
بسم الله الرحمن الرحيم

Investigation of particle geometry and inhomogeneity on the dynamics in microfluidic domains

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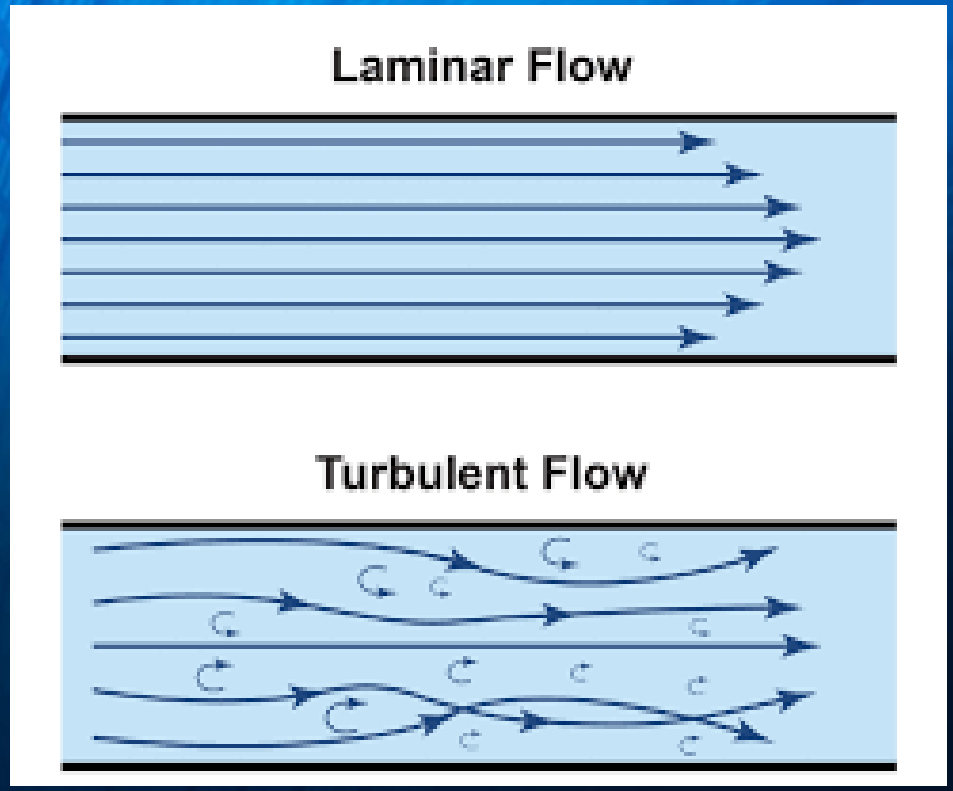
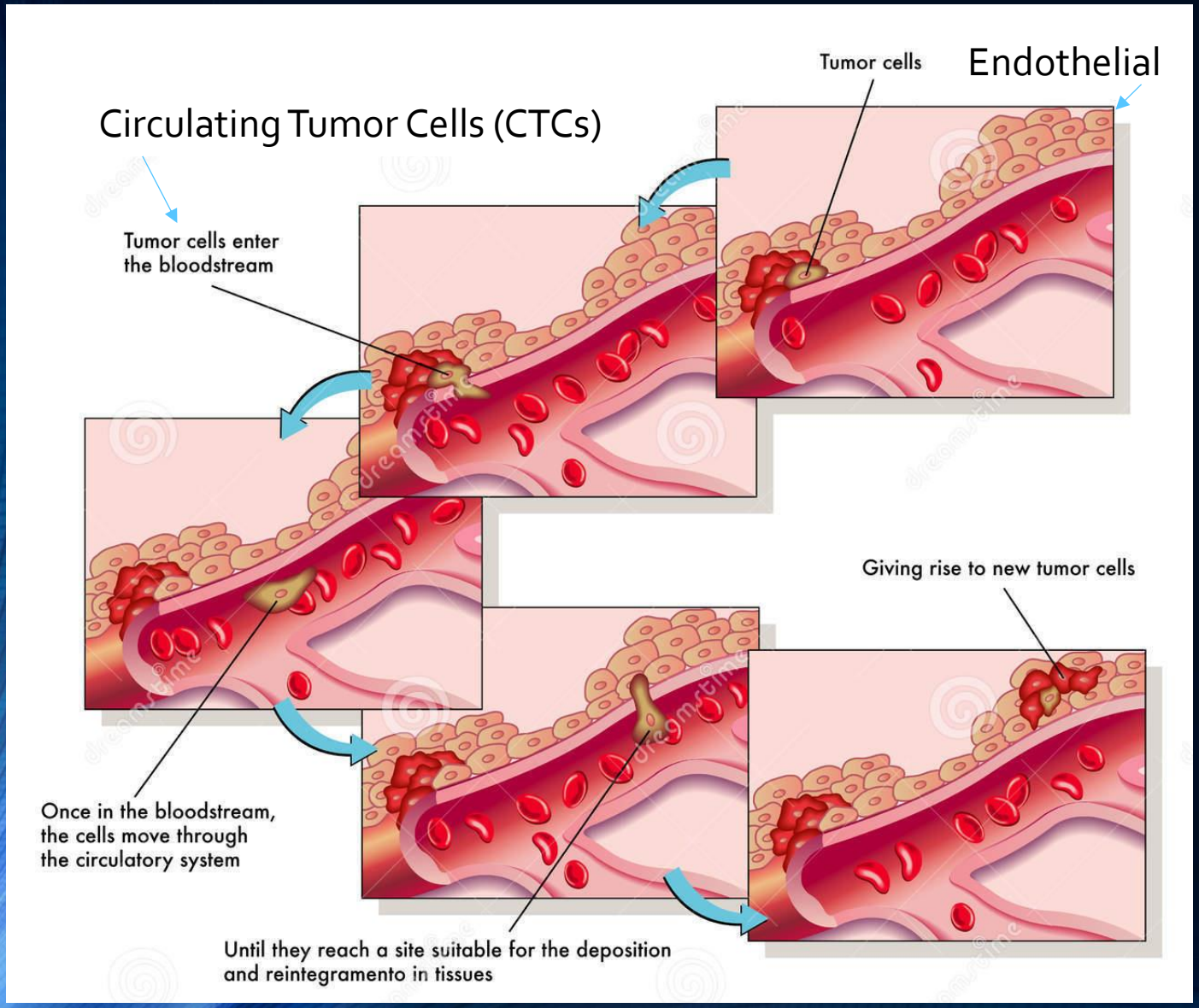
Content

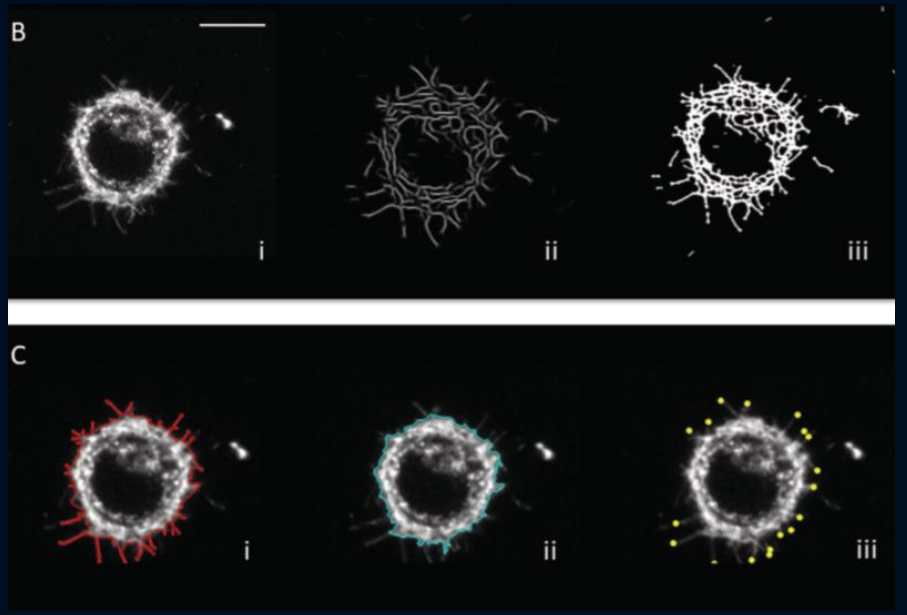
- Why Microfluidics?
- What's the history?
- Physics and how to do it.
- Particle motion
- A filter
- Out look

MICROFLUIDICS?



Metastasis



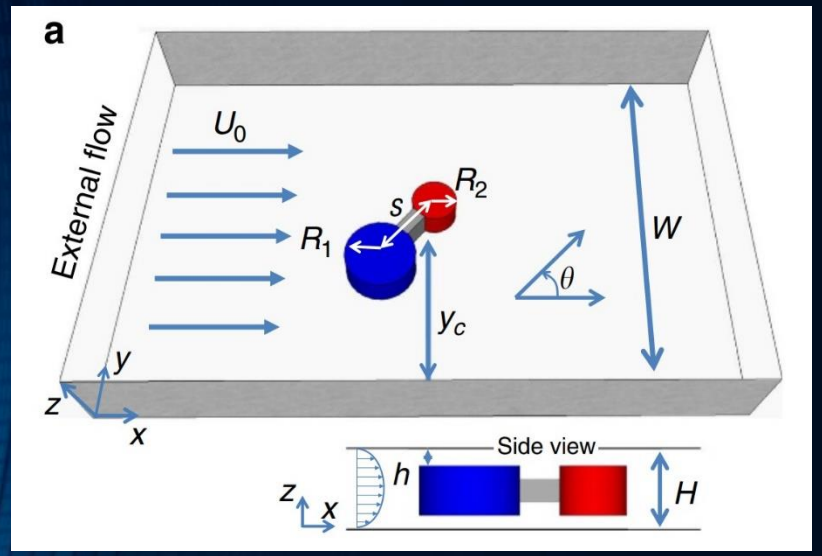


Ory et al., Oncotarget 8, 111567, 2017

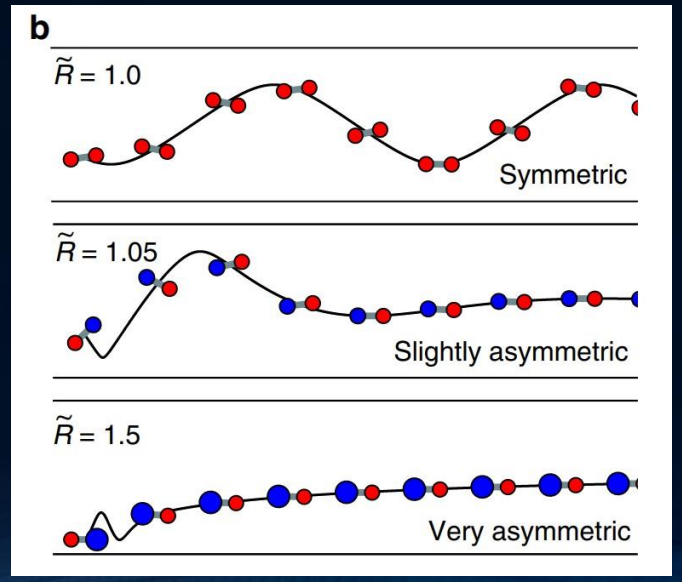
90 % of
(10, 000,000 Cancer death/ year) in 2017-2023

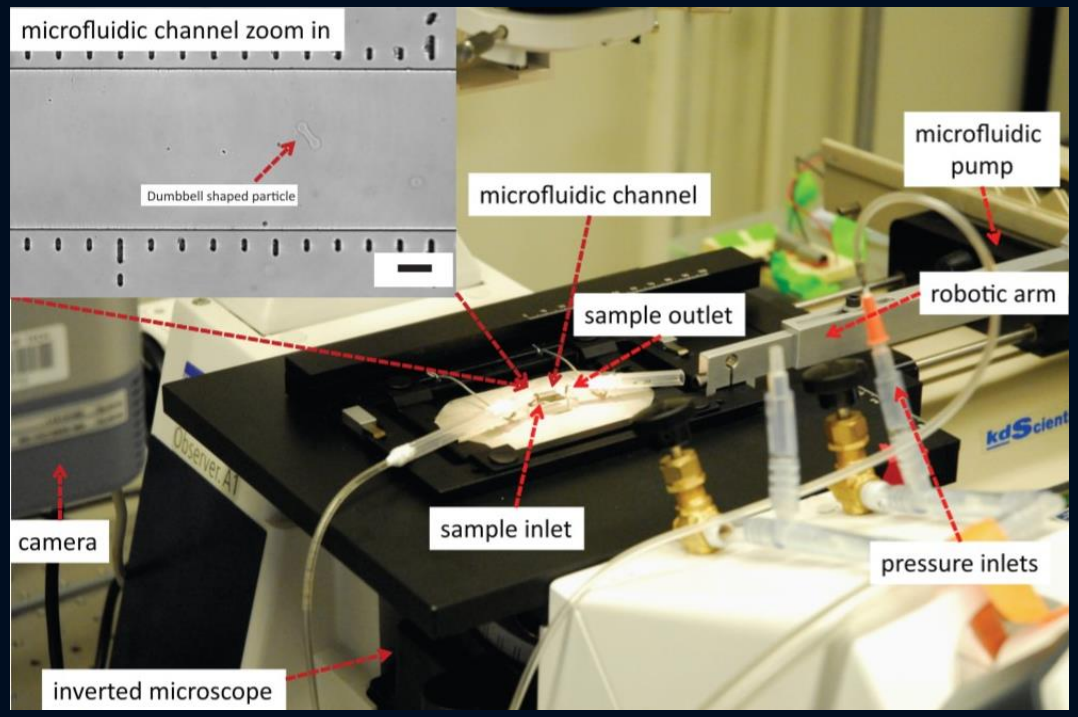
So WHAT?

Engineering Particle Trajectories



$$\tilde{R} \equiv \frac{R_1}{R_2}$$

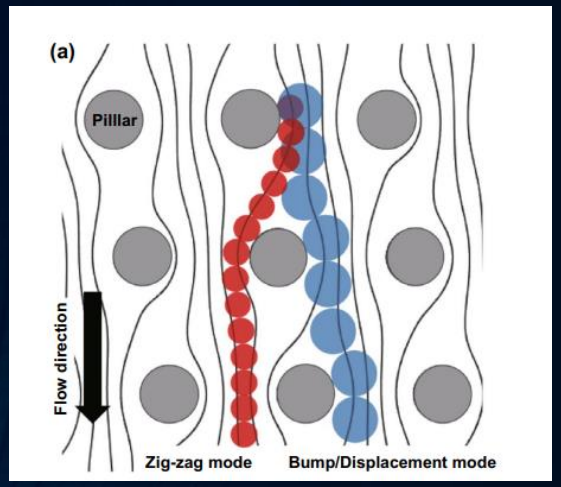




Uspal , et al., Nat Commun 4, 2666, 2013

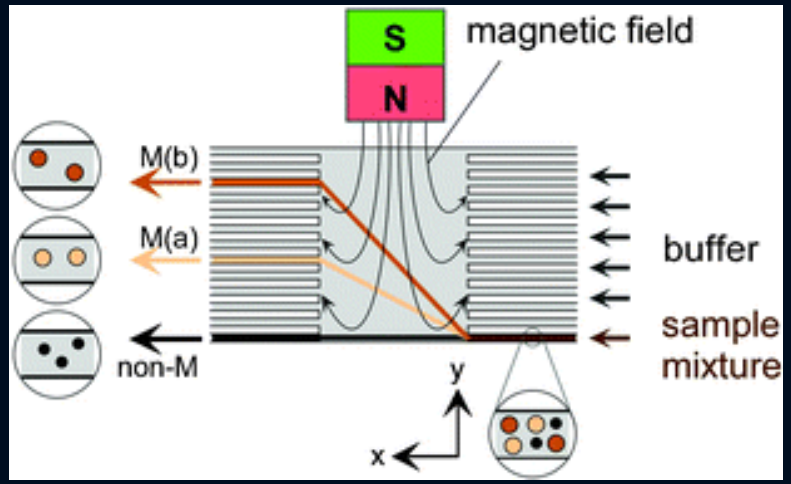
Particle Sorting

Fig 1



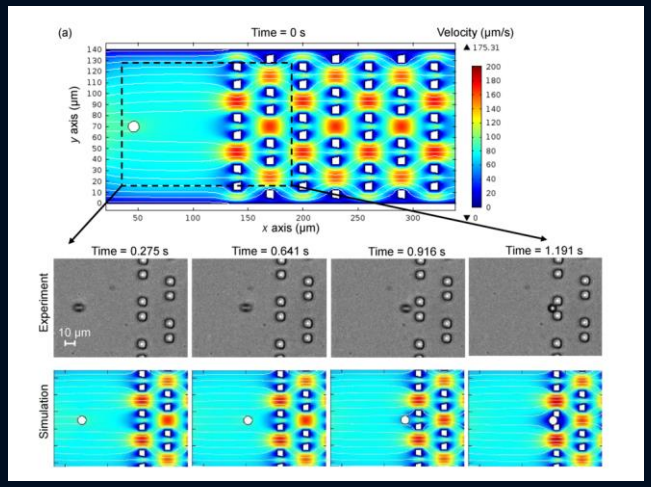
Salafi, et al., Nano-Micro Lett. 11, 77, 2019

Fig 2



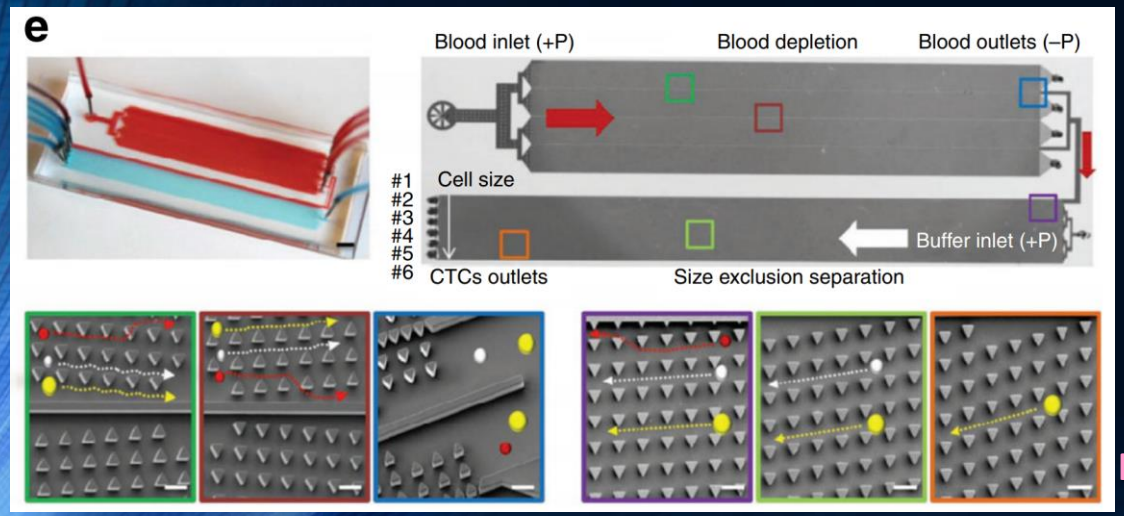
Pamme, et al., Lab Chip 6, 974, 2006

Fig 3



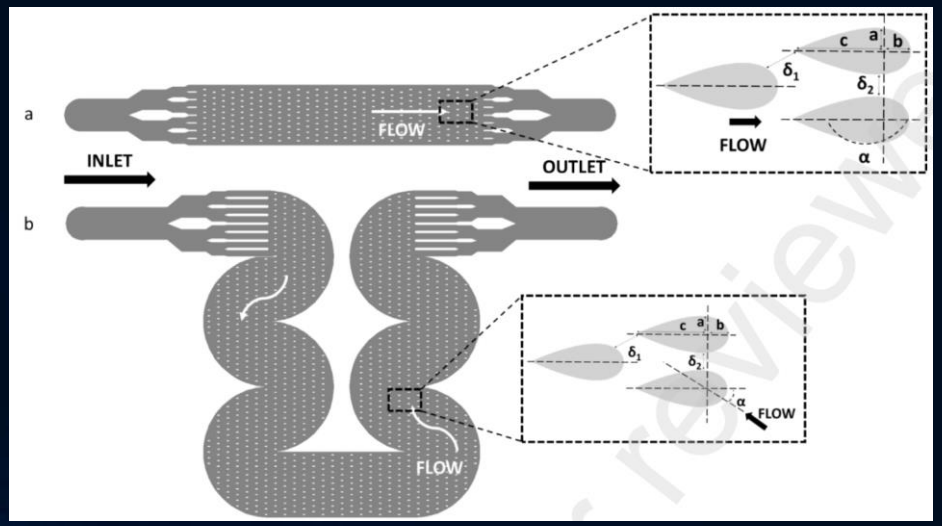
Xu et al., Biomicrofluidics 7, 054108, 2013

Fig 4



Liu, et al., Adv. Biosyst. 2, 1800200, 2018

Fig 5



88% CTC capture

Sen-Dogan, et al., Sensors and Actuators Reports 6, 100169, 2023

PHYSICS

Fluid Motion

$$\rho(\frac{\partial \mathbf{u}}{\partial t} + u.\nabla \mathbf{u}) = -\nabla \boldsymbol{\sigma} + \mathbf{F}$$

Euler **Eq 5**

$$\nabla.\mathbf{u} = 0$$

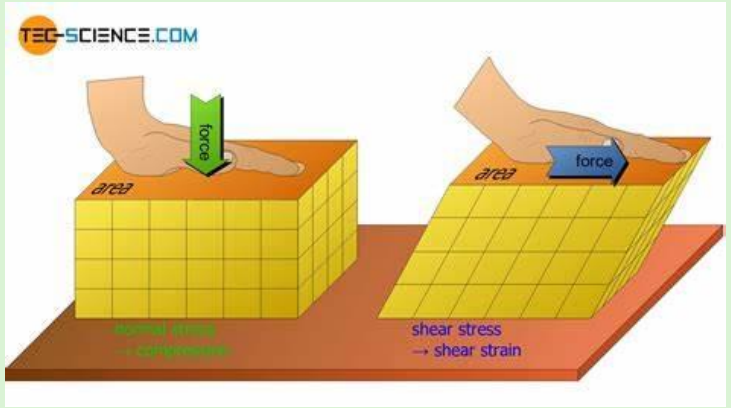
Incompressible **Eq 1**

$$\rho(\frac{\partial \mathbf{u}}{\partial t} + u.\nabla \mathbf{u}) = -\nabla P + \eta \nabla^2 \mathbf{u}$$

Navier-Stokes **Eq 6**

$$\tau = \eta \frac{\partial u}{\partial y}$$

Shear stress **Eq 2**



$$Re = \rho u H / \eta$$

Reynolds **Eq 7**

$$\boldsymbol{\sigma} = -PI + 2\eta D$$

Stress tensor **Eq 3**

$$D = \frac{1}{2}(\nabla \mathbf{u} + \nabla \mathbf{u}^T)$$

Deformability tensor **Eq 4**

$$-\nabla P + \eta \nabla^2 \mathbf{u} = 0$$

Stokes **Eq 8**

* Boundary con
* Initial con

Particle Motion

$$\mathbf{F} = \int \boldsymbol{\sigma} \cdot \mathbf{n}\, dS$$

Eq 9

$$T = \int (x_s - x_p) \times (\boldsymbol{\sigma} \cdot \mathbf{n})\, dS$$

Eq 12

$$m\frac{d\mathbf{u}_p}{dt} = \oint_s [-PI + \eta(\nabla \mathbf{u} + \nabla \mathbf{u}^T)].\mathbf{n}\, dS$$

Eq 10

$$I\frac{d\omega_p}{dt} = \oint_s ((\mathbf{x}_s - \mathbf{x}_p) \times [-PI + \eta(\nabla \mathbf{u} + \nabla \mathbf{u}^T)]).\mathbf{n}\, dS$$

Eq 13

$$x(t) = x(0) + \int_0^t \mathbf{u}_p(s)\, dt$$

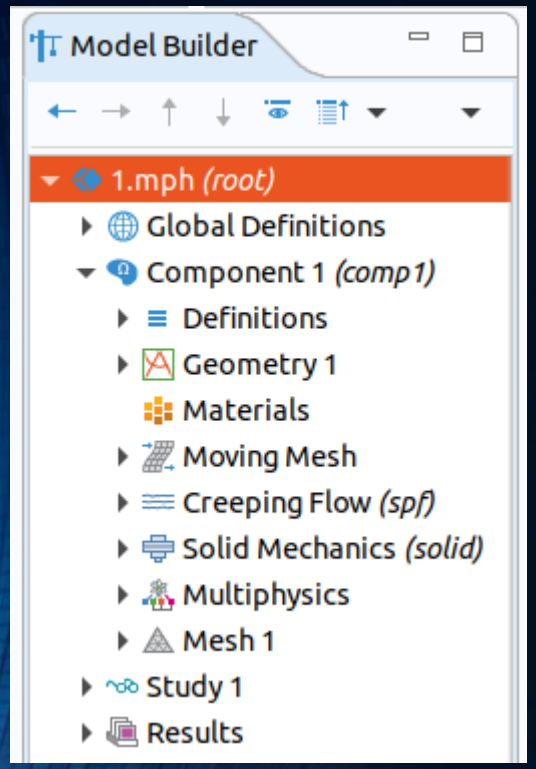
Eq 11

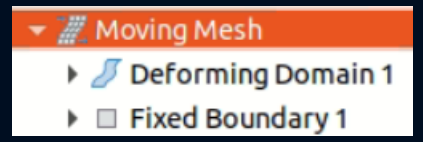
$$\theta(t) = \theta(0) + \int_0^t \omega_p(s)\, dt$$

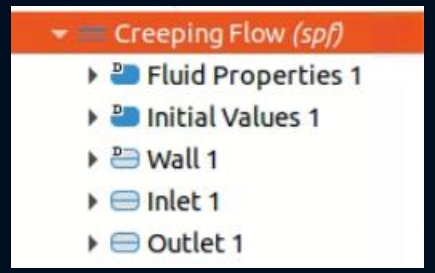
Eq 14

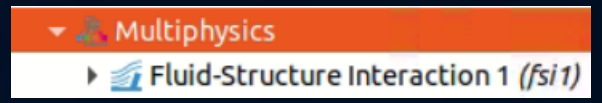
NUMERICAL CALCULATION

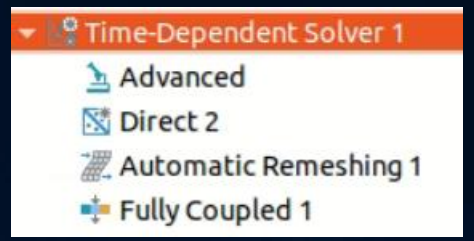
Fluid-Structure Interaction

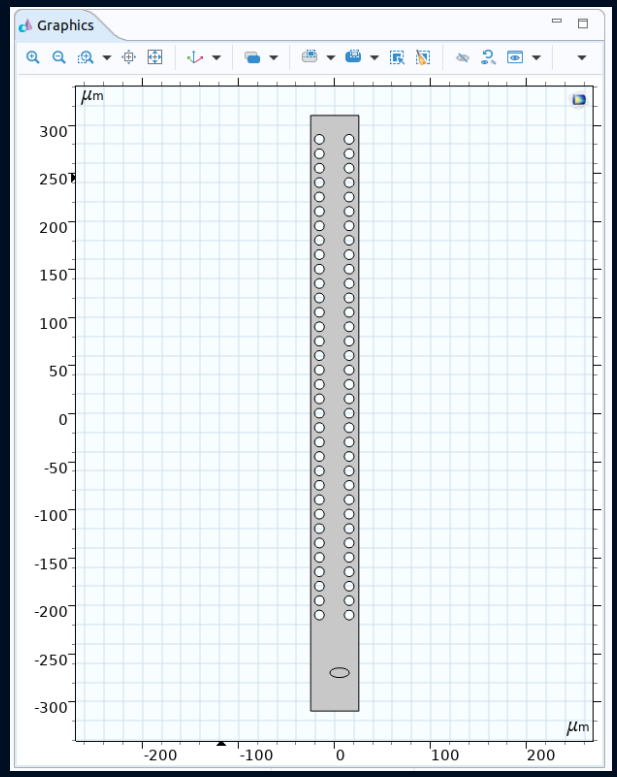


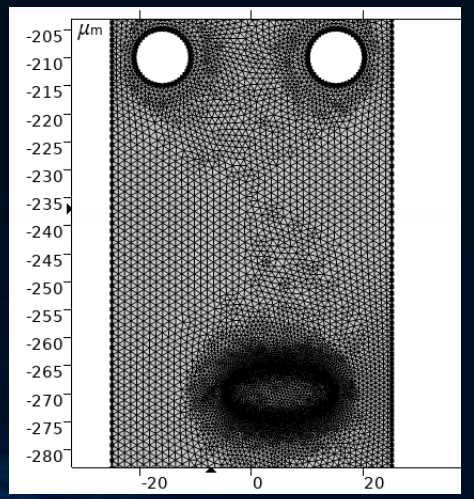








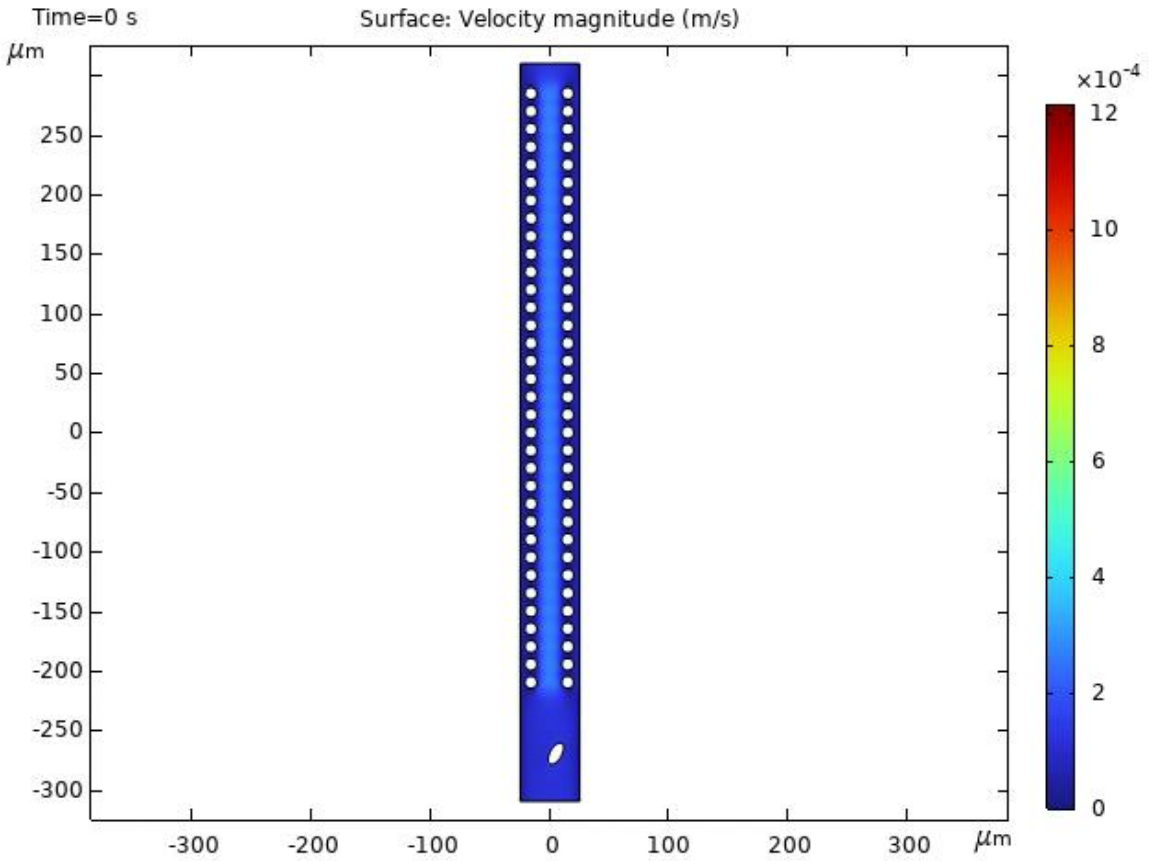




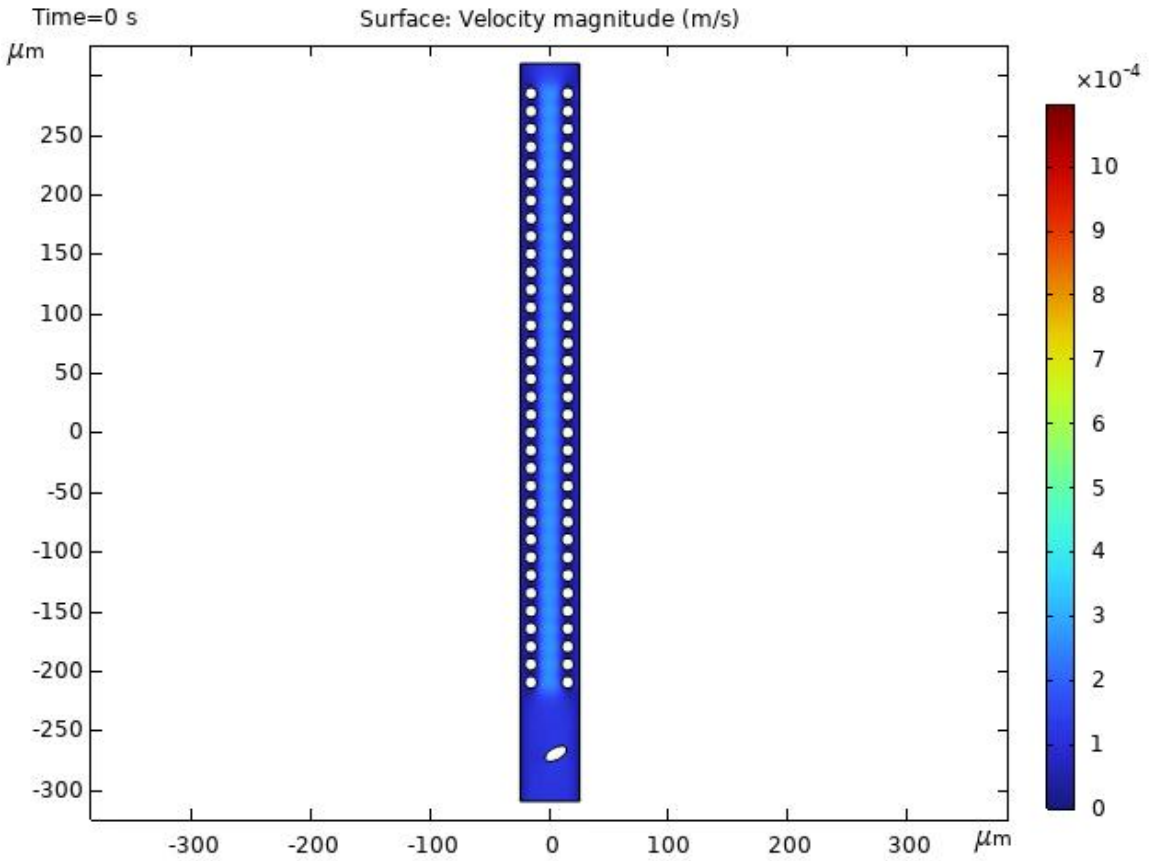
Pinterest

RESULTS

Initial Orientation = 60 [deg]



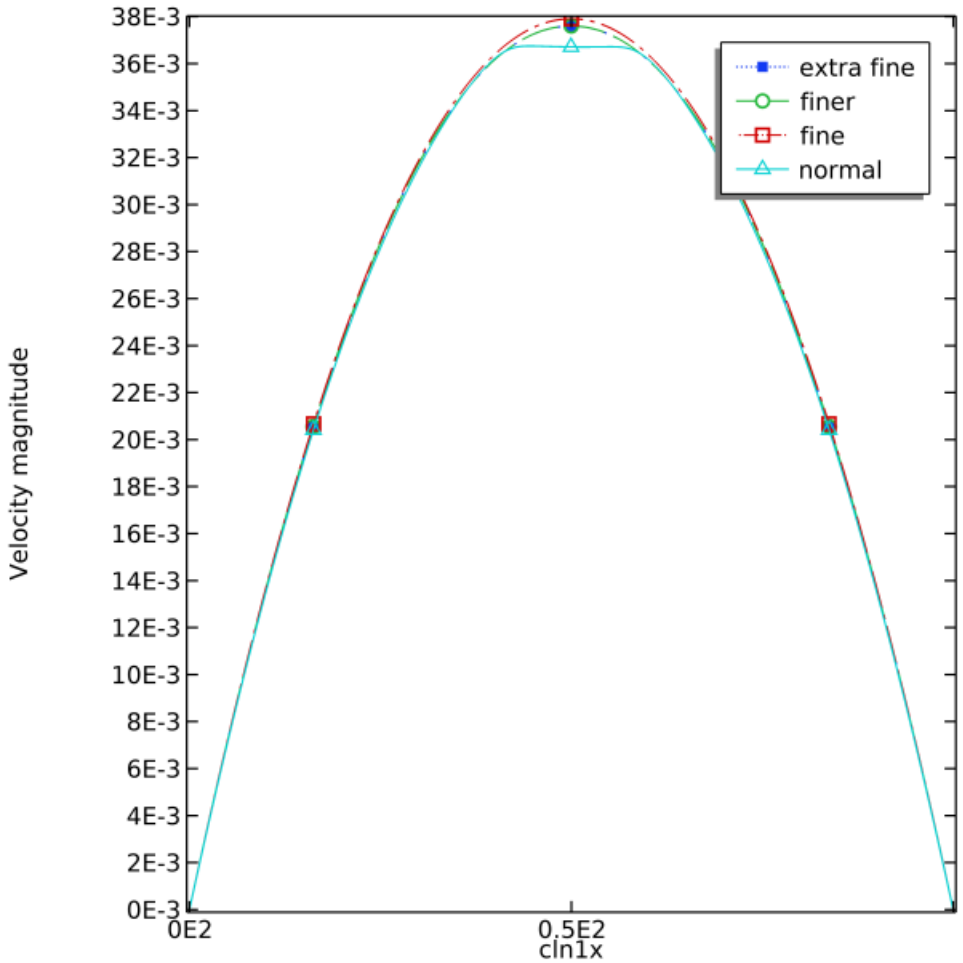
Initial Orientation = 30 [deg]

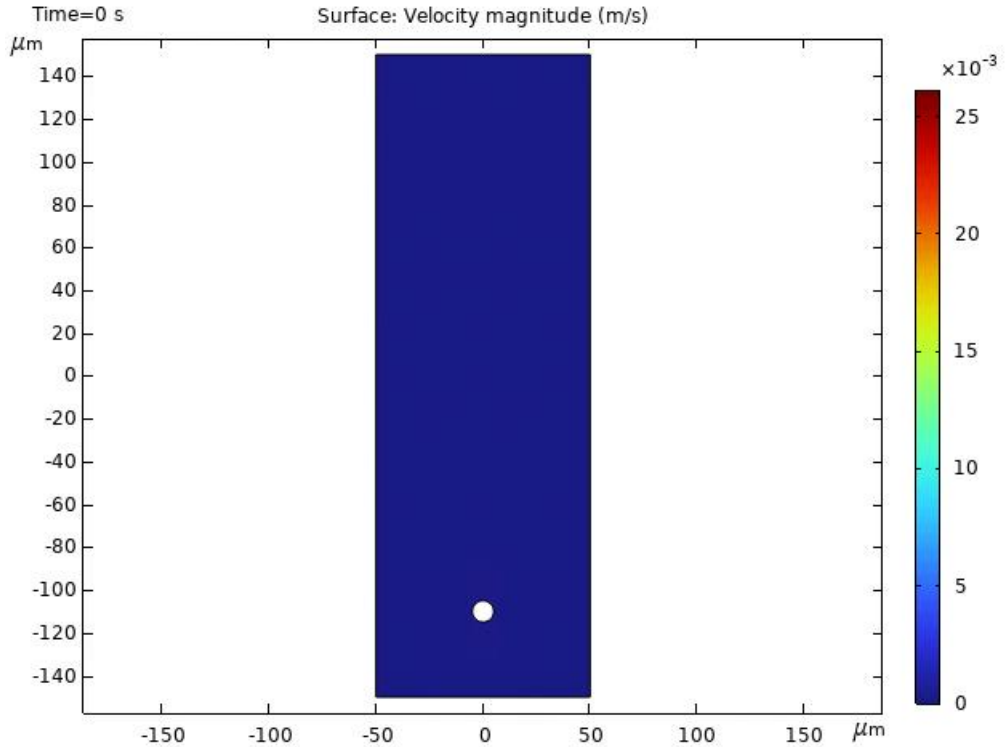


Aspect Ratio = 0.5

Initial X = 5 [μm]

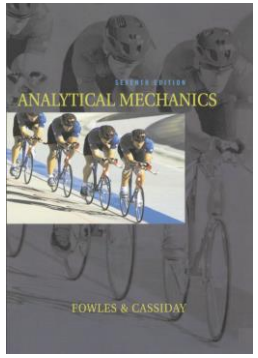
Mesh





Poiseuille Flow

Validation

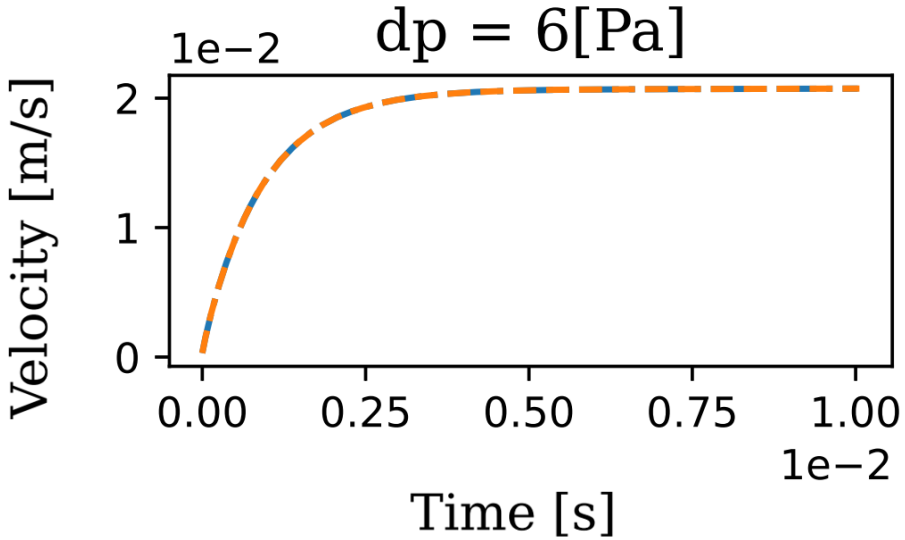


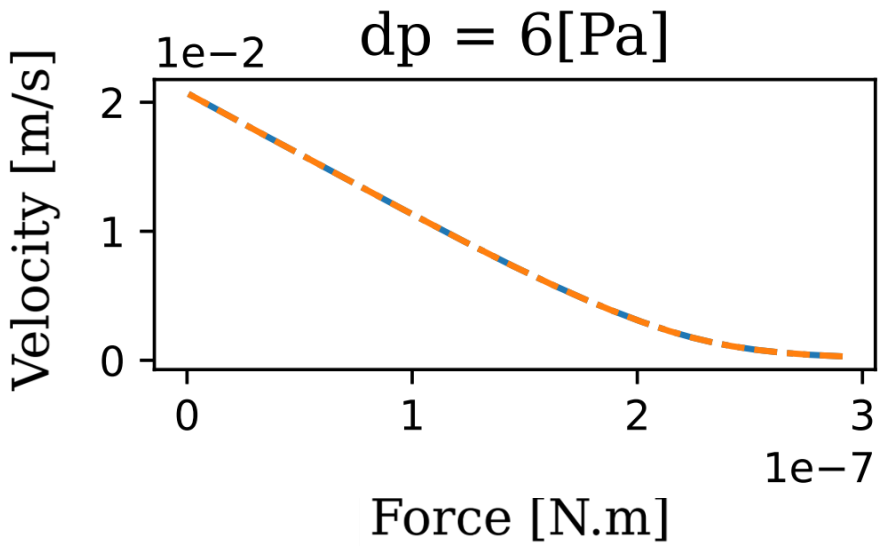
F. Grant and G. L. Cassiday.
Analytical Mechanics. 2005

Particle Velocity

$$v = -v_t(1 - \exp(-t/\tau))$$

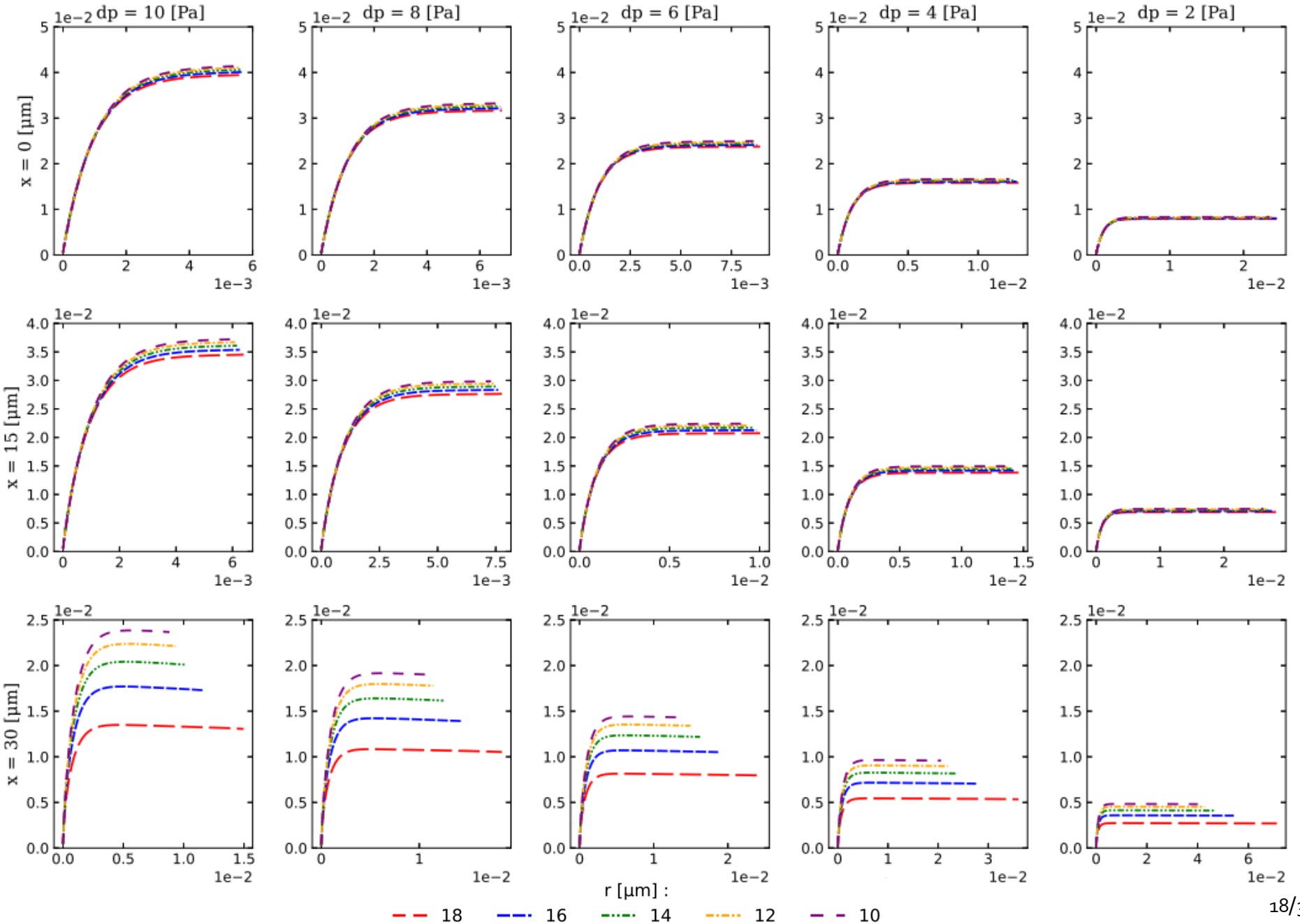
Circle is just another ellipse





Initial X = 15 [μm]
Radius = 18

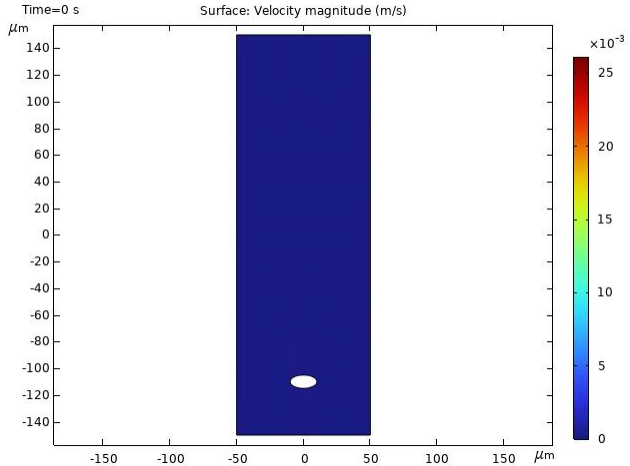
Time (s) - Velocity (m/s)

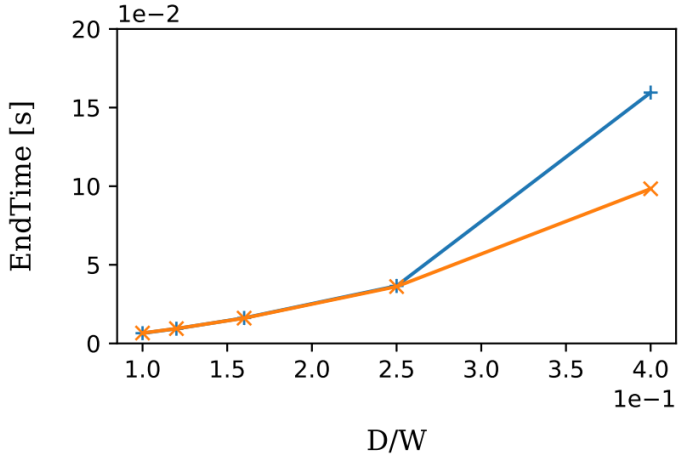


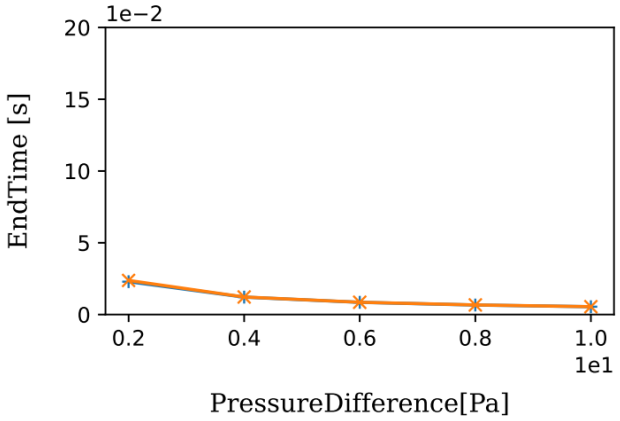
Every Parameter

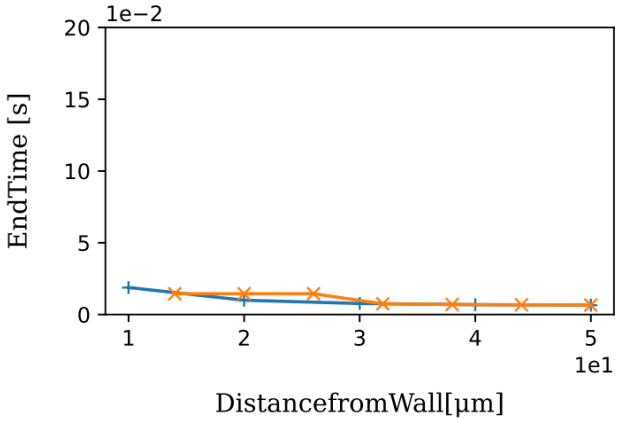
ellipse

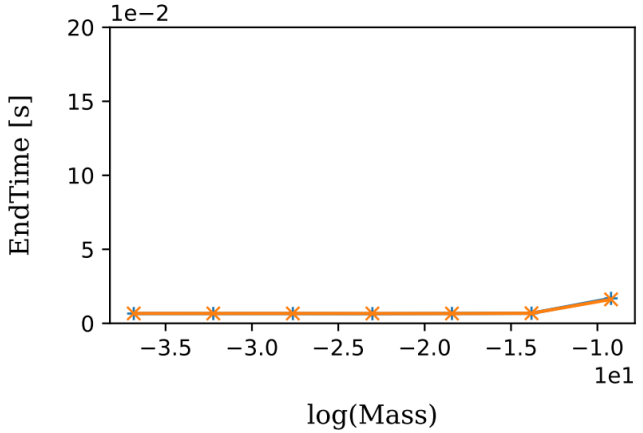
circle

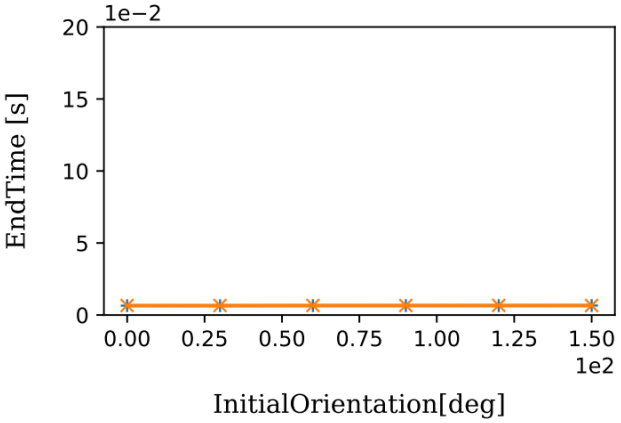


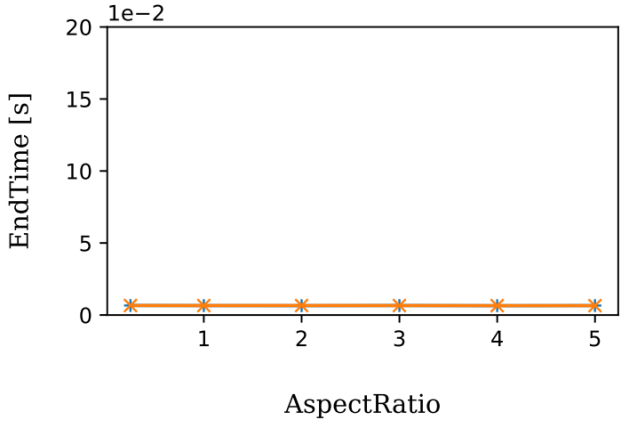


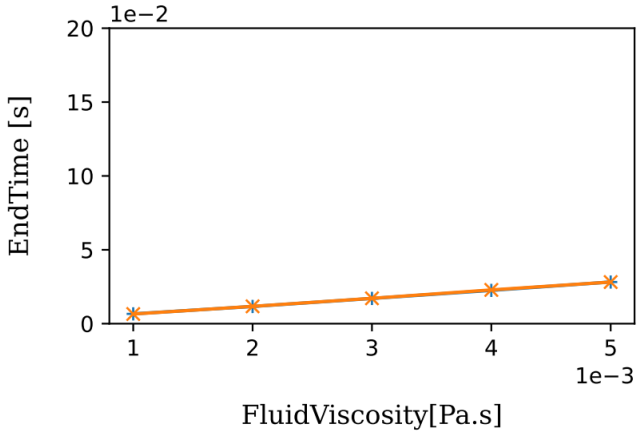




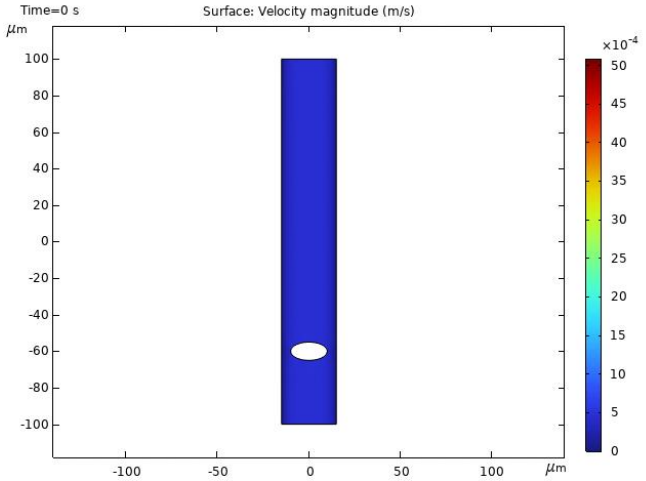


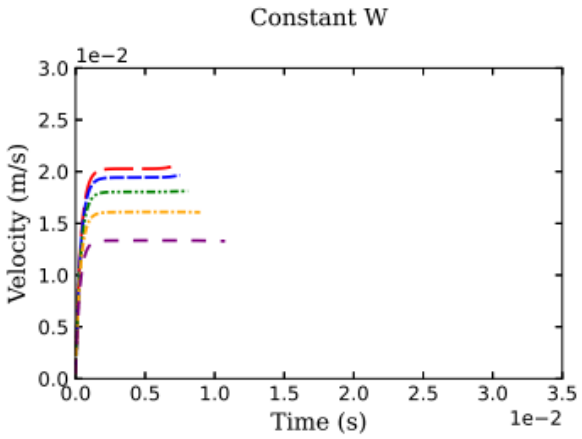


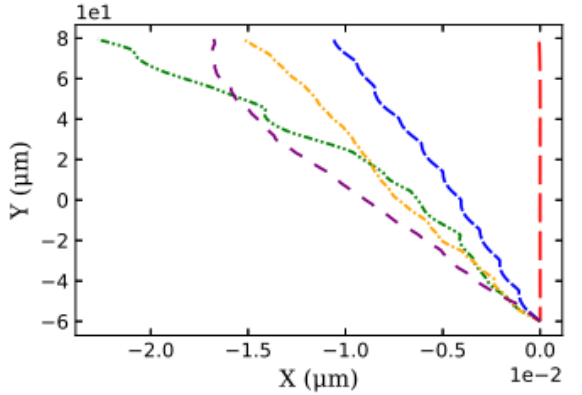


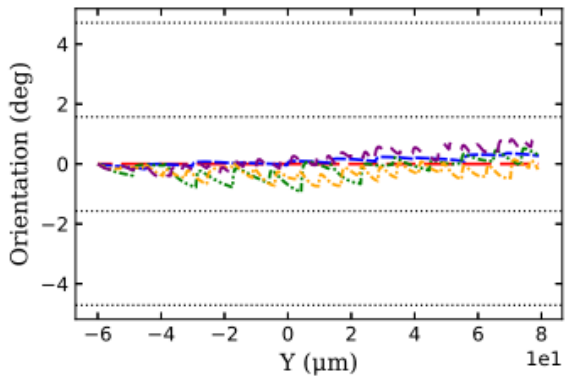


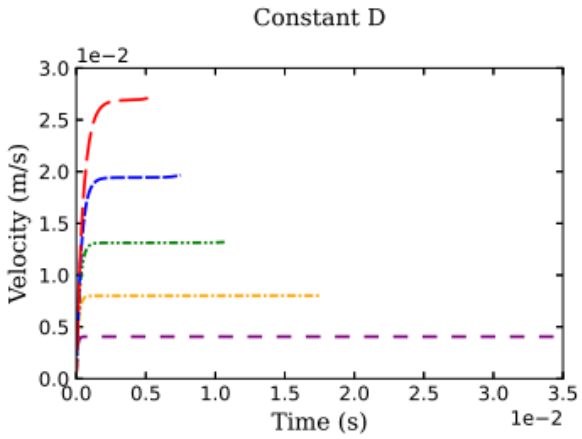
Narrow Channel

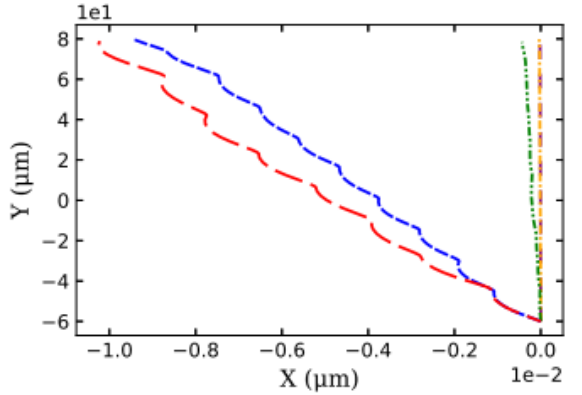


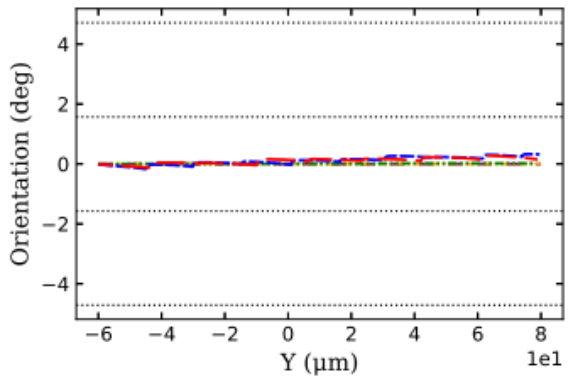












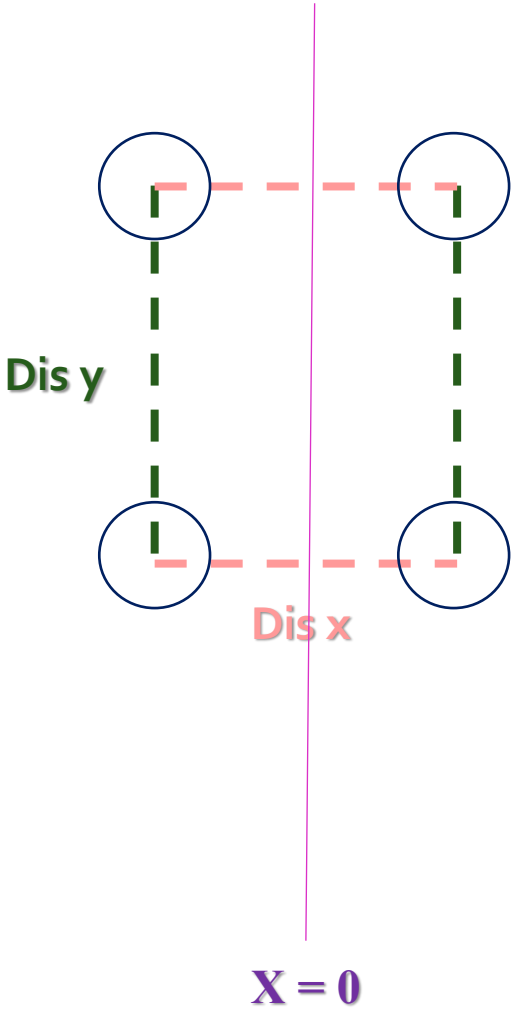
Constant Channel Width = 60 [μm]

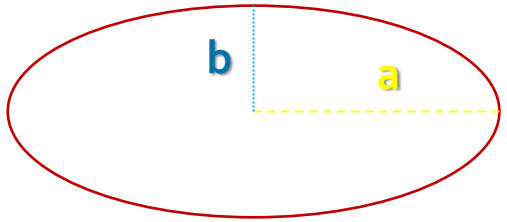
Constant Particle Diameter = 20 [μm]

Initial X = 0 [μm]

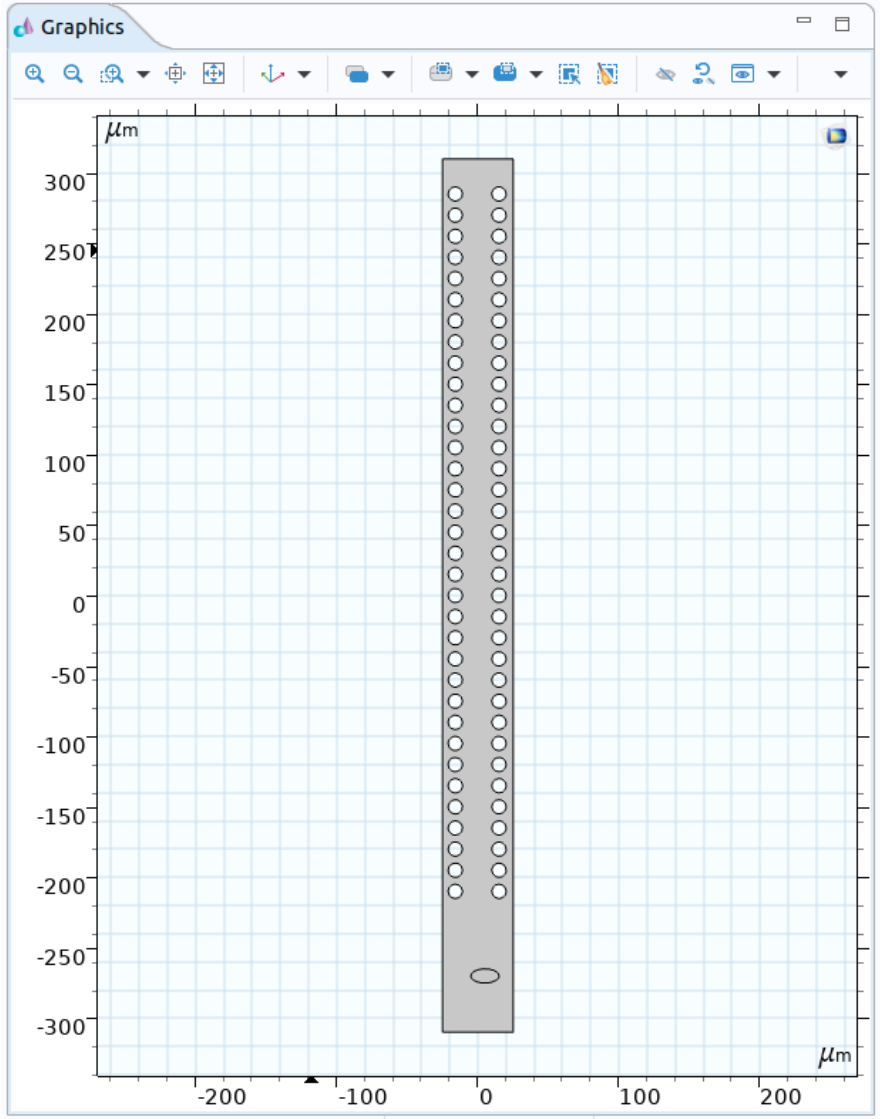
Initial Orientation = 0 [deg]

Parameters

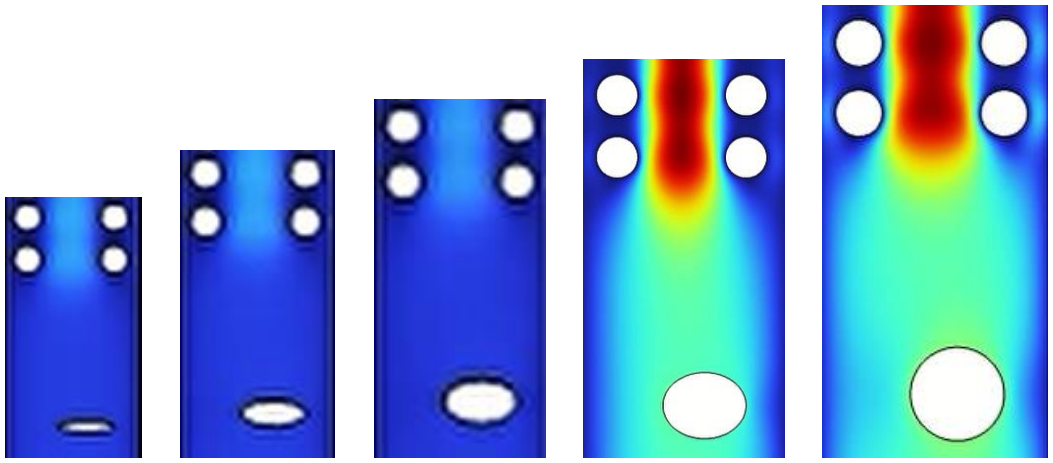


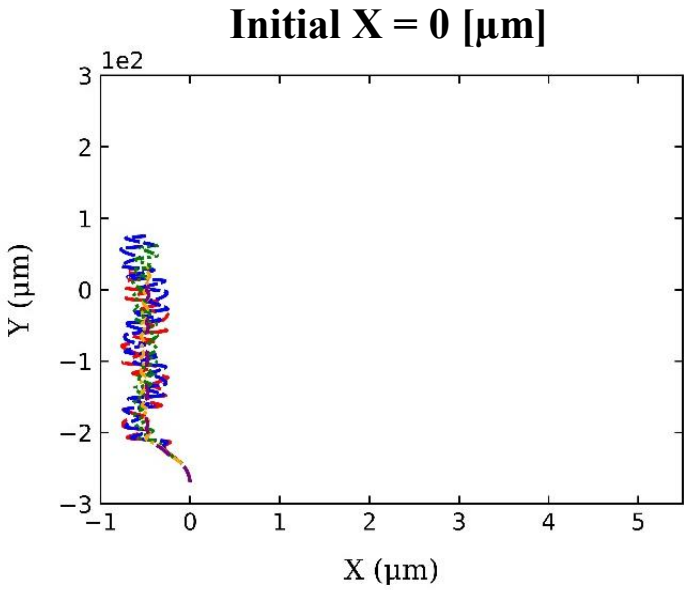


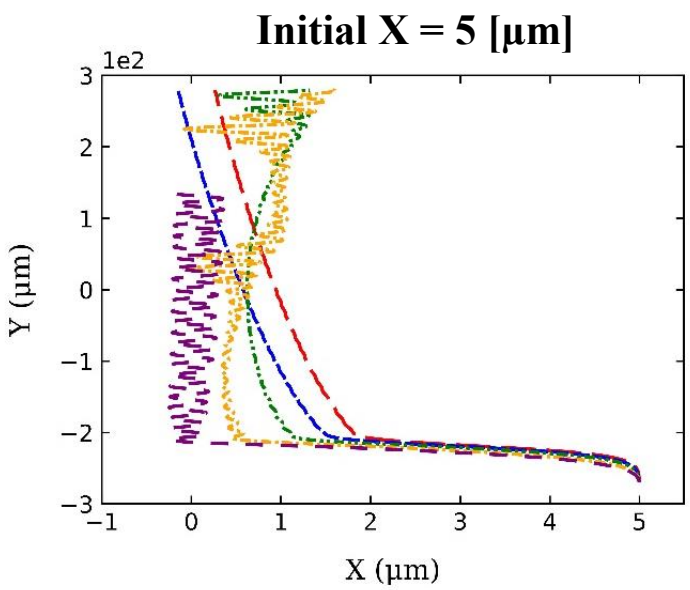
Aspect Ratio = a / b

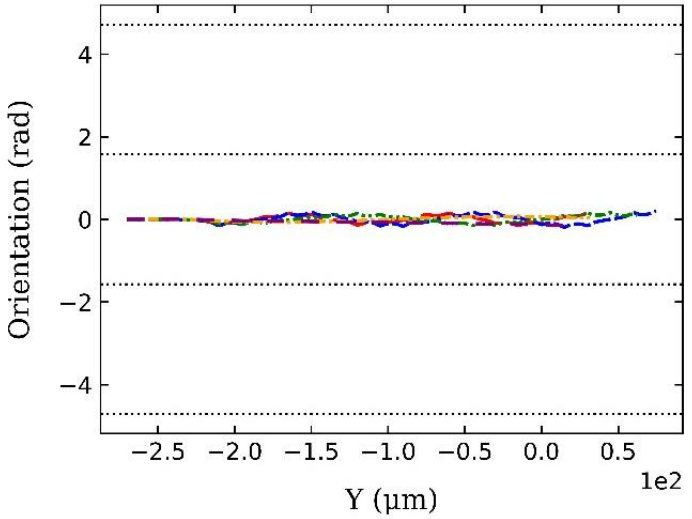


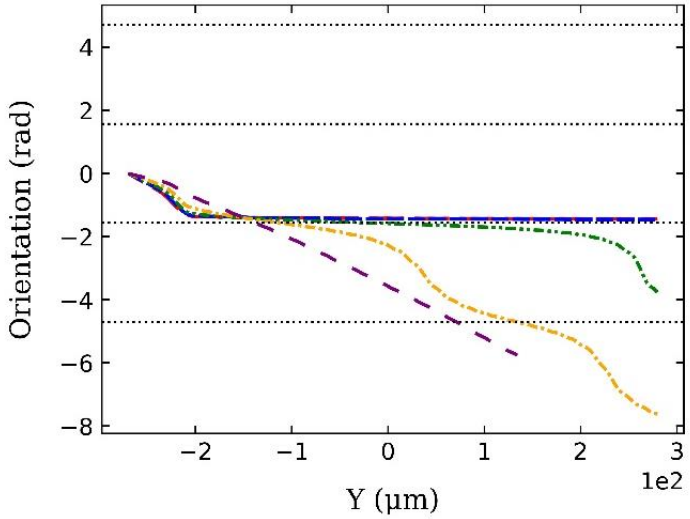
Aspect Ratio



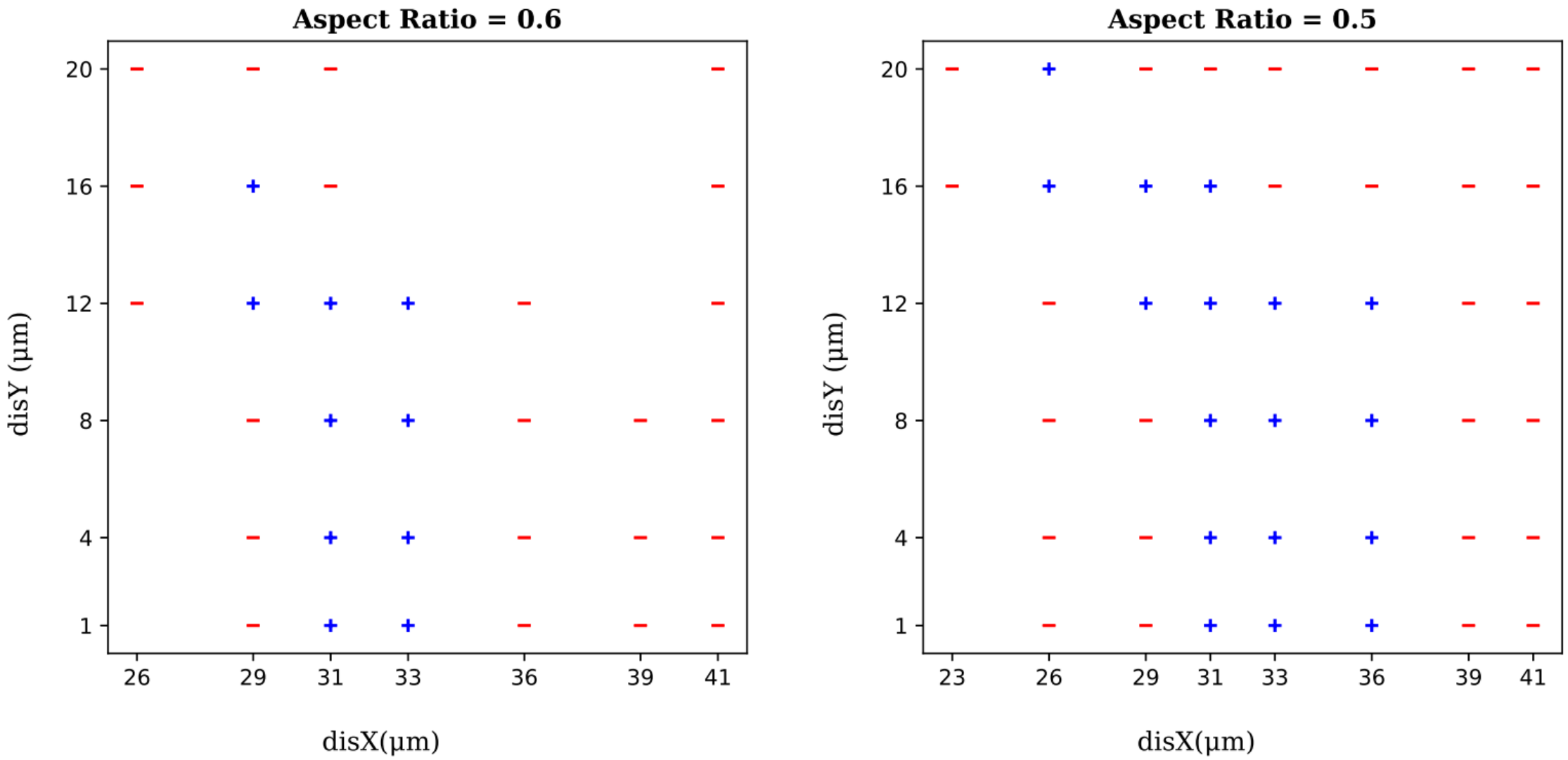






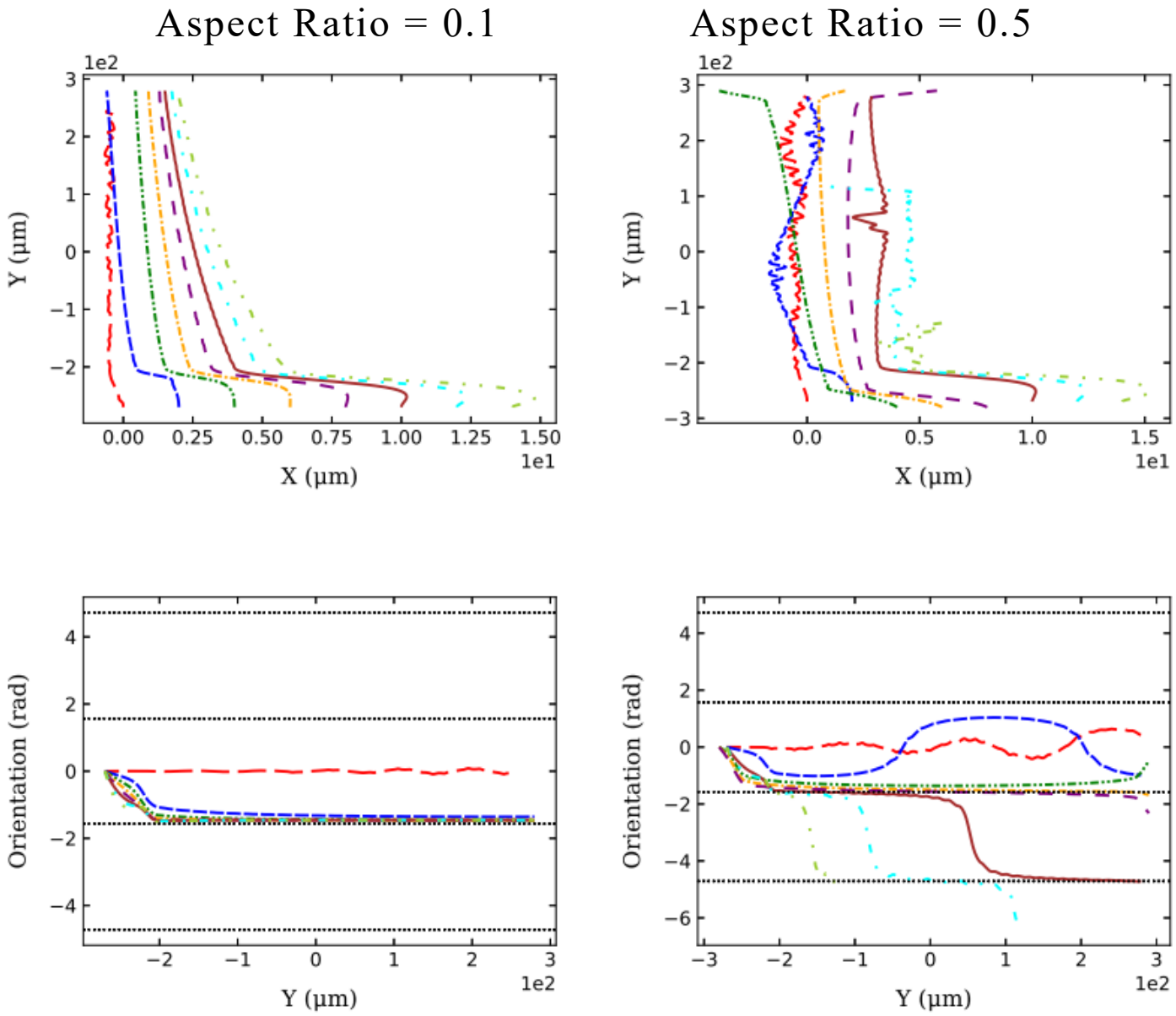


Alignment Phase Diagram



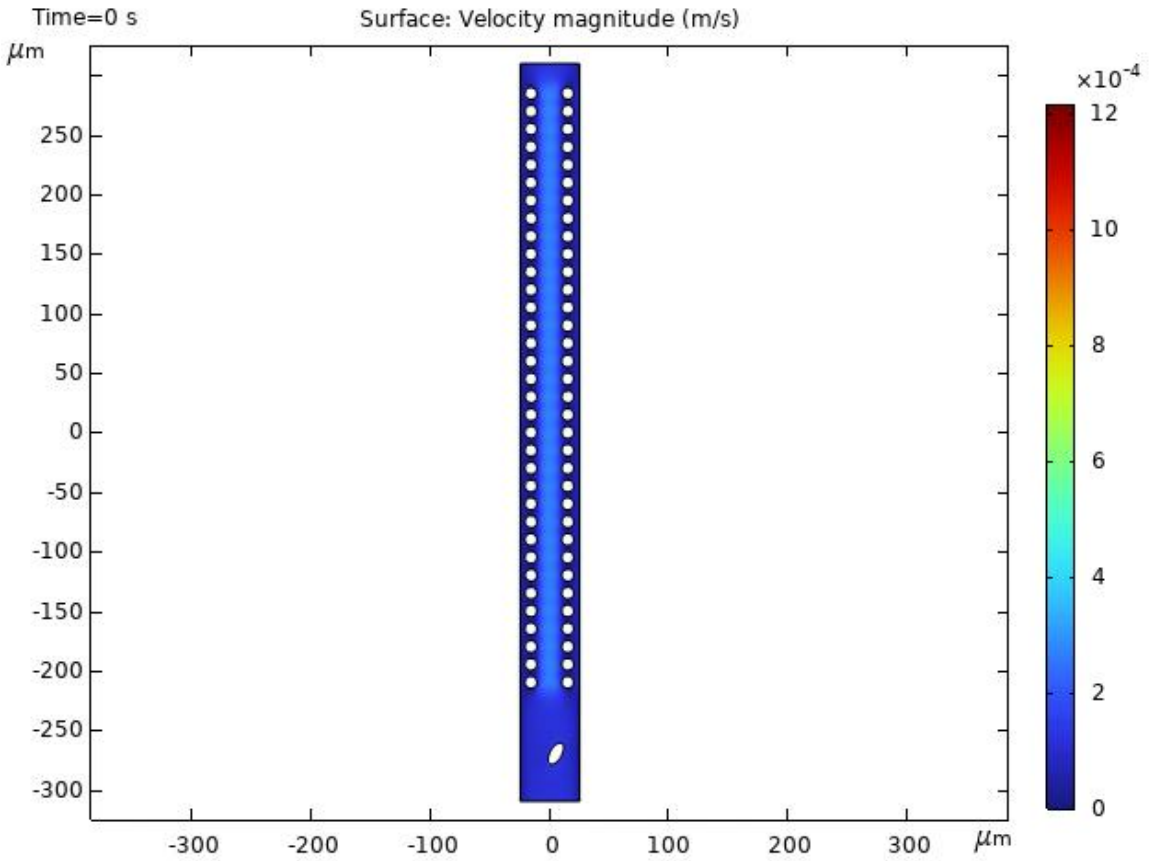
Particle Initial Condition

Initial X

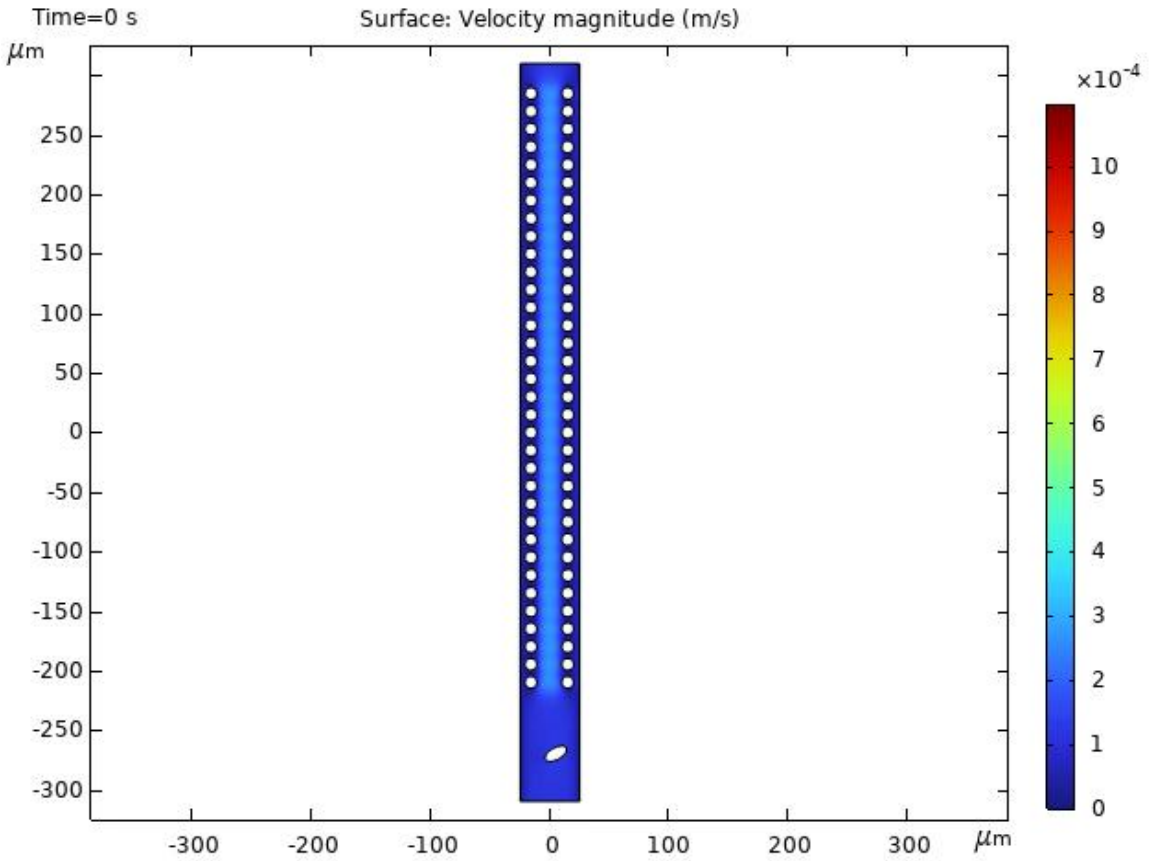


Initial Orientation = 0 [deg]

Initial Orientation = 60 [deg]

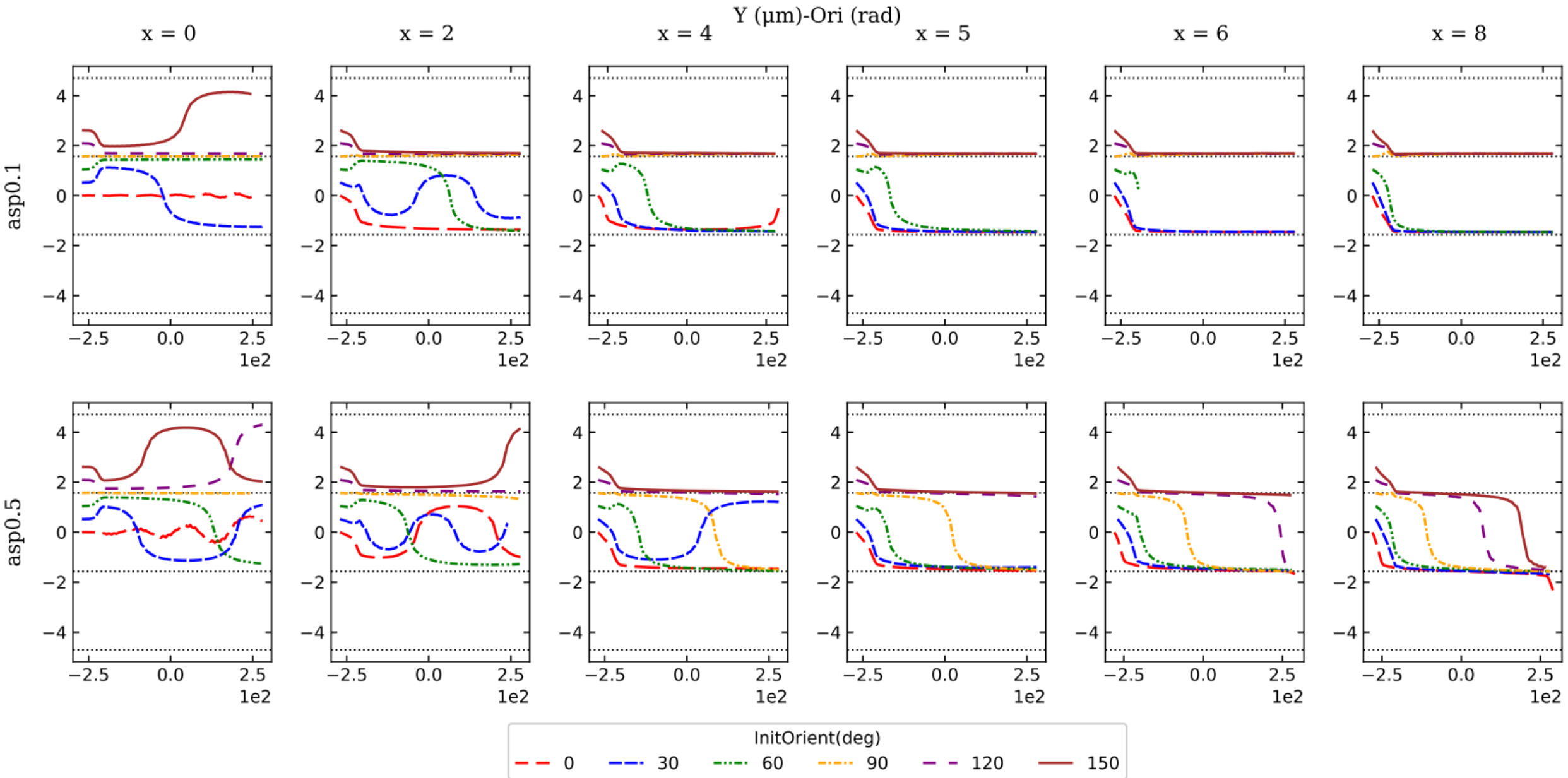


Initial Orientation = 30 [deg]



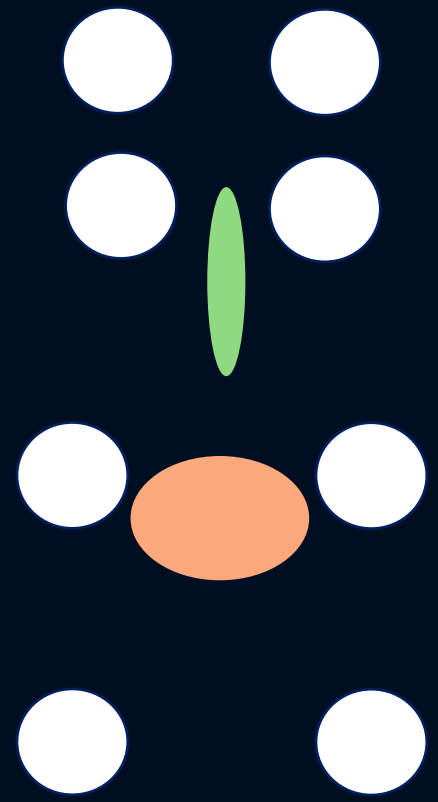
Aspect Ratio = 0.5

Initial X = 5 [μm]


Y (μm)-Ori (rad)
x = 0
x = 2
x = 4
x = 5
x = 6
x = 8
asp0.1
asp0.5
4
2
0
−2
−4
−2.5
0.0
2.5
1e2
InitOrient(deg)
0
30
60
90
120
150

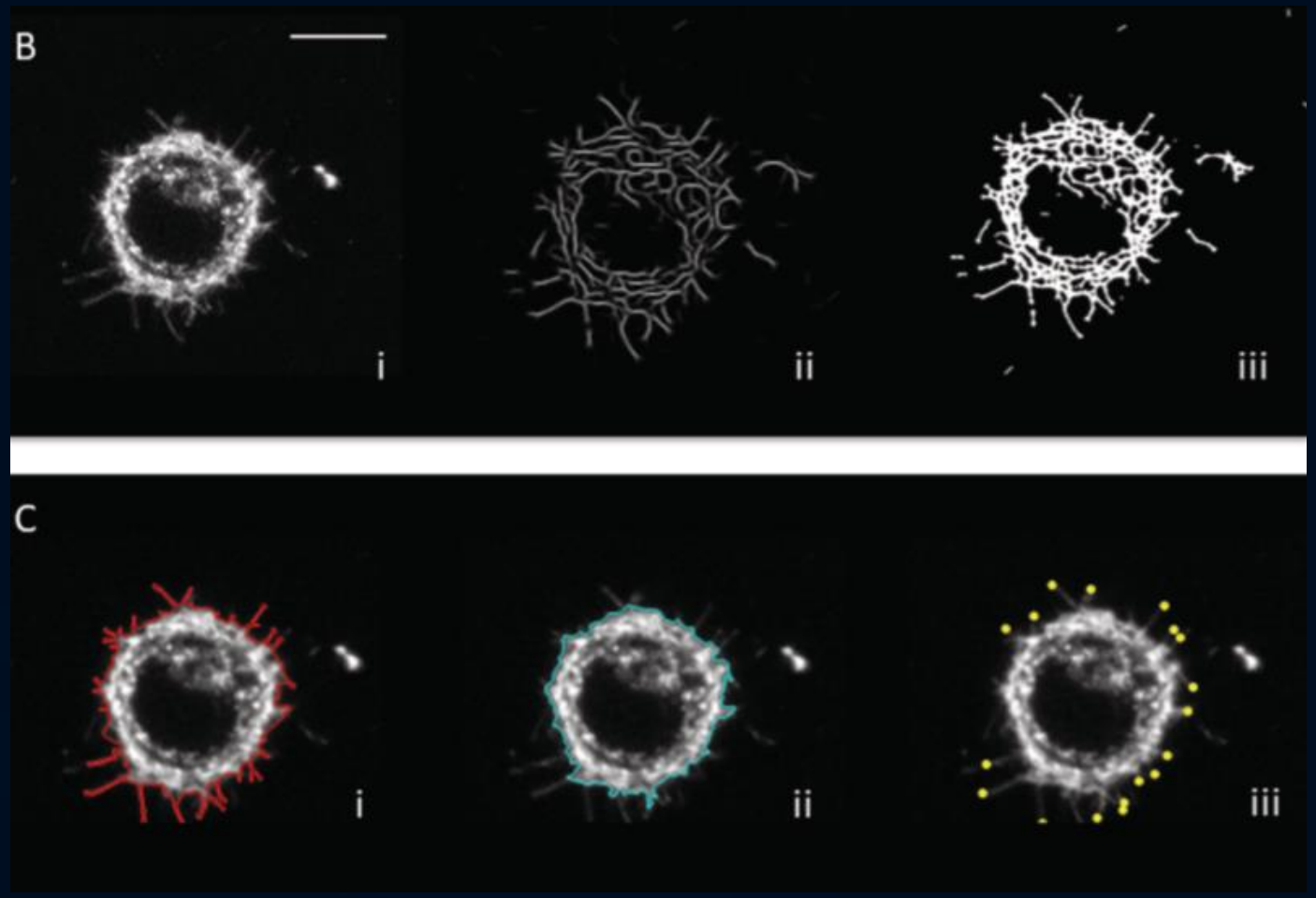
CONCLUSION

- ✓ Importance
- ✓ Physics
- ✓ COMSOL
- ✓ Particle Motion
- ✓ Narrow Channel
- ✓ Particle Alignment
- ✓ A Filter Based on Particle Geometry



What's Next?

- ❑ Deformability
- ❑ Interaction with wall
- ❑ Geometry



Ory et al., Oncotarget 8, 111567, 2017

THANK YOU

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