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Confluent to Non-confluent Non-equilibrium Phase Transitions in Cell Colonies

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Eukaryotic cells are distinguished by a rigid nucleus, whose role in shaping the collective behavior of cell aggregates is often underestimated. However, growing experimental evidence links nuclear modifications to phenotypic transitions, such as the epithelial-to-mesenchymal transition [1,2].

To interpret these observations, we introduce a novel class of self-propelled Voronoi models, where the nucleus is represented as a short-range repulsive force, accounting for nuclear/cellular compressibility. We demonstrate that the interplay between short-range repulsion and vertex interactions, mimicking cell-cell adhesion and cytoskeletal organization, drives a range of non-equilibrium phase transitions. These include Motility-Induced Phase Separation, mesenchymal-like phases, and disordered confluent states. Notably, we find that tuning nuclear size and compressibility offers an additional mechanism for transitioning between these phases [3].

[1] Verdone et al. (2014) https://doi.org/10.1002/pros.22908

[2] Fu et al. (2021) https://doi.org/10.1063/5.0072126

[3] Miotto et al. (2024) https://doi.org/10.48550/arXiv.2411.08012