Integrated Nano-Biomechanics for Cellular Scale Phenomena in Blood Flow

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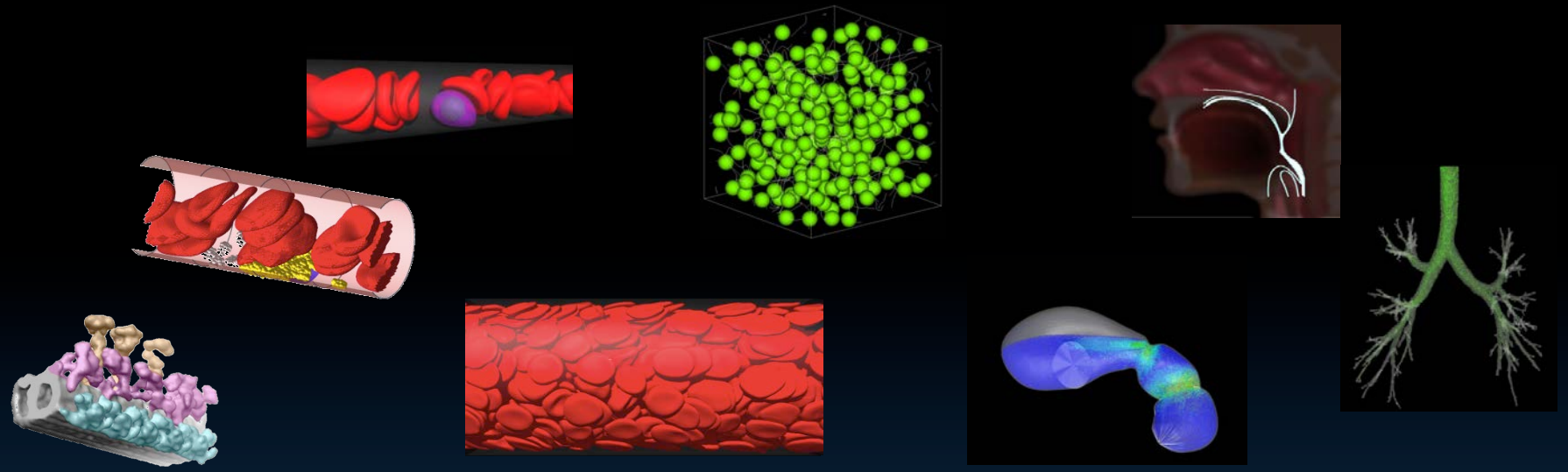
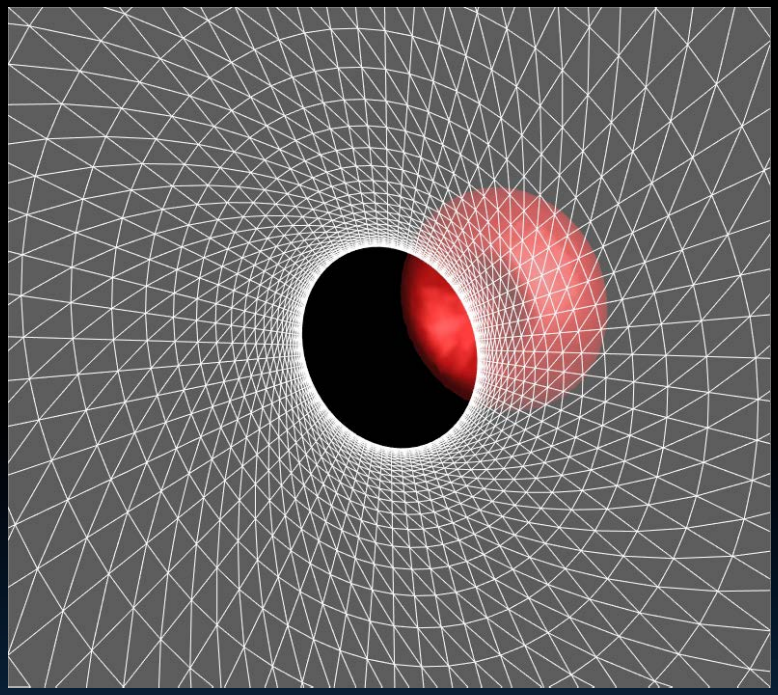
Computational biomechanics



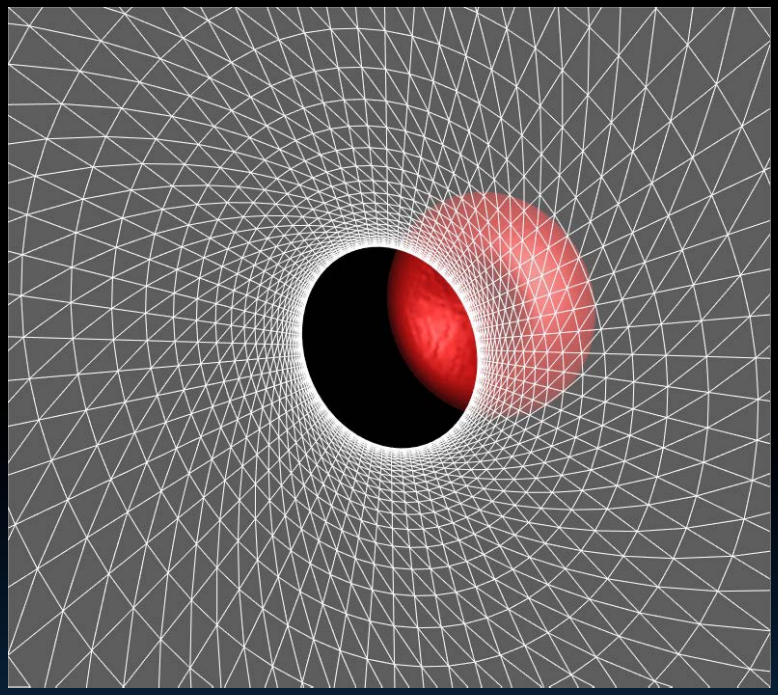
Molecule Cell Tissue Organ

Computational biomechanics on cardiovascular system

Cellular mechanics of RBCs



Viscosity ratio = 1

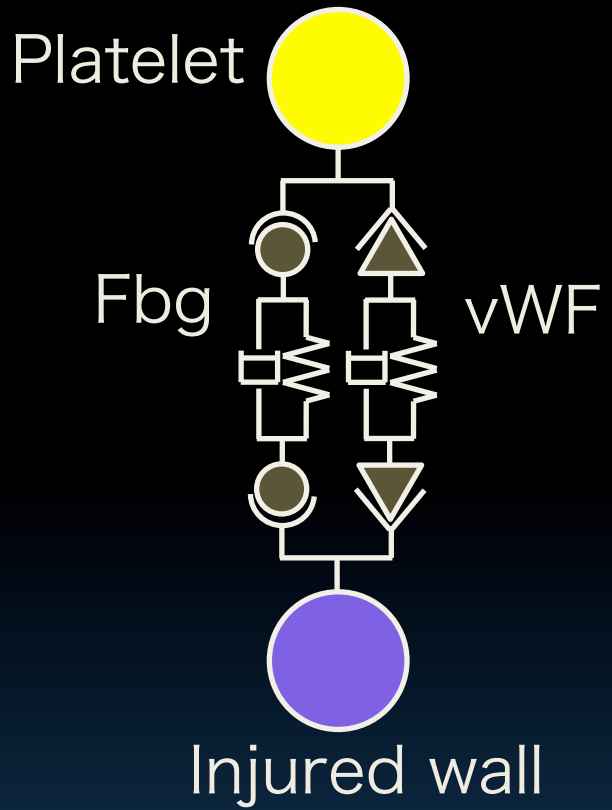


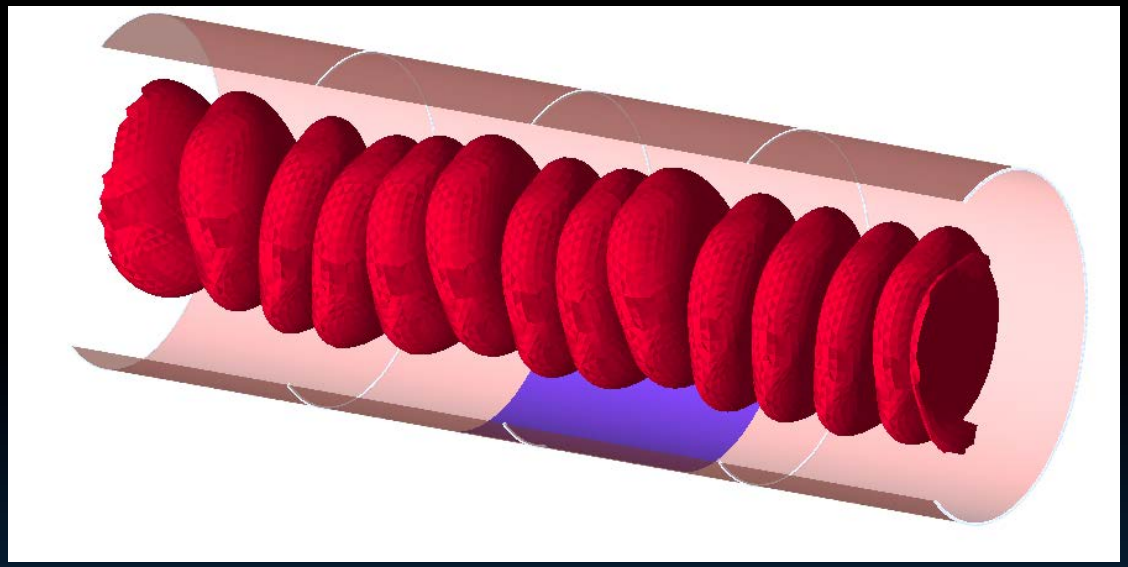
Viscosity ratio = 5

Passage time significantly increases by high viscosity ratio

Omori et al, Phys Rev Lett (2012)
Omori et al, Phys Rev E (2014)

Interaction between thrombus and RBCs

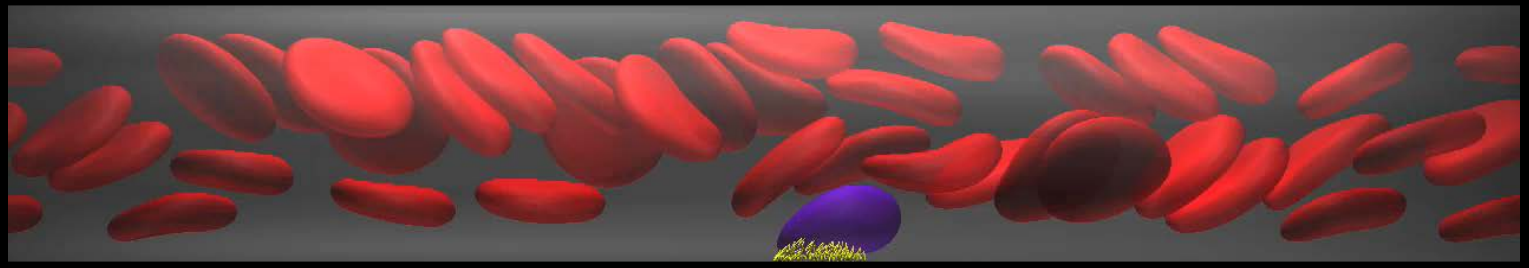


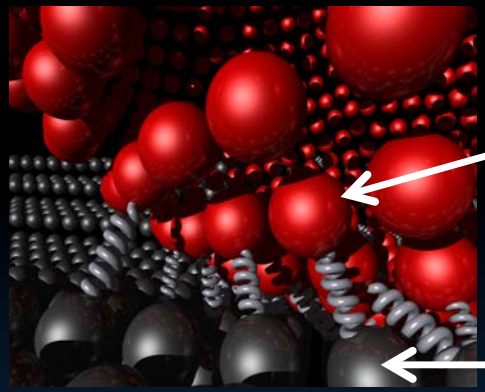


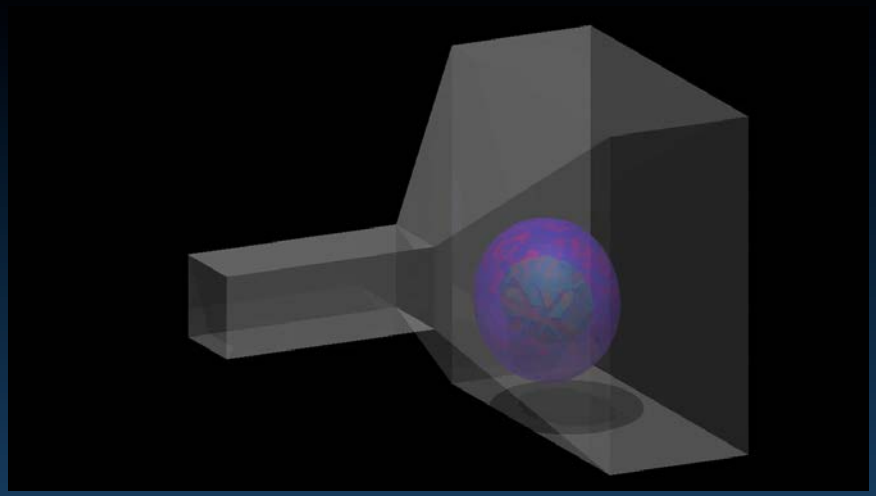
RBCs are highly deformed by thrombus

Kamada, Imai et al, Med Eng Phys (2012)
Kamada, Imai et al, Microvasc Res (2013)

RBCs infected by malaria (pf-RBCs)

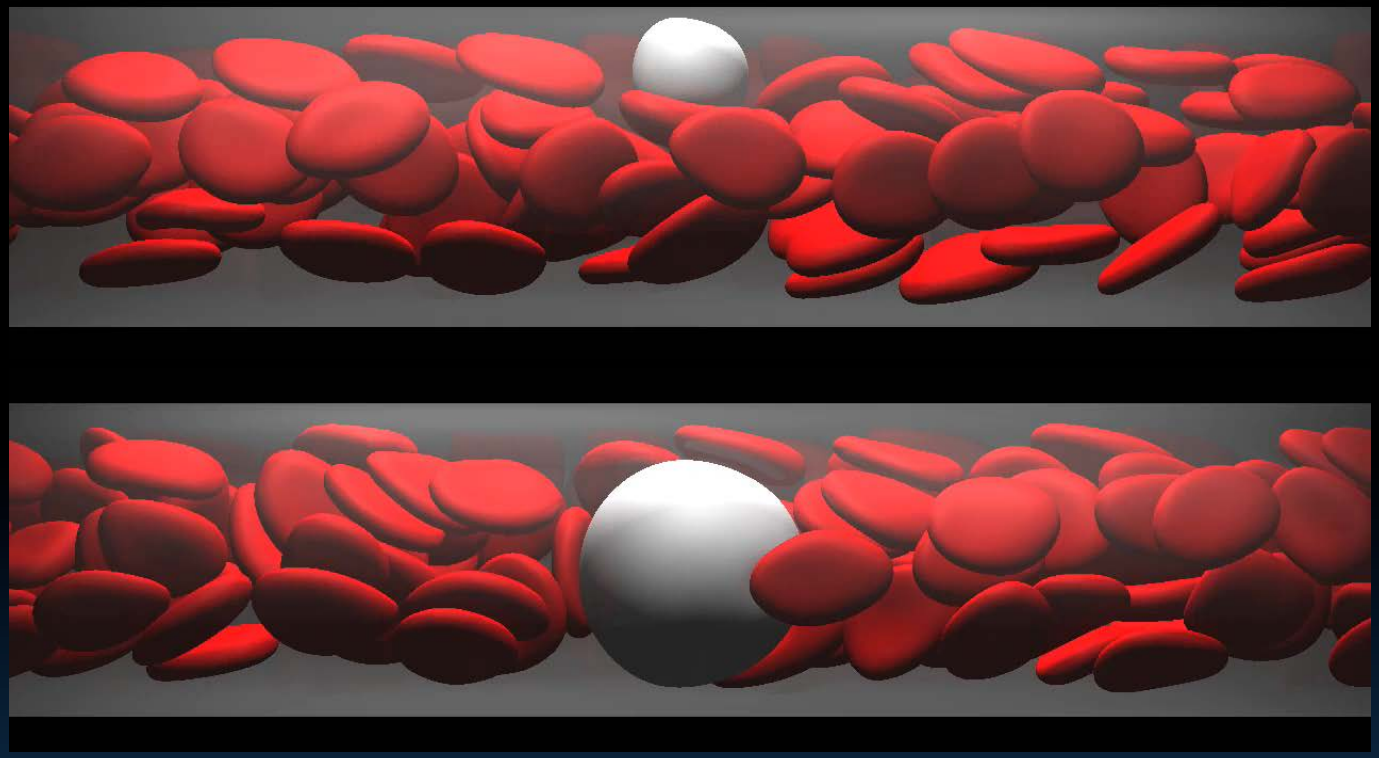






Kondo, Imai et al, Ann Biomed Eng (2009)
Imai, Kondo et al, J Biomech (2010)

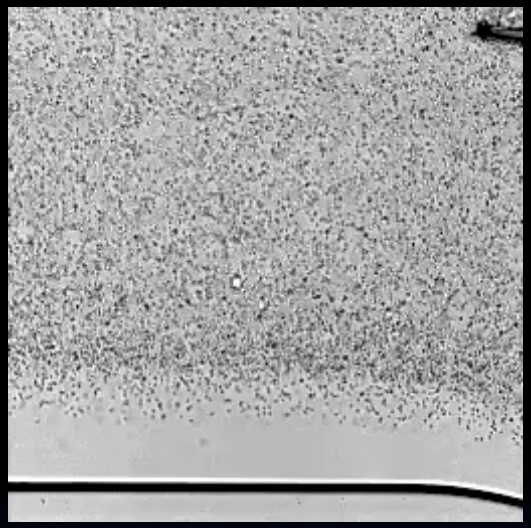
Margination of Leukocyte and CTC

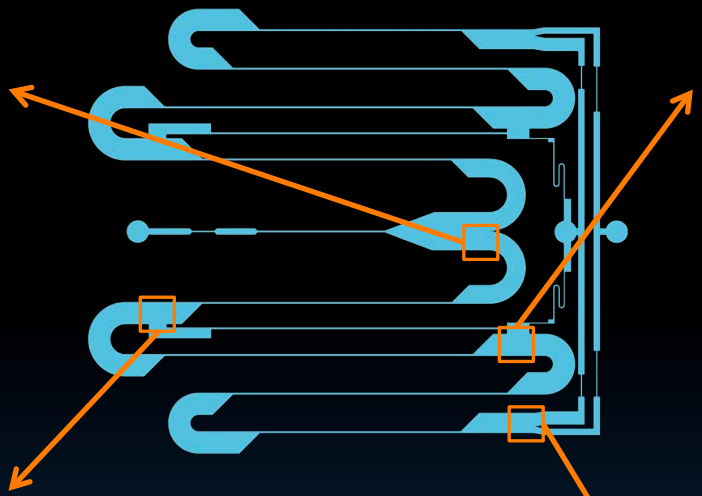


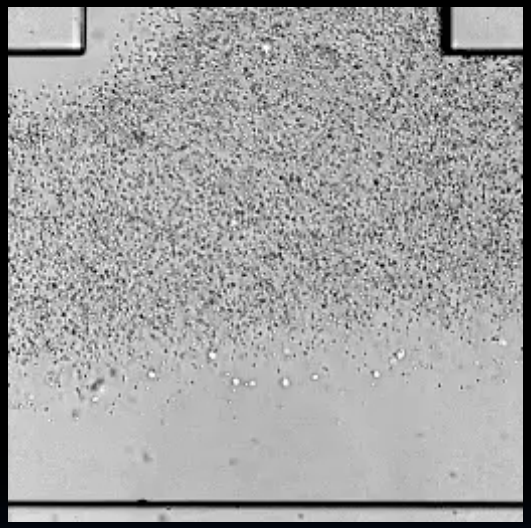
RBC passing is required for margination

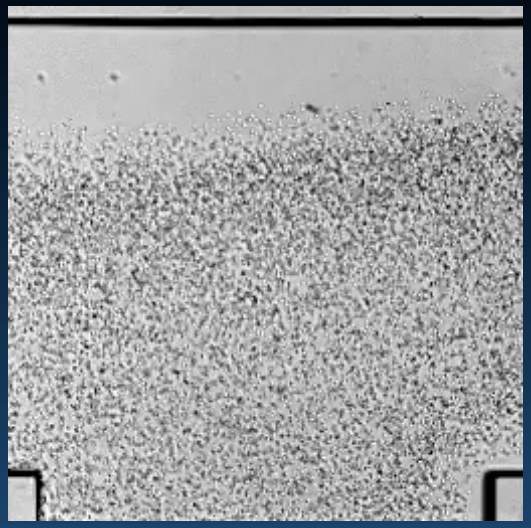
Takeishi, Imai et al, Physiol Report (2014)
Takeishi, Imai et al, in preparation

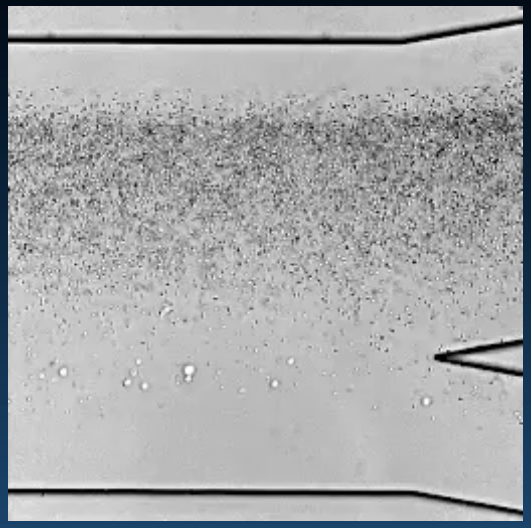
Microfluidic device for CTC separation using inertial migration





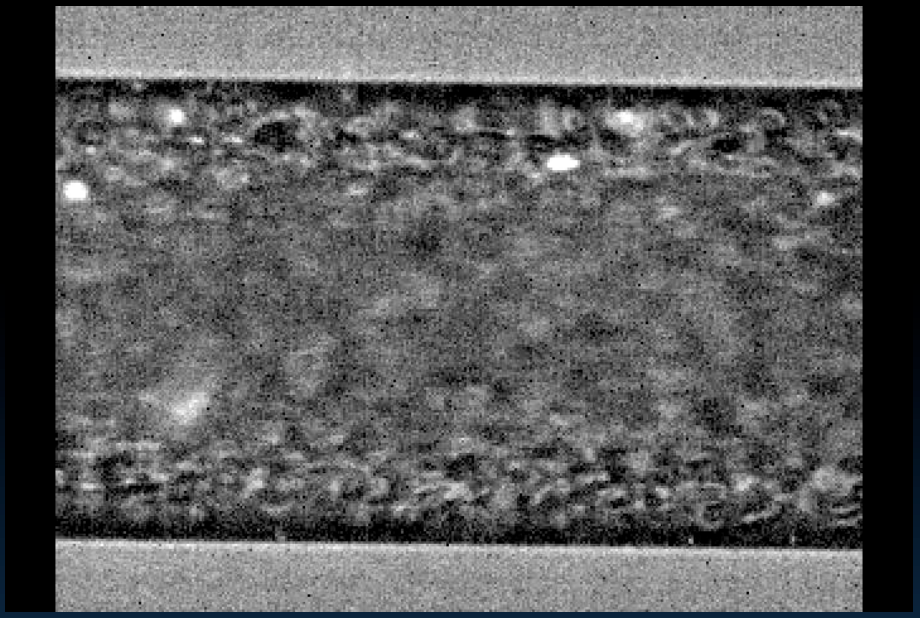






Tanaka, Ishikawa et al, Lab on a chip (2012)

Visualization of cellular flow



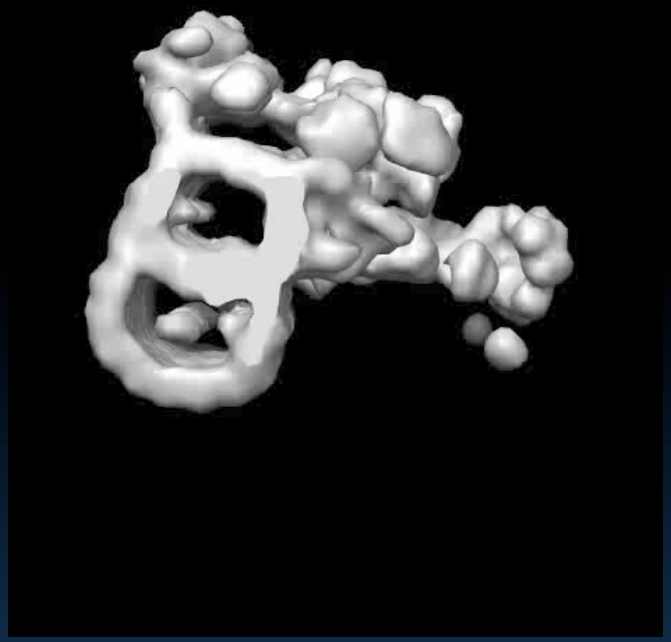
Confocal micro-PIV system

Large-scale numerical simulation

Lima, Ishikawa et al, Ann Biomed Eng (2009)
Alizadehrad, Imai et al, J Biomech, (2012)

Computational biomechanics on respiratory system

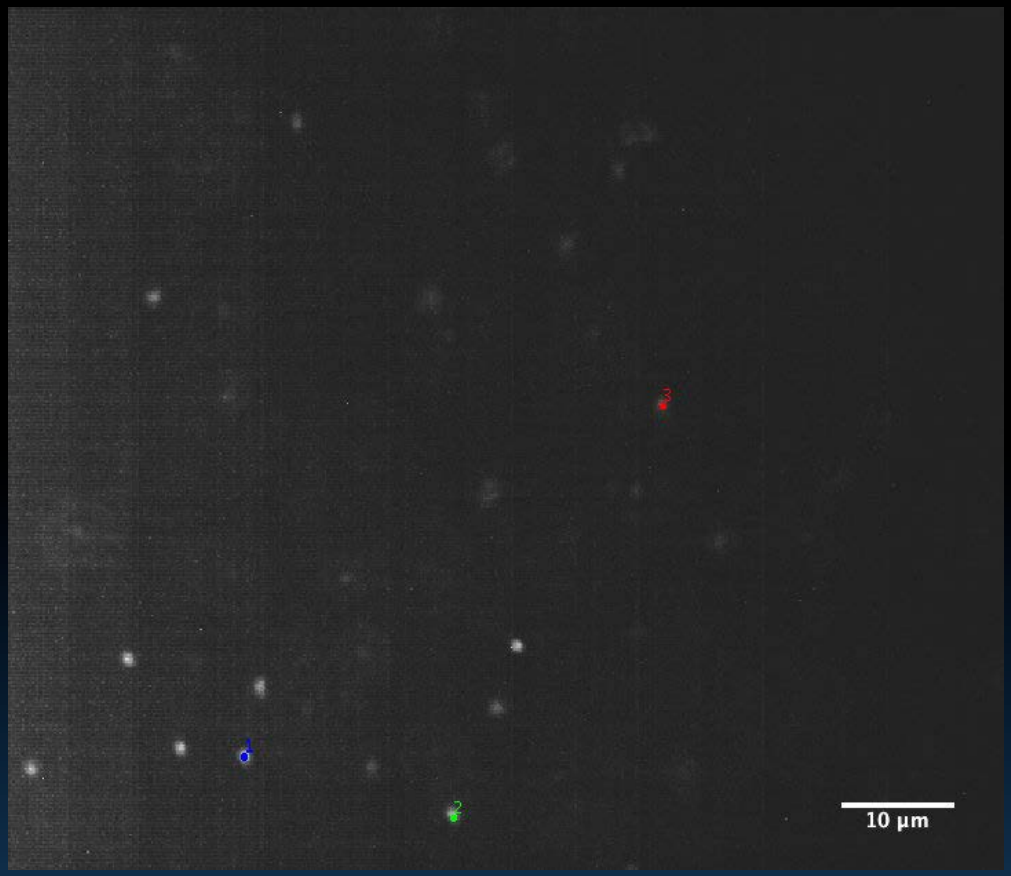
3D molecular structure of respiratory cilia

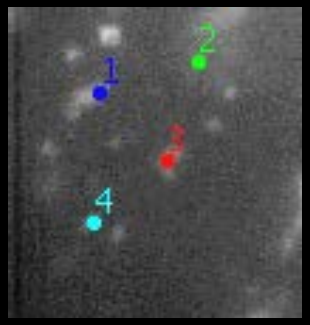


Cryo electron tomography

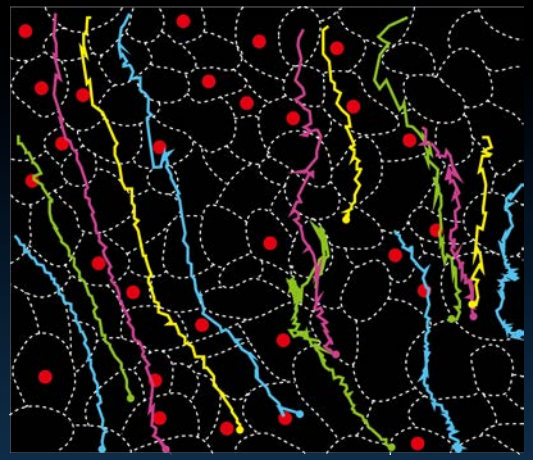
Ueno, Ishikawa et al, Nanomedicine (2012)

Flow field generated by ciliary motion





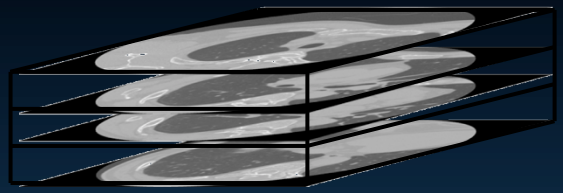
Ciliary Beat

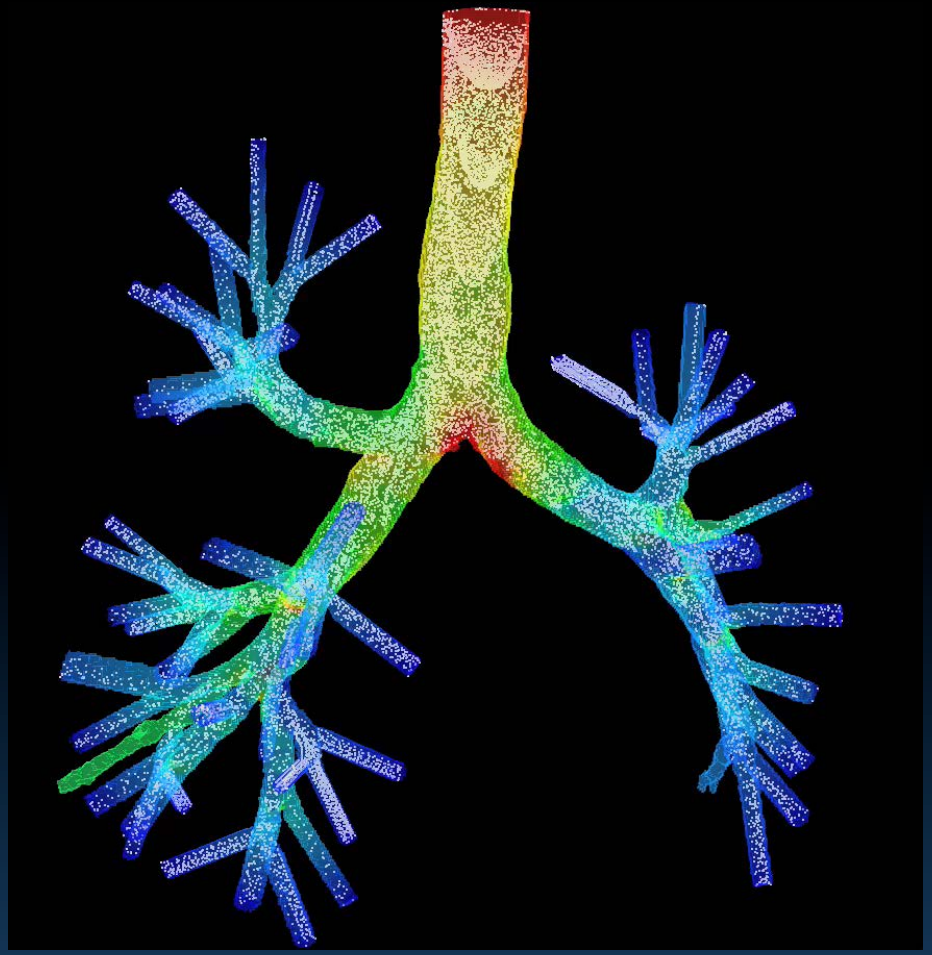


Trajectories of tracer particle

Kiyota et al, Am J Physiol **Lung** Cell Mol Physiol (2014)

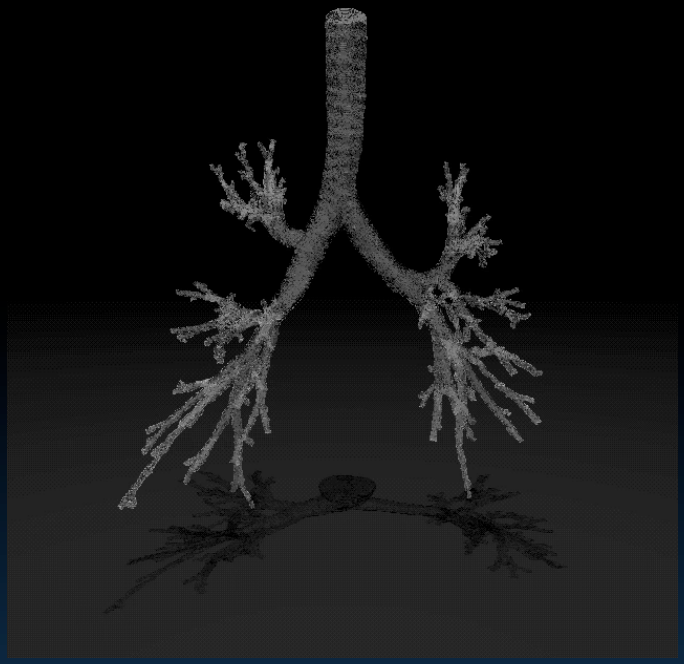
Patient-specific model of pulmonary airflow

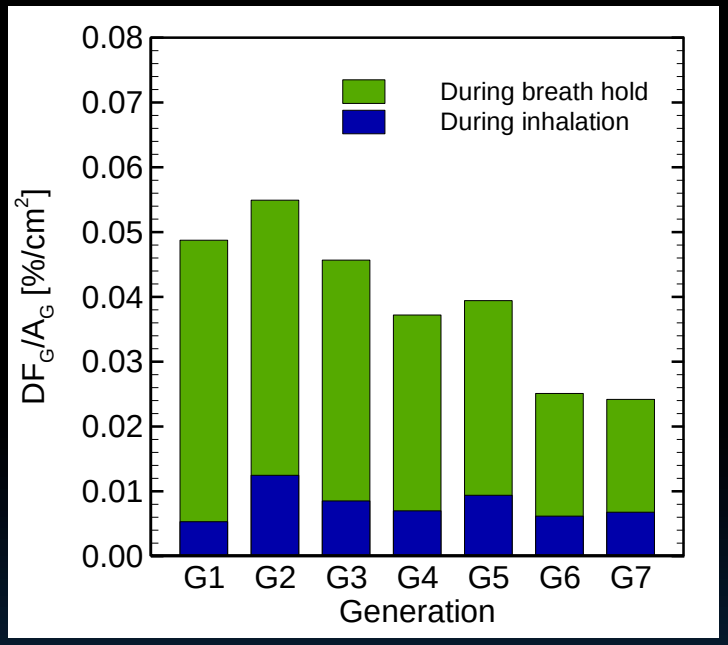




Miki, Imai et al, Int J Numer Meth Biomed Eng (2011)
Miki, Wang et al, Comput Meth Biomech Biomed Eng (2012)

Effect of breath holding on aerosol deposition





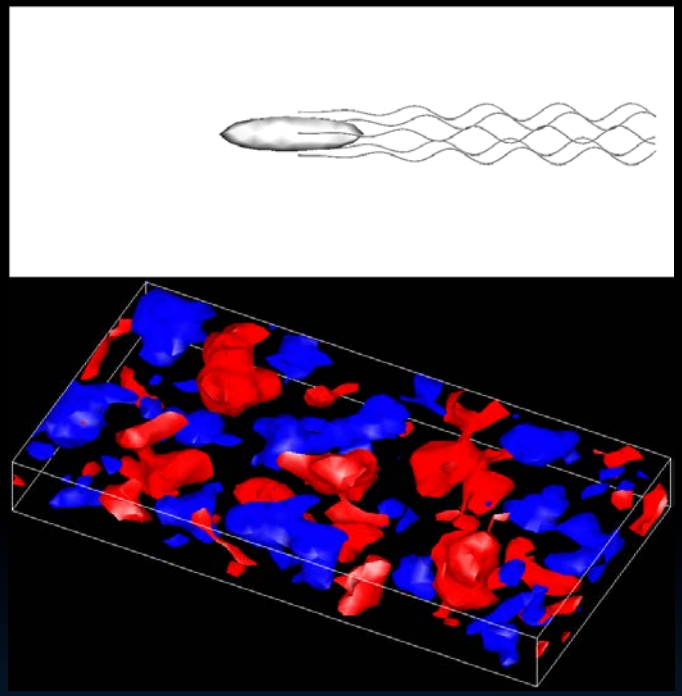
5μm particles

Deposition increases more than 5 times

Imai, Miki et al, J Biomech, (2012)

Computational biomechanics on digestive system

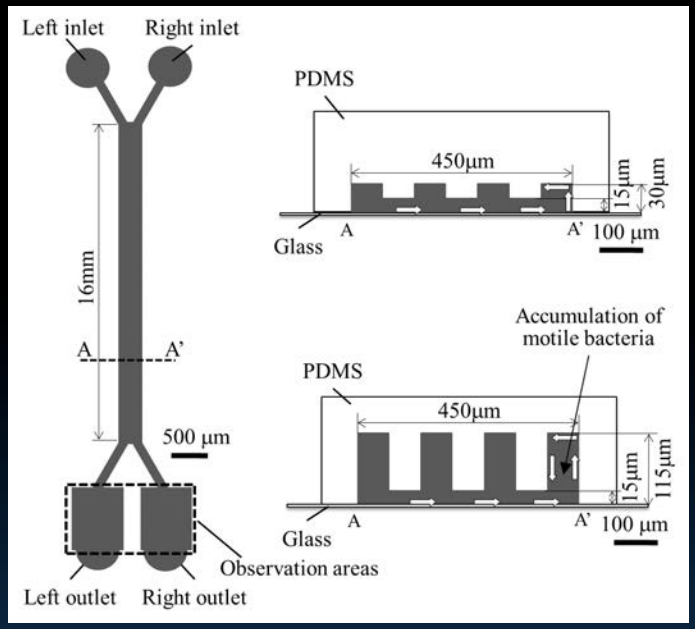
Collective swimming of bacteria

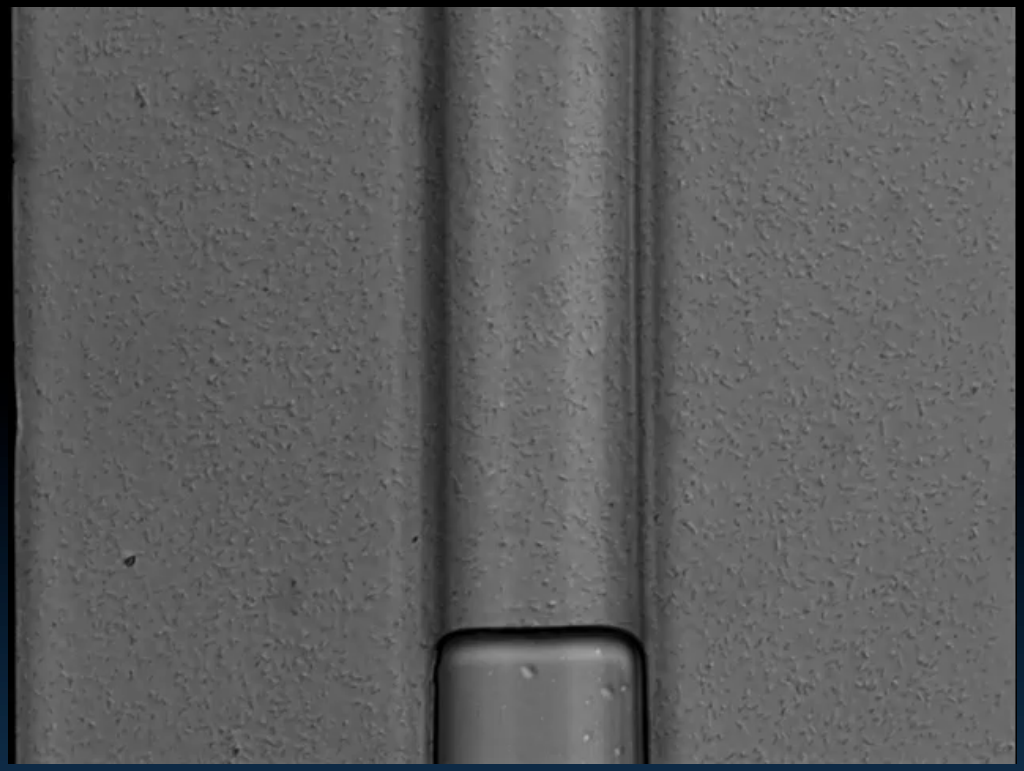


Collective swimming is efficient
in terms of energy

Giacche, Ishikawa, J Theor Biol (2010)
Giacche, Ishikawa et al, Phys Rev E (2010)
Ishikawa, Yoshida et al, Phys Rev Lett (2011)
Kanehl and Ishikawa, Phys Rev E (2014)

Biochip for bacteria separation

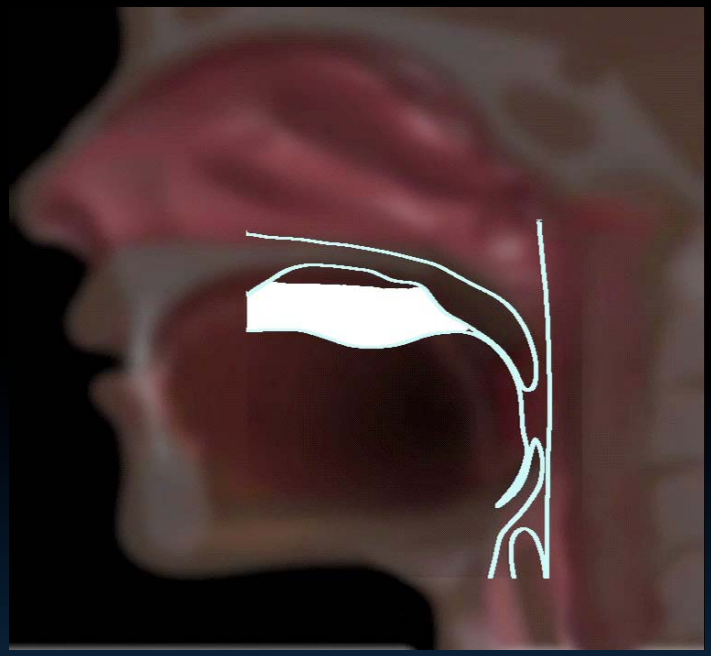




Highly motile cells go to right chamber

Ishikawa et al, Lab on a Chip (2013)

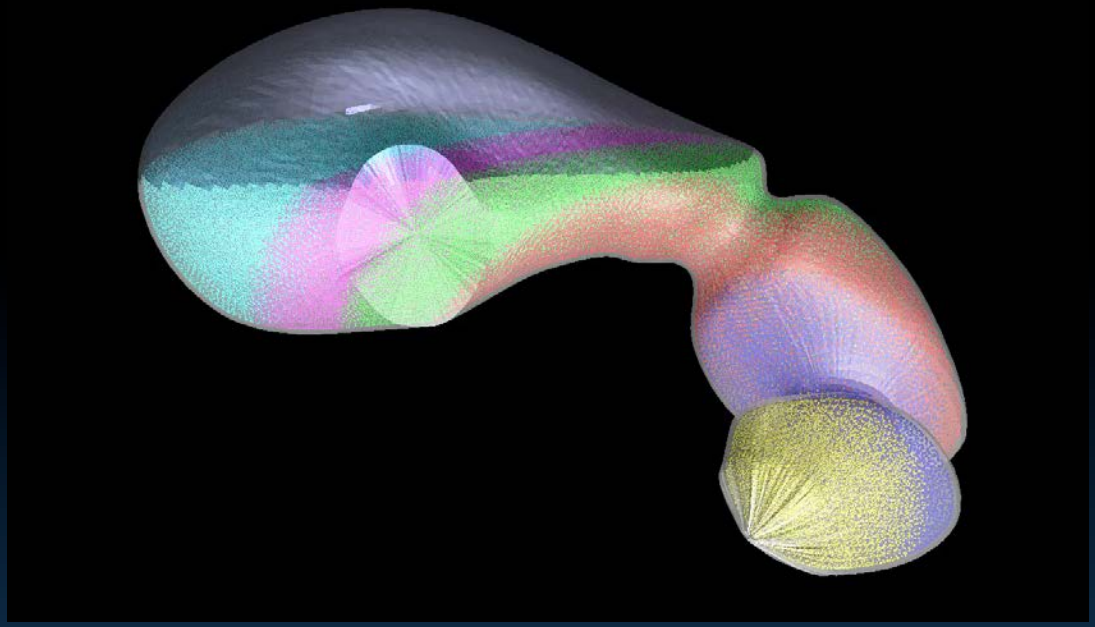
Swallowing



VF image-based numerical simulation

Ishida, Imai et al, in preparation

Gastric mixing

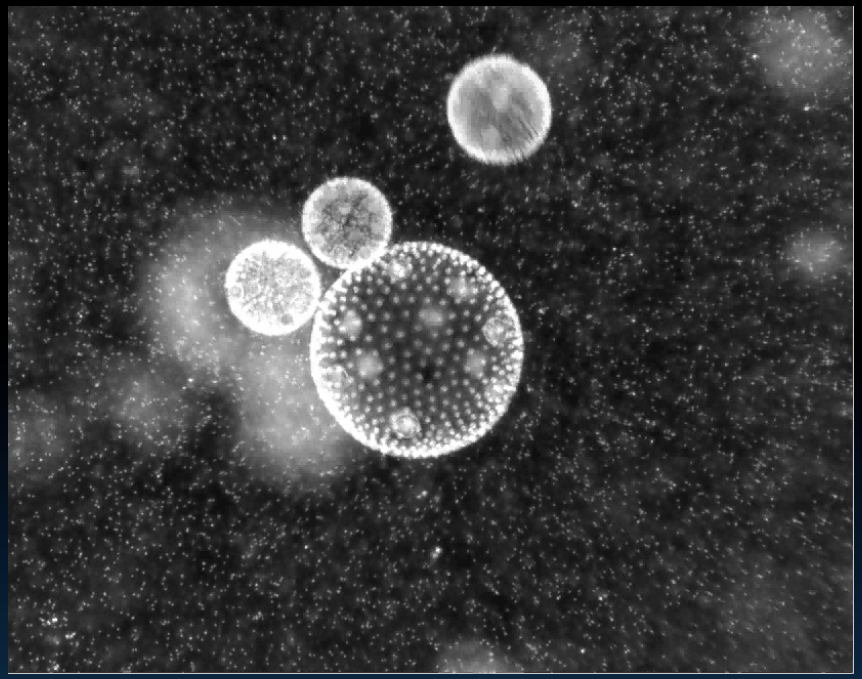


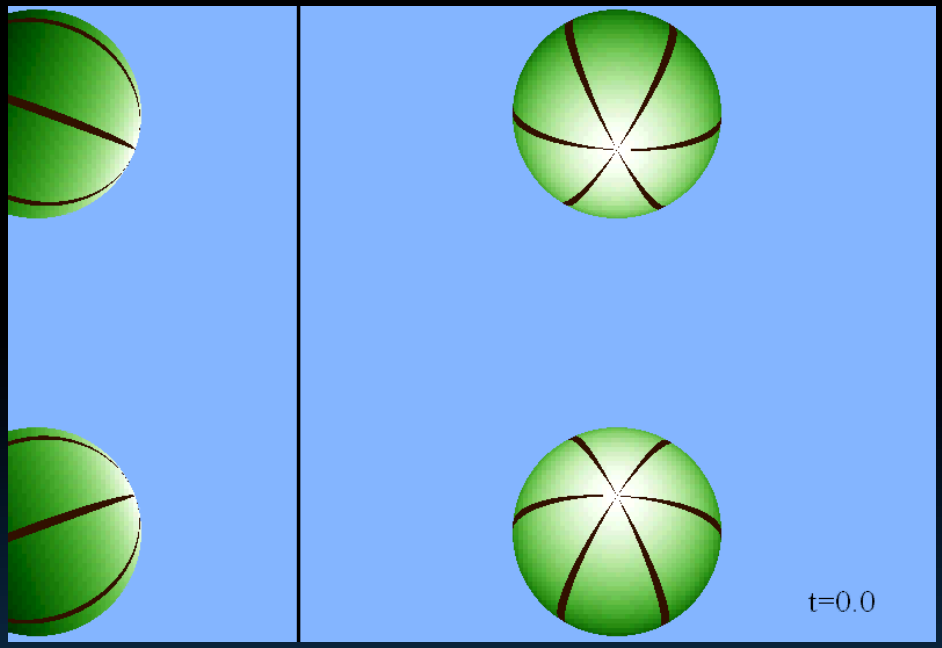
Antral recirculation mixes food in the stomach

Imai et al, AJP-Gastrointestinal and Liver Physiology (2013)

Computational biomechanics on microorganism suspension

Dancing volvox

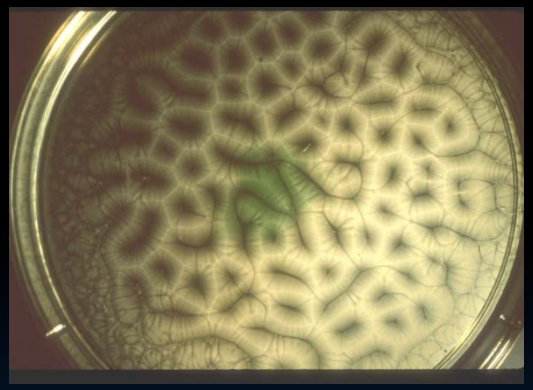


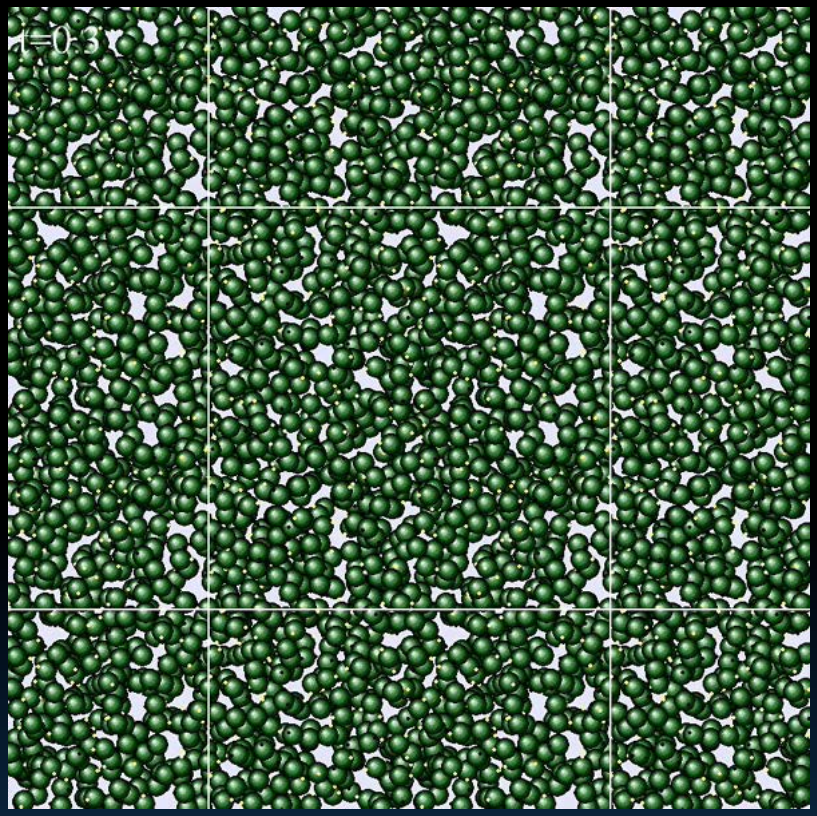


Two volvox “waltz” or “minuet” near a solid surface

Drescher, Kyriacos et al, Phys Rev Lett (2009)
Ishikawa, J Roy Soc Interface (2009)

Microorganism suspension

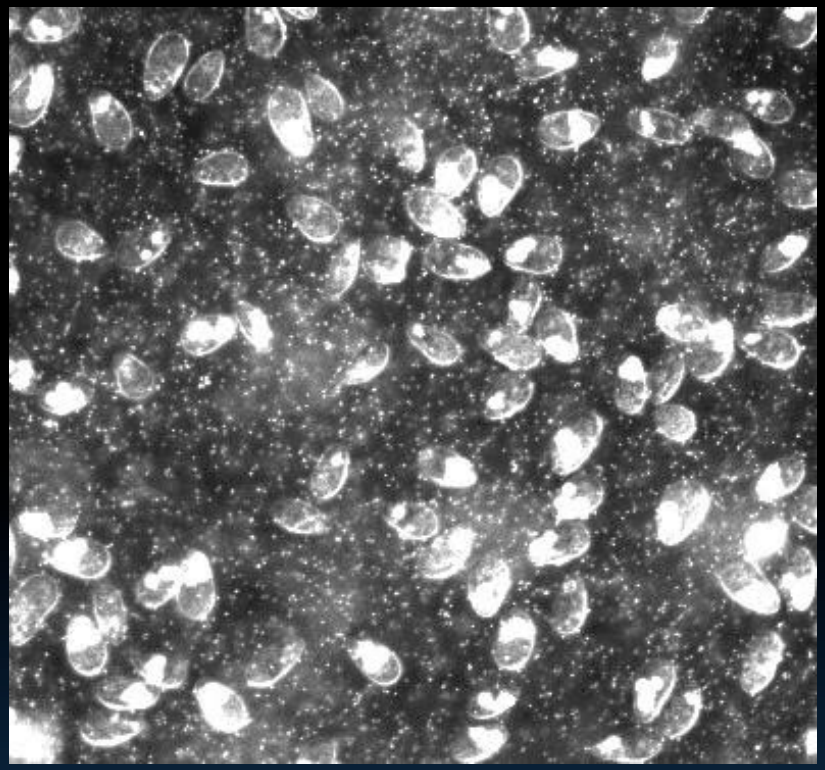




Cell-cell interactions generate coherent structure

Ishikawa, Pedley et al, Phys Rev Lett (2008)
Ishikawa, Locsei et al, J Fluid Mech (2008)
Ishikawa, Yamaguchi, Phys Rev E (2008)
Ishikawa, Locsei et al, Phys Rev E (2010)

Cell entrapment at air-liquid interface



Ciliates *Tetrahymena* are entrapped at the air-water interface

Ferracchi et al, PLoS One (2013)

Computational biomechanics with GPU computing

GPU computing

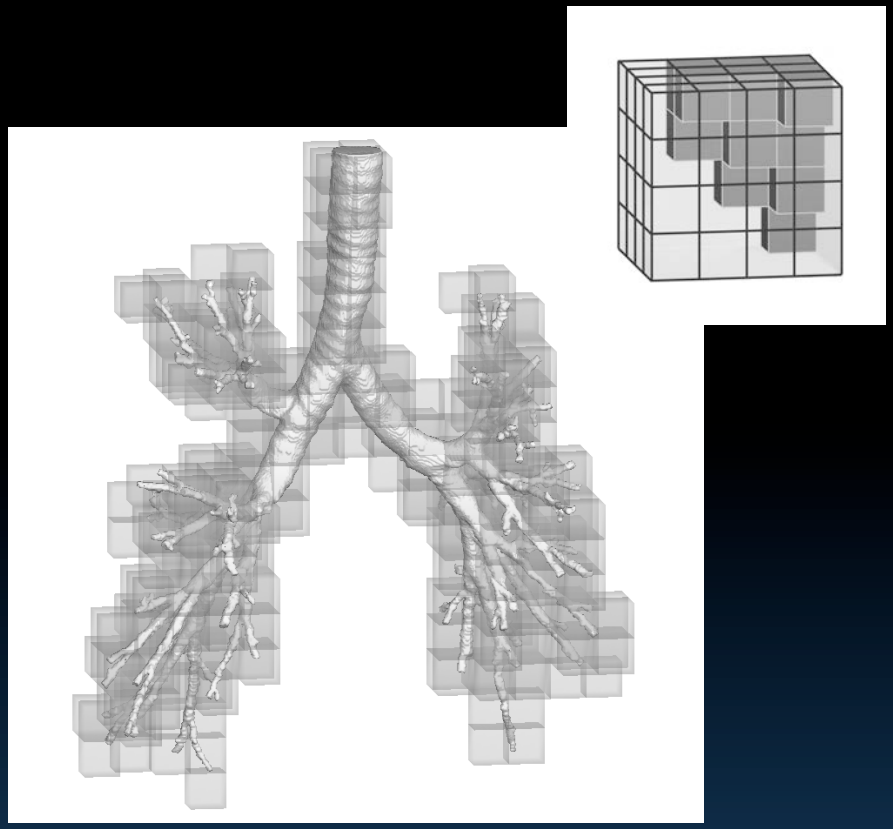
Graphics Processing Unit :

- High performance
- Wide memory bandwidth

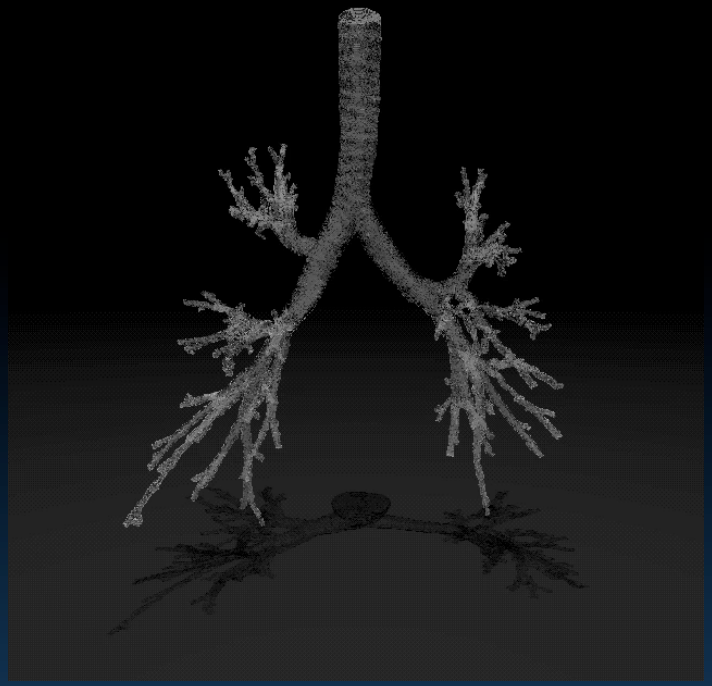
NVIDIA Tesla K20

GPU Cluster

Multi-GPU computing of pulmonary airflow

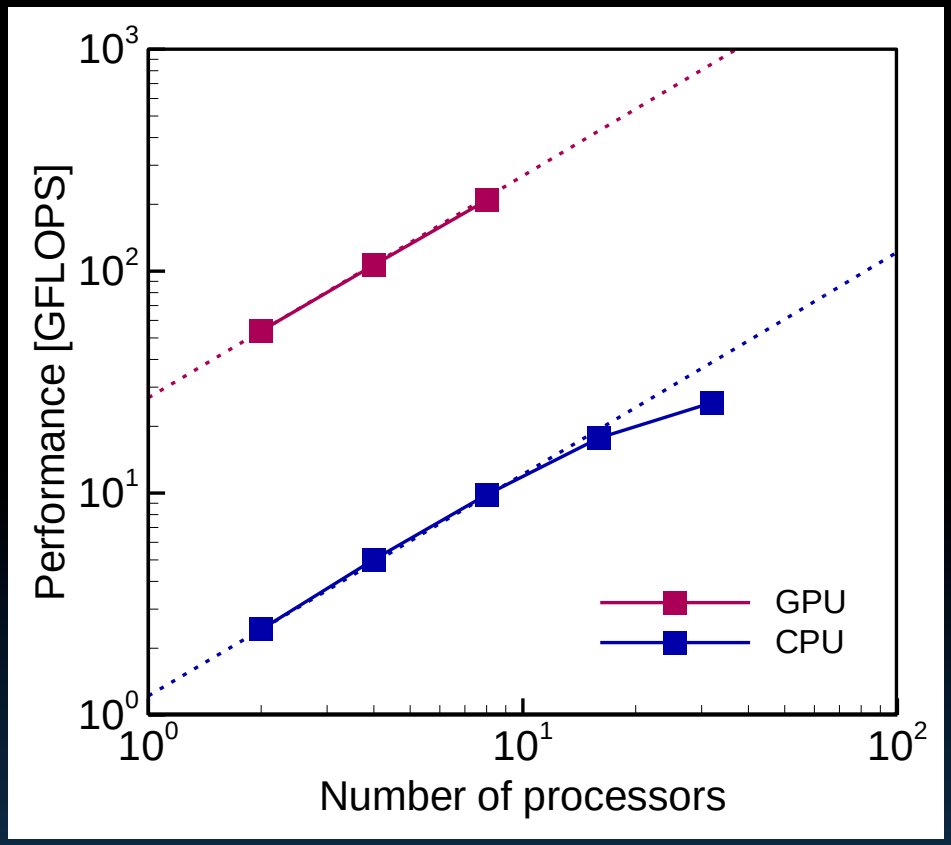


Adaptive sub-domain



Miki, Wang et al, Comput Meth Biomech Biomed Eng, (2012)

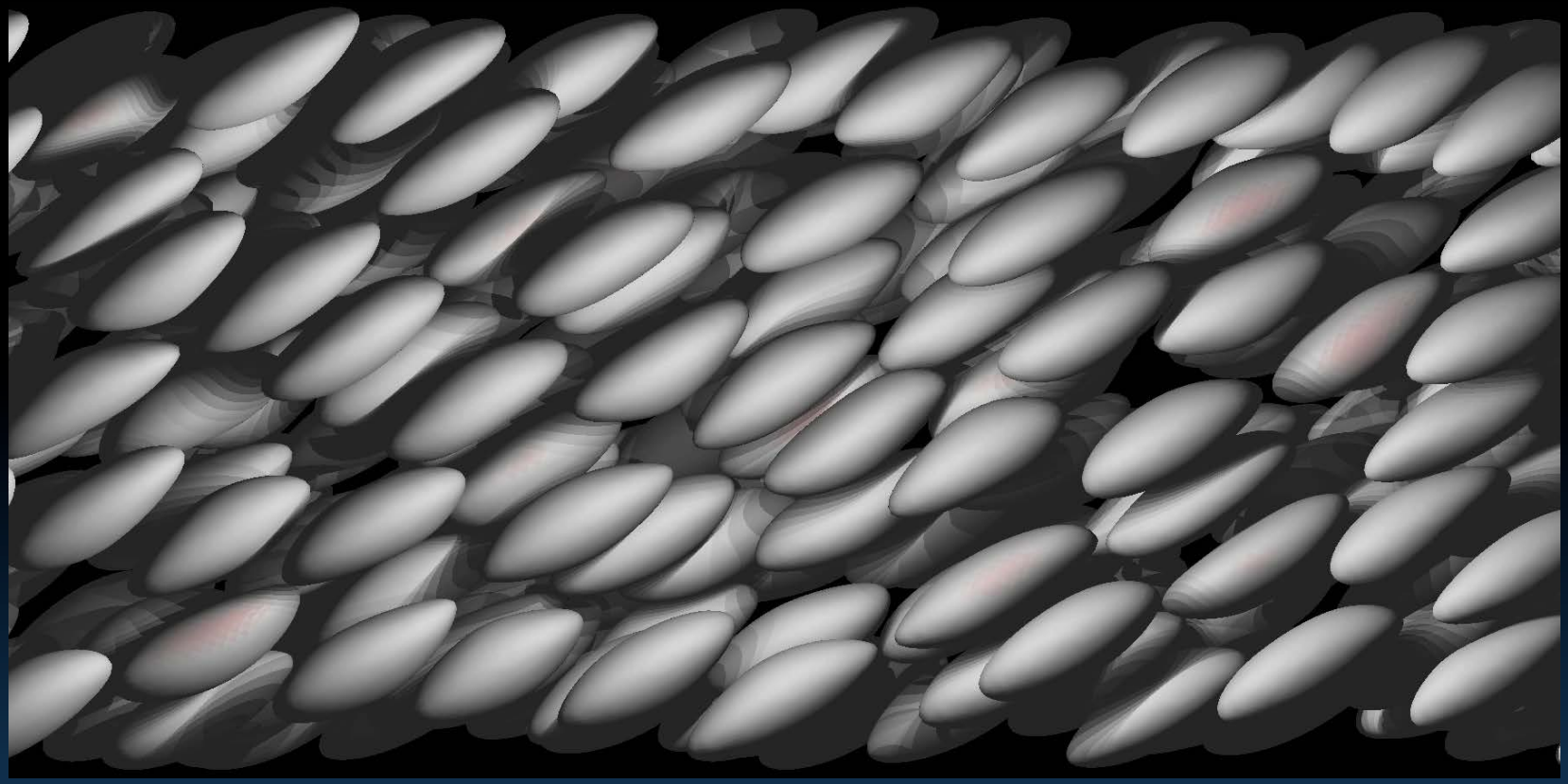
Multi-GPU computing of pulmonary airflow



20-30 Gflops/GPU

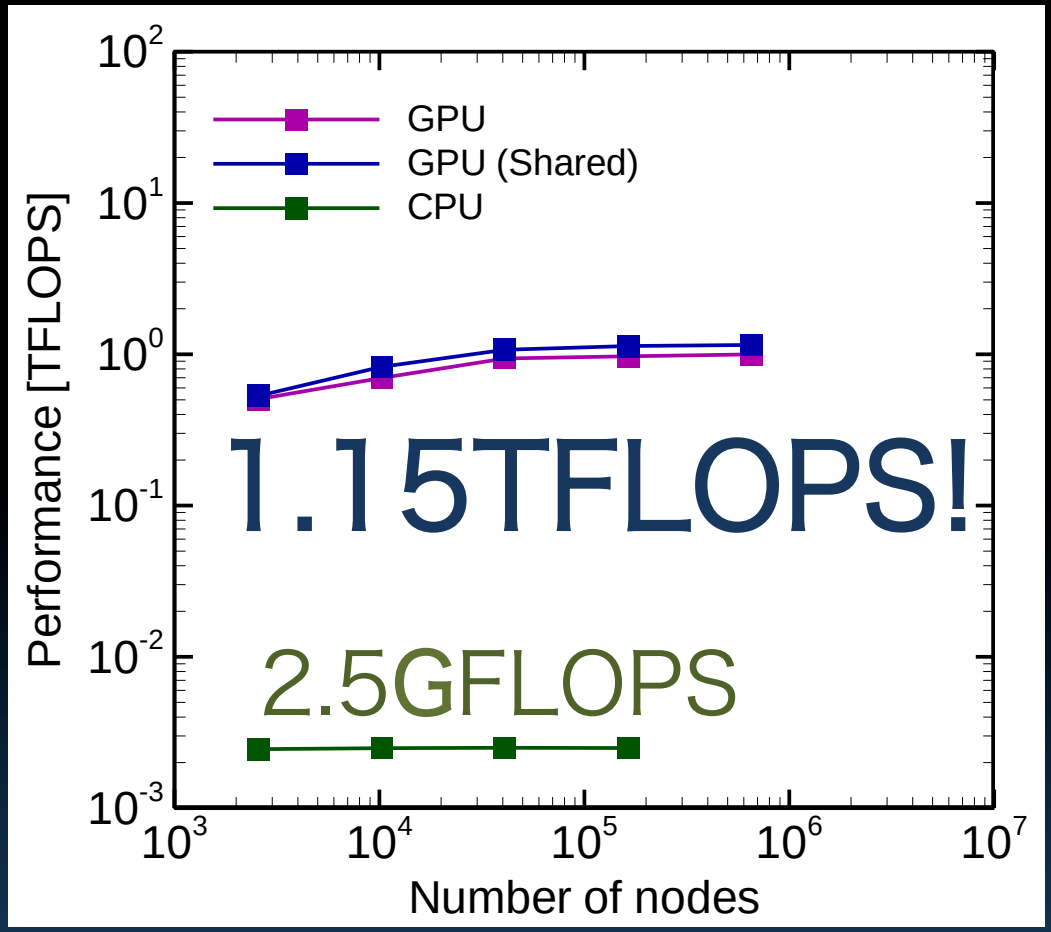
Miki, Wang et al, Comput Meth Biomech Biomed Eng (2012)

Multi-GPU computing of capsule suspension



Matsunaga, Imai et al, J Biomech Sci Eng (2014)

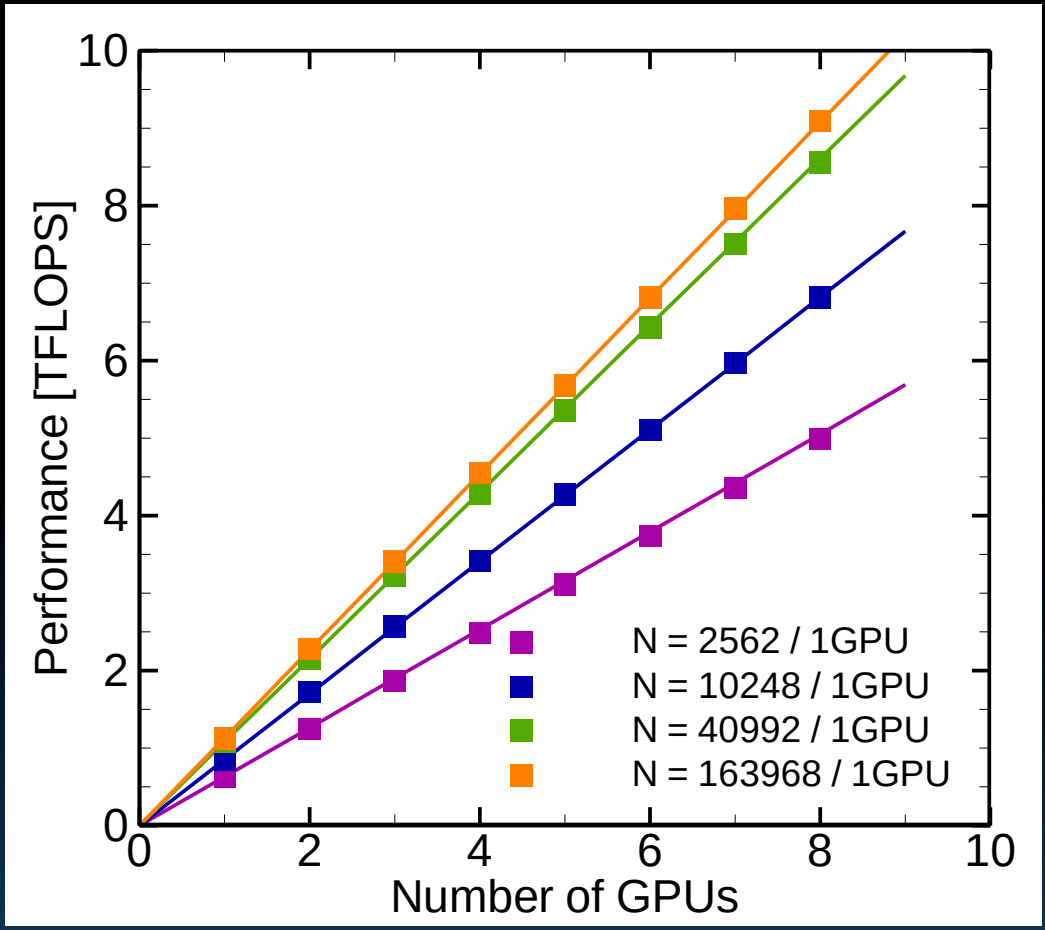
Multi-GPU computing of capsule suspension



500 times faster than CPUs

Matsunaga, Imai et al, J Biomech Sci Eng (2014)

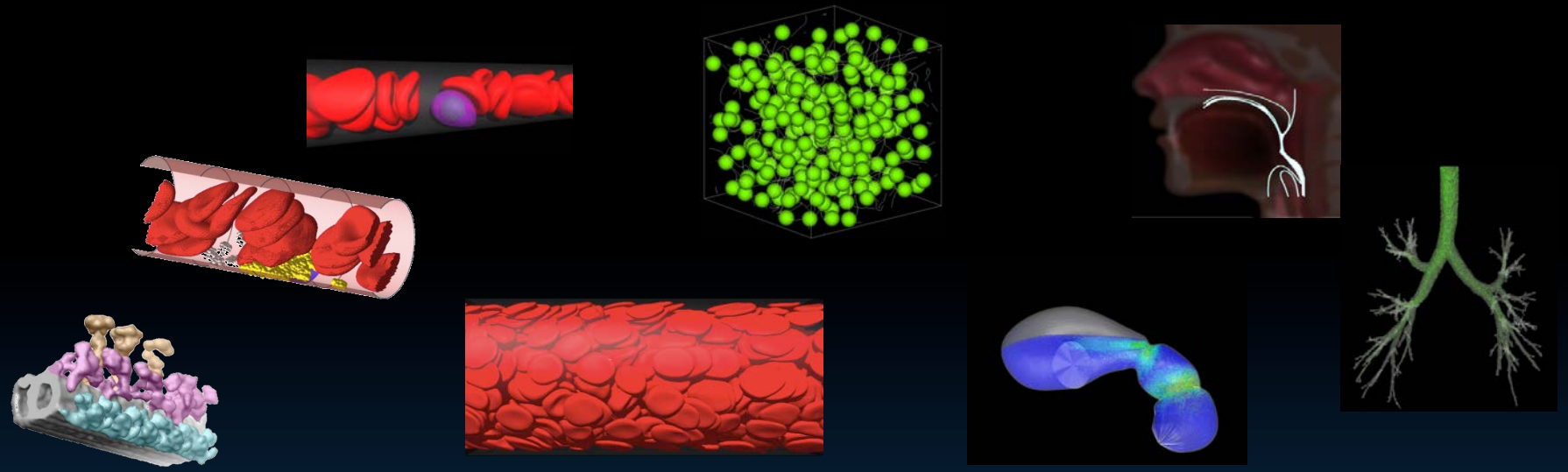
Multi-GPU computing of capsule suspension



Perfect weak scaling

Matsunaga, Imai et al, J Biomech Sci Eng (2014)

Computational biomechanics



Molecule Cell Tissue Organ