

Spatial competition in growing populations with selective pressure

In addition to selective pressure, genetic drift is now widely accepted to be a major evolutionary force. The term summarizes the effective stochasticity from chance effects in reproduction events, and can have significant impact in small populations or at the growth front of growing populations. This was studied under controlled experimental conditions for fluorescently labeled microbial organisms including *E. coli* and yeast, and various results are reported in [1]. Under rich growth conditions the only limiting factor is available space, and a coarsening process driven by genetic drift gives rise to segregation patterns of different strains, starting with well mixed initial conditions. The neutral case, where all strains have equal fitness and only genetic drift is present, has been understood in detail in recent theoretical work [1-3], where [2] studies the influence of reproduction time statistics and [3] the dependence on different geometries.

The aim of this project is understand the non-neutral case and the interaction between selective pressure and genetic drift in spatially extended populations. In this situation one strain is fitter than the others, resulting in a higher growth rate. Preliminary results in [1] provide a starting point, but make unrealistic assumptions about the fluctuations of sector boundaries, and the predictions do not quite match the experimental findings. Based on simple mass balance arguments, an improved effective law for the sector boundaries can be derived in a simple linear geometry, which will be tested against computer simulations. In a second step, we try to generalize to a circular expanding geometry with the help of results in [3].

Details.

Adnan Ali is currently doing a PhD studying the neutral model, and has developed an advanced code in C which simulates the population growth without an underlying lattice structure. This code can be modified rather directly to study the non-neutral case with assistance of Adnan. Alternatively, a lattice based code can be developed from scratch, which is significantly simpler than the continuous case.

After some introductory reading centered around [1-3], we will derive a theoretical prediction for the law of sector boundaries which is based on very simple arguments and rather straightforward. The main part of the work will be to verify this by simulation results. The generalization to circular expanding geometries is mathematically a bit more challenging, but is clearly within the scope of this project.

Collaboration, prospect for PhD project.

There are several directions in which this project can be extended for PhD. Following on from the work of Adnan Ali, an interesting question is to further study the role of realistic reproduction time distributions in the non-neutral case, which can lead to interesting effects.

An extension in a more theoretical direction could build on a successful EM MSc project from last year by Claudia Cioli on a simplified, lattice-based growth model with a single boundary between two species. This model can be mapped on a well-studied particle system in non-equilibrium statistical mechanics, the totally asymmetric simple exclusion process (TASEP). The location of a special particle in that process marks the position of the species boundary, also called competition interface. It can be studied by rigorous analytic methods (see [4]), and the non-neutral case would lead to an interesting extension.

References.

- [1] O. Hallatschek, D.R. Nelson, *Life at the front of an expanding population*. *Evolution* **64**(1), 193206 (2009), arXiv:0810.0053
- [2] A. Ali, E. Somfai, S. Grosskinsky, *Reproduction time statistics and segregation patterns in growing populations*. arXiv:1111.2992
- [3] A. Ali, S. Grosskinsky, *Pattern formation through genetic drift at expanding population fronts*. *Adv. Compl. Sys.* **13**(3), 349-366 (2010), arXiv:0912.2241
- [4] P.A. Ferrari, J.B. Martin, L.P.R. Pimentel, *Roughening and inclination of competition interfaces*. *Phys. Rev. E* **73**, 031602 (2006), arXiv:math/0412198

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