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Models of collective cell spreading with variable cell aspect ratio: A motivation for degenerate diffusion models

Continuum diffusion models are often used to represent the collective motion of cell populations. Most previous studies have simply used linear diffusion to represent collective cell spreading, while others found that degenerate nonlinear diffusion provides a better match to experimental cell density profiles. In the cell modeling literature there is no guidance available with regard to which approach is more appropriate for representing the spreading of cell populations. Furthermore, there is no knowledge of particular experimental measurements that can be made to distinguish between situations where these two models are appropriate. Here we provide a link between individual-based and continuum models using a multi-scale approach in which we analyze the collective motion of a population of interacting agents in a generalized lattice-based exclusion process. For round agents that occupy a single lattice site, we find that the relevant continuum description of the system is a linear diffusion equation, whereas for elongated rod-shaped agents that occupy L adjacent lattice sites we find that the relevant continuum description is connected to the porous media equation (pme). The exponent in the nonlinear diffusivity function is related to the aspect ratio of the agents. Our work provides a physical connection between modeling collective cell spreading and the use of either the linear diffusion equation or the pme to represent cell density profiles. Results suggest that when using continuum models to represent cell population spreading, we should take care to account for variations in the cell aspect ratio because different aspect ratios lead to different continuum models.