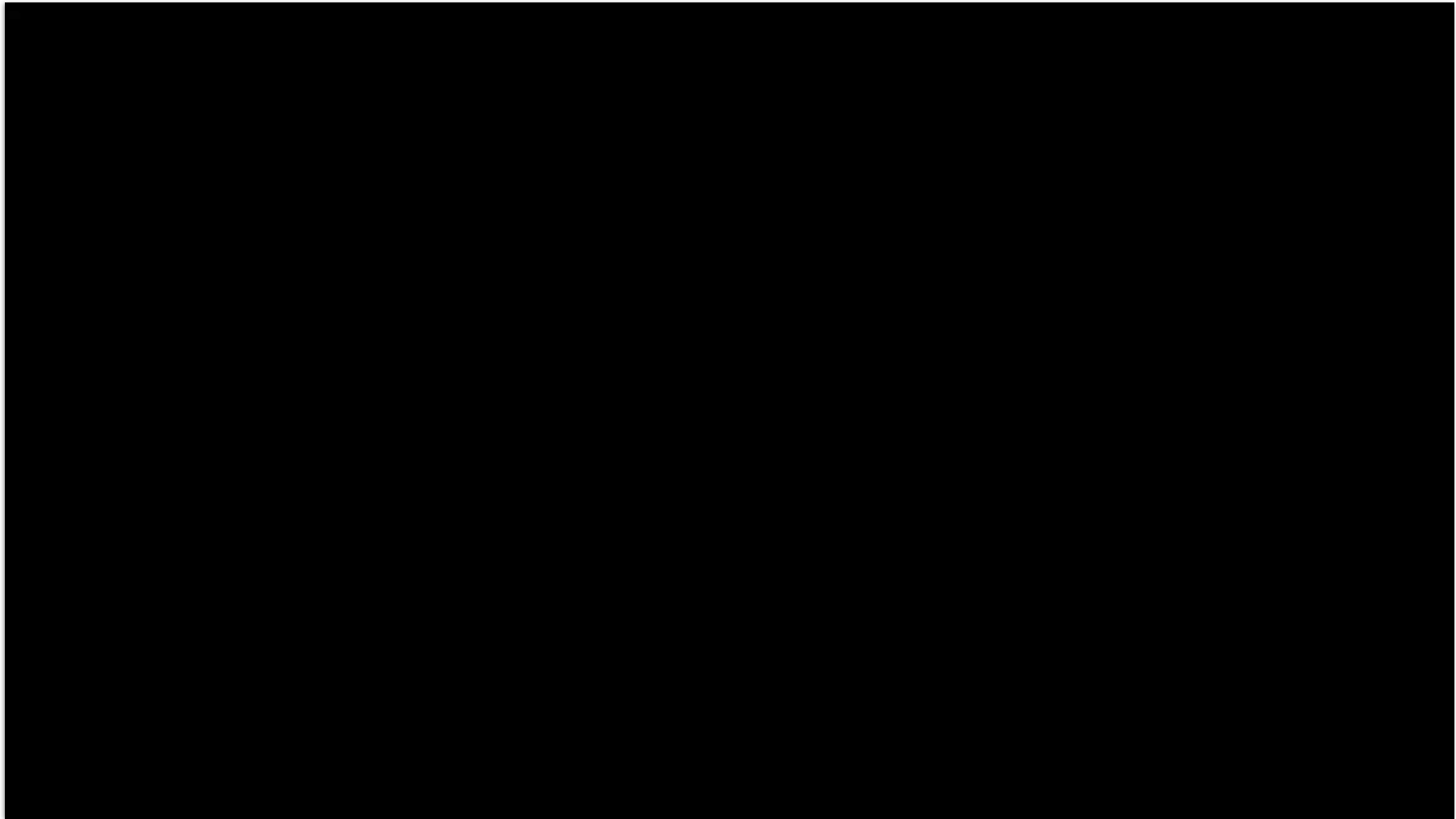


Particle-based tissue modeling

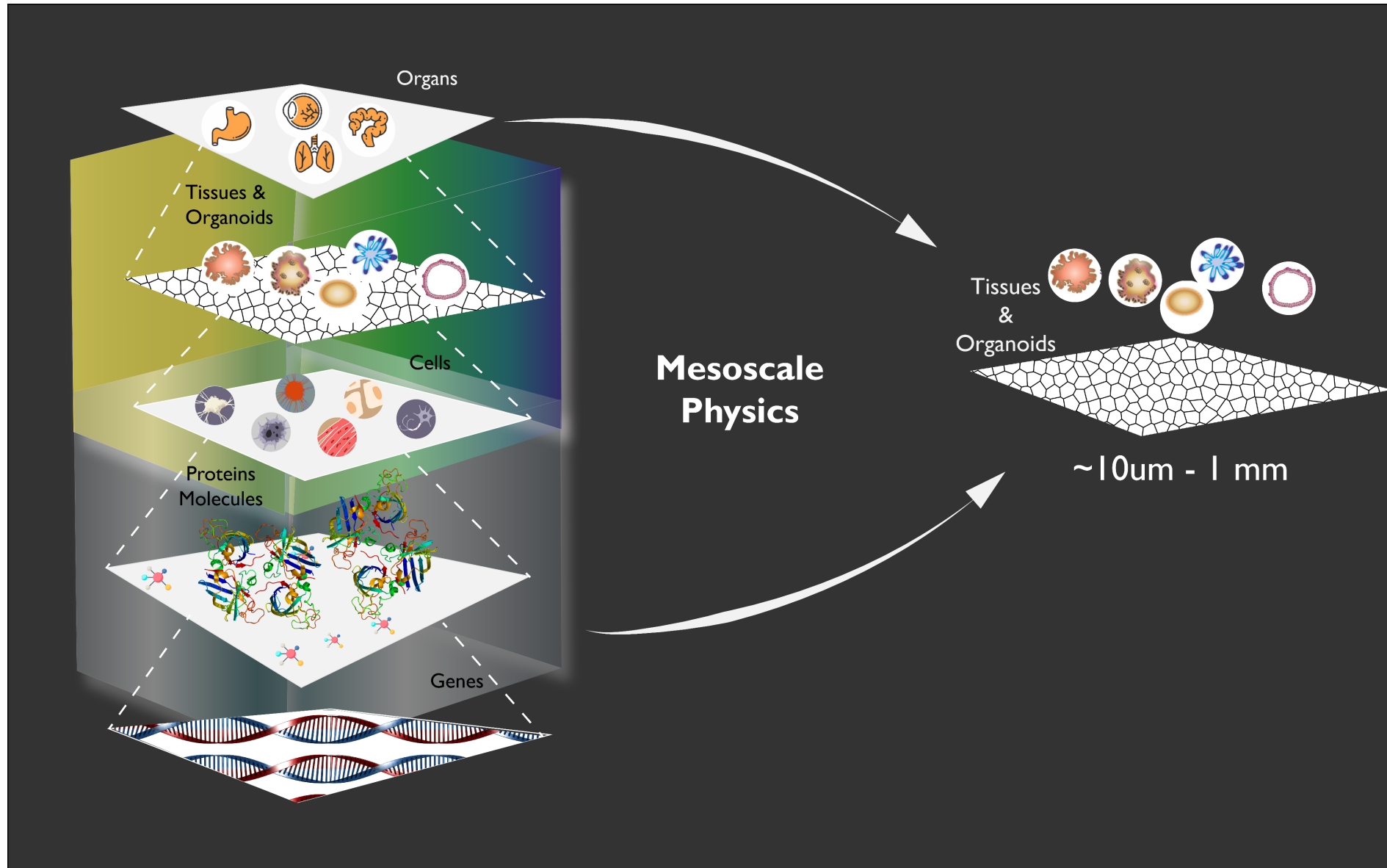


Growth, form and active mechanics in biology

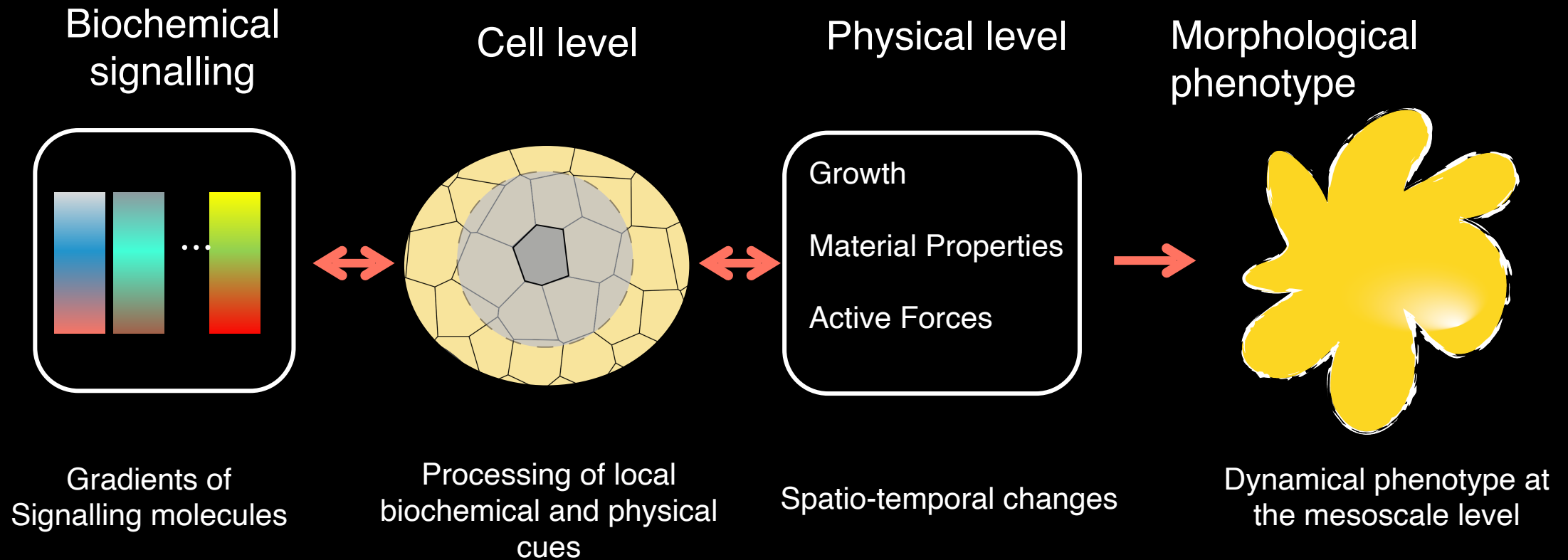


[Jan van IJken](#)

Soft Matter Physics: mesoscale



The interaction between components

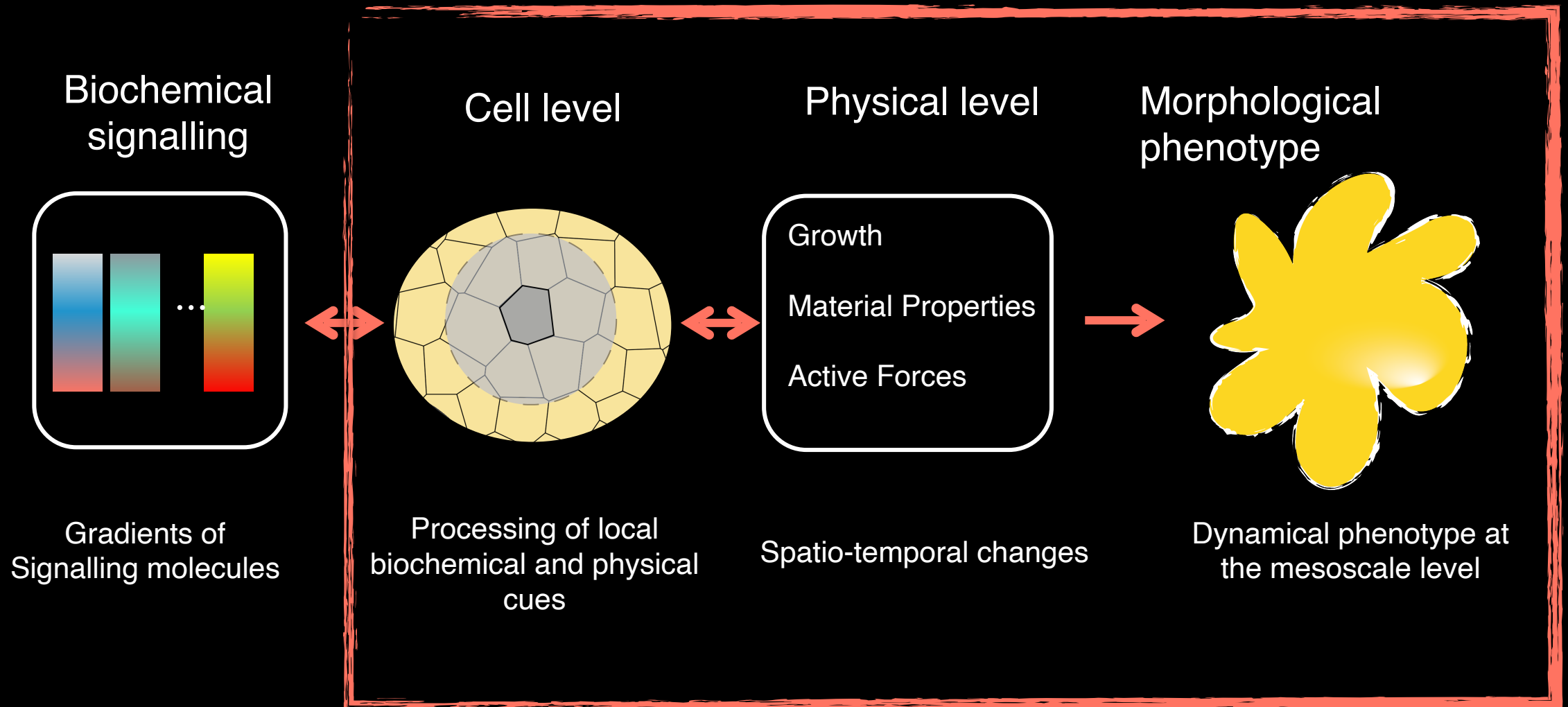


Adapted from:

Taber, Larry A. *Applied mechanics reviews* 48, no. 8 (1995): 487-545.

Stooke-Vaughan et. Al *Current opinion in genetics & development* 51 (2018): 111-119.

The interaction between components



Adapted from:

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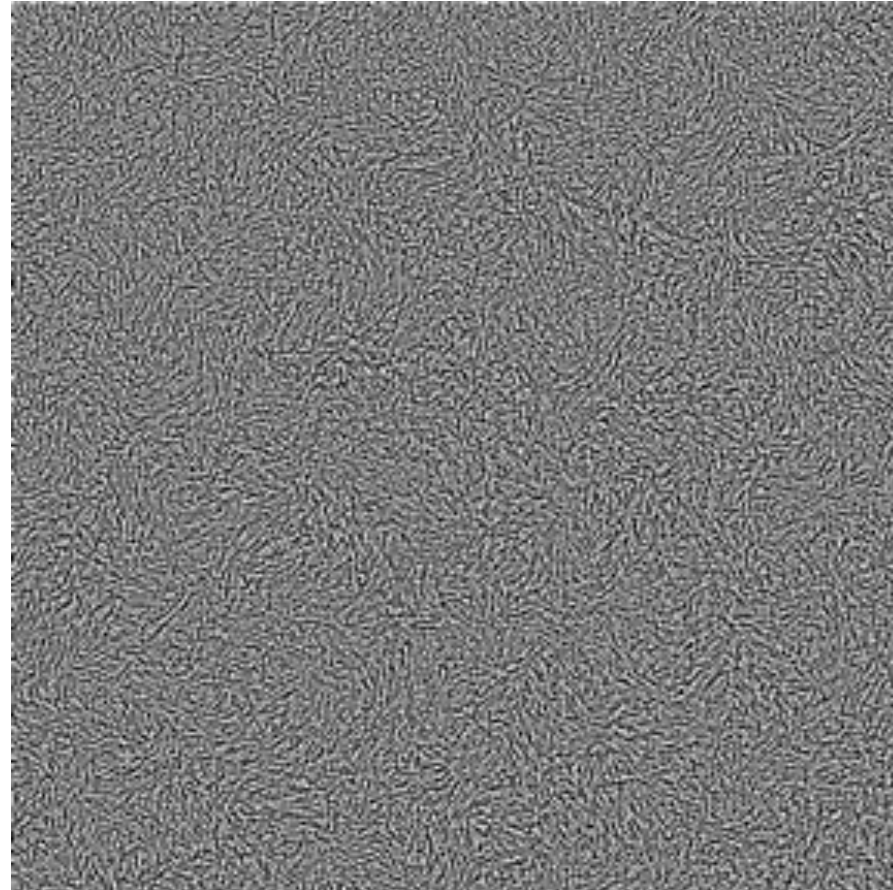
Active matter: what it is?



“Each active particle consumes and dissipates energy going through a cycle that fuels internal changes, generally leading to motion”

Dense active matter: active fluids

Active nematic



Turbulent phase in a quasi-2D homogeneous *B. subtilis*

Meso-scale turbulence in living fluids

Henricus H. Wensink et. al PNAS

Dense active matter: active fluids

Hydrodynamics of soft active matter

REVIEWS OF MODERN PHYSICS, VOLUME 85, JULY–SEPTEMBER 2013

Hydrodynamics of soft active matter

M. C. Marchetti* et al

Physics Department and Syracuse Biomaterials Institute, Syracuse University, Syracuse, New York 13244, USA

IOP Publishing

Rep. Prog. Phys. **81** (2018) 076601 (27pp)

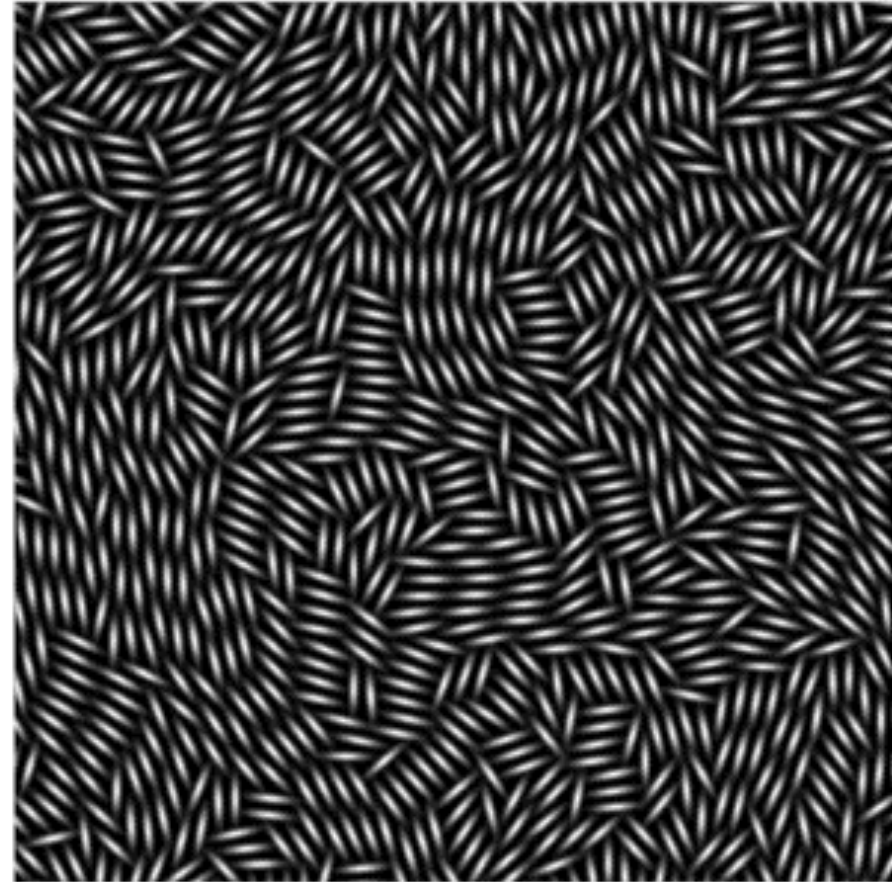
Reports on Progress in Physics

<https://doi.org/10.1088/1361-6633/aab6bb>

Review

Hydrodynamic theory of active matter

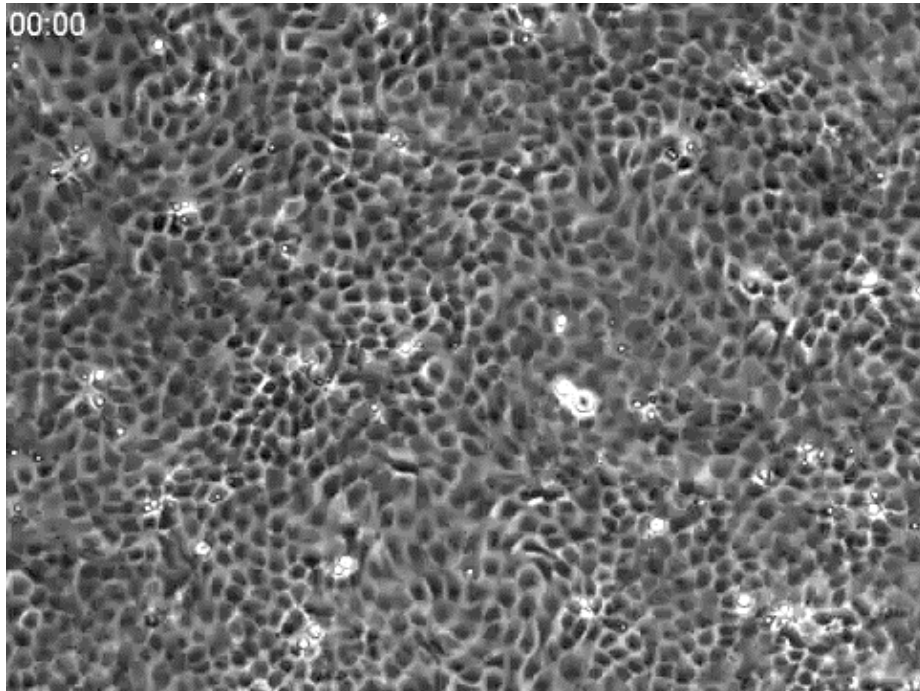
Frank Jülicher¹, Stephan W Grill² and Guillaume Salbreux^{1,3}



Meso-scale turbulence in living fluids
Henricus H. Wensink et. al PNAS

New physics in cell monolayers

Glass-like dynamics of collective cell migration
Thomas E. Angelini et al. PNAS (2011)



New class of materials

An **active glass** is an amorphous material which can undergo into reversible transition from a “**solid-like**” into a more viscous “**liquid-like**” state when “**activity**” is increased

The new *old* physics

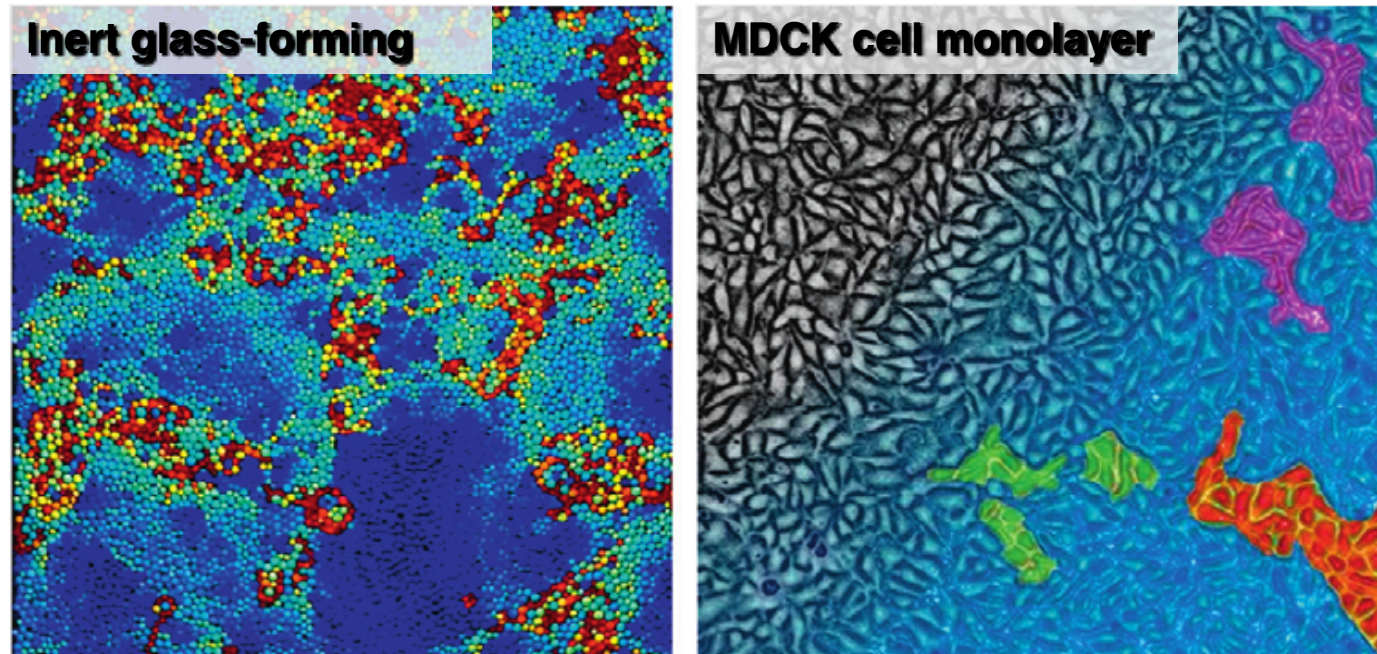
Amorphous solid:
A solid that **lacks** the **long-range order** that is characteristic of a crystal.

A glass is an amorphous material which can undergo reversible transition from a “**solid**” state into a “**liquid-viscous**” state as the “**temperature**” is increased

A physics point of view: Active Mechanics

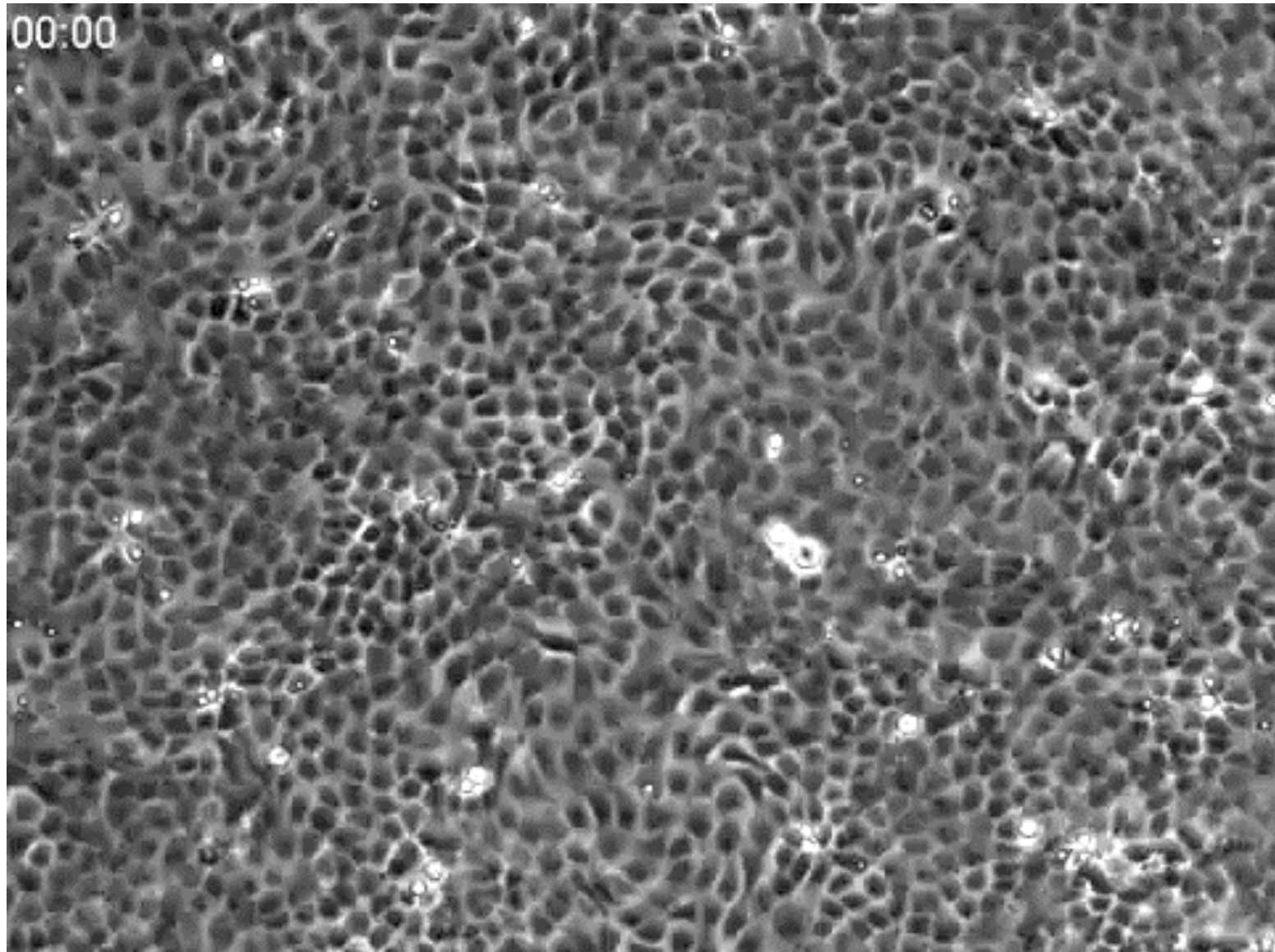
What can we learn from the dynamics of inert glasses?

Dynamic heterogeneity

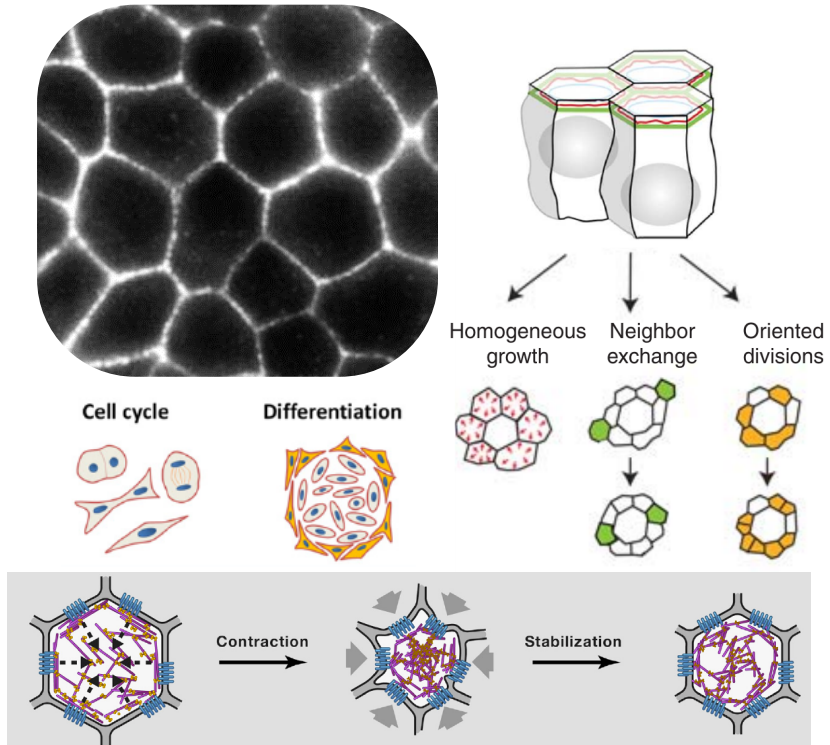


Particle/Cell mobility

Cell Monolayers

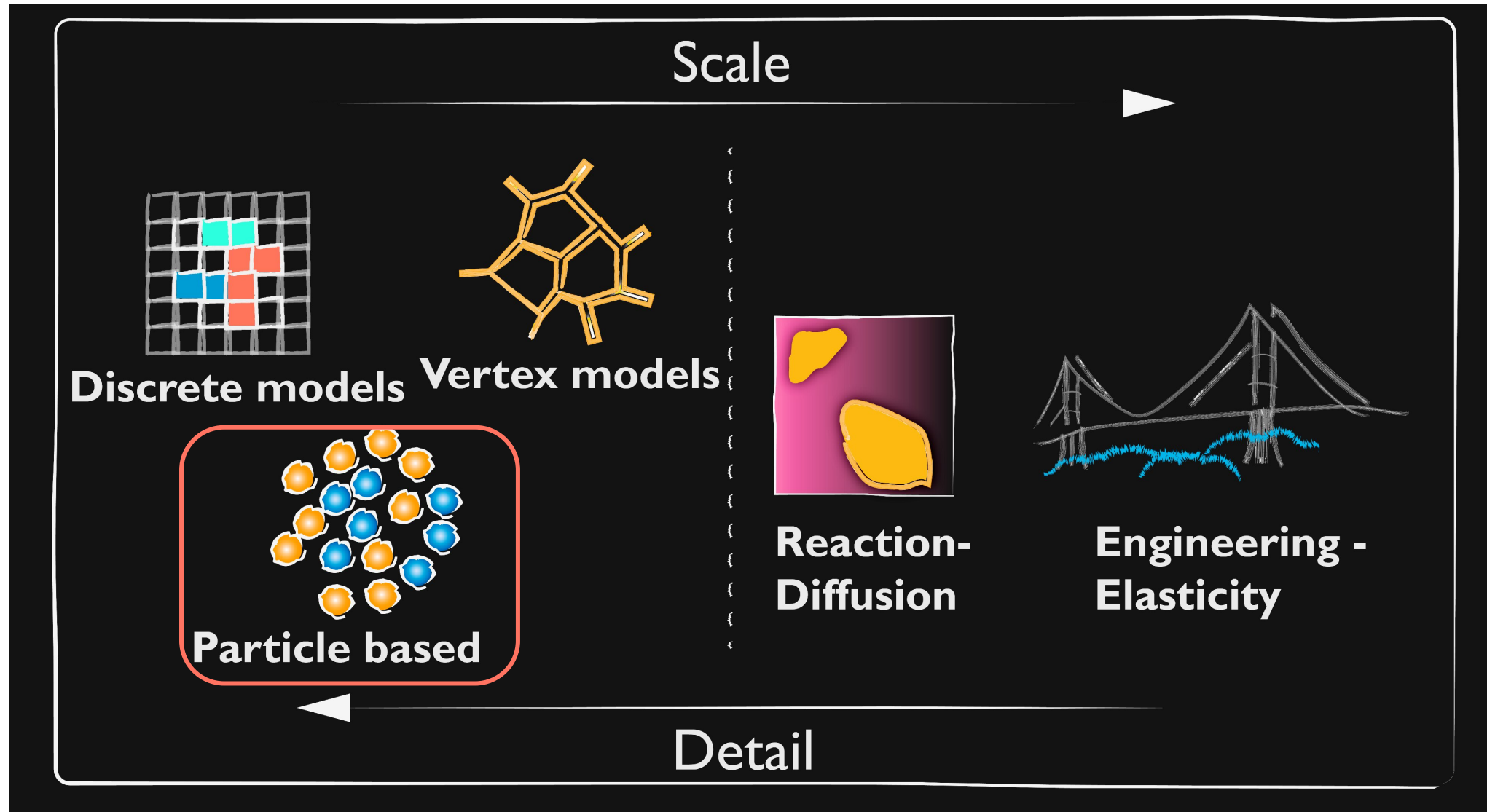


Active drivers in cell monolayers

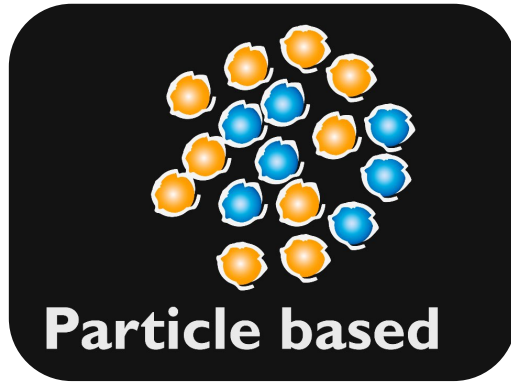


- Cell migration on substrate
- Cell division and death
- Cell ingressions
- Chemical signaling
- Cell-type interactions
- Junction contractions
- Shape fluctuations
- Boundaries and topology

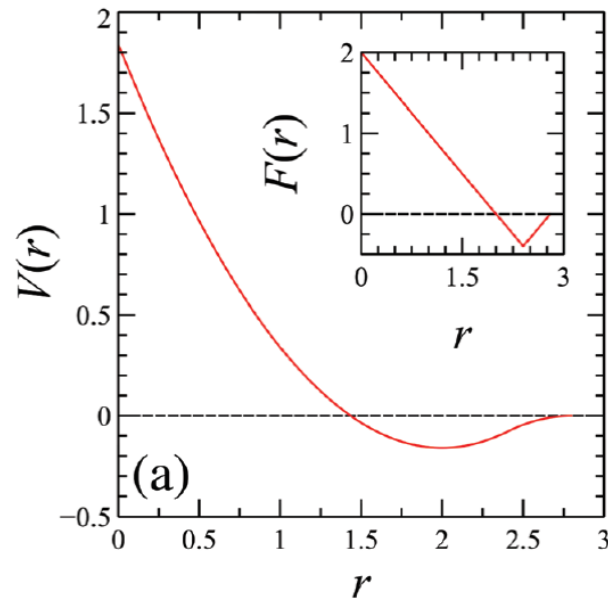
Modeling cell monolayers



A very simple model

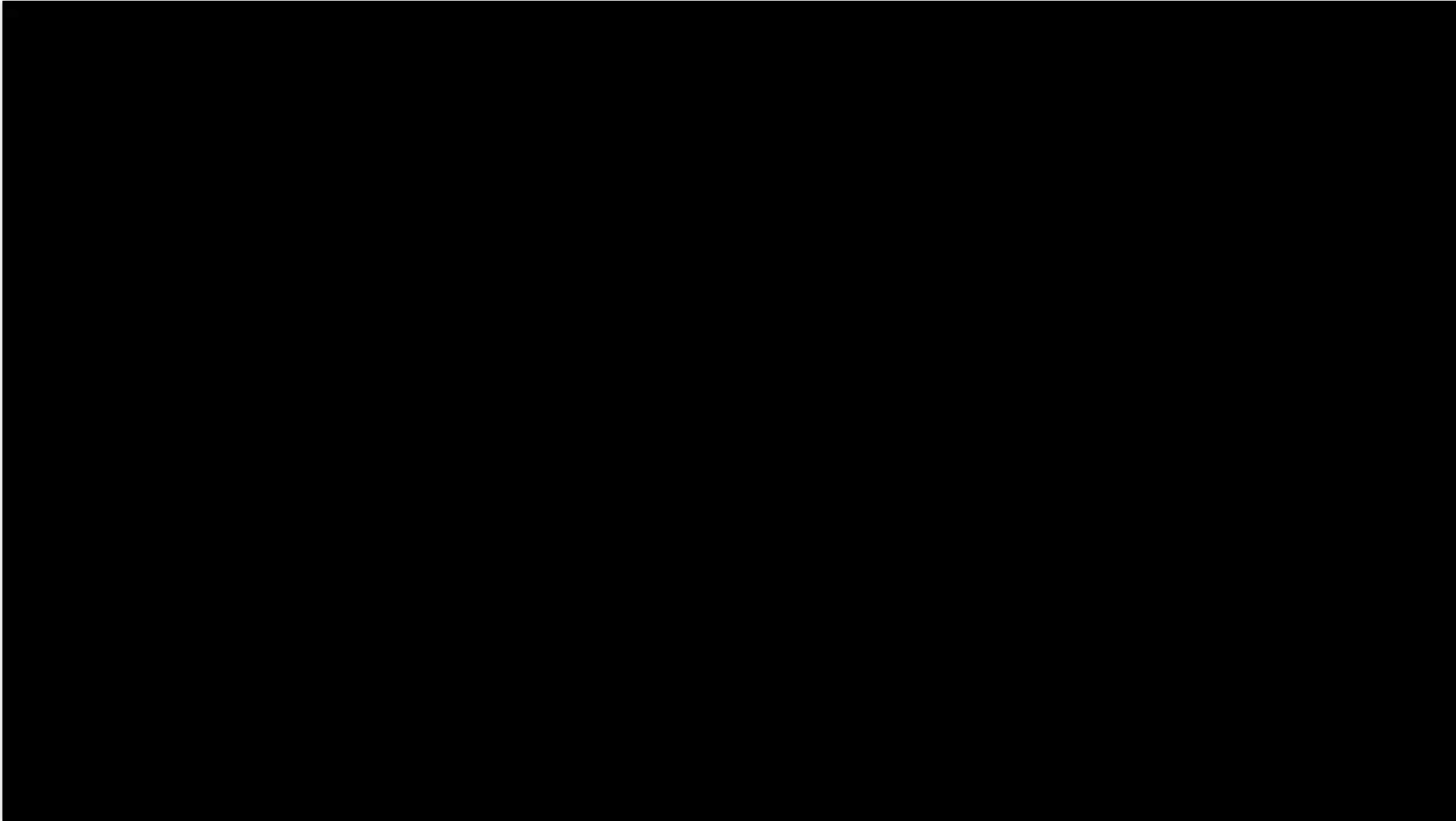


Soft Elastic Particles (Adhesion and Repulsion)

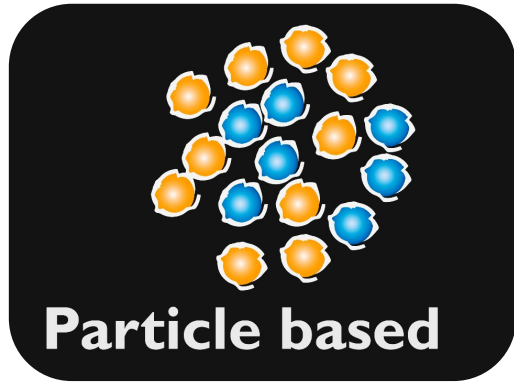


- Cell migration on substrate
- Cell division and death
- Cell ingressions
- Chemical signaling
- Cell-type interactions
- ~~Junction contractions~~
- ~~Shape fluctuations~~
- ~~Boundaries and topology~~

Cell division a main driver for morphogenesis

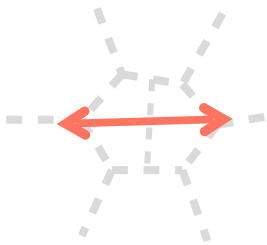


A very simple model

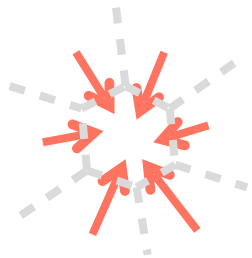


- Cell migration on substrate
- Cell division
- Cell ingressions (removal)
- ~~Chemical signaling~~
- ~~Cell-type interactions~~
- ~~Junction contractions~~
- ~~Shape fluctuations~~
- ~~Boundaries and topology~~

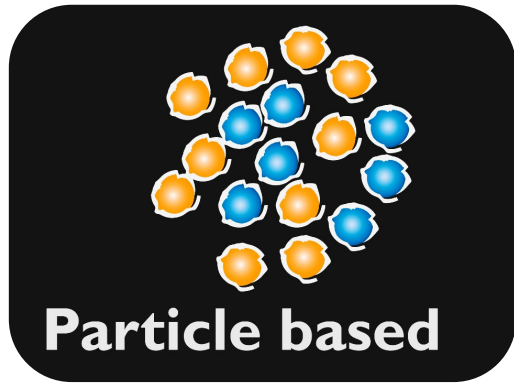
Cell division



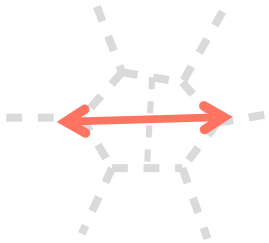
Cell removal



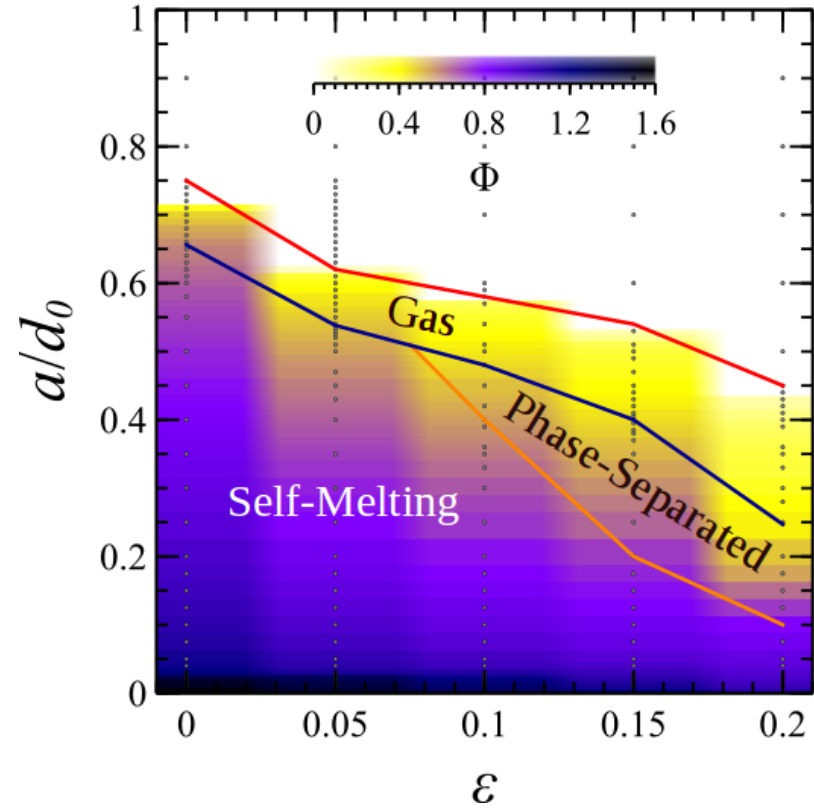
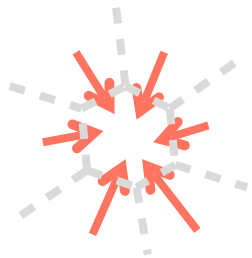
A very simple model



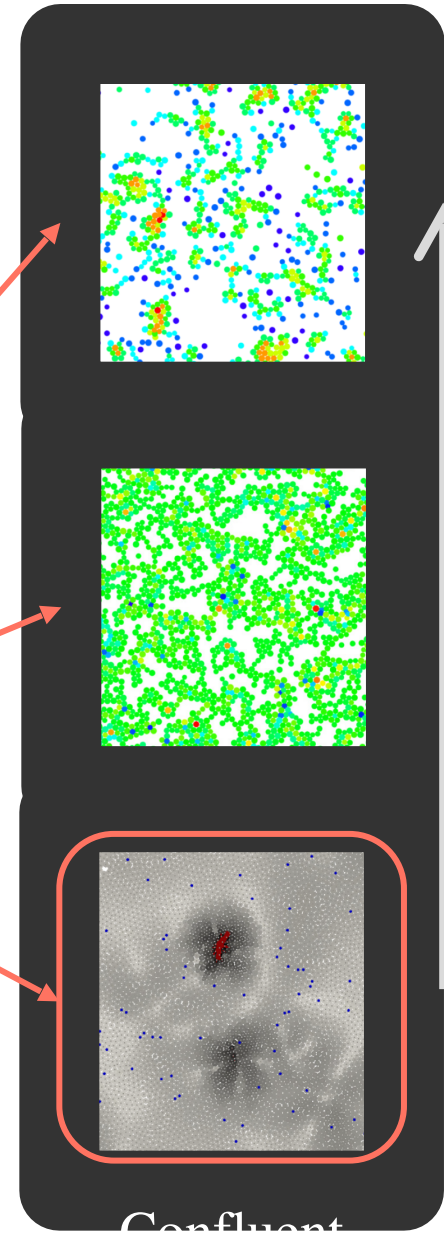
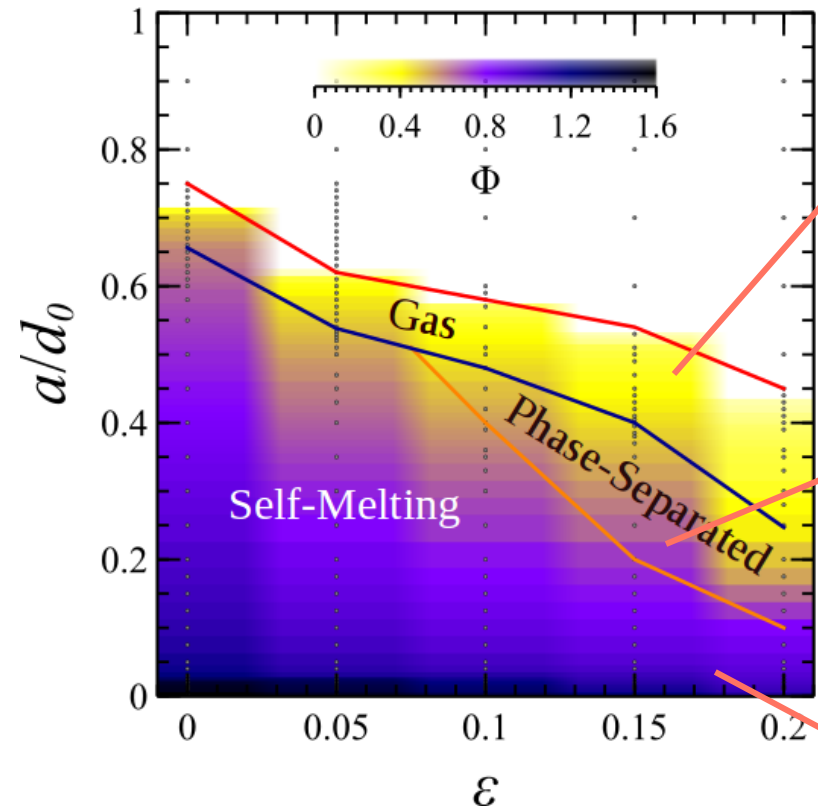
Cell division



Cell removal



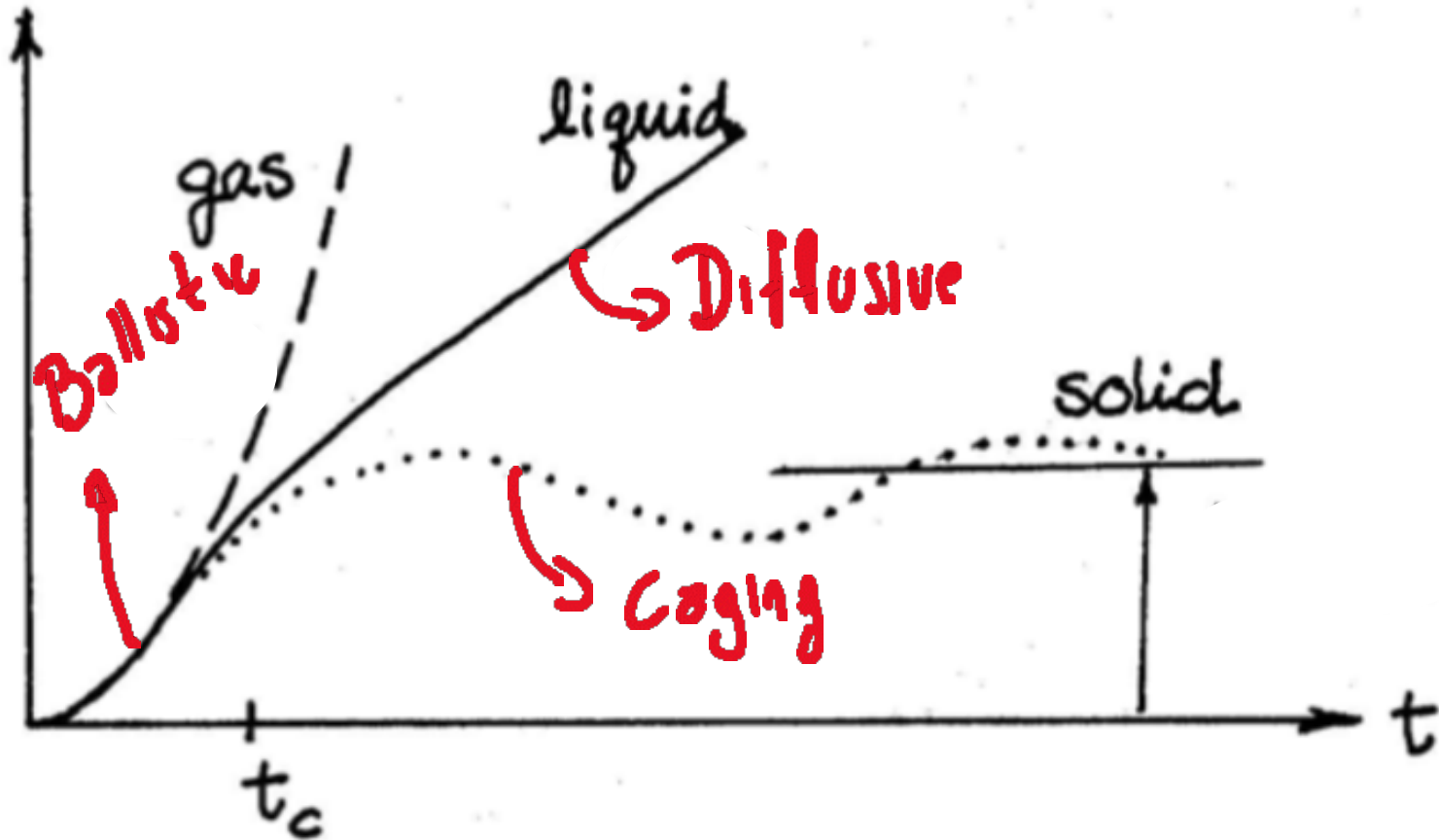
A very simple model

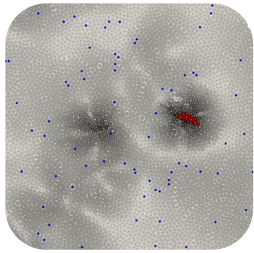


Confluent

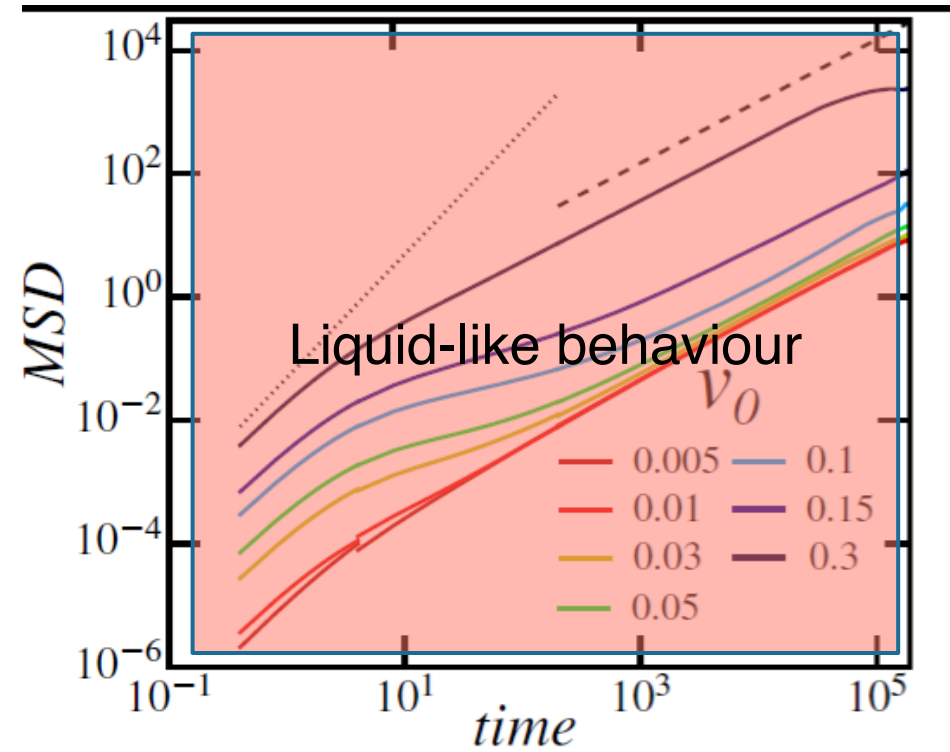
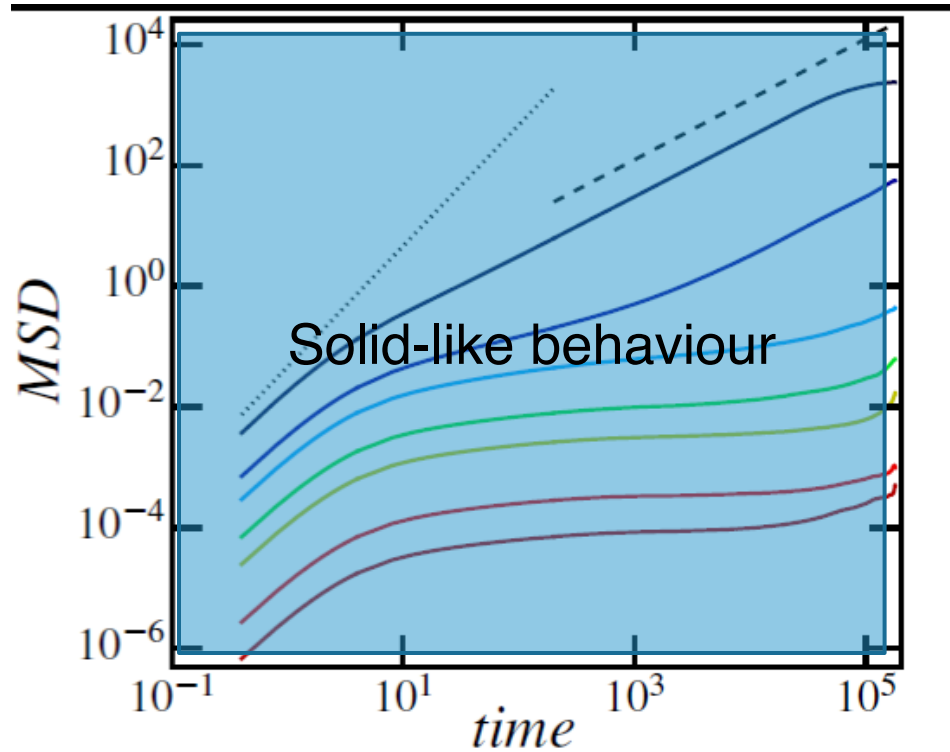
A very simple model: MSD

Mean squared displacement of three idealized systems



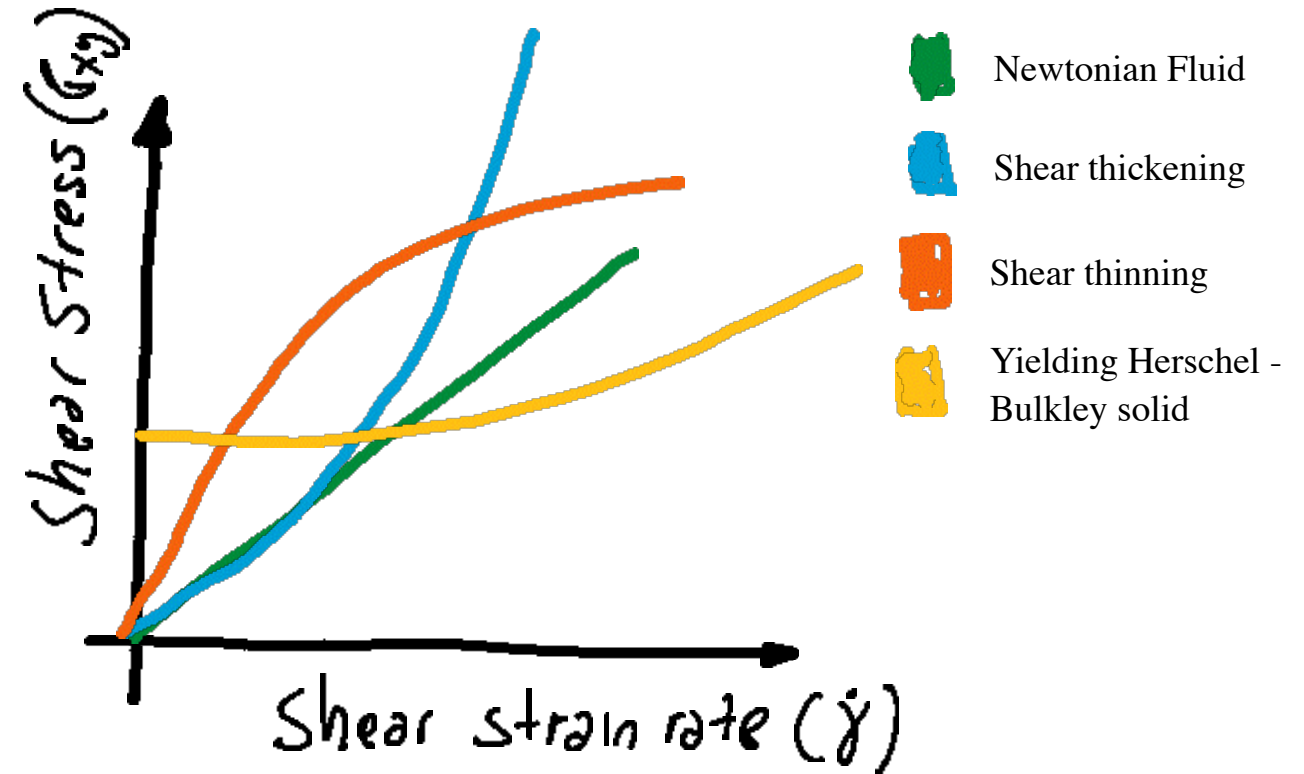
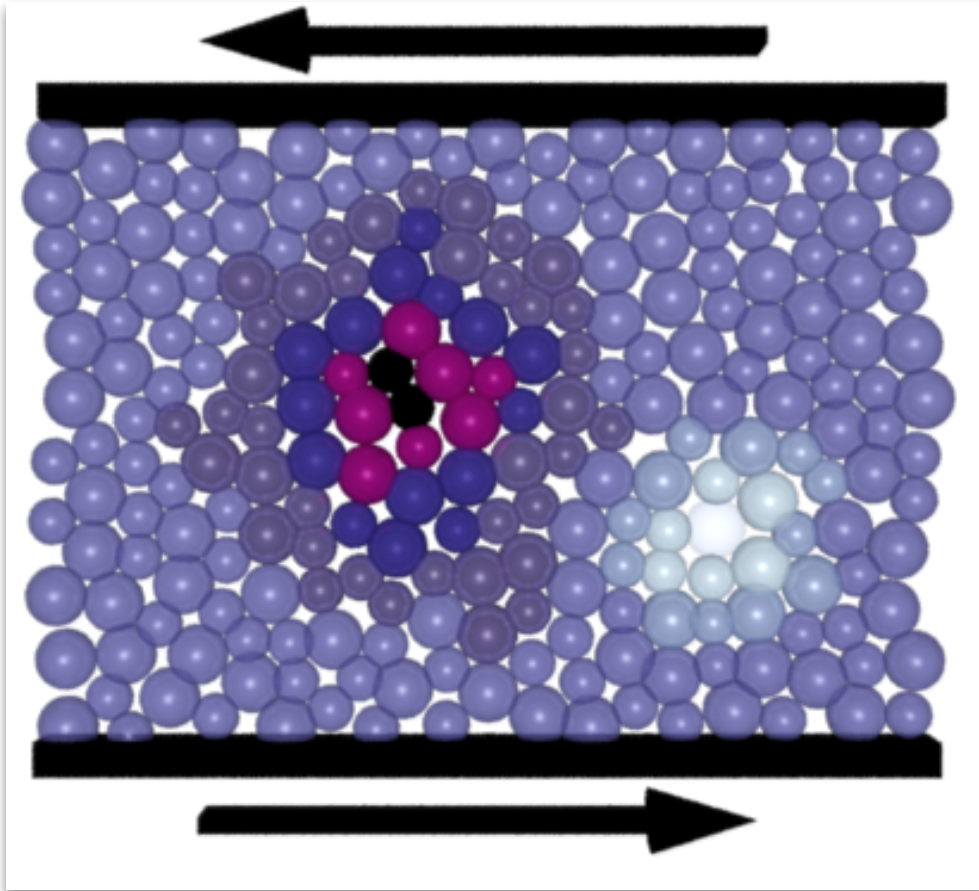


A very simple model



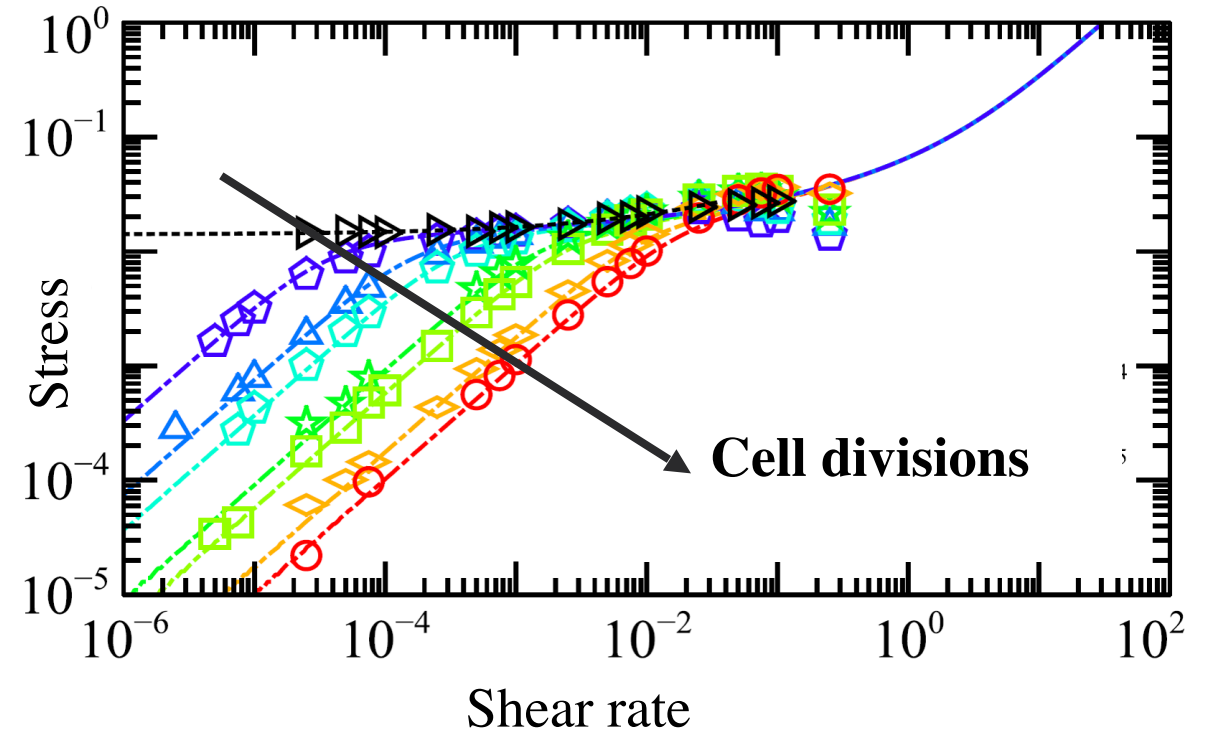
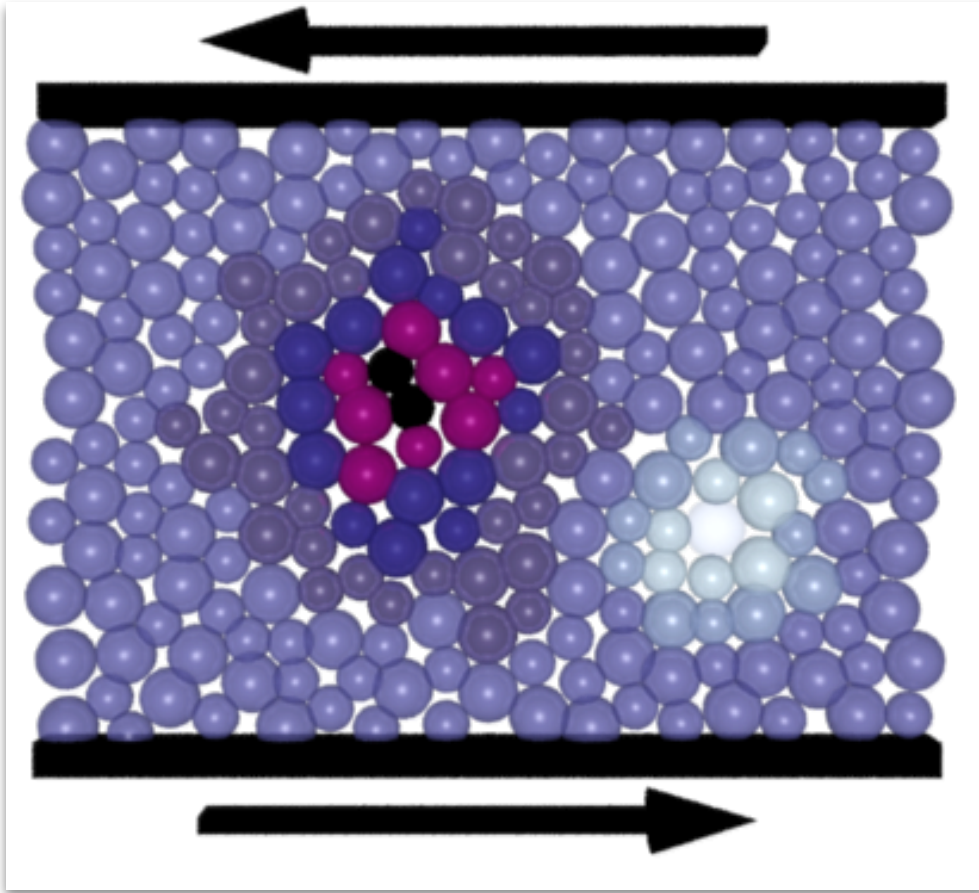
Rheology

In silico cell monolayer under shear



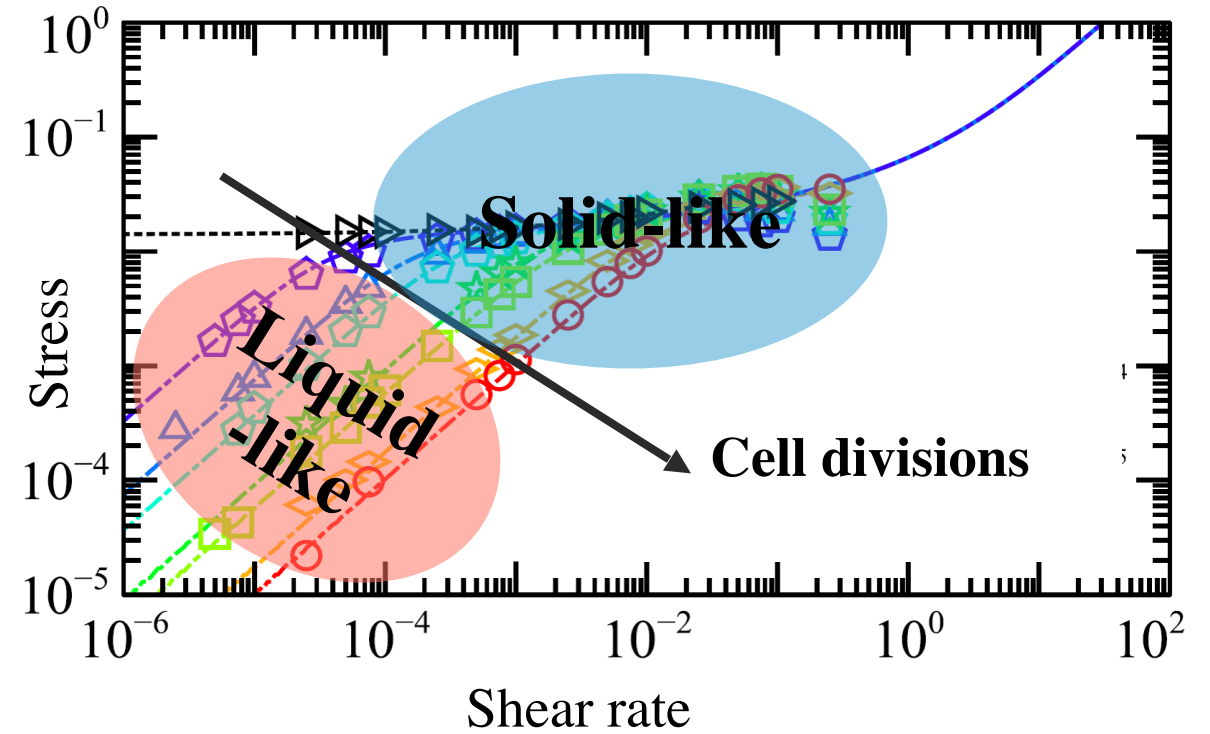
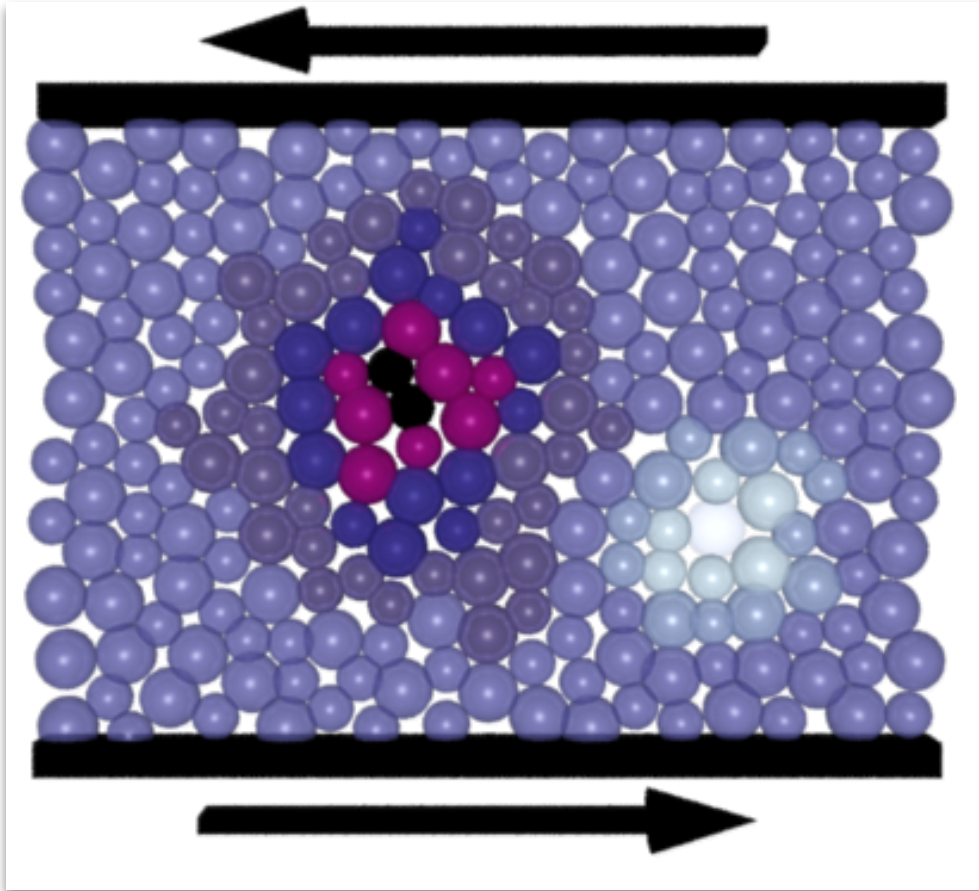
A very simple model: Rheology

In silico cell monolayer under shear



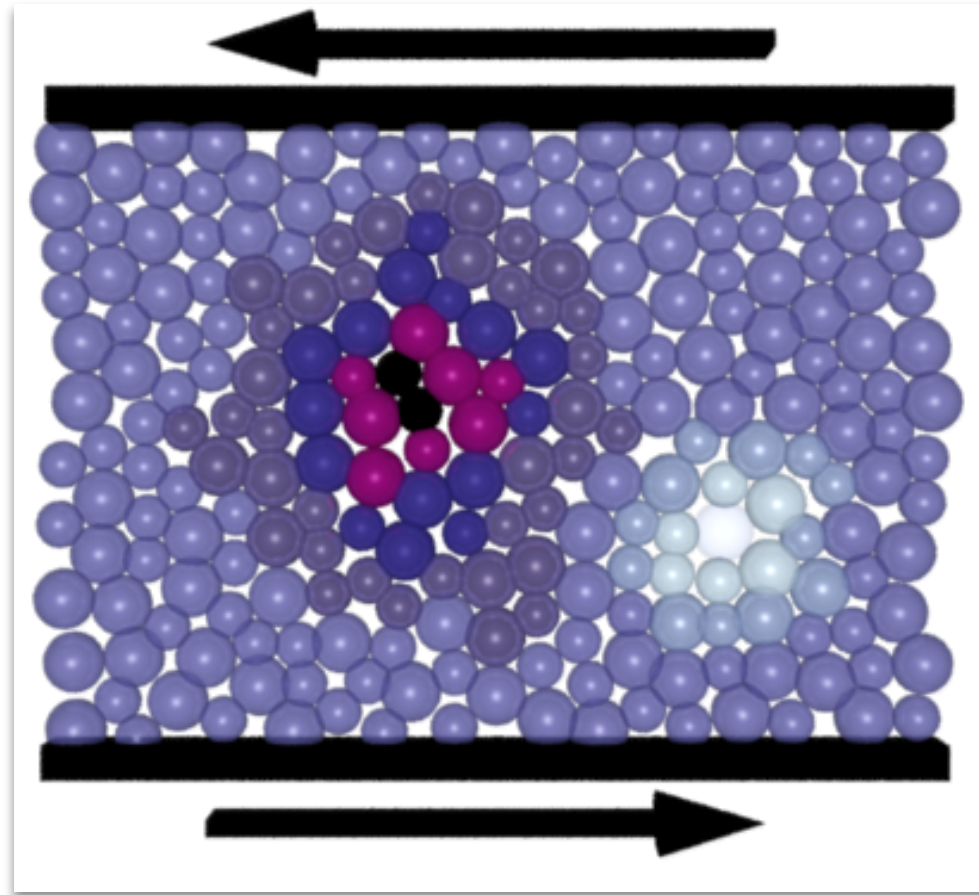
A very simple model: Rheology

In silico cell monolayer under shear



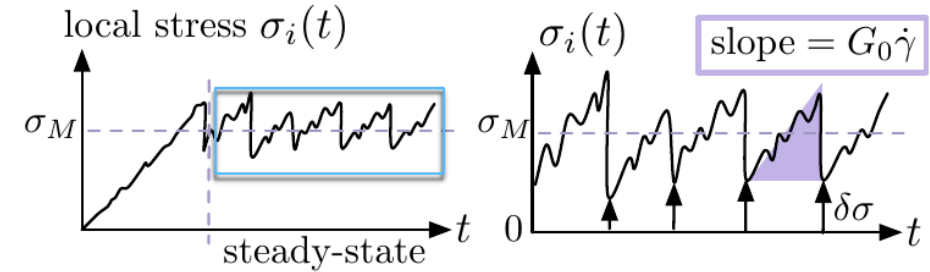
"Cell division makes the cell monolayer more fluid depending on the observation time scale"

How can we explain this phenomenon?



Mean-field models for active dynamics

$$\begin{cases} \partial_t \sigma(t) = G_0 \dot{\gamma} + \xi_{\text{mec}}(t) \\ \sigma > \sigma_c : \sigma \xrightarrow{1/\tau} 0 \quad \& \quad \rho(\sigma'_c) \end{cases}$$



VARIATION OF STRESS = ELASTIC SHEAR + **MECHANICAL NOISE**

MECHANICAL NOISE

PLASTIC NOISE

CELL ACTIVITY NOISE

$$\xi_{\text{mec}}(t) = \xi_{\text{pl}}(t) + \xi_{\text{act}}(t),$$

$$\langle \xi_{\text{mec}}(t) \rangle = 0$$

