MAR05-2004-000520
Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Using many-body theory to understand chemotactic movement in cellular systems, with application to the chick embryo

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Inter-cellular communication is essential for coordinated cell movement and spatio-temporal differentiation. Examples are collective behavior of unicellular organisms (such as Dictyostelium aggregation) and formation of structures in multi-cellular organisms (e.g. gastrulation in early embryos). Cells communicate with one another via short-range contact interactions and long-range interactions mediated by chemical signaling fields. In the examples given above the number of cells varies between hundreds to tens of thousands, and the cell population may have strong phenotypic heterogeneity. It is therefore important to develop a model framework which retains discrete cell identity, and allows a flexible description of cell-cell interactions. We present one such framework here, inspired by the many-body formulation of interacting systems, and constructed using approximations which are biologically plausible. We describe a perturbative analysis of chemotactic aggregation, which illustrates the importance of statistical correlations between cells. We also discuss the implementation of this framework as an optimized numerical algorithm, and show some early results on primitive streak formation in the chick embryo.