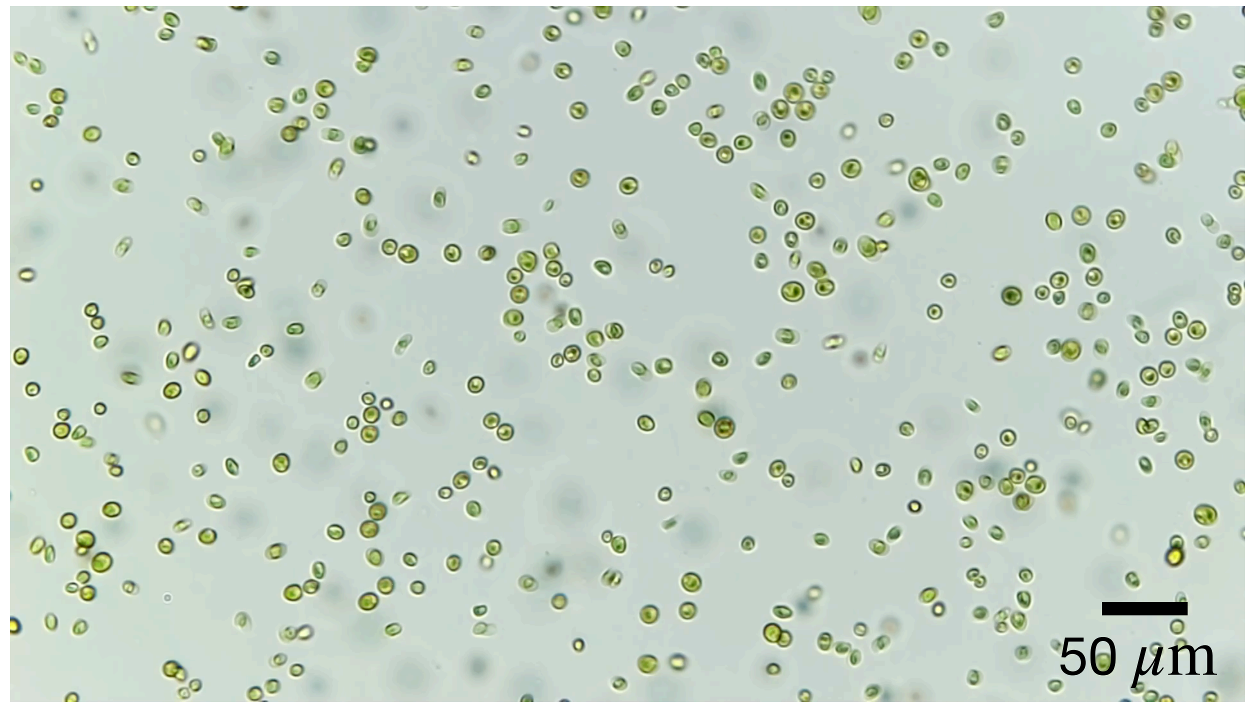
TÉCNICO LISBOA

inesc mn Microssistemas e Nanotecnologias

GULBENKIAN CIÊNCIA

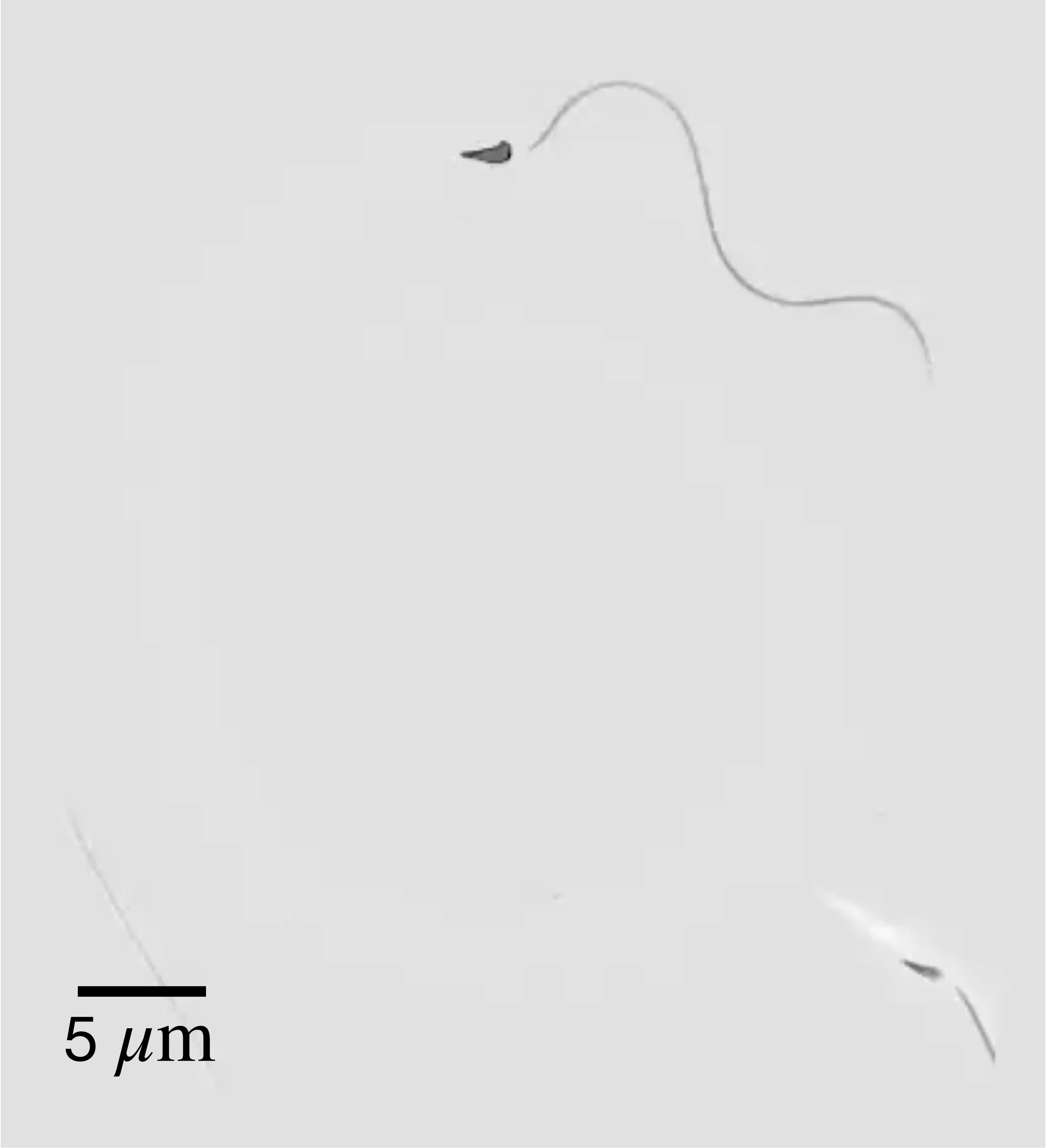
Long-time characterization of single-cell swimming behavior



Camila Costa Pablo Sartori Vania Silverio Yatharth Bhasin

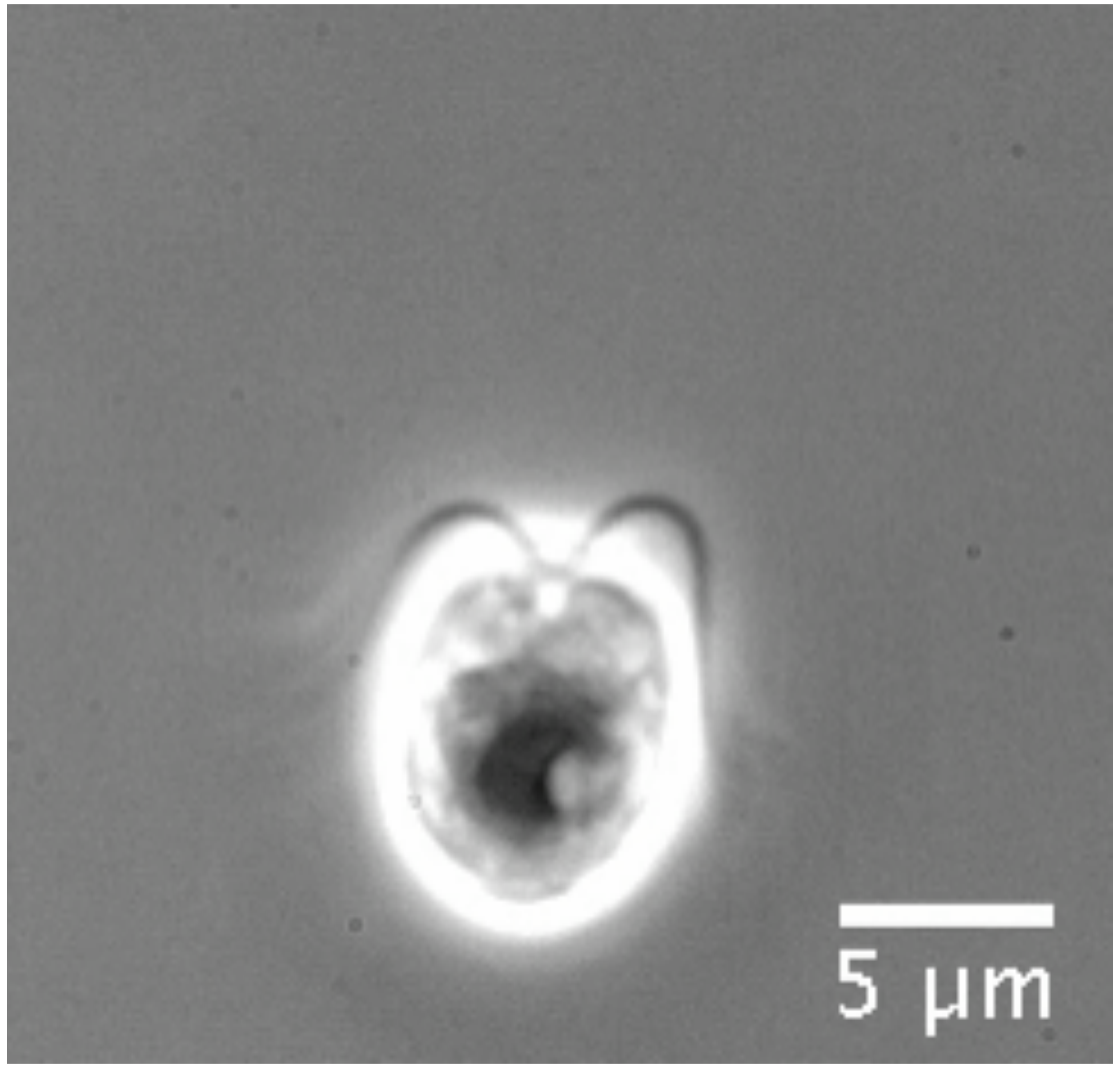
Swimming is crucial for many unicellular “organisms”

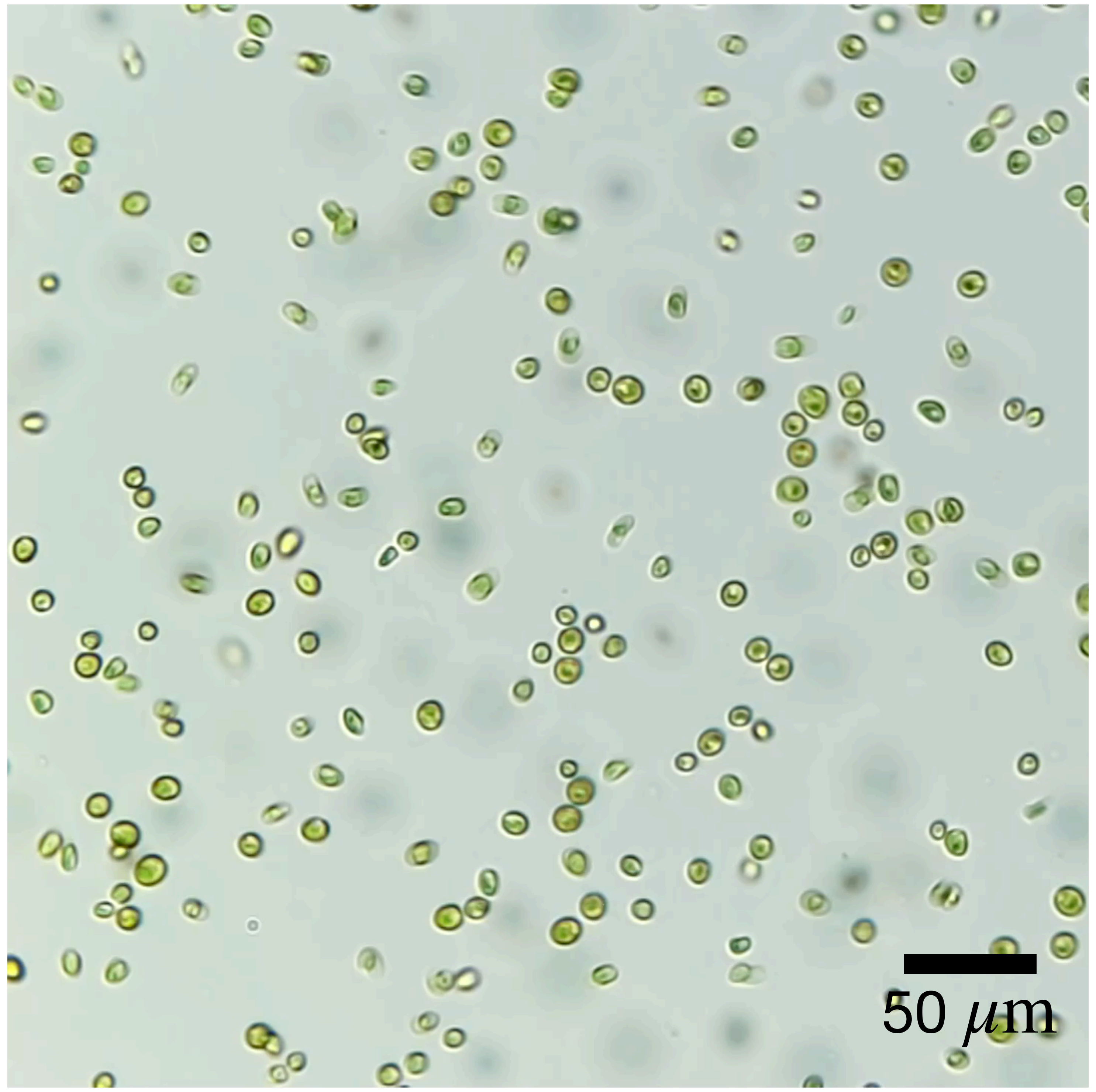
Sea urchin sperm



Courtesy of V. Geyer

Chlamydomonas

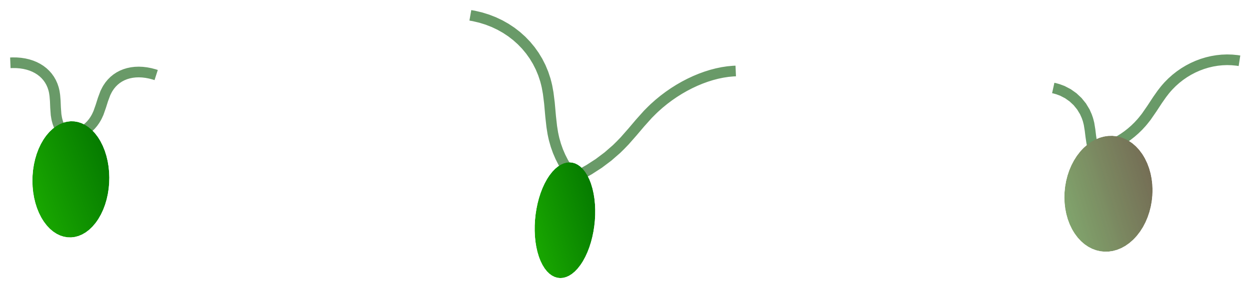




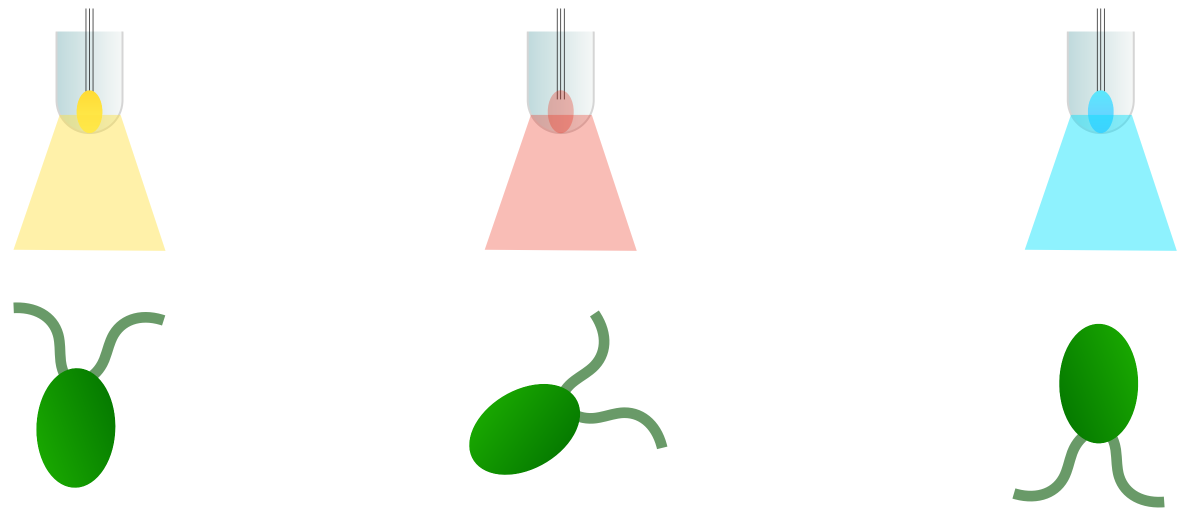
Courtesy of V. Geyer

Swimming is influenced by different sources of variability

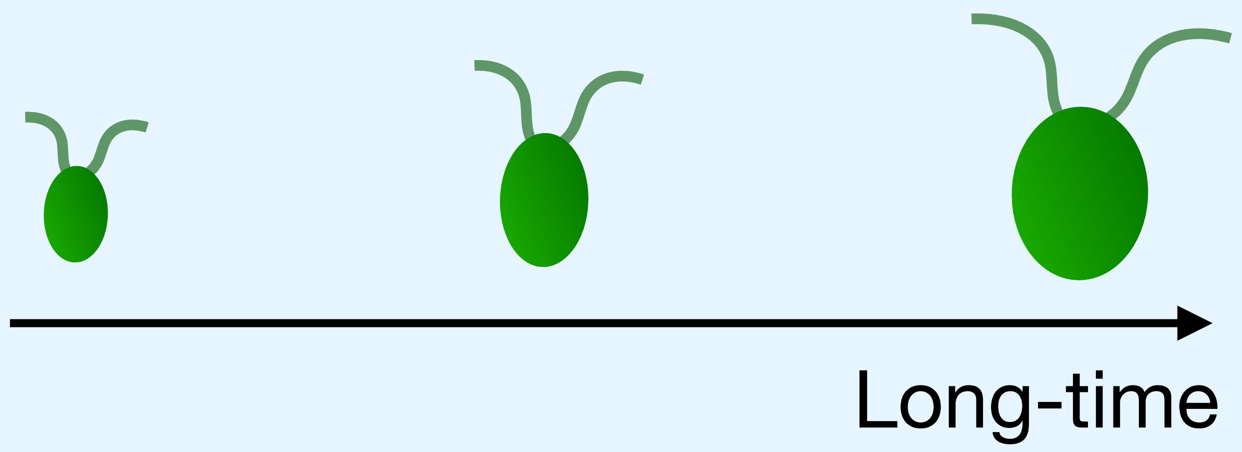
- Genotype



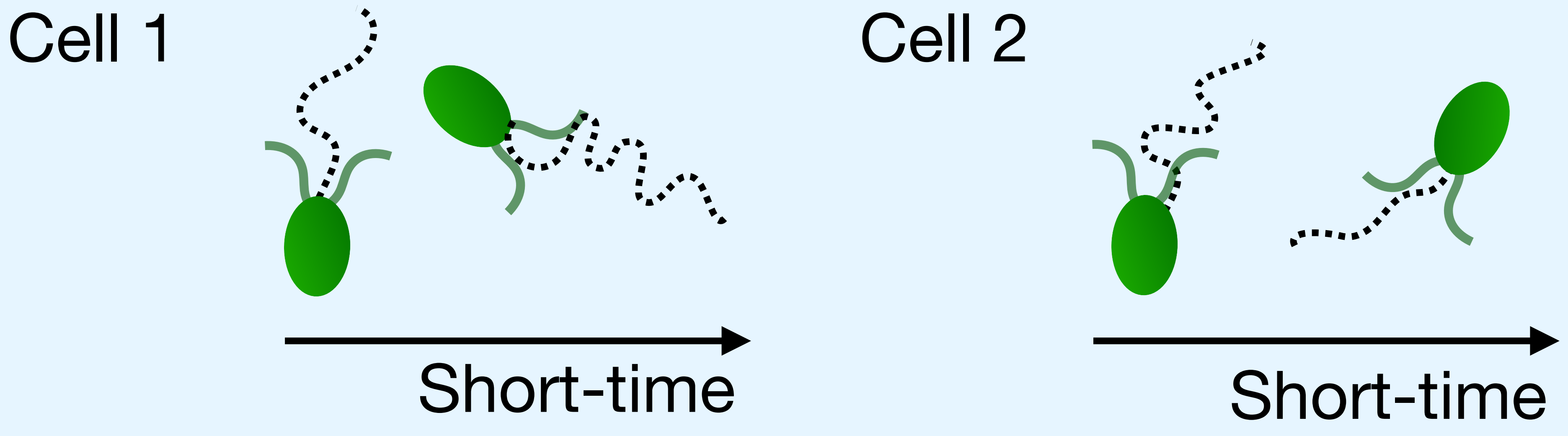
- Environment



- Developmental time



- Stochasticity (temporal and isogenic)



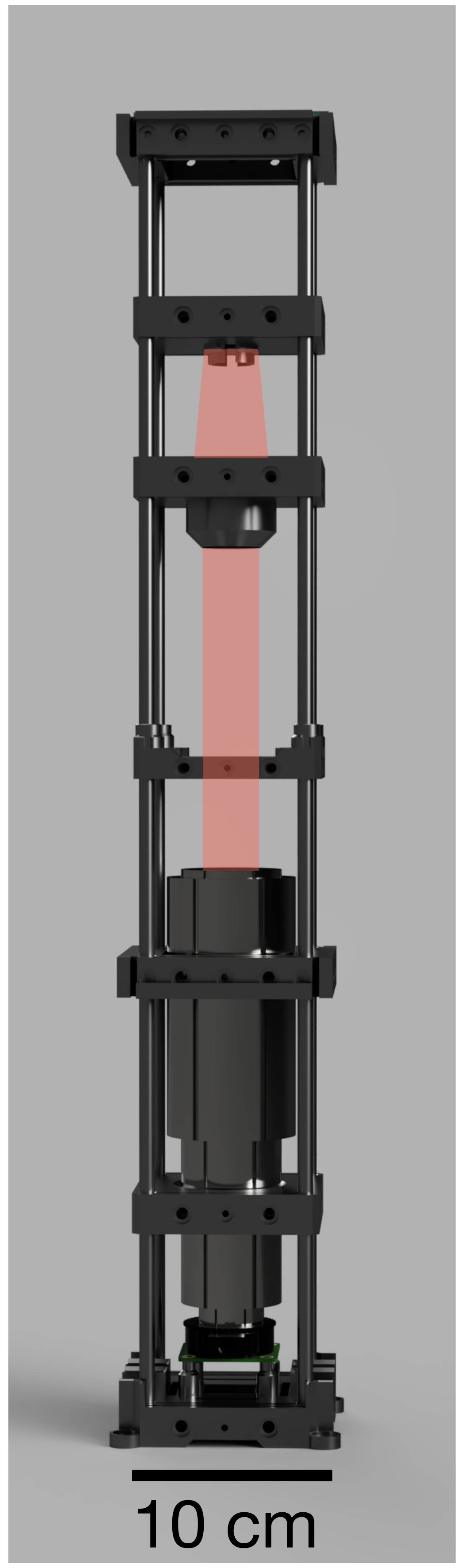
Questions addressed in this work

1. How to characterize the swimming behavior of single cells?

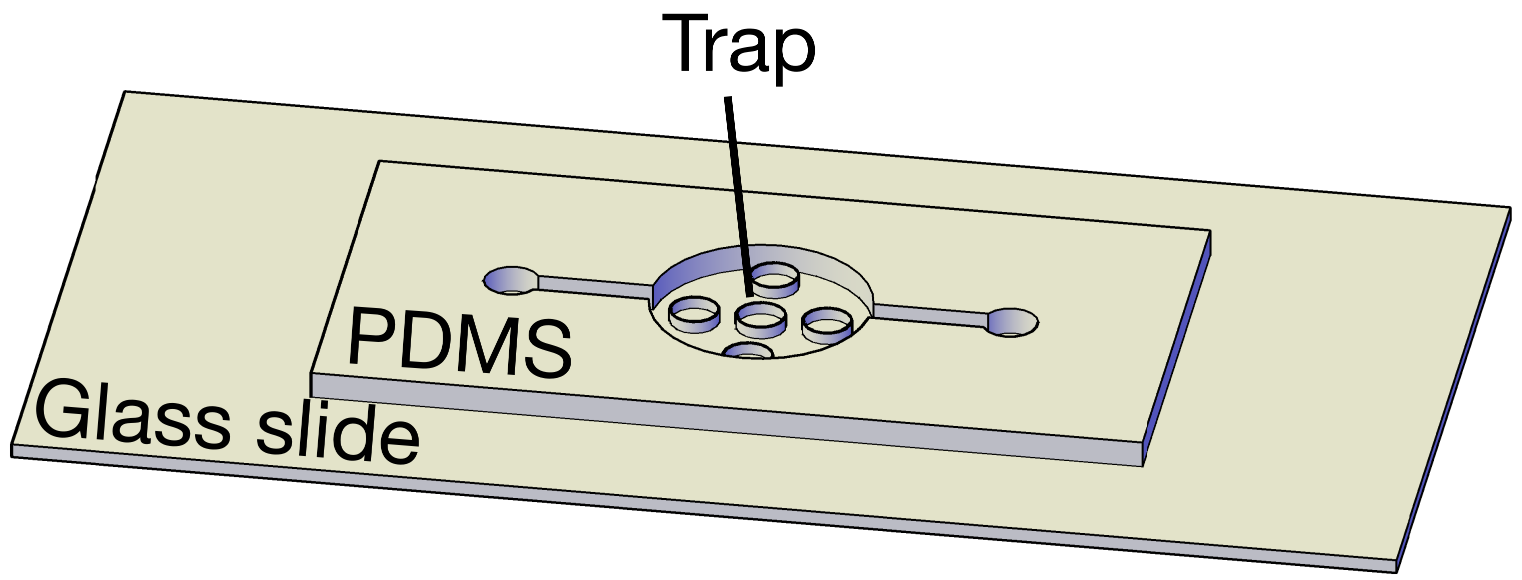
2. Which properties of swimming are maintained throughout the lifetime of cells?

We built a setup to image single cells for long-time periods

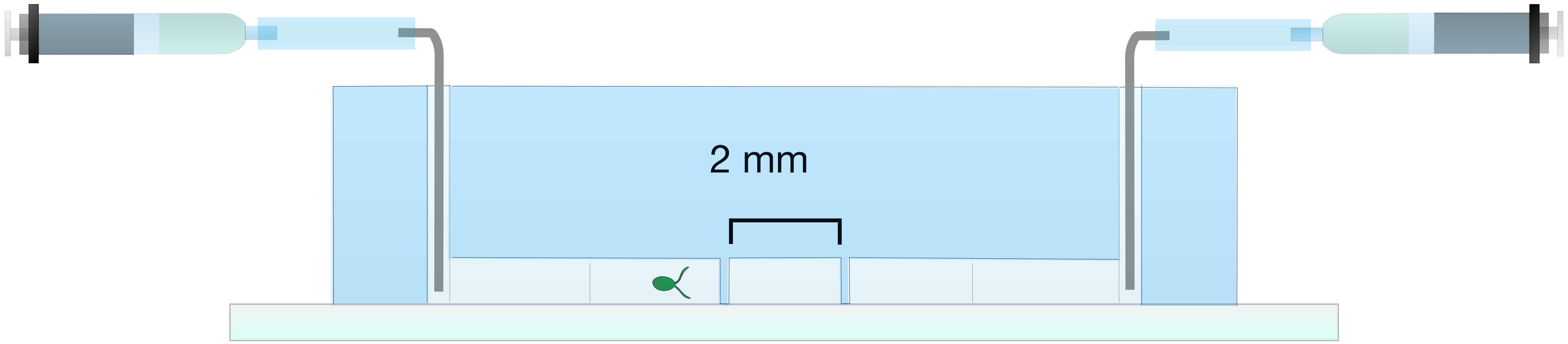
Compact microscopes + Microfluidic device



x 4



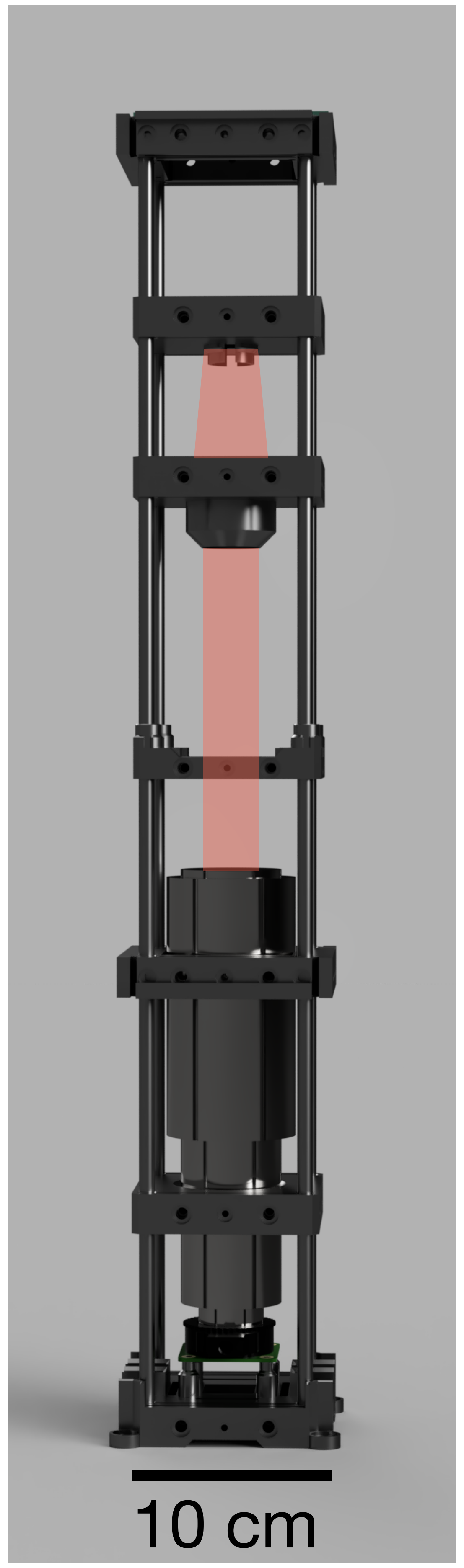
Single-cell confinement



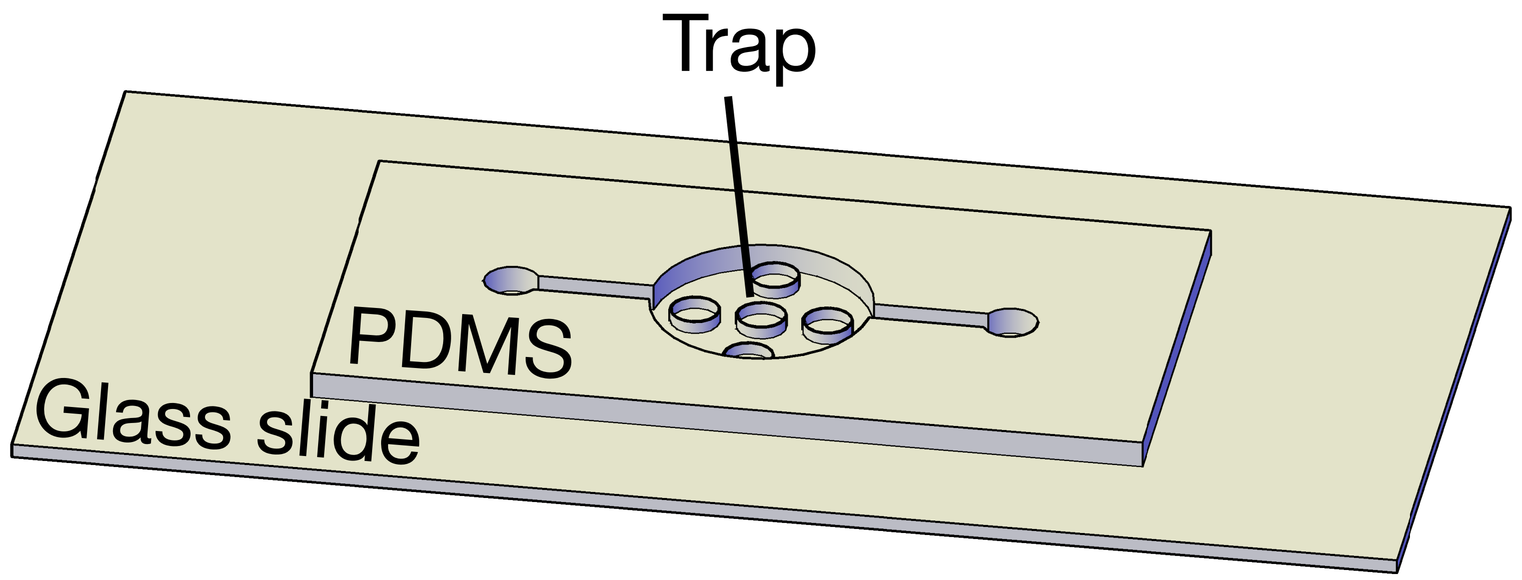
Not to scale

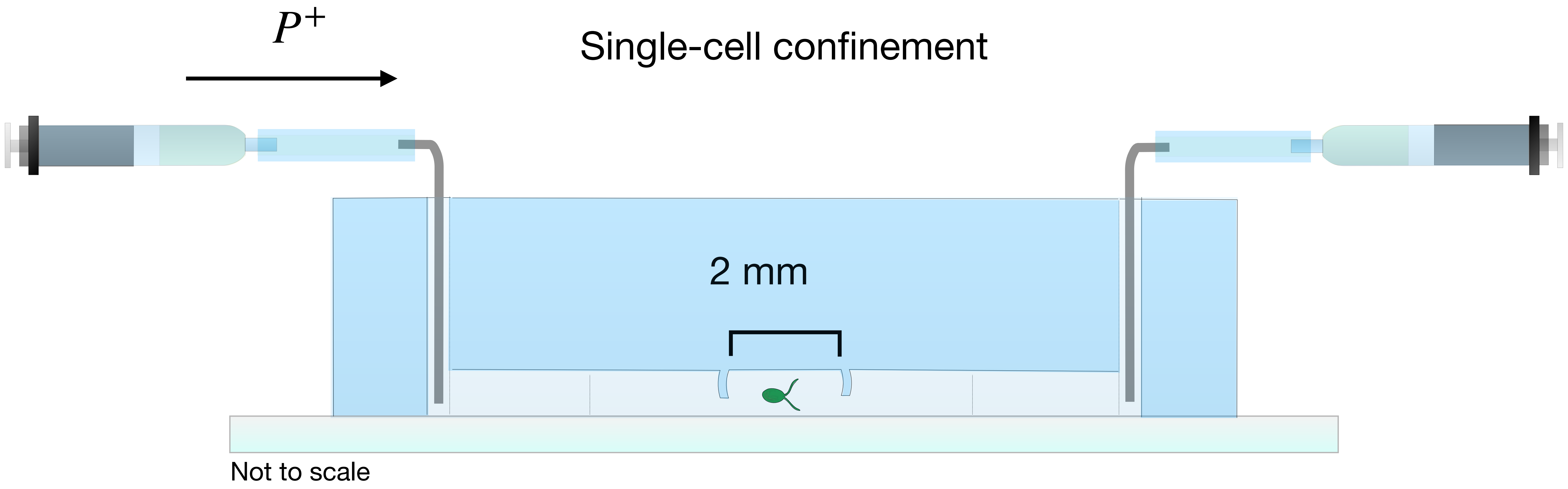
We built a setup to image single cells for long-time periods

Compact microscopes + Microfluidic device



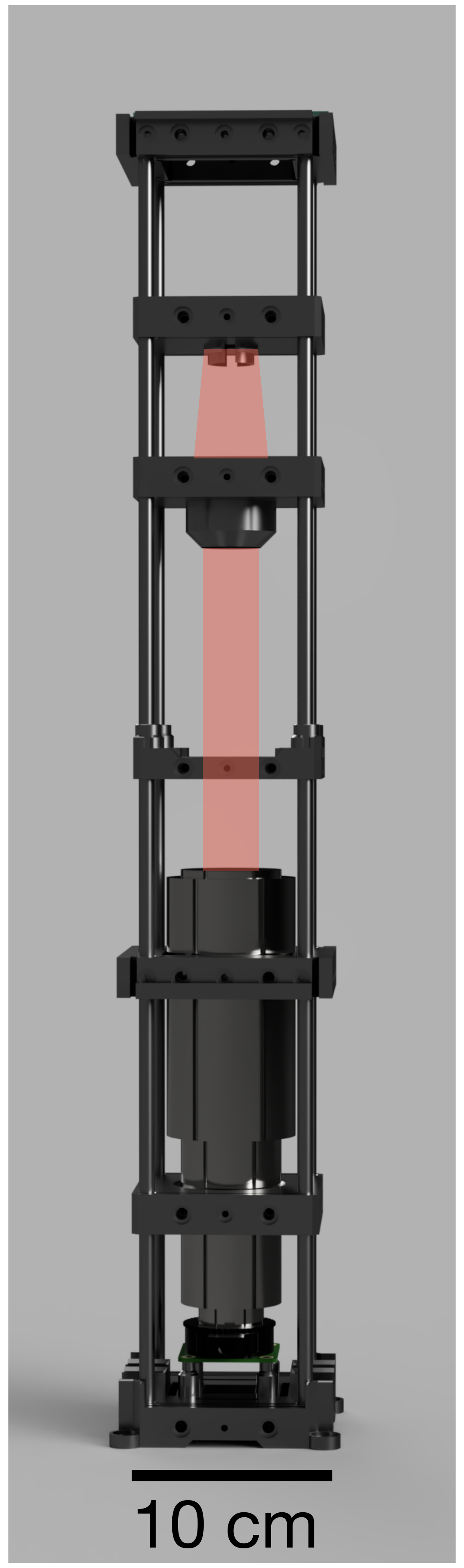
x 4



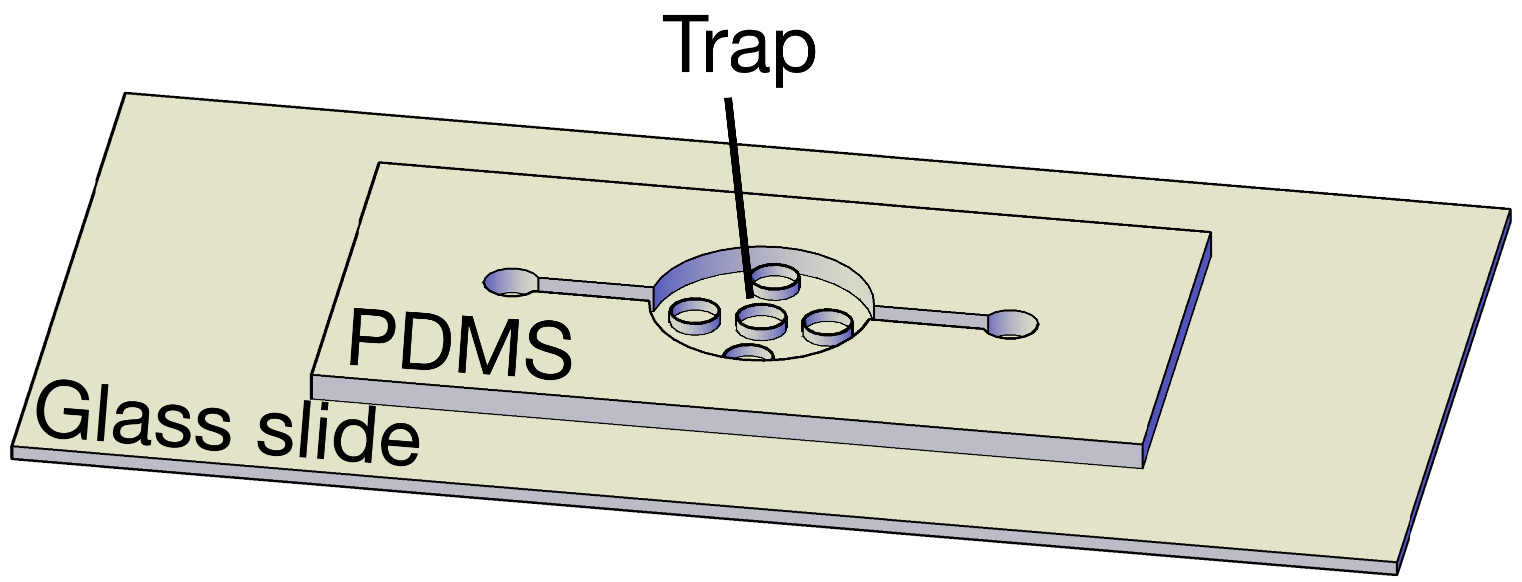


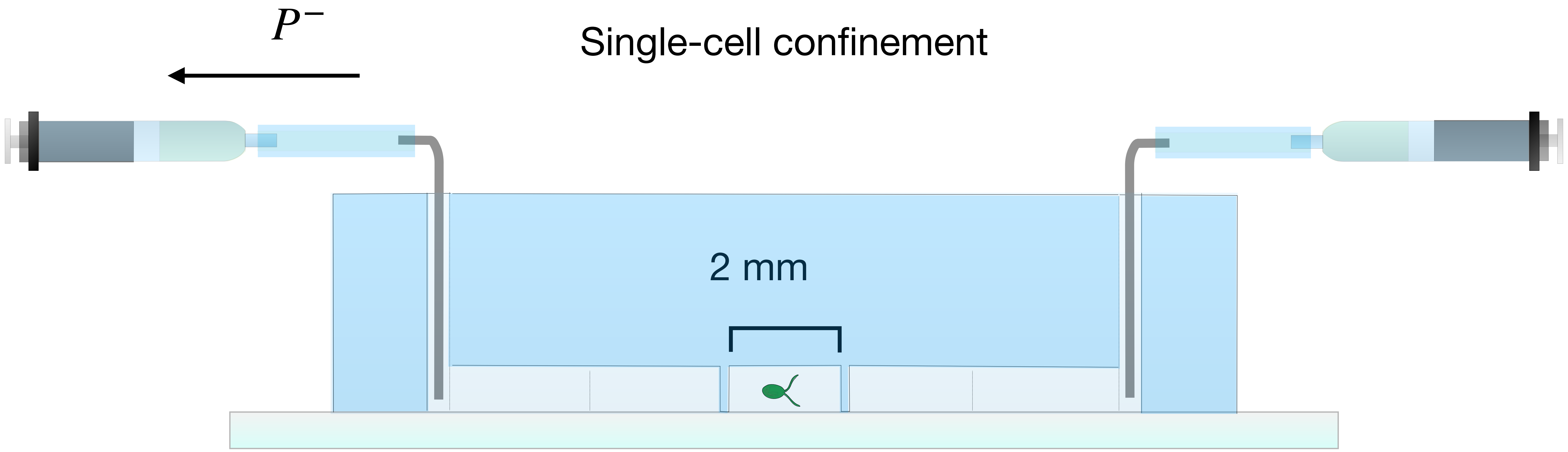
We built a setup to image single cells for long-time periods

Compact microscopes + Microfluidic device



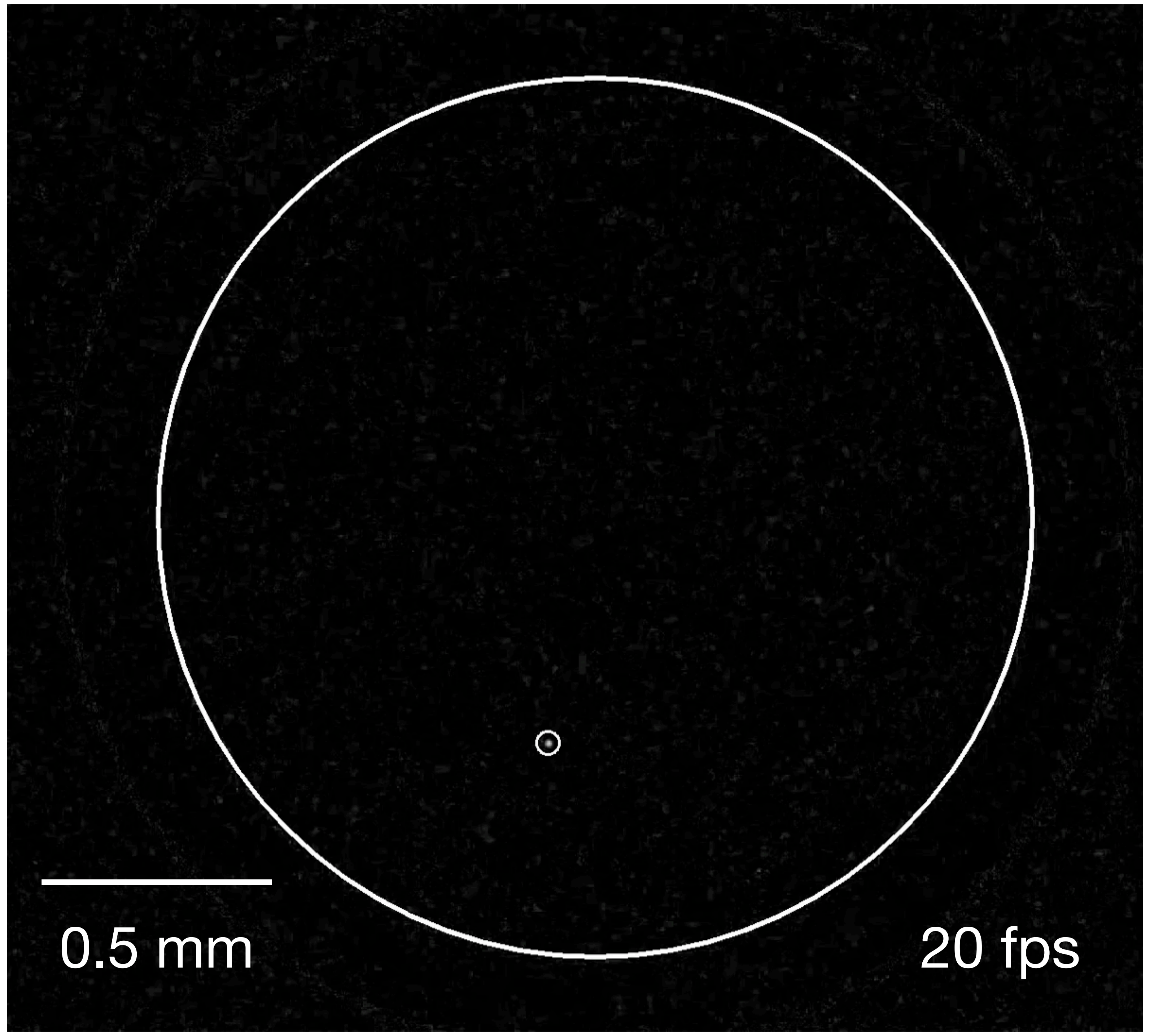
x 4





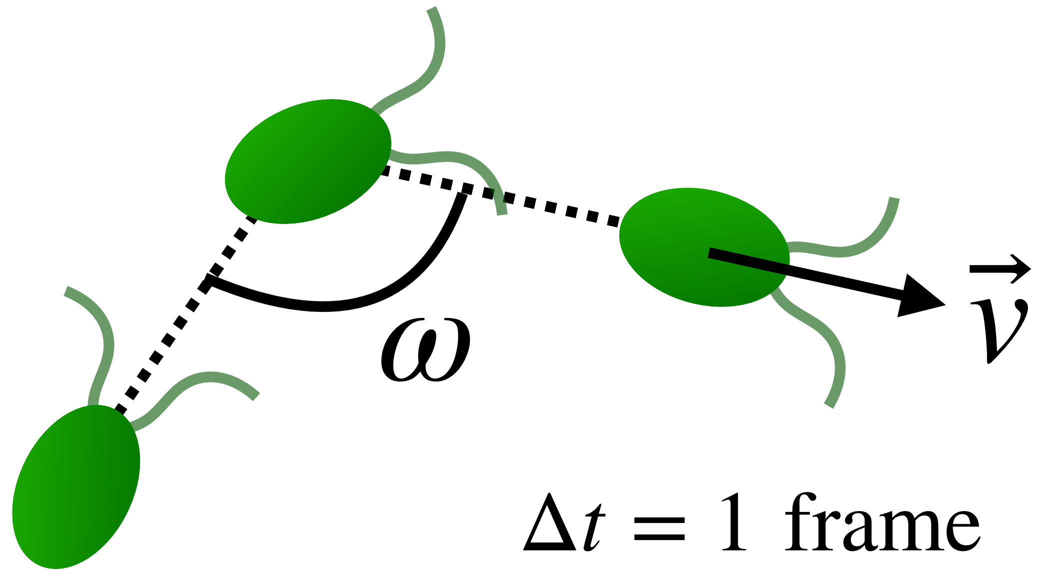
Not to scale

Tracking single cells

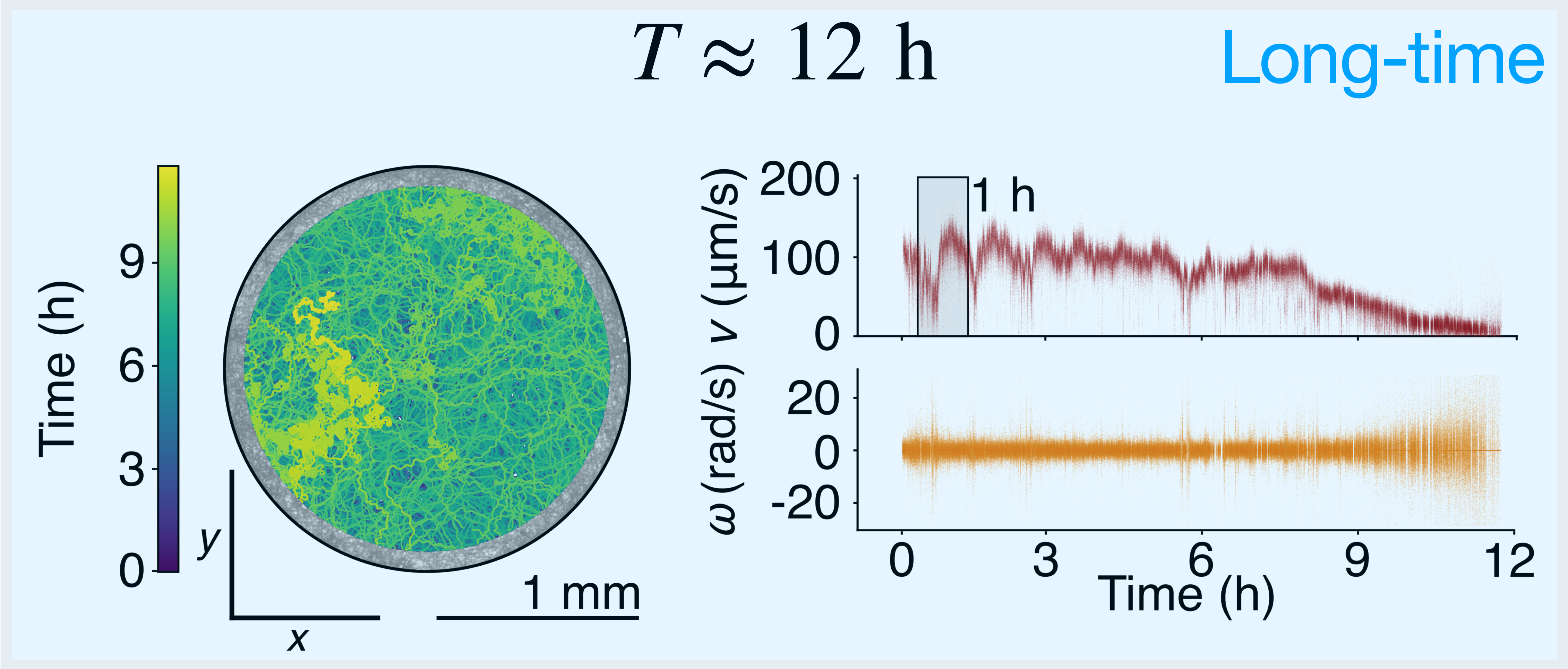


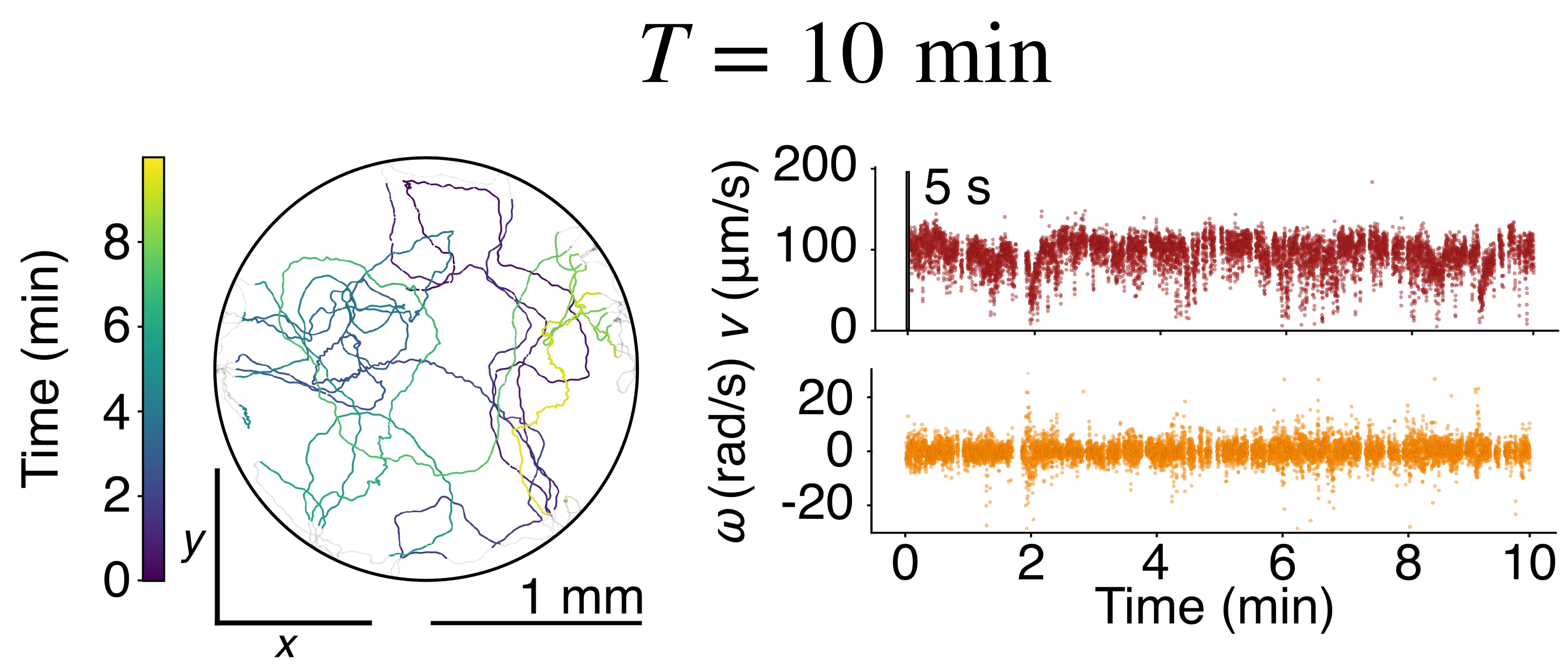
Variables of motion

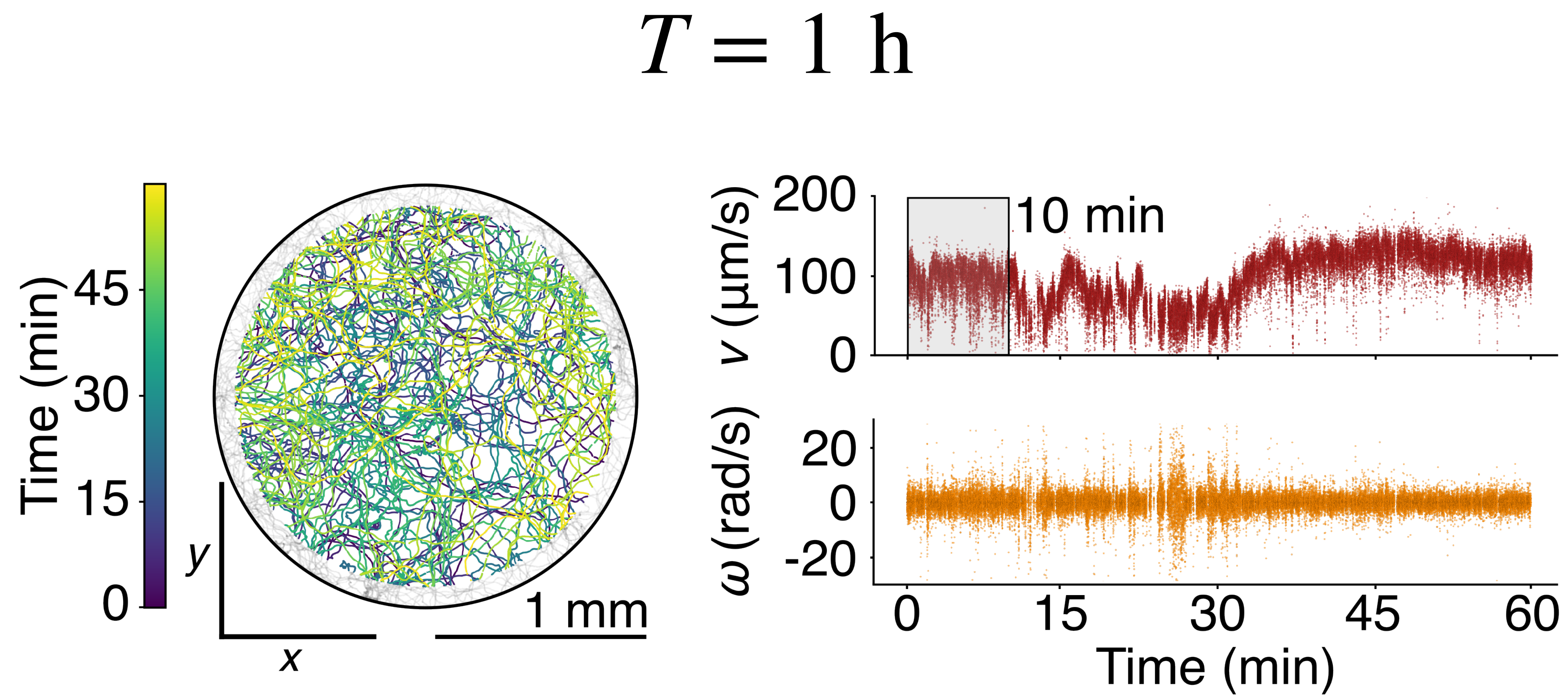
- Linear speed, v
- Turning speed, ω

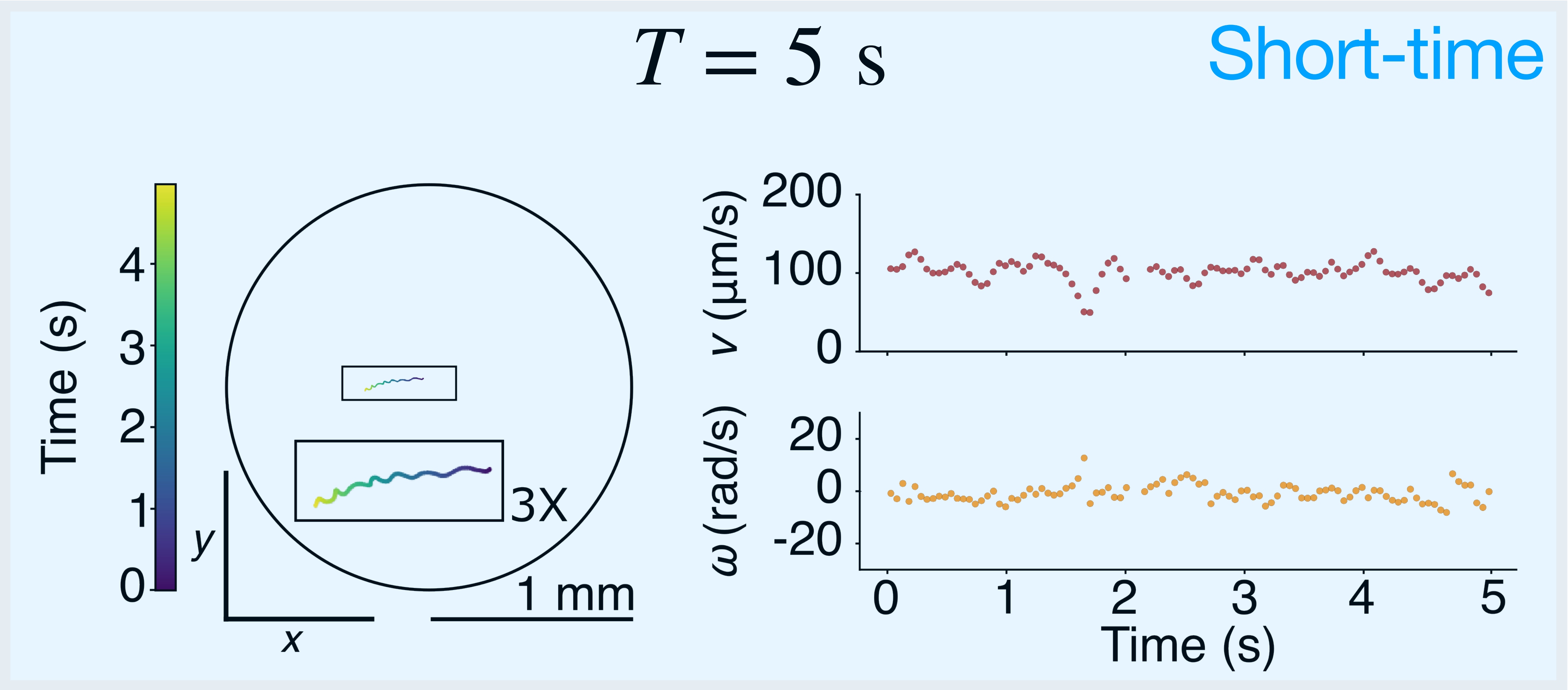


Swimming presents features at multiple time scales

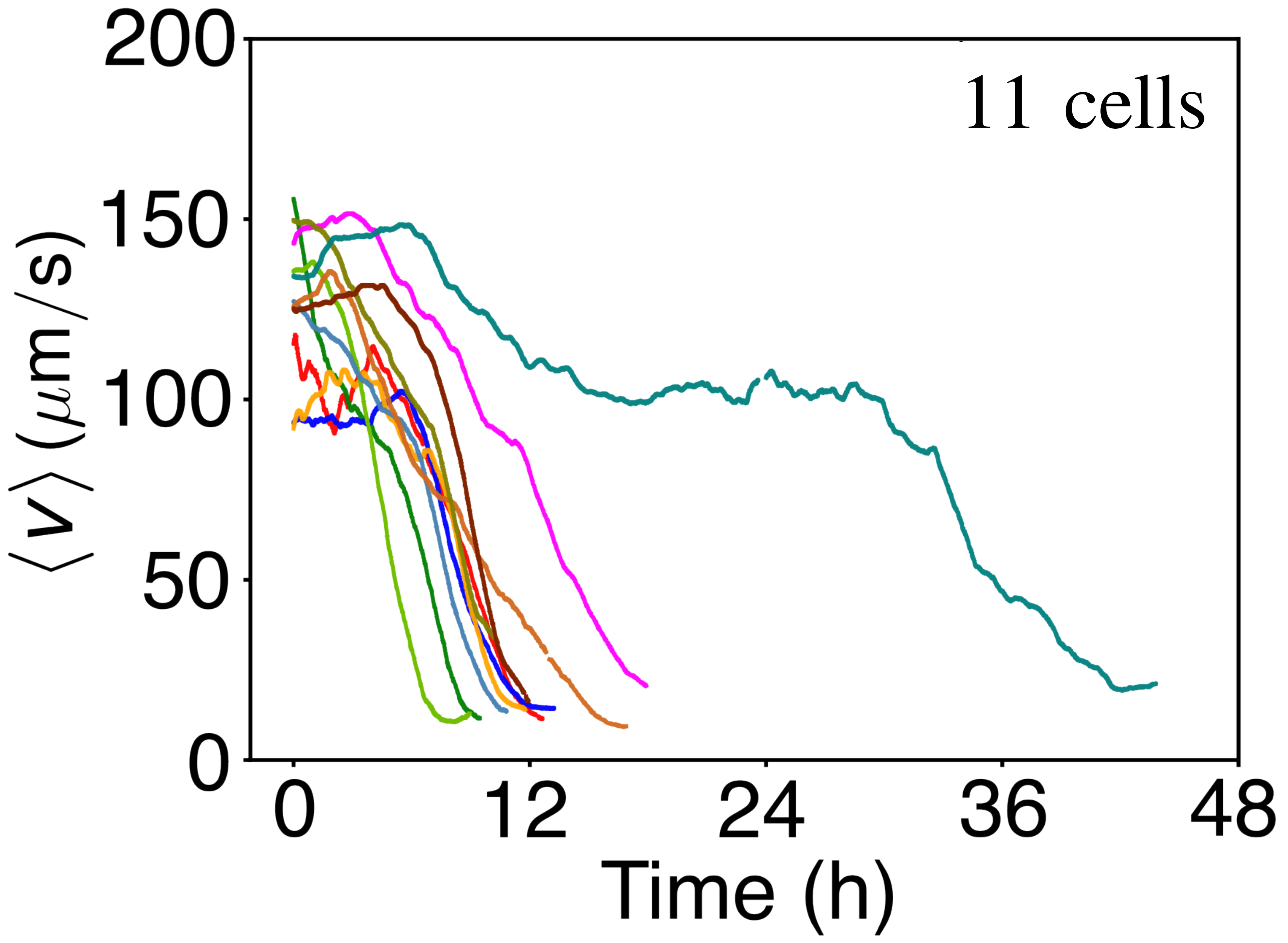




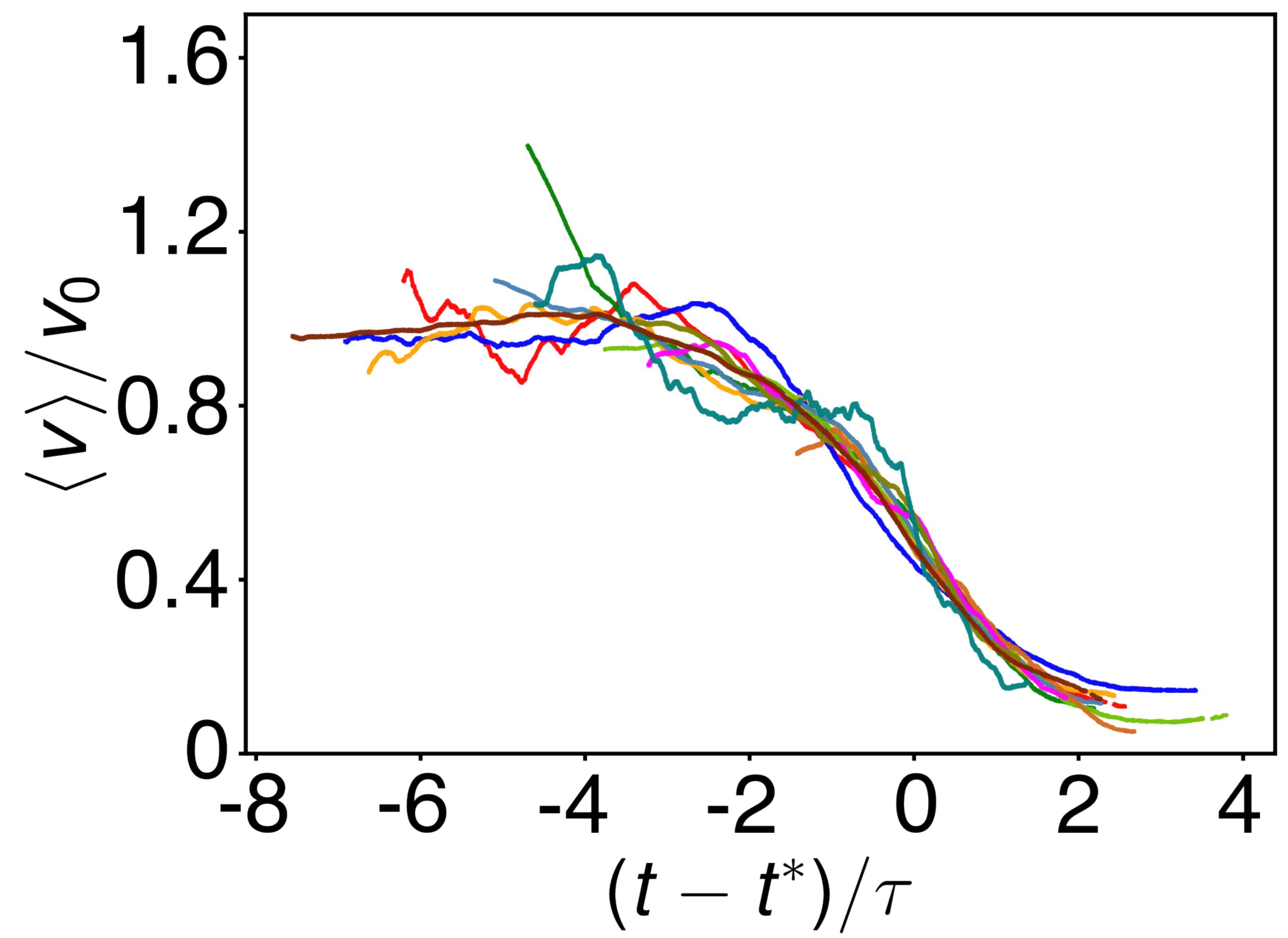




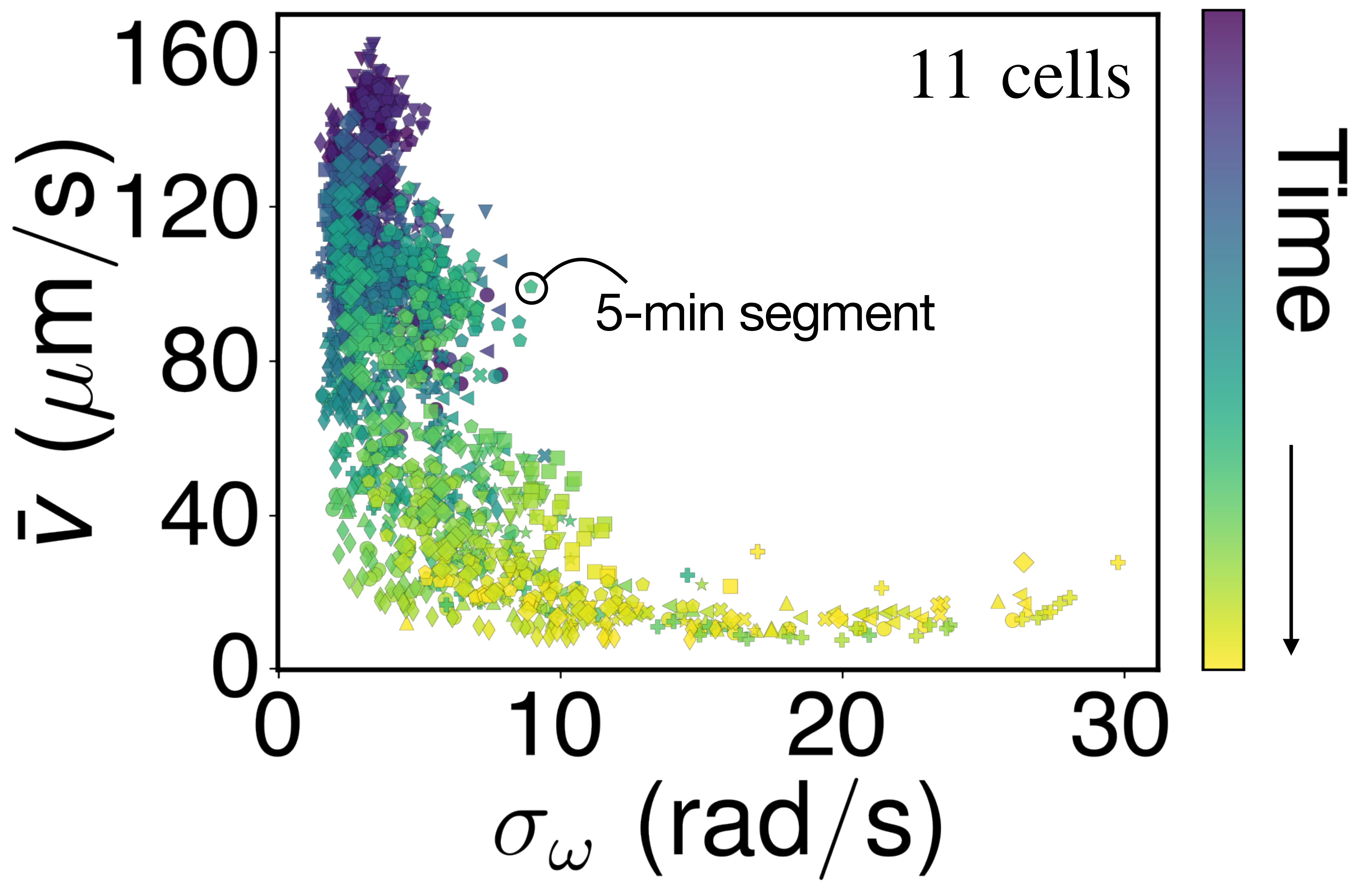
Cells slow down over their lifetime



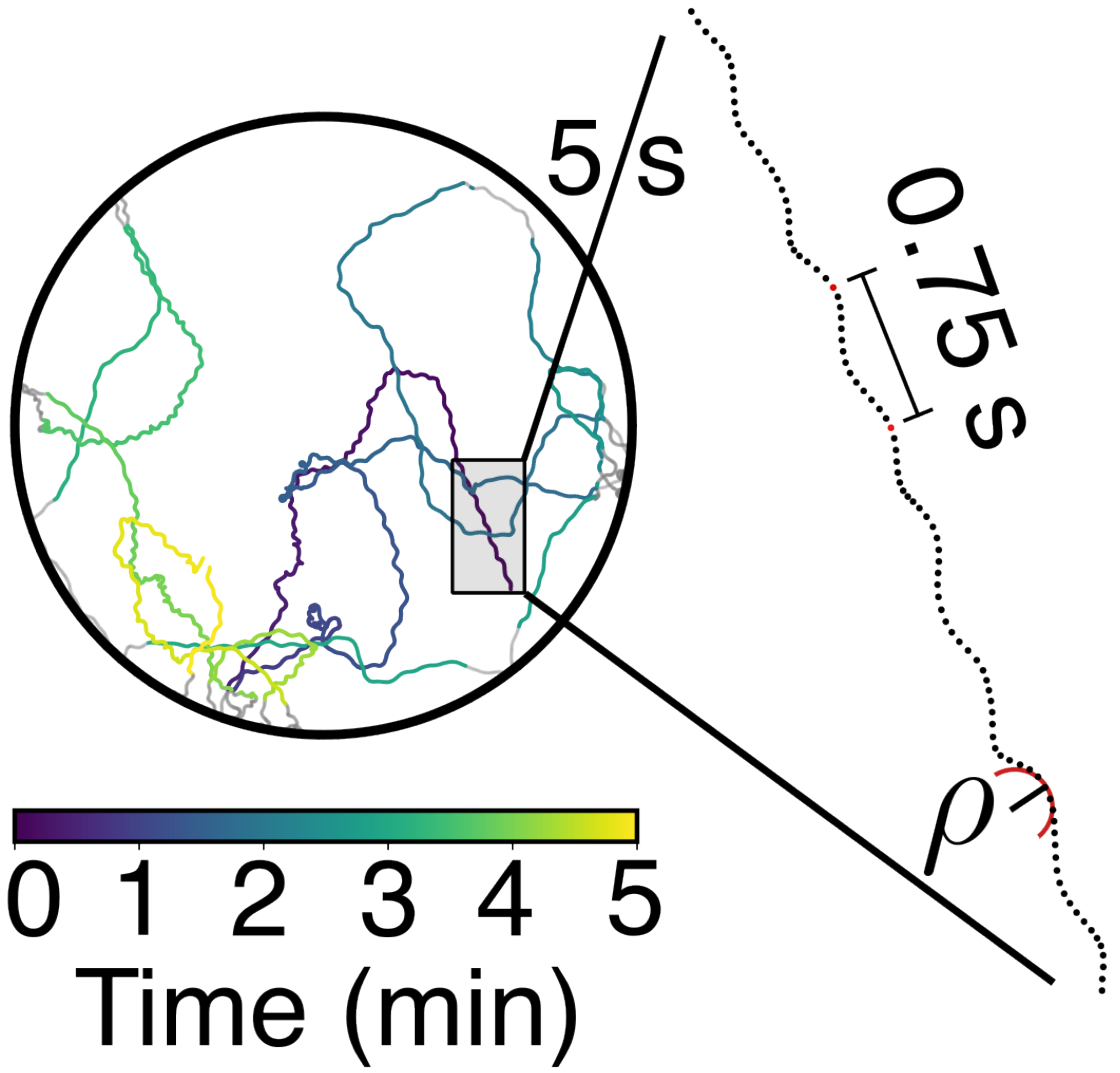
$$\langle v \rangle(t) = \frac{v_0}{1 + e^{(t-t^*)/\tau}}$$

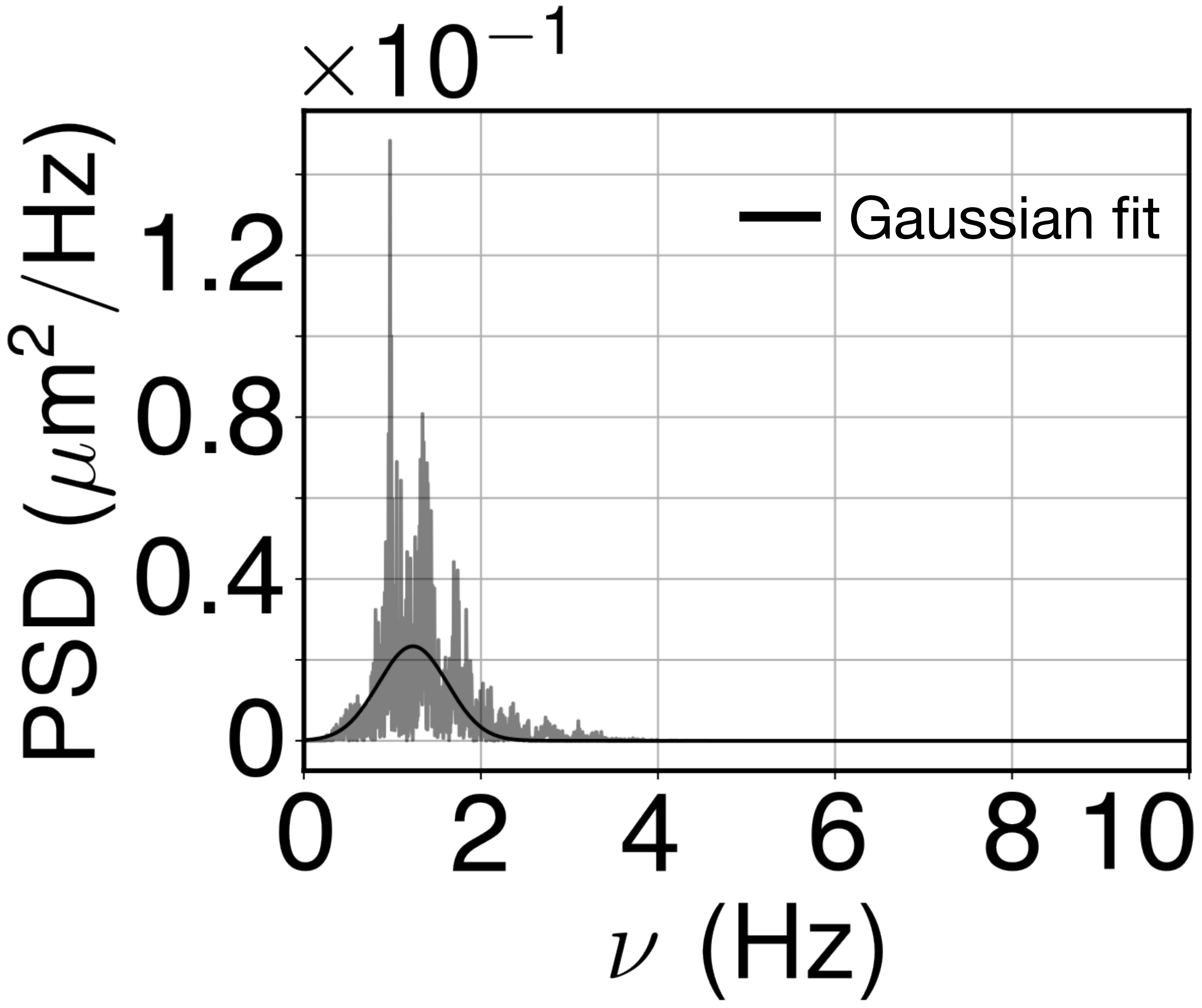


Older cells turn more



Cells oscillate at short time scales





$$\bar{\nu} = (1.21 \pm 0.02)\ \mathrm{Hz}$$

Conclusion

1. How to characterize the swimming behavior of single cells?

   By combining compact microscopes with microfluidic devices, we acquired long-time quantitative data of single-cell swimming

2. Which properties of swimming are maintained throughout the lifetime of cells?

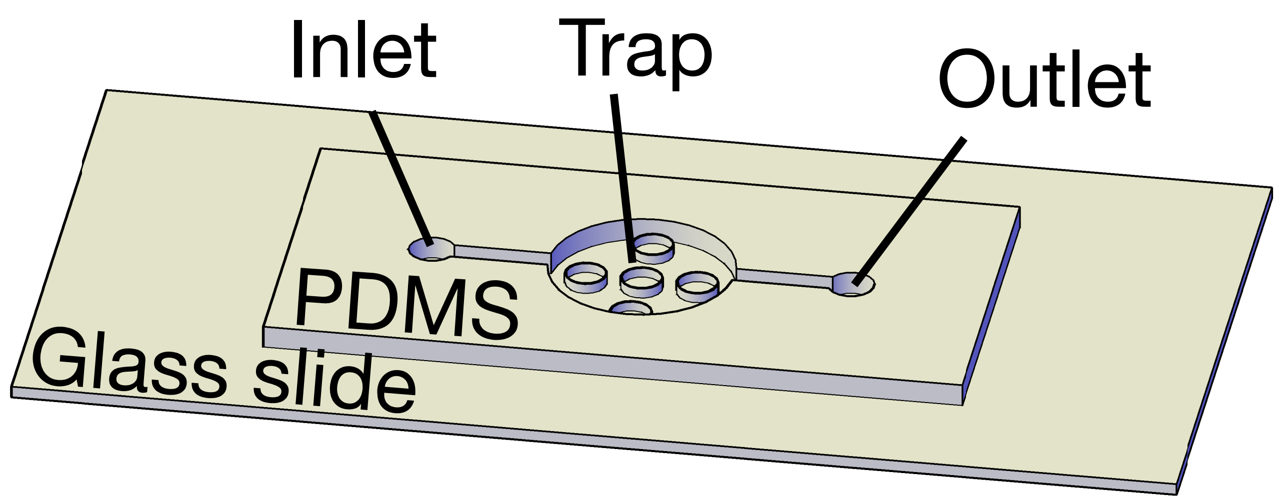
   - Cells slow down and turn more over their lifetime
   - Despite different initial speeds and decay times, cells slow down similarly
   - Oscillatory motion is maintained, but with wide frequency spectra

Thank you! Questions?

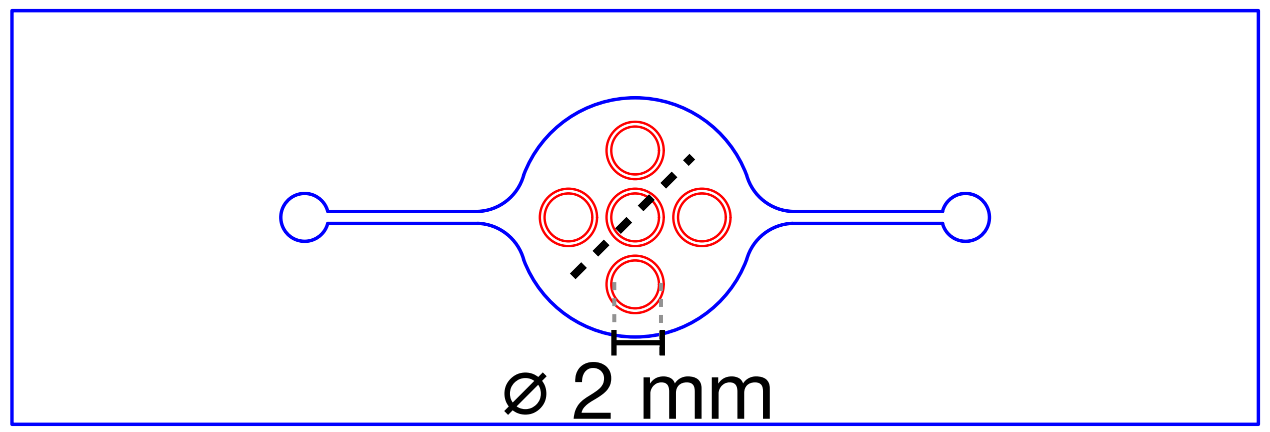
Supplementary slides

Microfluidic device to confine swimming cells

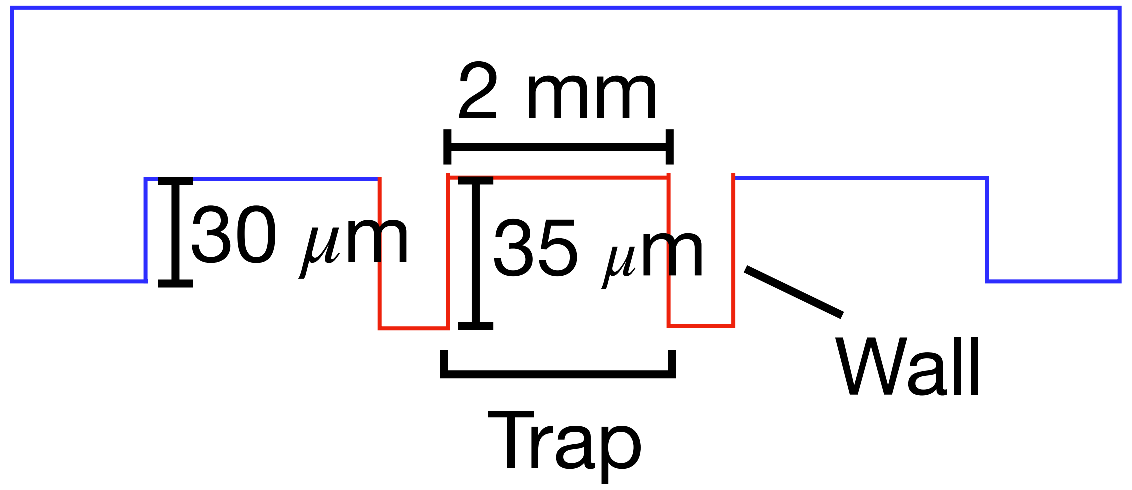
Design



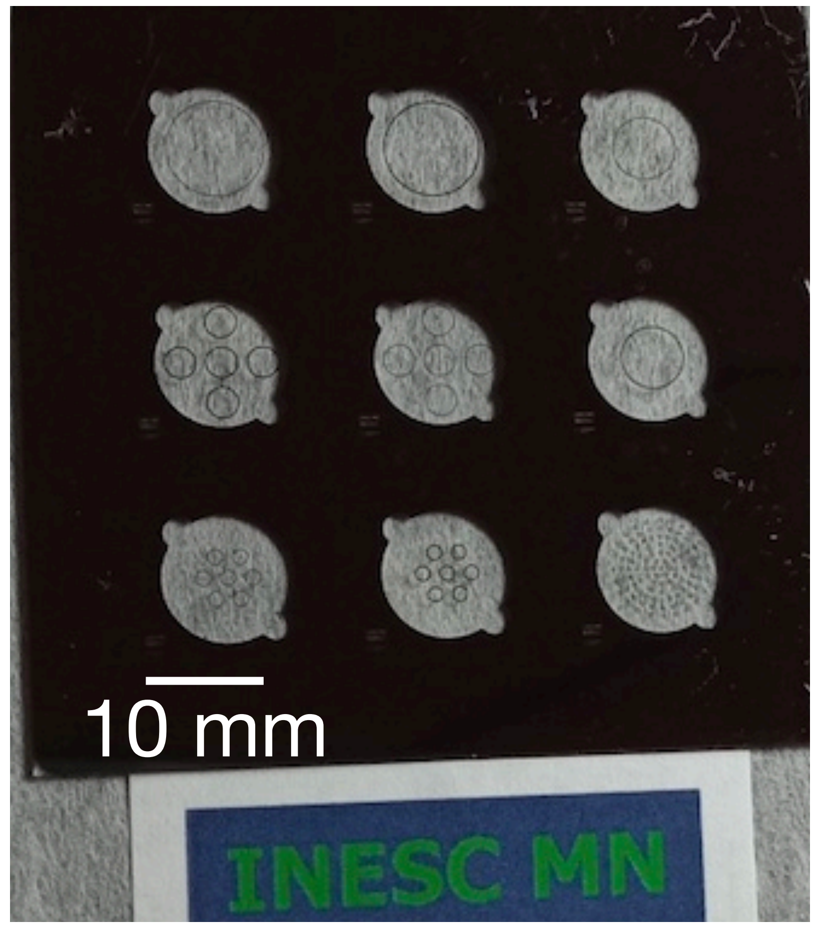
Top view



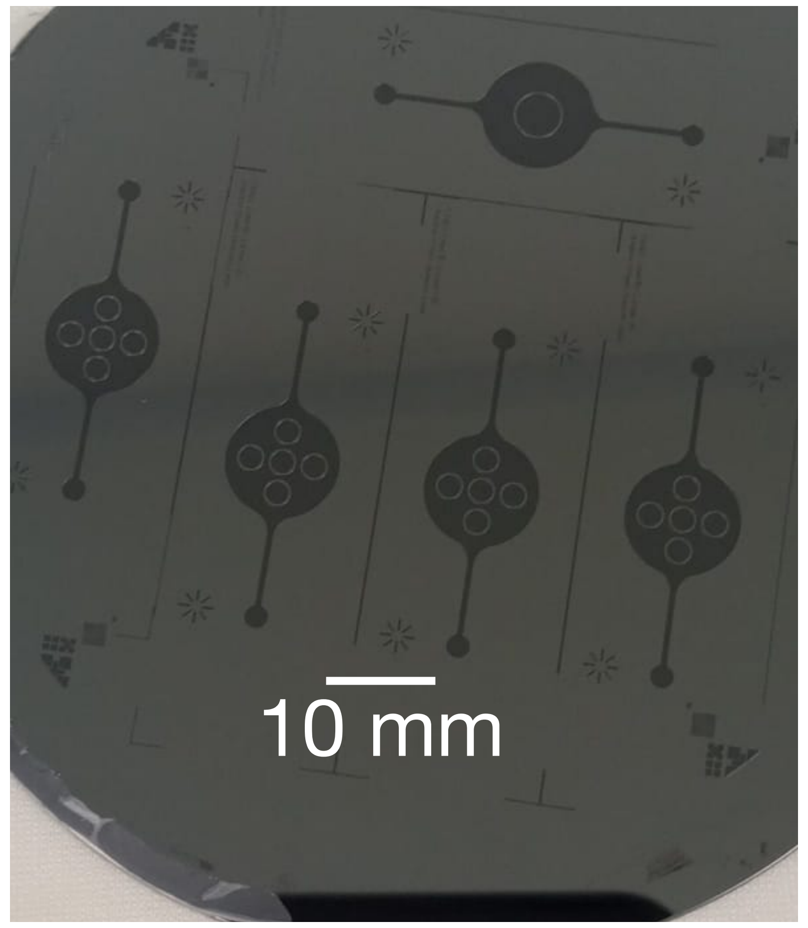
Sectional view



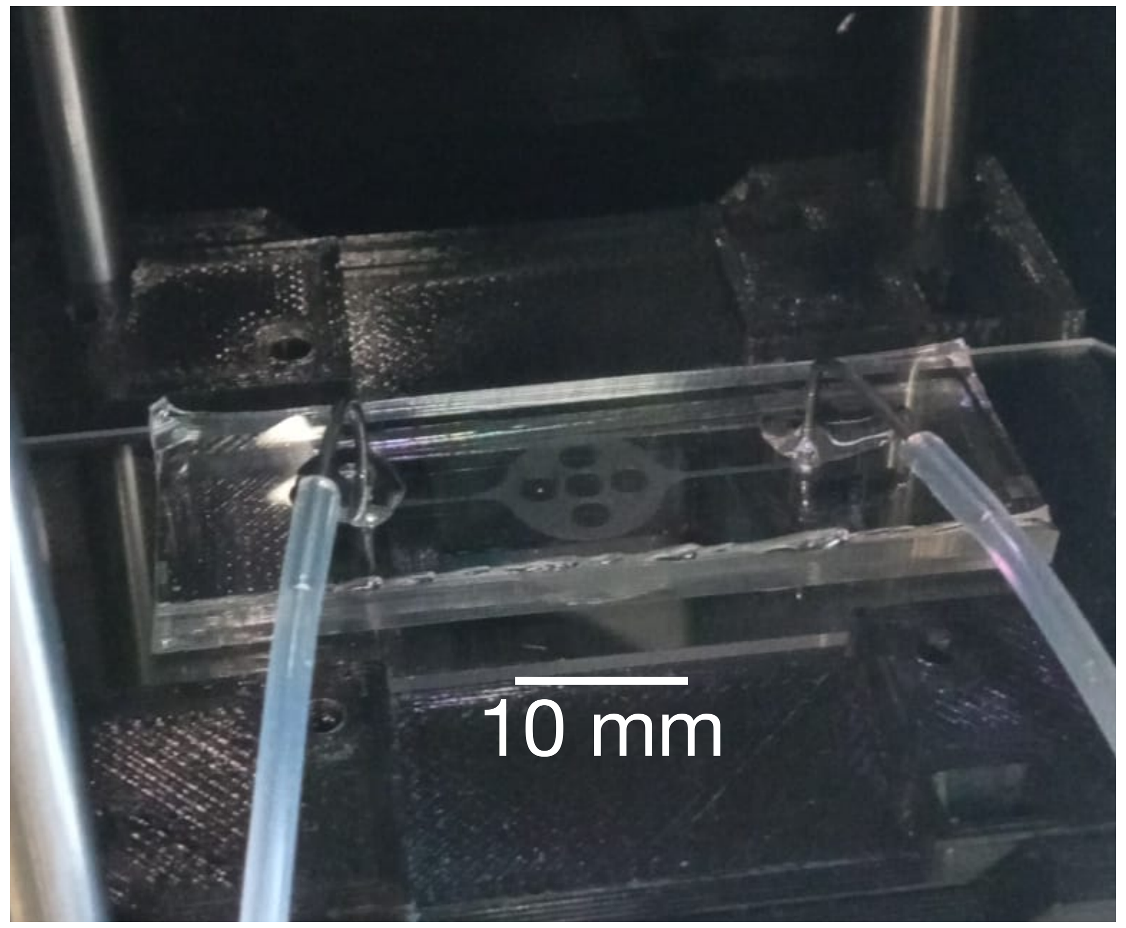
Hardmask



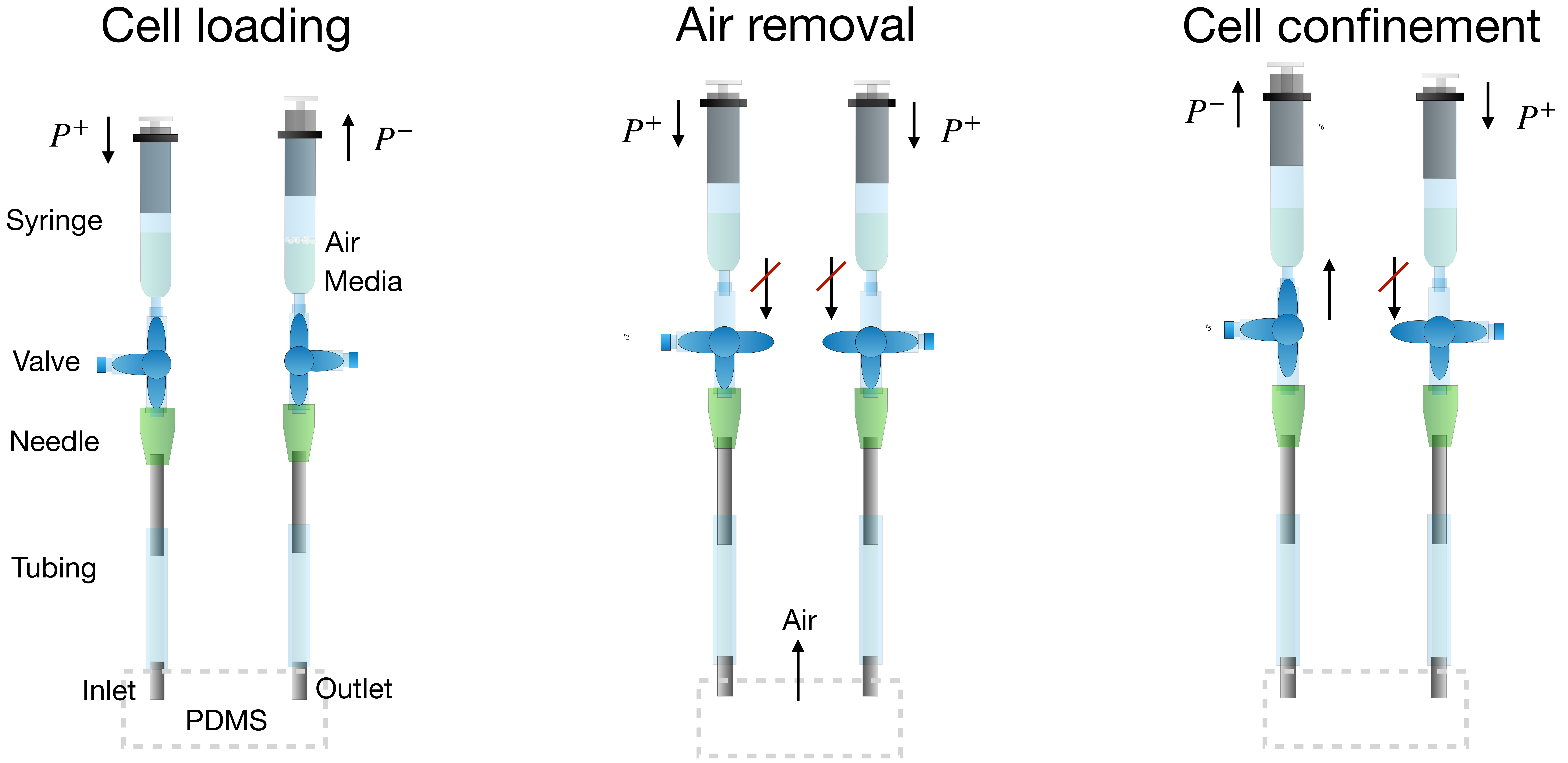
Master mold



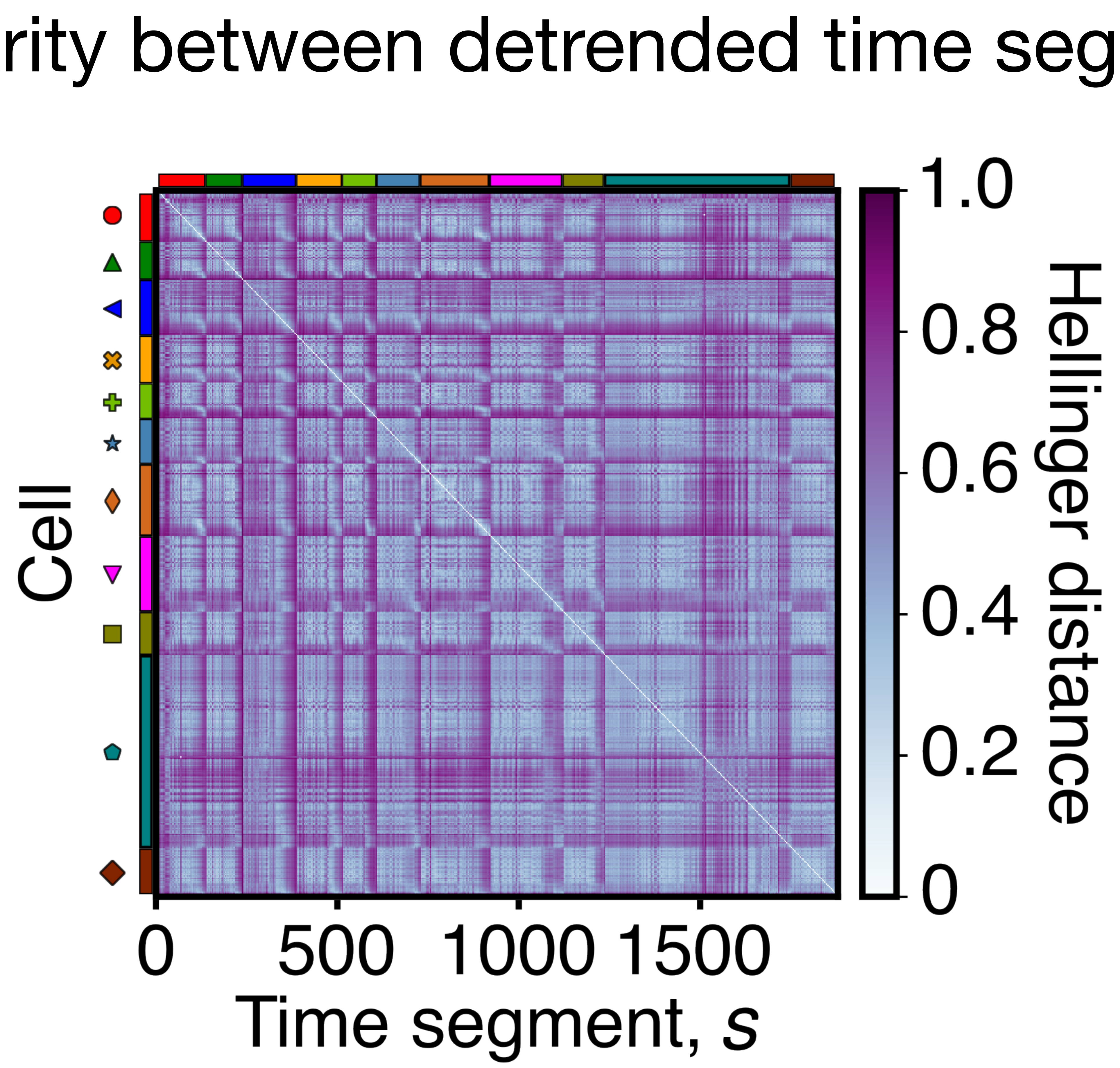
Microfluidic device



Cell loading and confinement

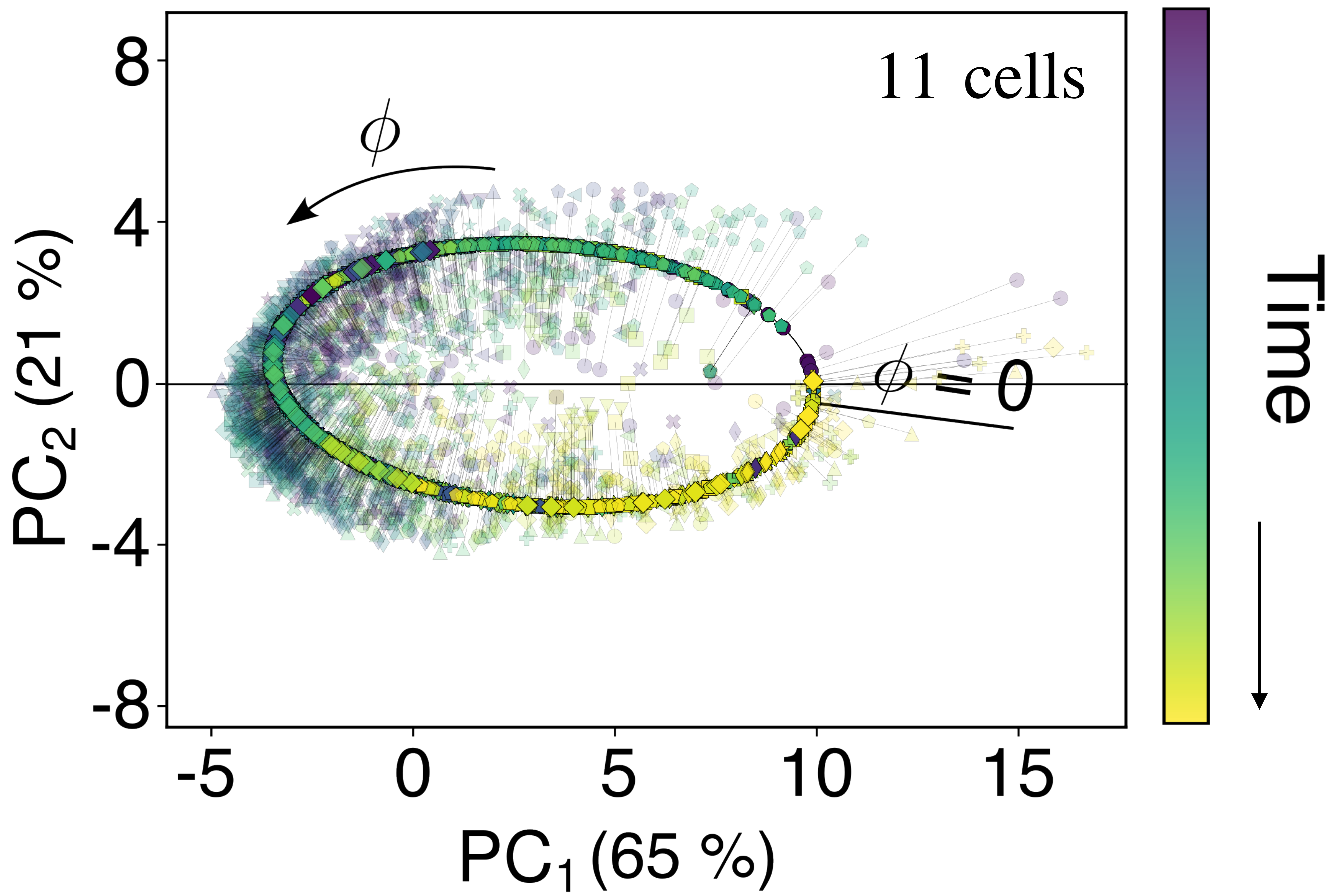


How does behavior vary beyond the slow-down?

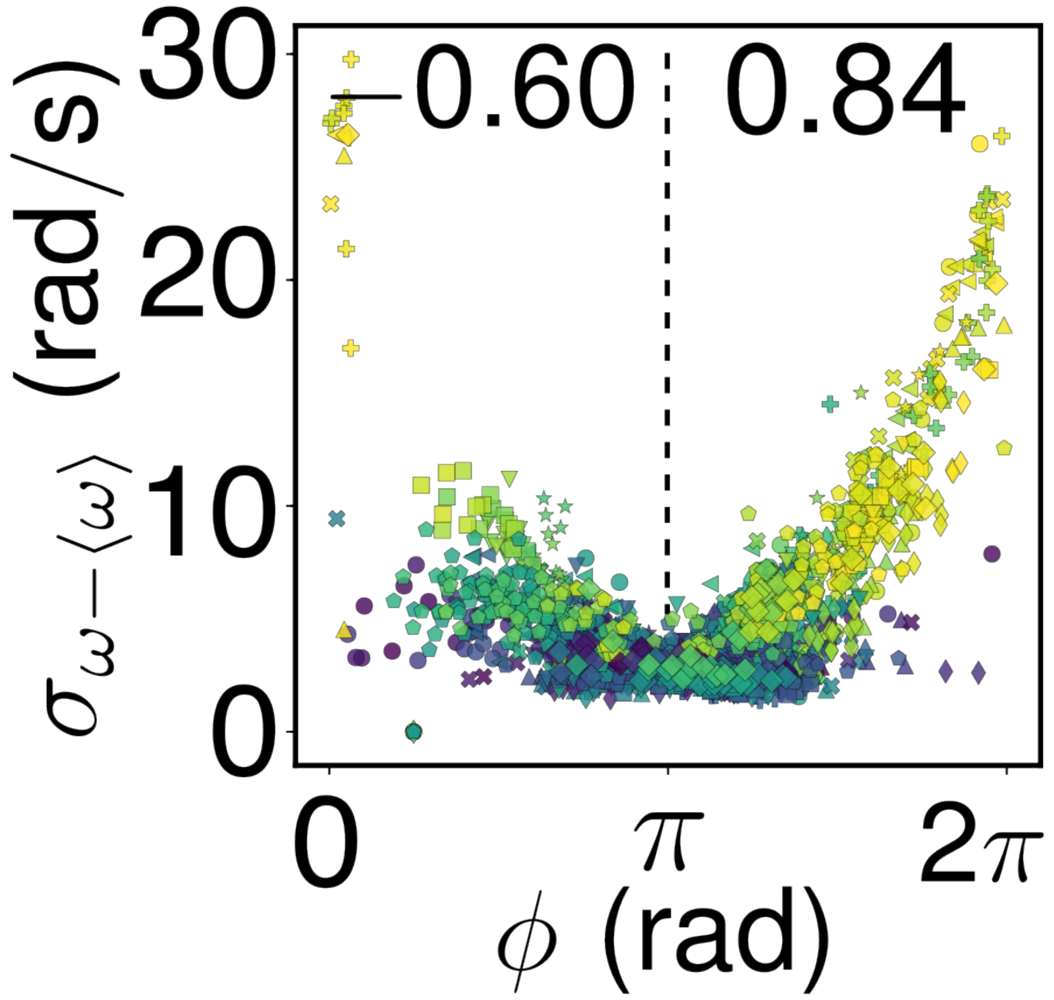


Turns explain variability beyond slow-down

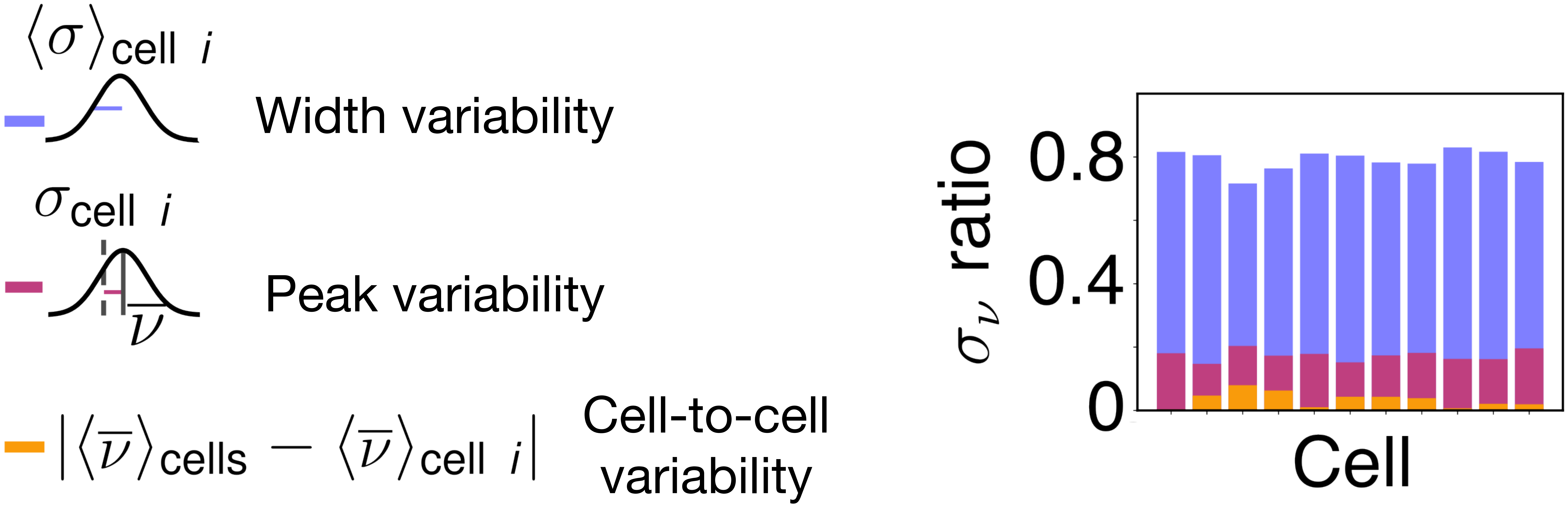
Low-dimensional embedding



Correlations

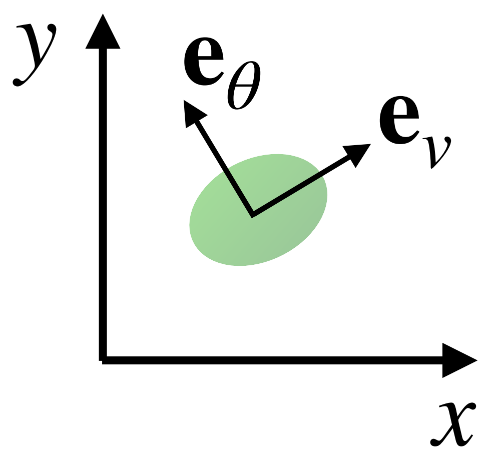


The variability of oscillatory motion is mostly intra-individual



Active brownian particles

e.g.:



$$\dot{\mathbf{v}} = \dot{v}\mathbf{e}_v + v\dot{\theta}\mathbf{e}_\theta$$

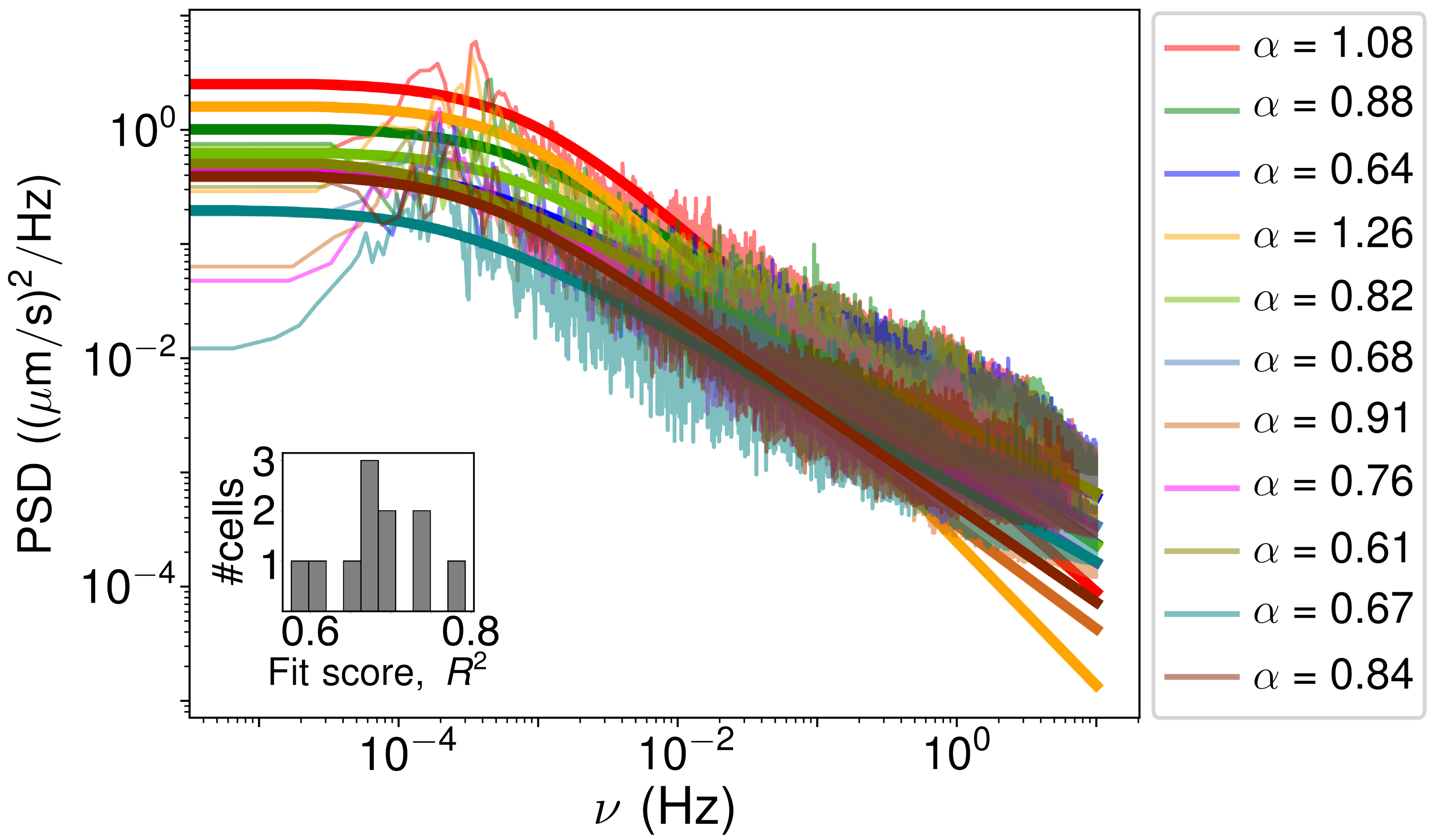
$$\eta = \eta_v\mathbf{e}_v + \eta_\theta\mathbf{e}_\theta$$

$$\dot{v} = -\gamma(v)v + \eta_v$$

$$v\dot{\theta} = \eta_\theta + \text{oscillations}$$

$$\gamma(v)v = \frac{1}{\tau_v}(v - v_{\text{trend}})$$

Compare statistical quantities with data; for instance, $\text{PSD}(\nu)$:



Work in progress!