Growth and adaptation to an uncertain environment

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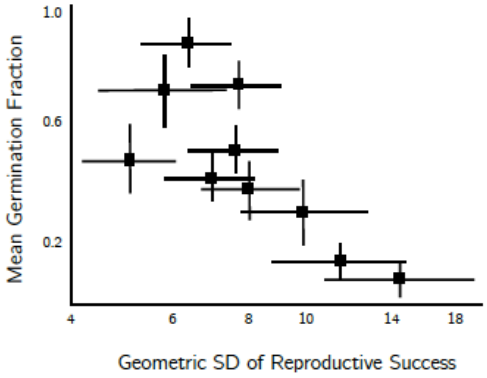

Figure. Left: a species of wildflower of the southwestern United States believed to implement a bet-hedging strategy. Right: An inverse relationship between the germination fraction and the standard deviation in reproductive success in deserts. From D. Venable, Ecology (2007)

Résumé

In recent work of the group, we have studied evolutionary strategies used by biological or ecological populations to cope with uncertain environments by drawing analogies with a model of gambling known as Kellys's model.

In this model, a gambler strives to maximize his/her capital growth by placing appropriate bets. The strategy of maximizing the long term growth rate of the capital is optimal but risky in practice. Recently, we have revisited this model by including a penalization due to the risk, measured in practice by the fluctuations of the growth rate, and we have studied the corresponding trade-off between growth and risk [1]. We found the same trade-off to be also relevant for a biological population in a fluctuating environment with individuals stochastically switching between two phenotypes [2].

In biology, individuals take decisions (for seeds this can mean whether to germinate or not as illustrated in figure) in order to adapt to a possibly harmful environment. Individuals also often sense their environment and use that information to survive or grow in a process called adaptive sensing. In a simple illustration of that idea, the learning process can be modeled using Bayesian inference [3].

The goal of this internship/thesis is to further extend these ideas using methods from Non-equilibrium Statistical Physics. We ask what are the fundamental limits of adaptation or sensing from the point of view of thermodynamics and information theory ? Under what conditions do these strategies emerge ? How general is the trade-off between growth and risk mentioned above ?

The work will be mainly fundamental and theoretical but we also plan to model an experiment carried out by colleagues in a nearby institute, in which colonies of yeast cells growing in a reactor are exposed to a fluctuating environment.

[1] Phase transitions in optimal betting strategies, L. Dinis, J. Unterberger and D. L., Eur. Phys. Lett., 131, 60005 (2020).

[2] Pareto-optimal trade-off for phenotypic switching of populations,L. Dinis, J. Unterberger and D. L., J. Stat. Mech. (2022) 053503.

[3] Adaptive strategies in Kelly's horse race model, A. Despons, L. Peliti, and D. L., J. Stat. Mech. (2022) 093405.

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