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Spatial moment description of birth-death-movement processes incorporating the effects of crowding and obstacles

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Birth-death-movement processes, modulated by interactions between individuals, are fundamental to many biological processes such as development, repair and disease. Similar interactions are also relevant in ecology. A key feature of the movement of cells within *in vivo* environments are the interactions between motile cells and stationary obstacles, such as the extracellular matrix and stationary macromolecules. Here we propose a multi-species individual-based model (IBM) of individual-level motility, proliferation and death. In particular, we focus on examining the case where we consider a population of motile, proliferative agents within an environment that is populated by stationary, non-proliferative obstacles. To provide a mathematical foundation for the analysis of the IBM, we derive a system of spatial moment equations that approximately governs the evolution of the density of agents and the density of pairs of agents. By using a spatial moment approach we avoid making the usual mean field assumption so that our IBM and continuous model are able to predict the formation of spatial structure, such as clustering and aggregation. We explore several properties of the obstacle field, such as systematically varying the obstacle density, obstacle size, and the nature and strength of the interactions between the motile, proliferative agents and the stationary, non-proliferative obstacles. Overall we find that the spatial moment model provides a reasonably accurate prediction of the dynamics of the system, including subtle but important effects, such as how varying the properties of the obstacles leads to different patterns of clustering and segregation in the population.

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