Numerical Computation of Equilibria of Cell Population Models with Internal Cell Cycle

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Although a key mechanism in life, the cell cycle still has some mysteries. J.J. Tyson and B. Novák developed several widely used models for the cell cycle of budding yeast, fission yeast and other organisms. A striking feature in the behaviour of such models is the funnel effect, by which the internal structure of the cell in the later phases of its cycle (shortly before division) is nearly independent from its structure in the earlier phases of the cycle. This mathematical property of the models makes biological sense.

We study the behaviour of the cells at the population level by incorporating these models in structured cell population ODE models. We investigate how different division assumptions influence the behaviour of the population of cells and in particular how they affect the equilibrium states, i.e. constant distributions of the masses of cells born per unit of time.

Numerically, we obtain the equilibrium as the fixed point of a map, namely the output of a large collection of integrations over age for cells born with a given birth mass, followed by its implications for the consumption of nutrient. At least in some cases the orbit of the map converges to a stable fixed point. This equilibrium can be studied under parameter variation, for which natural parameters are the concentration of nutrient and the death rate of the cells. An important feature is that although the birth mass space is discretised in every step of the map, this discretisation is not fixed and is adapted according to which cells are born during the age integrations.

We will discuss the results we obtained so far, starting with a model with a fairly simple choice for the cell cycle mechanism that is based on the Toy Model of Tyson and Novák, present the fixed point and its dependence on different division assumptions and parameter values for both the nutrient level and the used discretisation.