Electronic Supplementary Material (ESI) for Soft Matter.

Supporting Material

Spontaneous Spatiotemporal Ordering of Shape Oscillations Enhances Cell Migration

M. Campo, S.K. Schnyder, J.J. Molina, T. Speck, and R. Yamamoto

SINGLE CELL'S CYCLIC MOTION

By changing the duration of the contraction-extension cycle, the steady state properties of single cell migration change, see Fig S1 and Supplementary Movie 6. As mentioned in the main text, the steady state velocity of the cell $v_{\mathrm{ss}}^{\Delta T}$ decreases, while the collective migration counterintuitively improves, see Main Text and Supplementary Movies 3 and 4. For cycle duration $\Delta T \approx 0.9\tau$, which is where the collective migration is enhanced the most at $\phi = 1.1$, $v_{\mathrm{ss}}^{\Delta T}$ is around 20% lower compared to the case $\Delta T = 0$. The averaged (over one cycle) length of a cell at steady state, $r_{\mathrm{ss}}^{\Delta T}$, is also decreased upong increasing ΔT. While the average length of the cell is shorter, the amplitude of oscillation is higher. Since the maximum length of the cell R_{max} is fixed and the steady state speed $v_{\mathrm{ss}}^{\Delta T}$ decreases, the migration time $\tau^{\Delta T}$ increases.

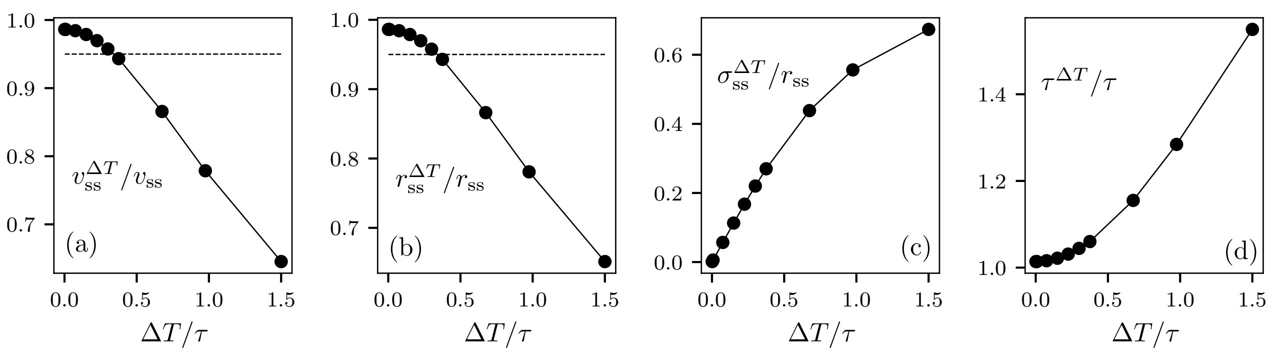

FIG. S1. Motion of the single cell under periodic extension-contraction cycles ($\Delta T > 0$). Quantities are normalized to the model with $\Delta T = 0$, where no explicit cycle is performed. (a) Steady state speed $v_{\mathrm{ss}}^{\Delta T}$, averaged over one cycle. (b) steady state length of the cell $r_{\mathrm{ss}}^{\Delta T}$, averaged over one cycle. (c) standard deviation of the cell's length $\sigma_{\mathrm{ss}}^{\Delta T}$ during a cycle. (d) migration time $\tau^{\Delta T}$. Full lines are a guide to the eye, and the dashed lines in (a,b) indicate where the values drop below 95% compared to the case $\Delta T = 0$.

METASTABLE VORTICES

In systems with CIL it is possible to observe long lasting metastable vortices before the occurrence of the steady state collective migration. Such states are characterized by the presence of two vortices of opposite charge for the system sizes we have so far considered (up to $N = 10^4$), see Supplementary Movie 5. The occurrence of vortices depends solely on the initial conditions, since the model does not employ any random noise, and it is observed more frequently (from 10% to 50% of the samples) in the region of packing fractions $0.65 \leq \phi \leq 1.0$. For this reason, we have excluded from the presented data those runs where the vortices where particularly stable to last for the majority of the simulation time.

MOVIES

- Movie S1: Single cell's migration for different cycle durations ΔT, comparison.
- Movie S2: 2500 cells at $\phi = 0.85$ and $\Delta T = 0$, showing traffic waves at moderate packing fraction. Cells are coloured according to their length, from blue(short) to red(long). We coloured one single cell in bright red to show the queueing motion.

- Movie S3: 2500 cells at $\phi = 1.12$ and $\Delta T = 0$, showing traffic waves at high packing fraction. Cells are coloured according to their length, from blue(short) to red(long). We coloured one single cell in bright red to show the queueing motion.
- Movie S4: 10000 cells at $\phi = 1.1$ and $\Delta T = 0.9\tau$, showing the absence of traffic waves, the enhanced migration and the mechanism of lane change discussed in the main text. In the first part of the movie, the screen is split into two: in the top left side the cells are coloured according to their length; in the bottom right side we show the displacement vectors on top of cells. The second part of the movie shows cells coloured according to their stage (blue: expansion, green: contraction). We indicate with a red circle an exemplary 'lane change' event, as described in the main text.
- Movie S5: 10000 cells at $\phi = 1.11$ and $\Delta T = 0.9\tau$, showing the metastable vortices described above.