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Single Cell Biology

Opinion Article

Extension of Single Cell Evolved into Multicellular Cell

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DESCRIPTION

Multicellularity can be defined by mathematical models in terms of individual cell fitness vs. collective fitness, as well as the spatial and temporal organisation that results. The formation of early multicellular groups has been studied in the context of the evolution of cooperation. It was discovered that adhering groups of cooperating individuals evolve by incorporating game theoretical interactions and transient compartimentalisation or the possibility of differential assortment. Reproductive trade-offs, on the other hand, can lead to division of labour and the production of a higher level proto-organism capable of self-regeneration in a structured environment. However, little attention has been paid to the evolution of emergent functions as a result of adhesion-mediated self-organization. Simple considerations regarding the ecology of the unicellular ancestor and the fitness benefit that cells gain by living in groups can yield a variety of multicellular life-cycles. Once multicellular clusters have been established, the spatial organisation of their constituent cells can play a key role in determining group-level reproduction, potentially leading to the evolution of cell death or different cell shapes, as well as specific modes of aggregate fragmentation that boost overall population growth. Multicellularity is either assumed or predetermined in these models by social dynamics, directly boosting the fitness of cells in aggregates, or bad environmental conditions that necessitate substantial trade-offs. Here we examine the origin of this selection pressure, motivated by the idea that multicellular groups arise as a byproduct of cellular self-assembly and cell-environment interactions, and subsequently alter the evolution of the cells that make them up. We anticipate that selective aggregation pressures can arise from emergent multicellular group functions without requiring explicit selective advantages and disadvantages for cells in a group. Therefore, we present a computational model of an evolving cell population in which fitness is solely based on how well a cell responds to a spatially and temporally heterogeneous environment, regardless of whether they belong to an aggregate. In this study, we inspired by the collective movement of groups of cells such as the aggregate phase of the slime mold Dictyostelium Discoideum (DD), other simple multicellular organisms, and many processes within complex multicellular organisms, such as embryogenesis, tissue repair, and cancer. Previous models have shown how cellular collectives can integrate noisy information from the environment, for example when moving up a shallow gradient of chemoattractants. We use the Cellular Potts Model (CPM) to study collective cell movement as an emerging driver of multicellularity during evolution. The CPM formalism is a spatially extended mesoscopic description of cells that explicitly accounts for cell shape, size and allows easy implementation of various cellular processes in complex and potentially self-assembling environments. We include four key elements: Cells in a seasonally changing environment that regularly introduces new resources in different locations, they can perform chemotaxis by detecting a chemoattractant produced by these resources, they reproduce depending on their proximity to resources and they can develop their adhesion to other cells. Because the gradient generated by the resource is loud and flat, we found that single cells follow the chemotactic signal inefficiently. Instead, cells that adhere to each other within clusters transfer information across the gradient in a self-assembled manner, enabling efficient chemotaxis. We show that this emergent property of cell groups is sufficient for longer seasons to select for high levels of adhesion and multicellularity, although fitness is only defined at the cellular level.

CONCLUSION

The evolutionary transition of multicellular has occurred many times throughout life, but the evolutionary history of this transition is not well understood. However, volvocin green algae include a variety of unicellular, colonial, and multicellular species. Due to the large number of member's volvocin with different degrees of complexity, it is possible to study different stages leading up to multicellularity. Volvocin has also evolved recently (when the first dinosaurs emerged during the Triassic), and the multicellular mystery remains in the age of evolution.

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