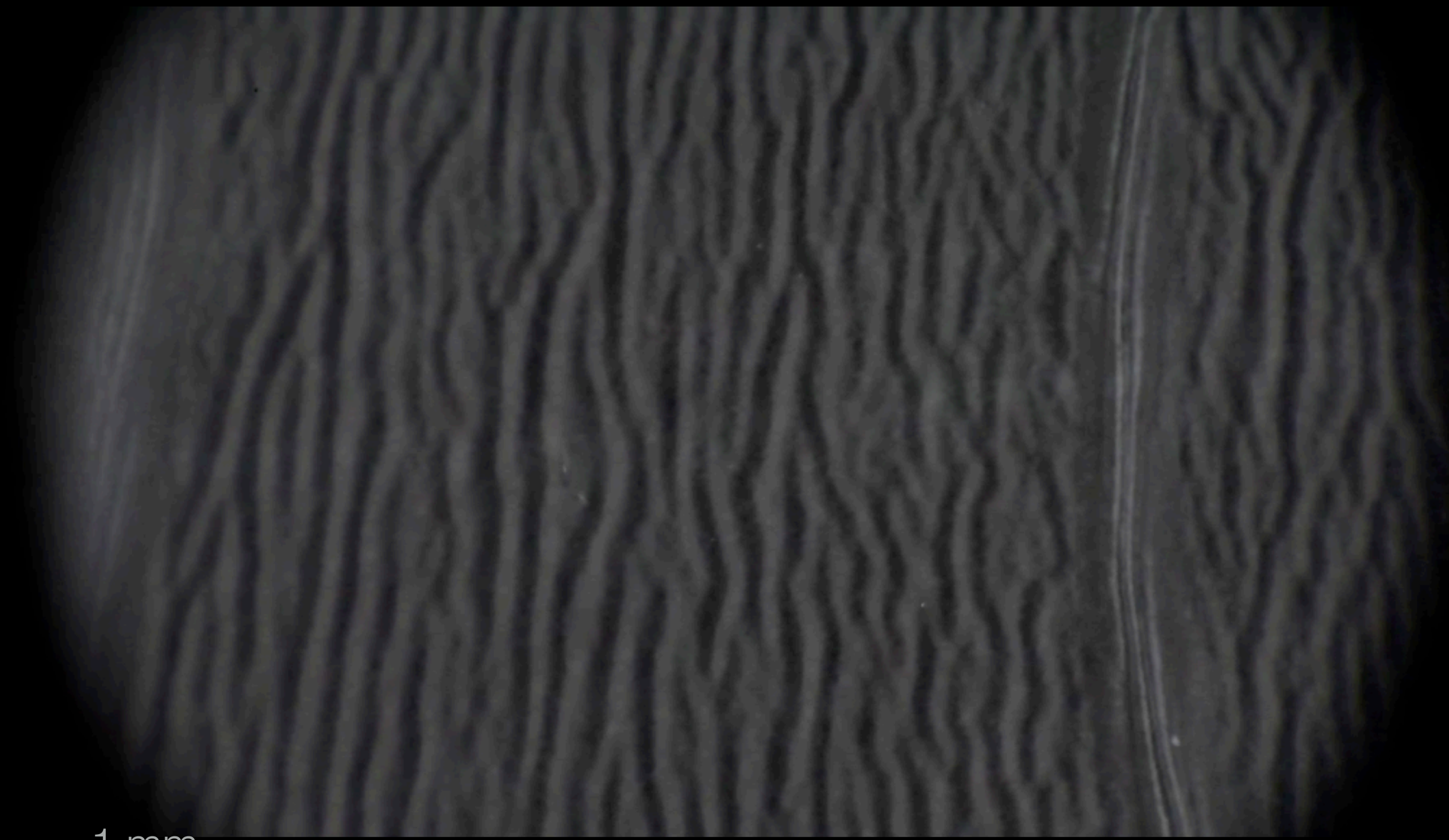
A better model



$$\frac{L}{W} = 0.38$$

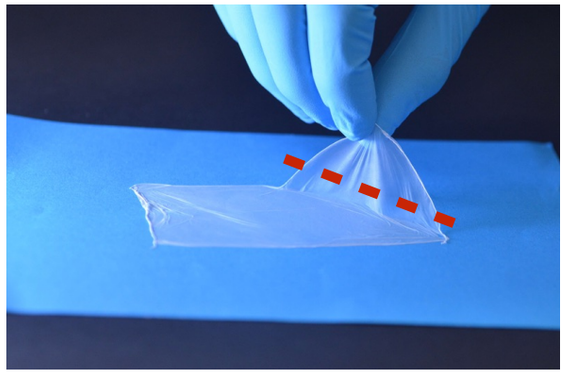
Where did the **membrane** go?

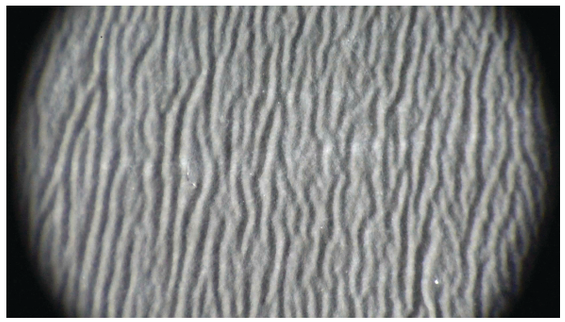

g
1 cm

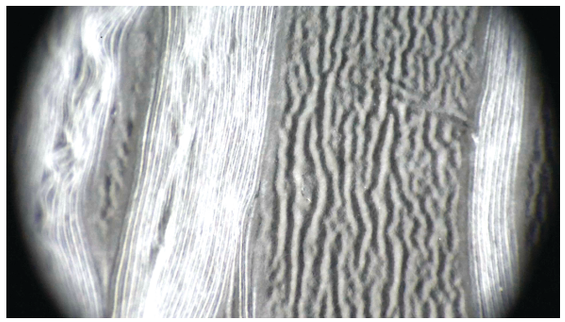

1 mm
Real Time

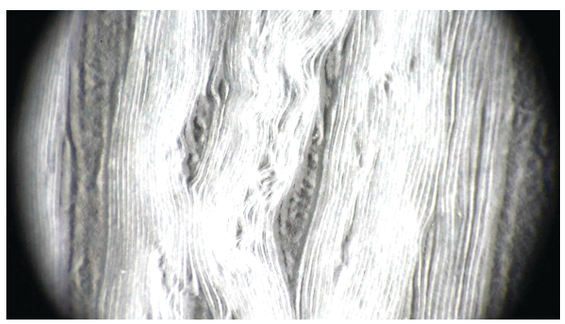
Why **wrinkling**?

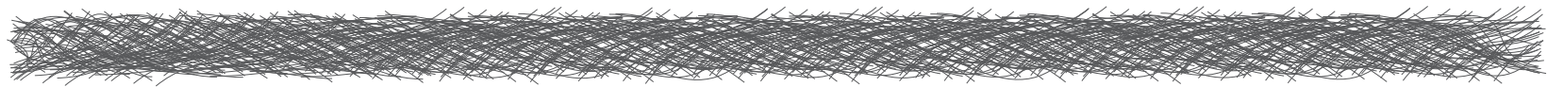
Physics of **elasto-capillary** wrinkling

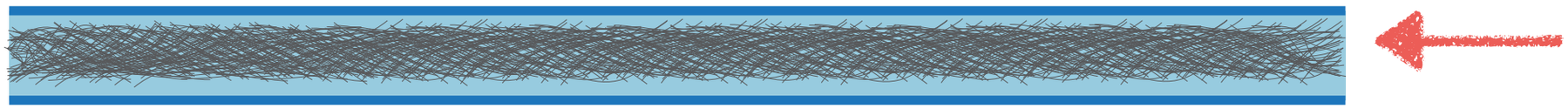




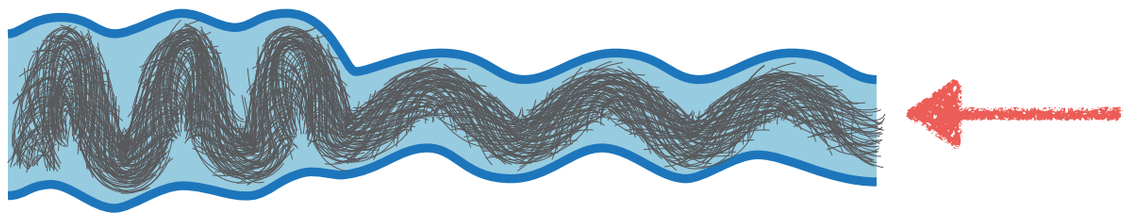


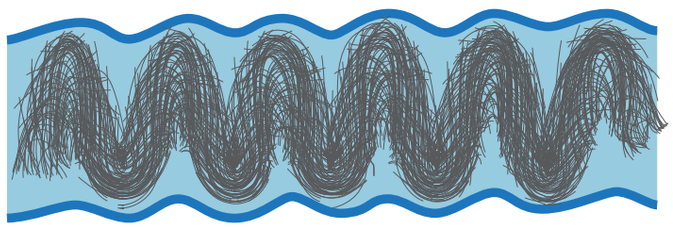




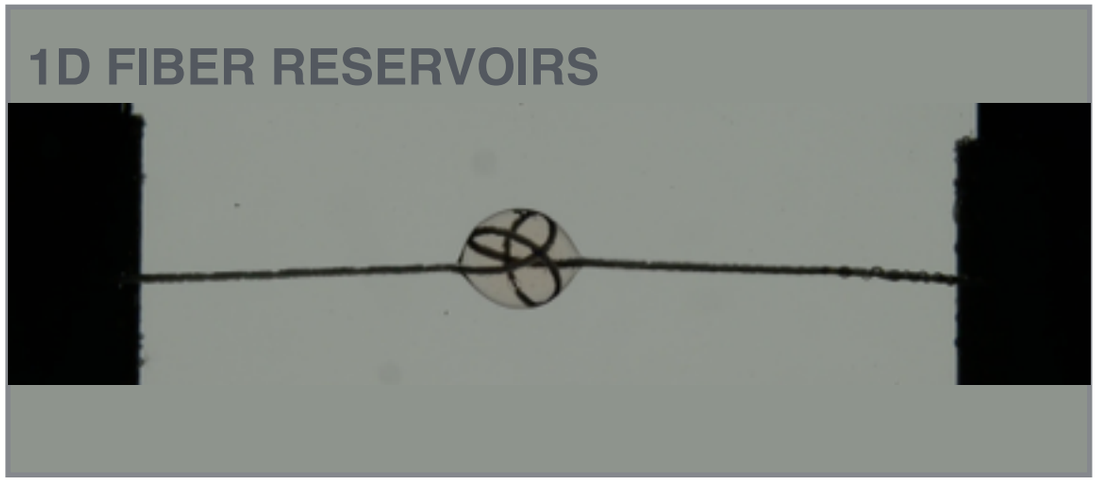


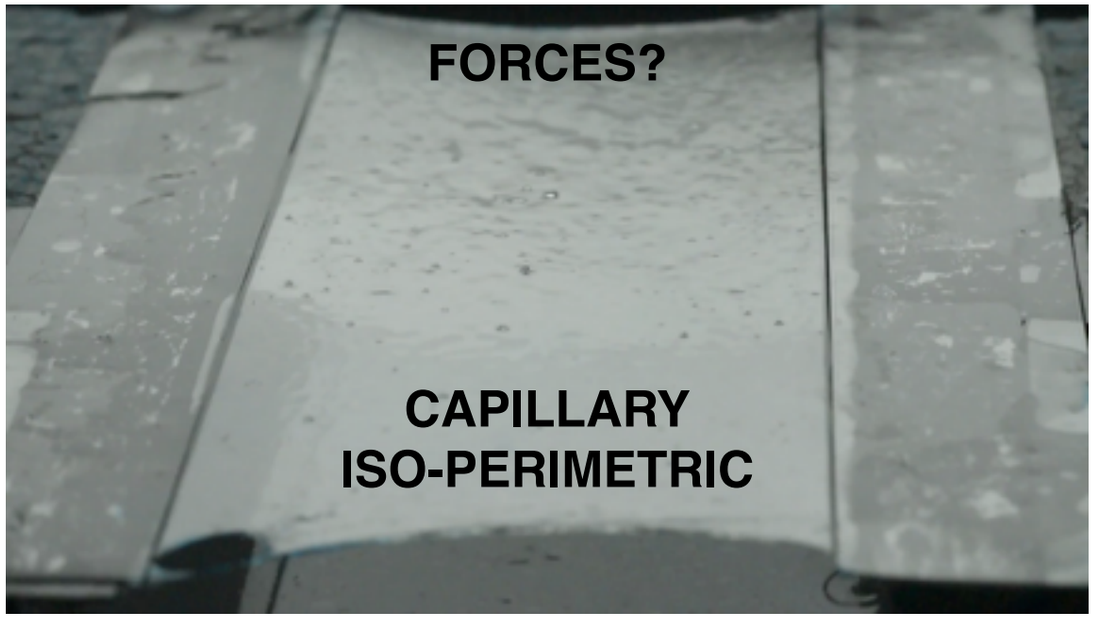
Minimizing : (**elastic** energy) + (**capillary** interface energy)





My talk in **one** slide





1 cm

Thank you!