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The role of motility and nutrients in bacterial competition and colony formation

Bacterial competition and colony formation are an important component in many practical applications such as plant roots colonization and medicine (especially in dental clinics). Motility is a pivotal bacterial trait for the successful colonization of plant roots. Bacterial motility has two types of mechanisms — directed movement (chemotaxis) and undirected movement. Motivated by a series of petri dish experiments, we study undirected bacterial movement which is rarely considered in literature. To study bacterial competition and colony formation in a petri dish, we modify and extend the model used in Wei et al.(2011) to obtain a group of more general and realistic PDE models. We explicitly consider the nutrients and incorporate two bacterial strains characterized by motility. We use different nutrient media such as agar and liquid in the theoretical framework to discuss the results of competition and colony formation. The consistency of our numerical simulations and experimental data illustrates the existence of undirected motility in bacteria. In agar, the motile strain has higher total density while in liquid, the immotile strain has a similar total density. When we place two drops of these bacterial strains around the middle of the petri dish, we find that 1) in agar, after half a day, the density of the motile strain is high on the boundary of the petri dish; in contrast the density of the immotile strain is high in the middle of the petri dish; 2) in liquid, bacterial motility is not that important because liquid nutrients move almost infinitely fast compared to bacterial movement. Furthermore, we find that in agar as bacterial motility increases, the extinction time of the motile bacteria decreases without competition but increases in competition. When the nutrient media varies from agar to liquid, the extinction time of the motile strain decreases while the extinction time of the immotile strain increases, and the total density ratio of motile to immotile decreases dramatically. In addition, we show the existence of traveling-wave solutions mathematically and numerically.