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Physics of embryonic cavity formation by hydro-osmotic coarsening

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The blastocoel is a fluid-filled cavity characteristic of the blastula stage during embryonic development. Its formation is a keystone in the morphogenesis of the mammalian embryo, yet the physical mechanism for its emergence remains unclear.
We recently showed that the blastocoel results from micron-sized cavities, nucleating at the adhesive side of cells and coarsening in a process akin to Ostwald ripening [1].
We investigate theoretically and numerically the collective dynamics of a one-dimensional chain of micro-cavities as a minimal model for cavity formation, considering explicitly the osmotic effects. We include permeation of water and osmolytes through the cellular membrane that may screen exchanges between micro-cavities [2].
We show that the coarsening of the chain is reminiscent of dewetting films, with a dynamical scaling law for the number of micro-cavities [3]. This scaling law is controlled by a screening length associated with water permeation, while the influence of osmotic inhomogeneities remains limited.
Finally, we consider active osmolyte pumping, that can lead to a novel dynamical scaling law dominated by the coalescence of micro-cavities, and that may also direct the position of the final cavity and break the radial symmetry of the embryo.

References

[1] Dumortier et al., Science, 2019

[2] Le Verge–Serandour and Turlier, bioRxiv, 2021

[3] Gratton and Witelski, Physica D, 2009

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