

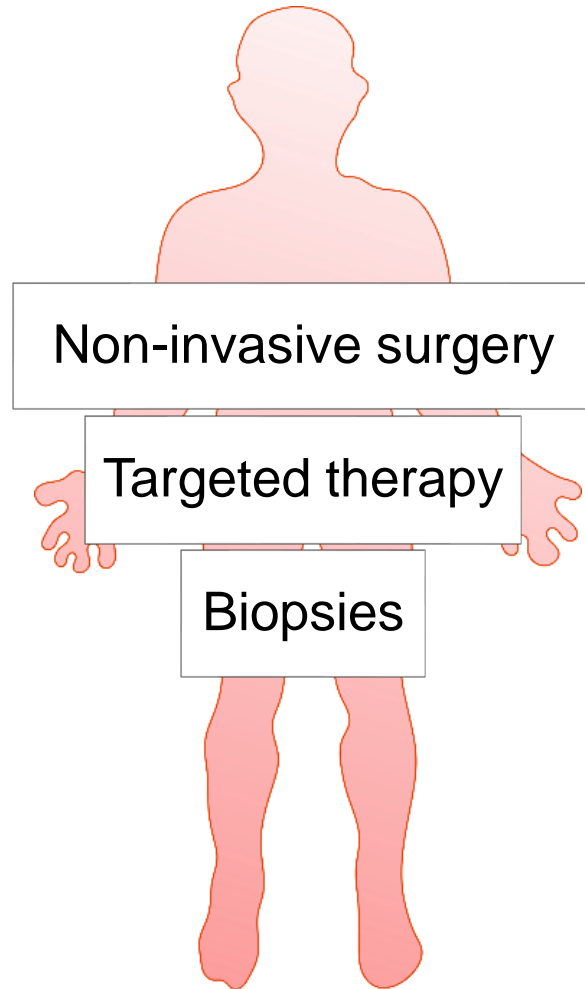
Sonobots: Ultrasound Manipulation In Vivo

Daniel Ahmed

D-MAVT, Acoustic Robotics Systems Lab



Motivation and Challenges of Micro- and -Nanorobotics



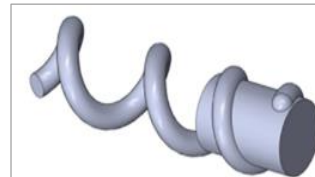
Chemical



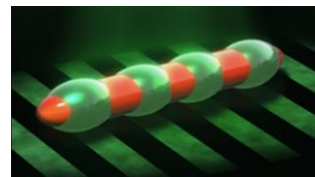
Acoustics



Magnetics



Optics

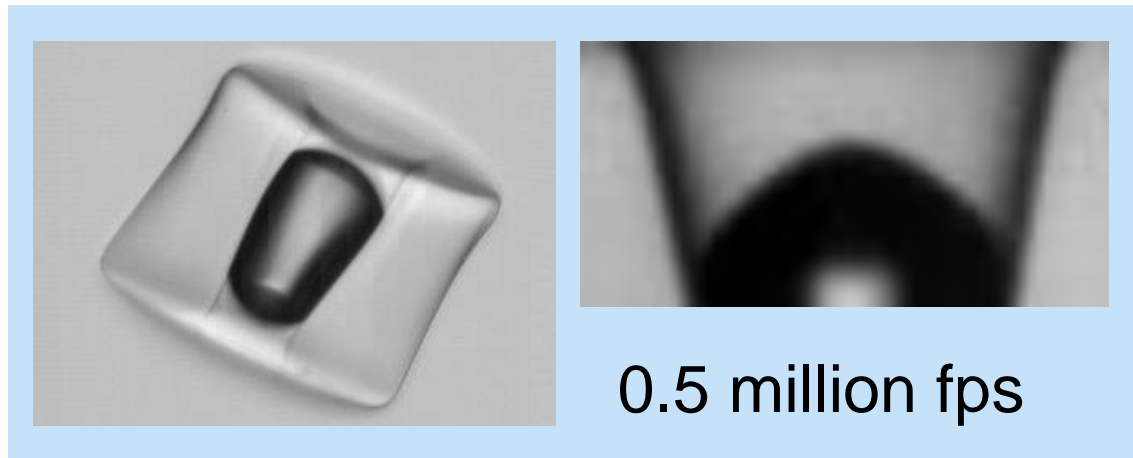
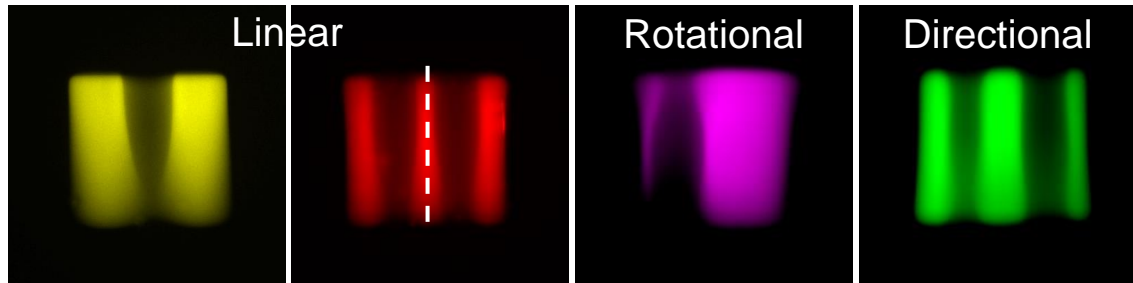


Challenges

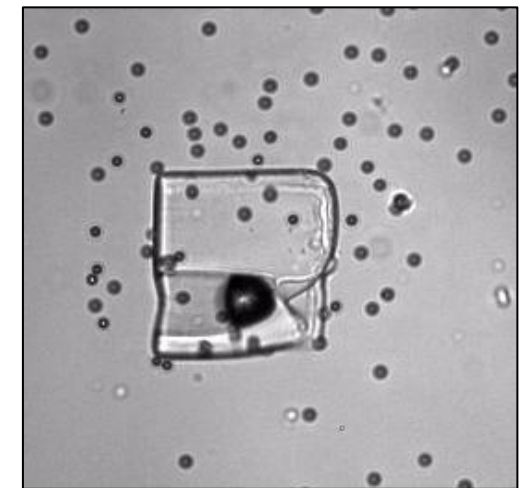
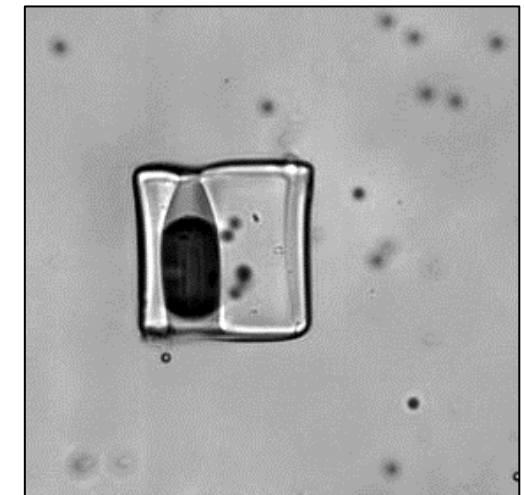
- Lack of upstream propulsion
- Lack of imaging
- Poor navigation
- Lack of biocompatibility

Translation to *in vivo*

Ultrasound-based Microrobots

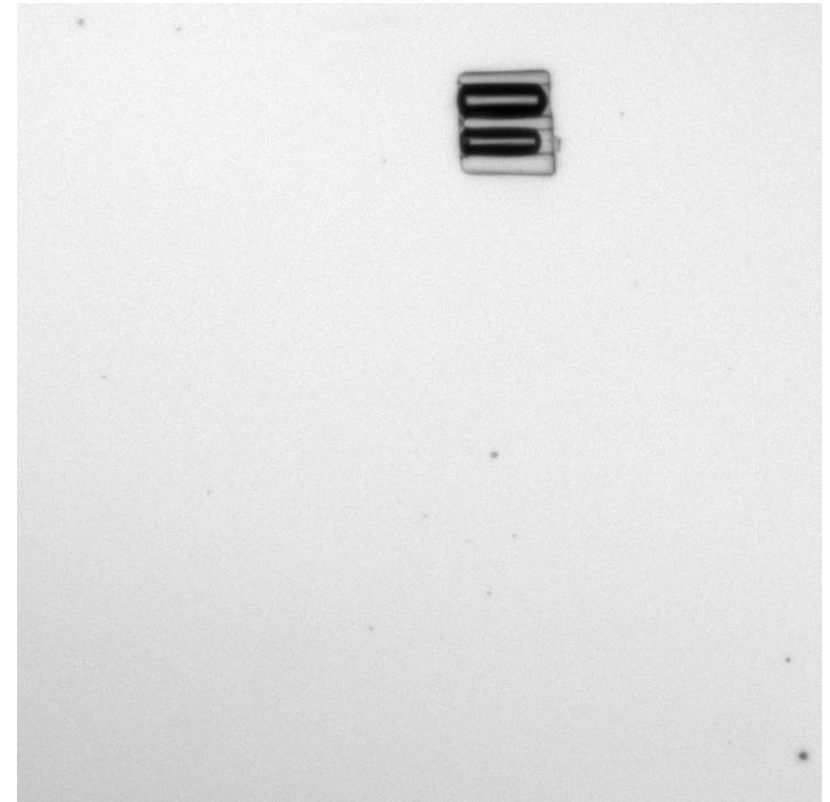
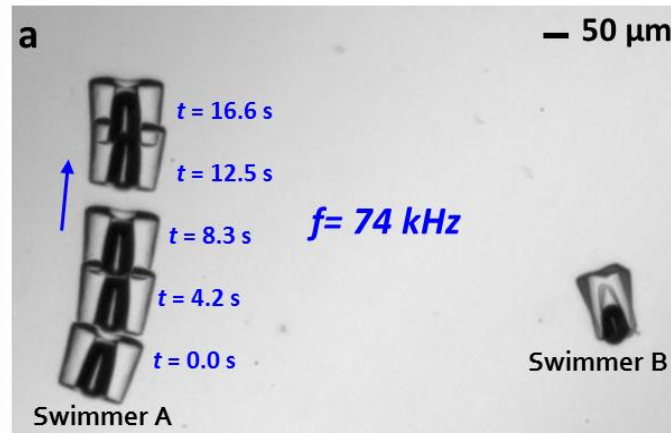
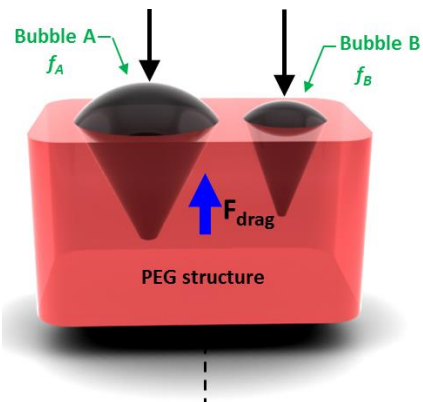
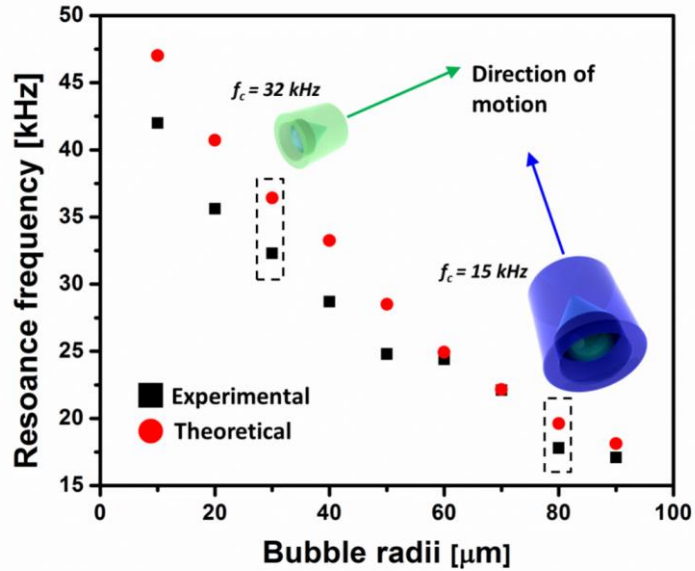


Safe, noninvasive, penetrate deep in the body, and widely used.



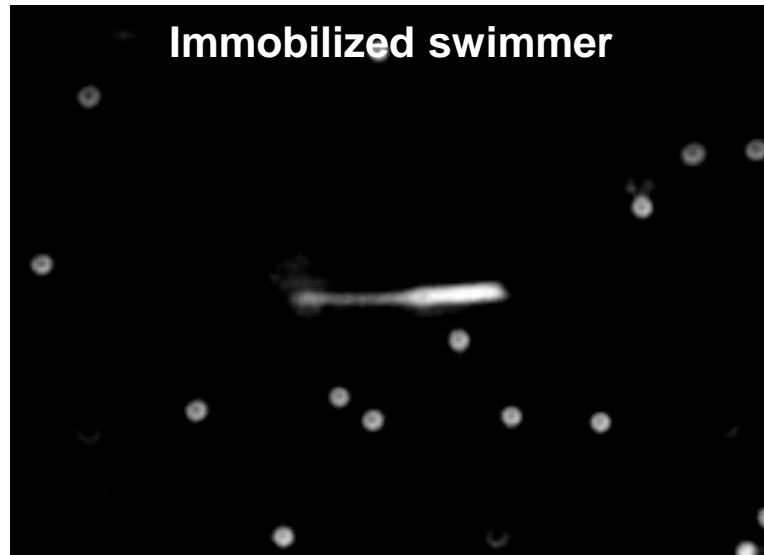
Daniel Ahmed *et al.*, Selectively manipulable acoustic-powered microswimmers, *Scientific Reports*, Vol. 5, pp. 9744, 2015.

Ultrasound-based Microrobots

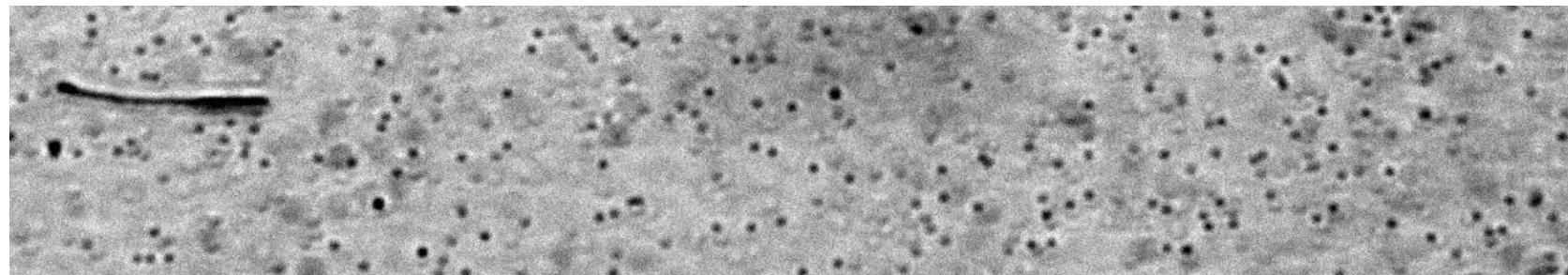


Daniel Ahmed *et al.*, Selectively manipulable acoustic-powered microswimmers, *Scientific Reports*, Vol. 5, pp. 9744, 2015.

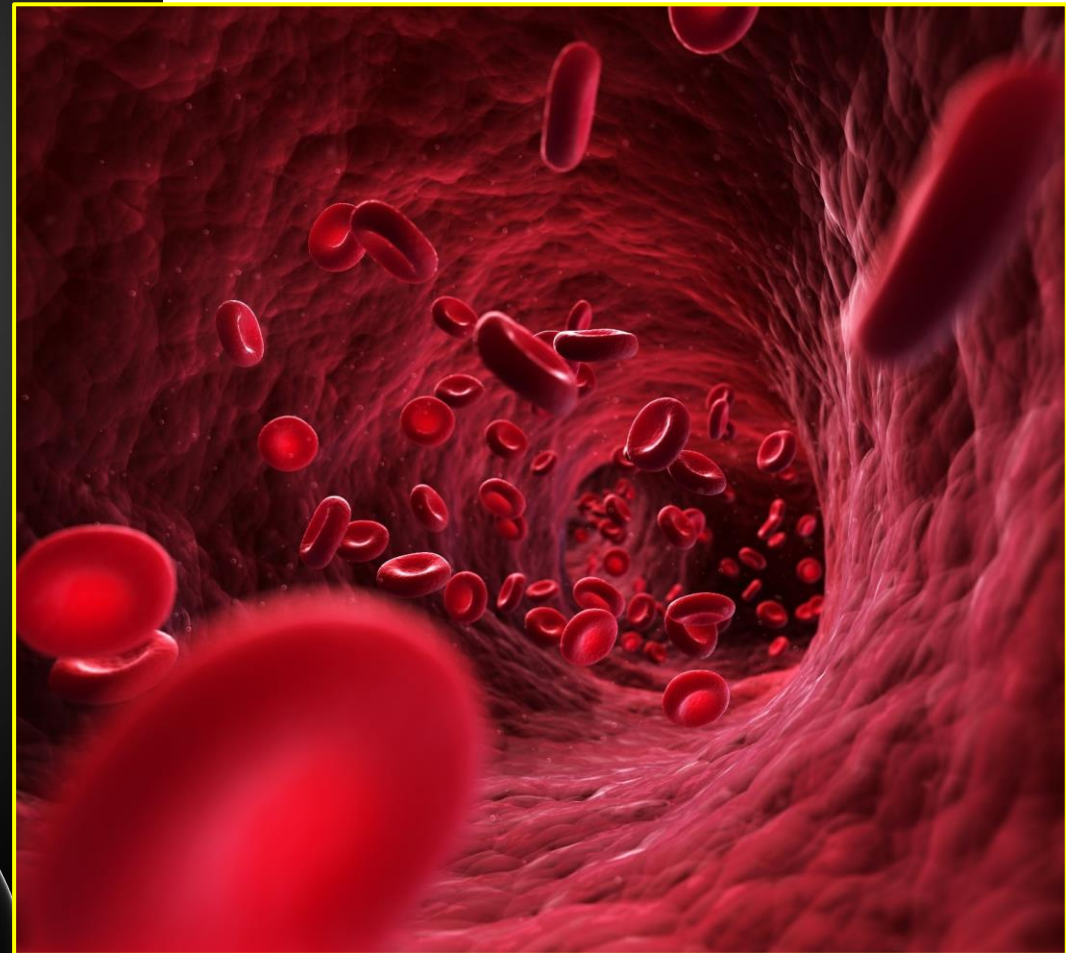
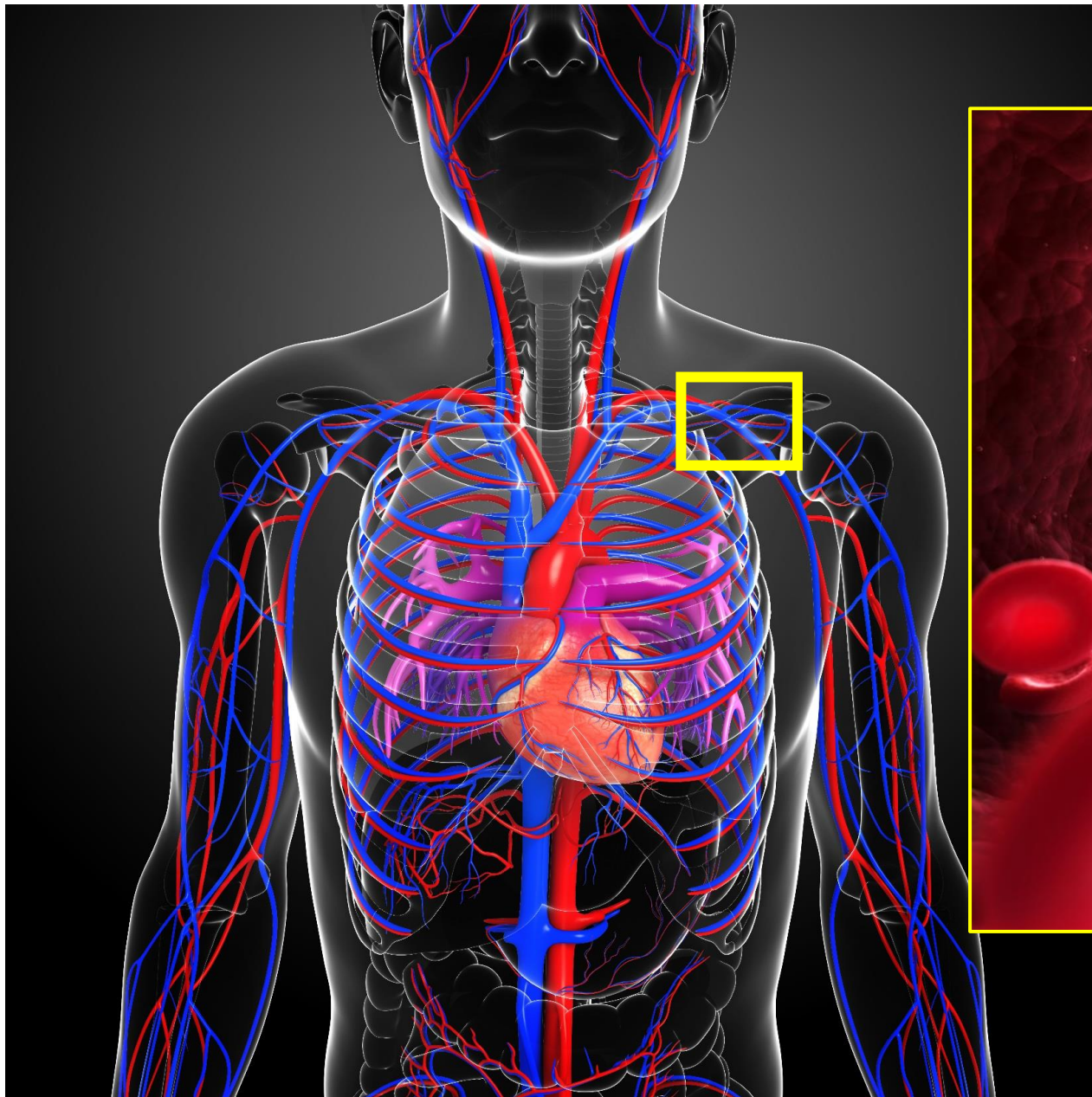
Ultrasound-based Nanorobots



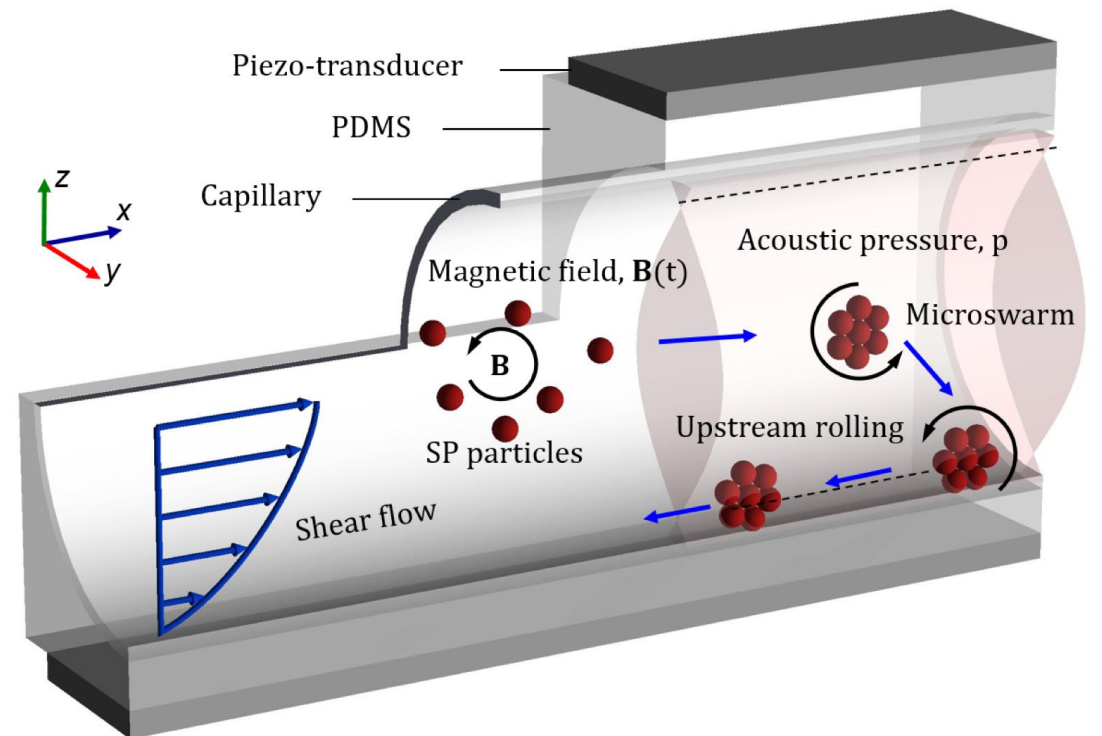
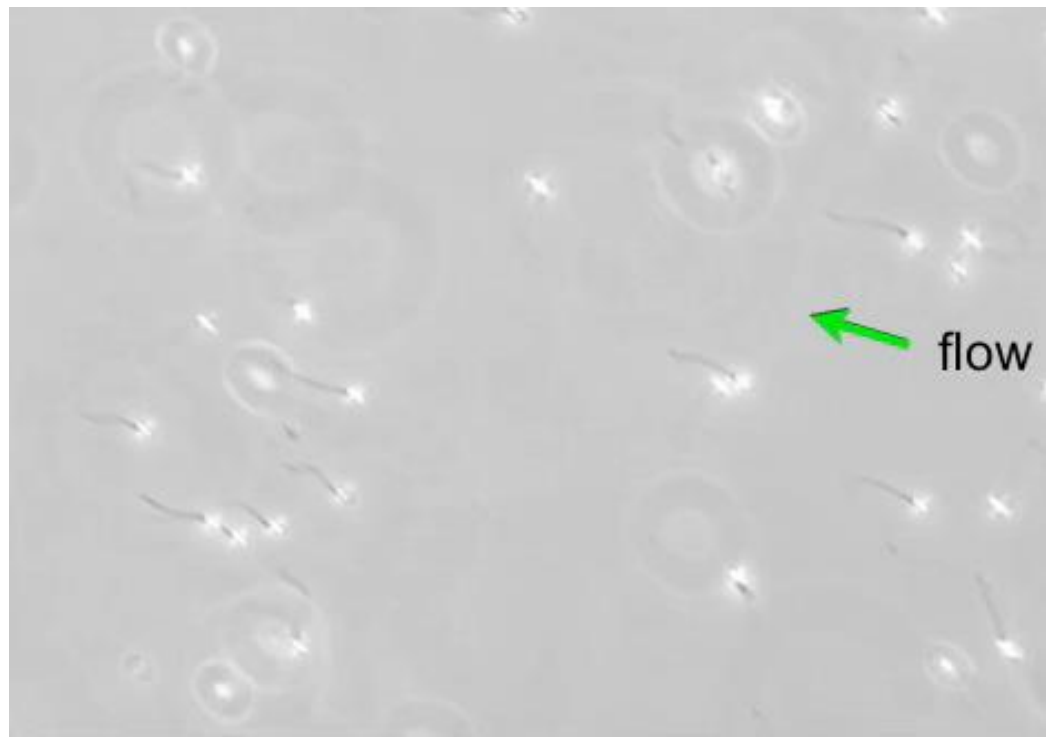
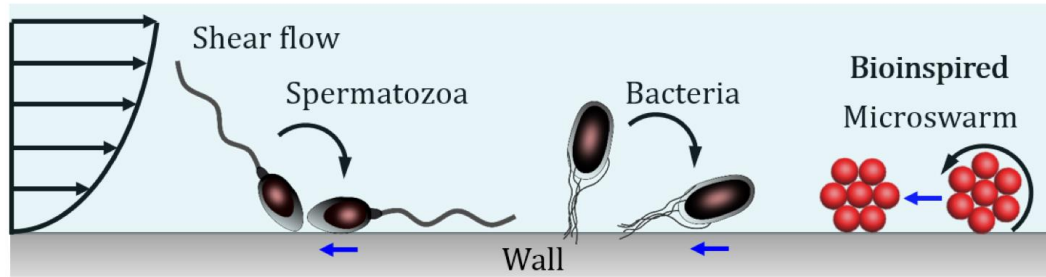
$$F^{rad} = \oint [\langle \sigma_2 \rangle - \rho_0 \langle v_1 v_1 \rangle] \cdot n da$$



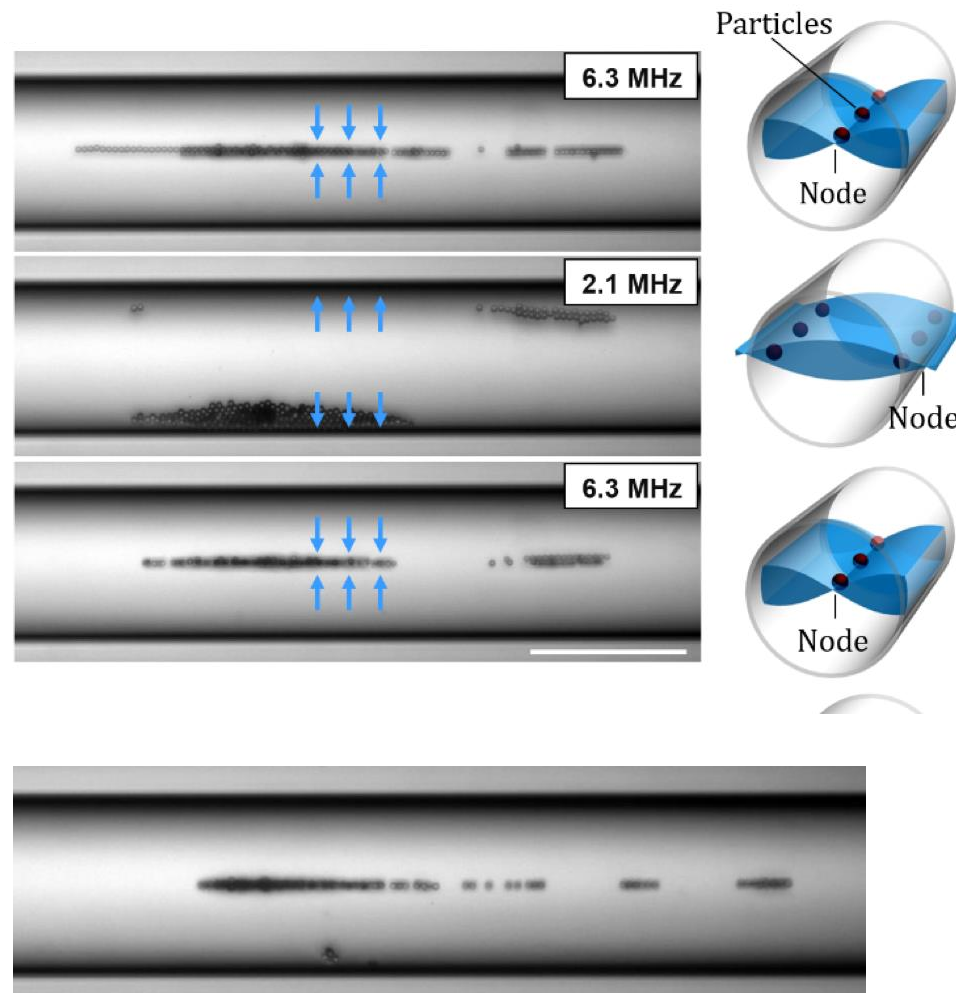
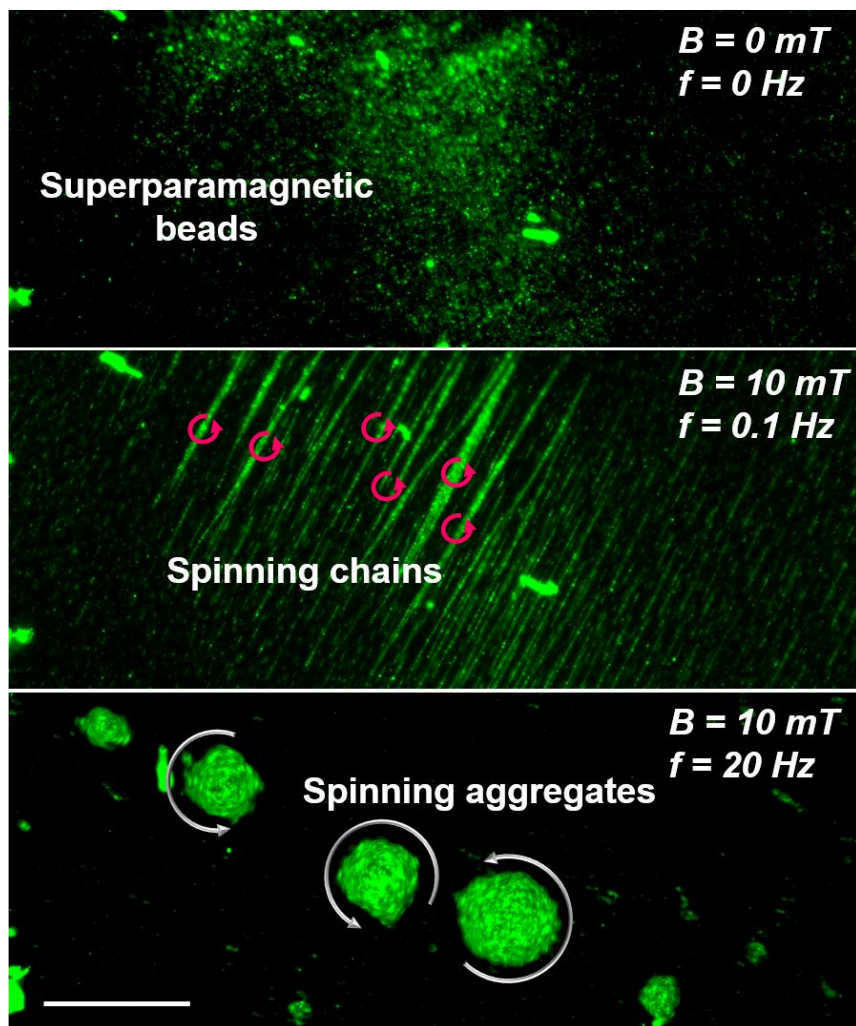
Daniel Ahmed et al., Artificial swimmers propelled by acoustically activated flagella, *Nano Letters*, 16 (8), pp 4968–4974, 2016.



Upstream or Navigation Against the Flow

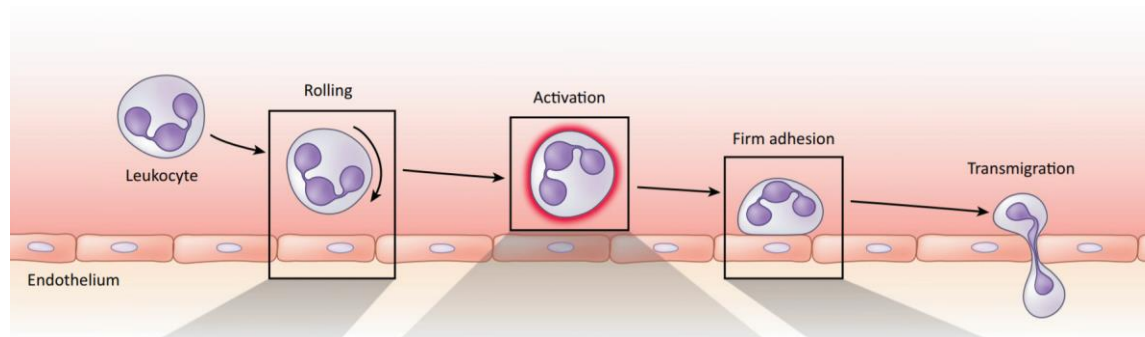
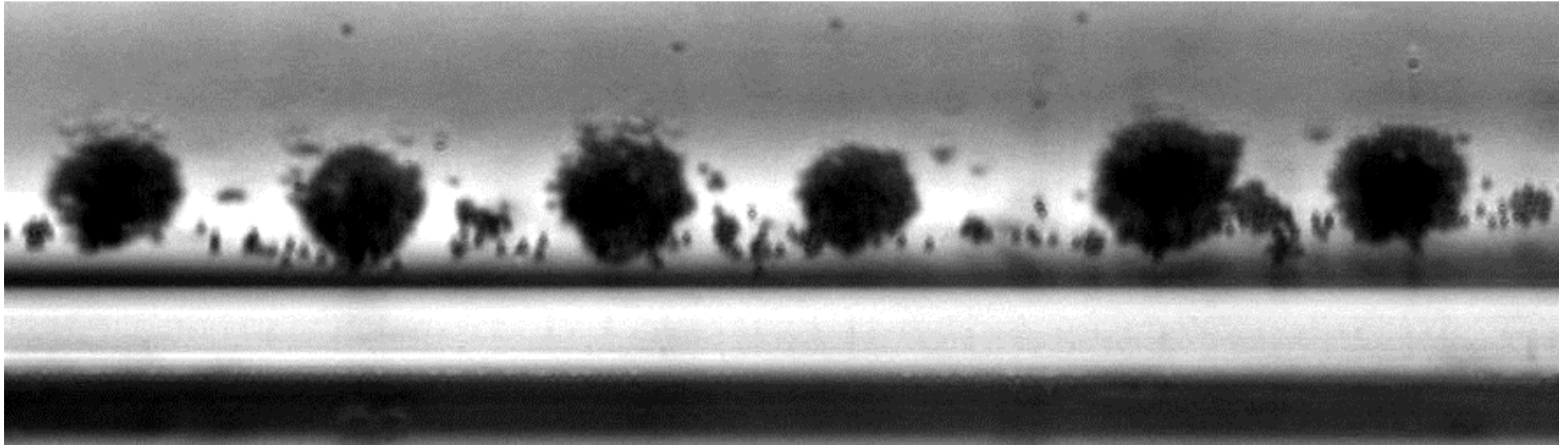


Particle Interaction in acoustic and magnetic field



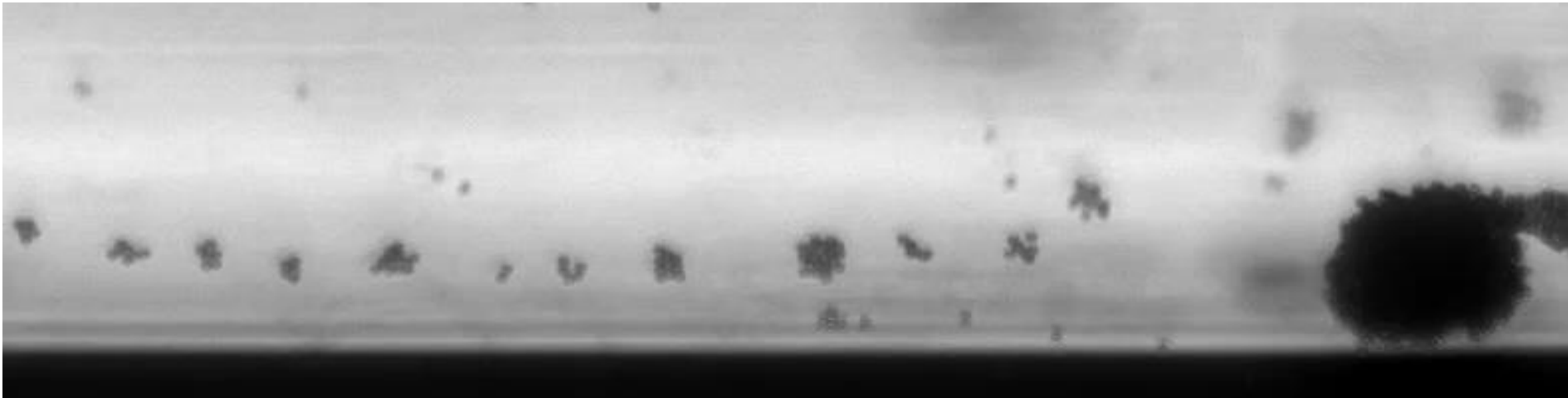
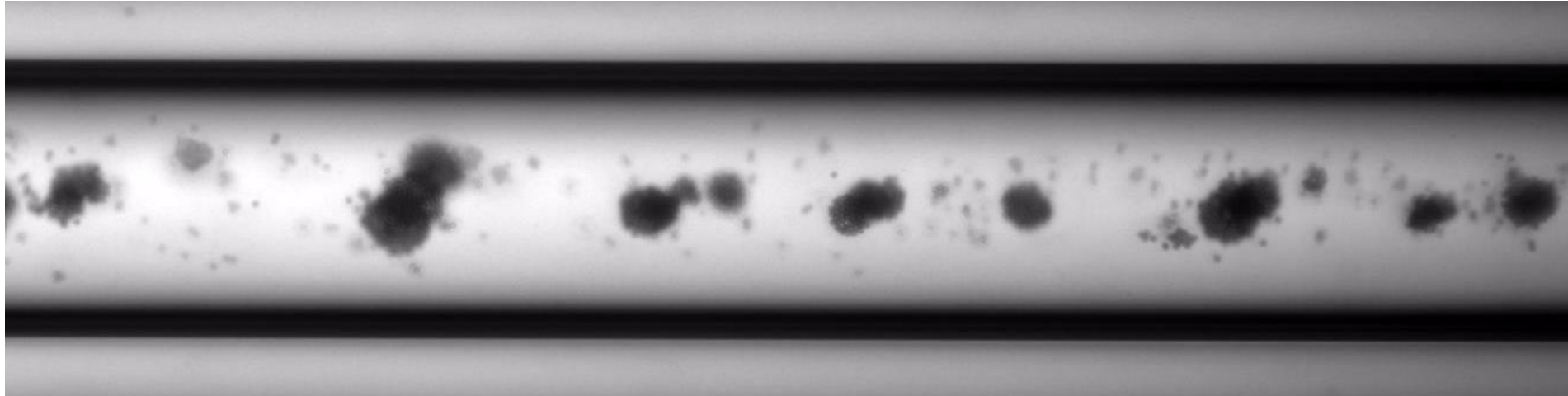
Daniel Ahamed *et al.*, Neutrophil-inspired propulsion in a combined acoustic and magnetic field, *Nature Communications*. DOI: 10.1038/s41467-017-00845-5, 2017.

Microswarms Recruitment Against the Flow at Wall



Mimicking Neutrophil

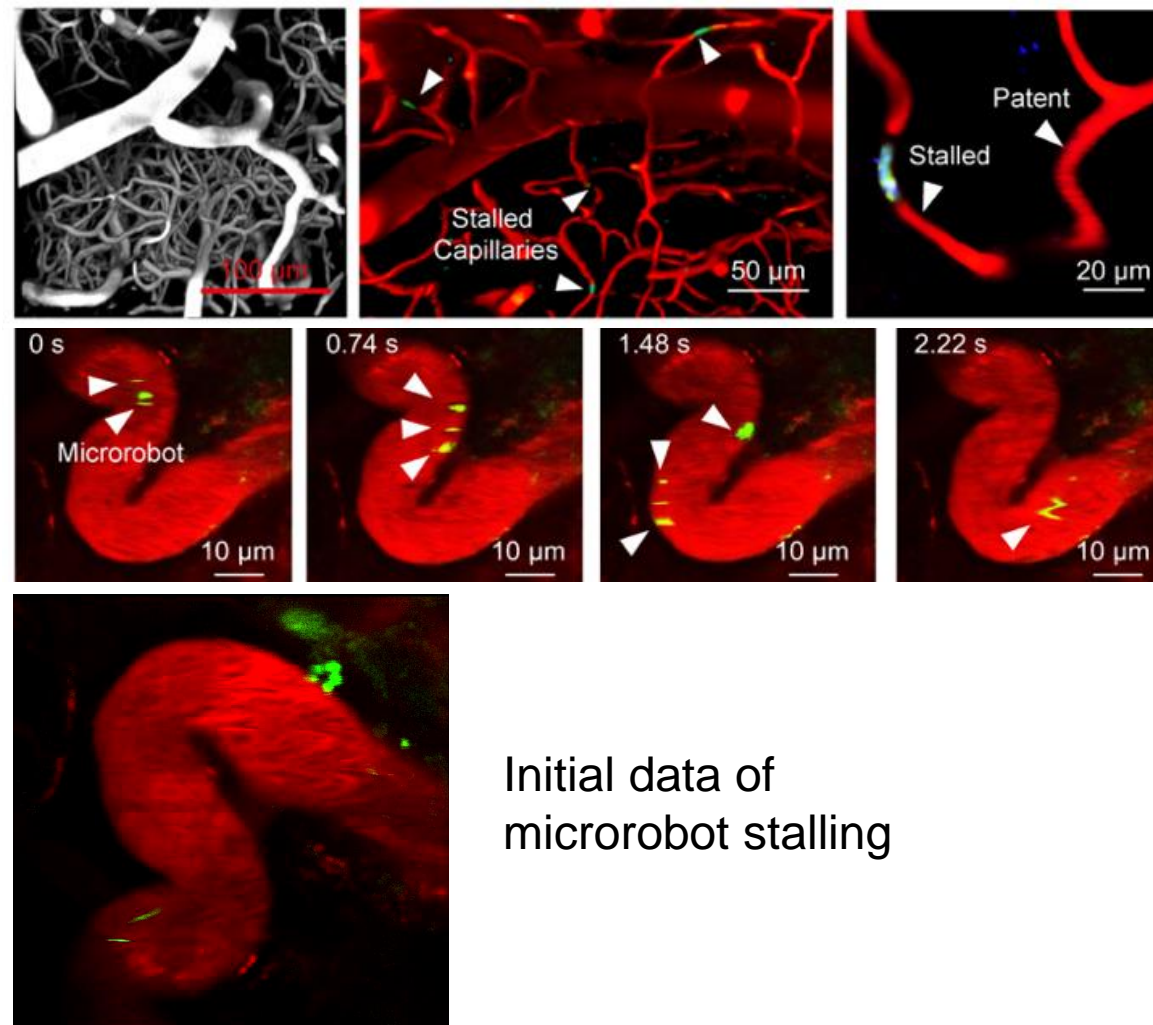
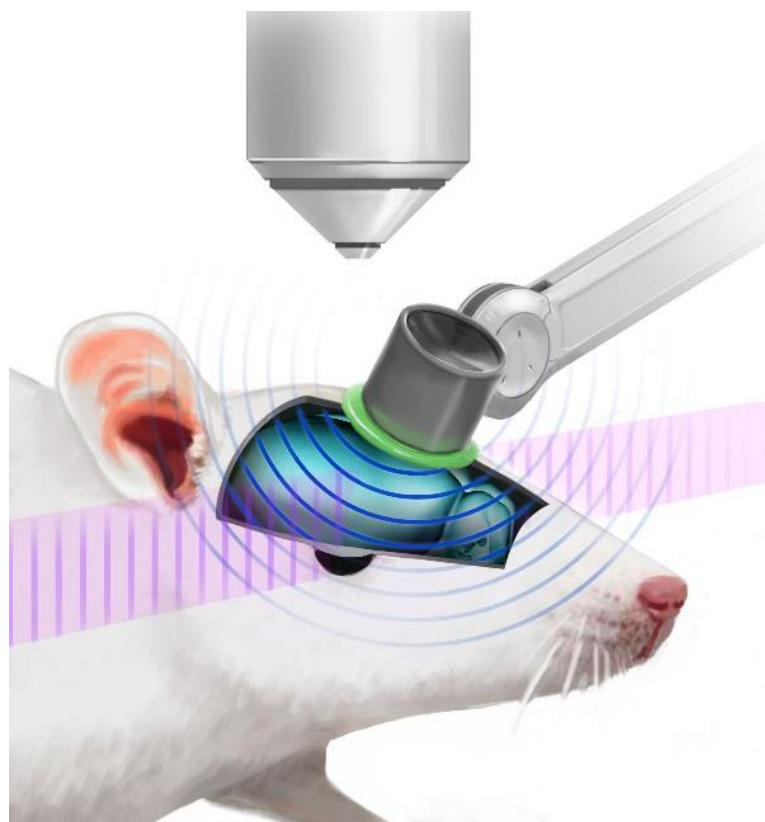
Upstream Propulsion



Daniel Ahmed *et al.*, Bio-inspired Acousto-magnetic Microswarm Robots with Upstream Motility, **Nature Machine Intelligence**, accepted.

Microrobotics manipulation *in vivo*

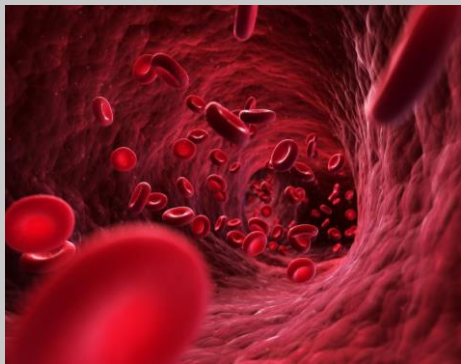
In collaboration with UZH



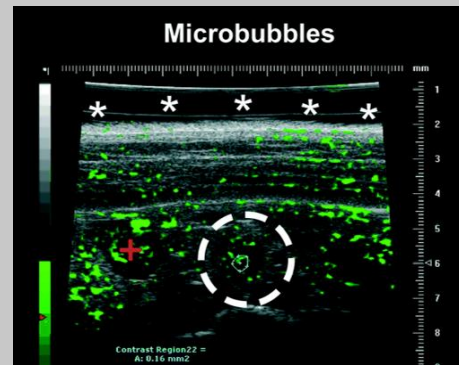
Initial data of
microrobot stalling

Conclusion and Future Perspective

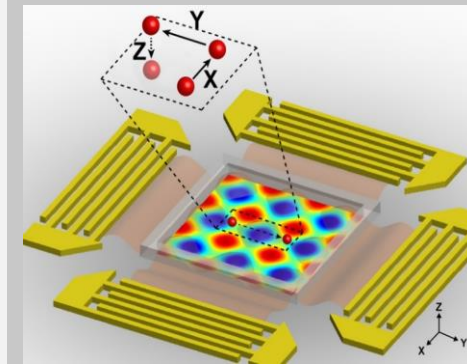
- ❑ Develop travelling acoustic-based microrobots.
- ❑ Developed a propulsion strategy to manipulate microparticles against flow.



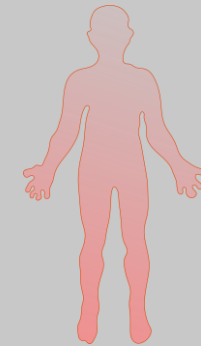
Fluid dynamics



Imaging & track.



Manipulation



Biocompatibility

- The fluid dynamics of micro and -nanorobots under blood flow
- Real time imaging & tracking capabilities
- *In vivo* acoustic manipulations systems
- Biocompatibility and removing of robotics materials

Thank you for your attention!

Professor Daniel Ahmed
Dahmed@ethz.ch

ETH Zurich
D-MAVT
RSA G 324
Säumerstrasse 4
8803 Rüschlikon
Switzerland

www.arsl.ethz.ch