

# Do gene waves exist in excitable biosystems?

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## ABSTRACT

We consider a community of highly interactive organisms and suppose that a novel gene is introduced into this community. Will this gene spread through the community and if so how quickly? In addition, how does this gene affect the stability of the system? Such questions are critically important for developing effective biological control strategies. Early work has suggested that advantageous genes can propagate like waves in excitable media [1,2,3,4]. Such excitable systems yield interesting spatiotemporal dynamics that are interpretable in terms of the individual's biological fitness and the competitive interactions between genes.

In this poster we examine the relevance of gene waves to biological systems subject to genetic manipulation. These gene wave problems can be analyzed within an excitable media framework, which is dependent on the properties of the gene, the species and the surrounding environment. The interaction between these three properties yields a multitude of complex behavior that can be analyzed using existing tools that have been developed for excitable media.

In particular, the initial amount and distribution of the carriers of a gene impact on the ability of the gene to propagate through a population. This gene propagation can be understood using concepts of threshold phenomena, free energy functionals, and critical nuclei, which have previously been developed in phase transition theory [5]. These physical ideas allow the probability of gene propagation through a population as a function of the initial gene carrier distribution and the advantageous attributes of the gene to be determined, and yield valuable insight into the gene propagation problem.

This threshold problem is important for release maximization problems, where complete genetic substitution is required in a minimal period of time. Conversely, threshold estimation is fundamental for estimating the risk of gene release into the environment. However, biological systems are typically non-homogeneous, anisotropic, and seasonal as well as exhibiting a wide range of dispersive transport processes such as non-localized dispersion. Such considerations introduce subtle changes in the gene propagation dynamics and the gene propagation thresholds. Gene propagation in these more realistic biological environments is of major interest, and it is crucial to understand the relationship between the dispersive transport mode and the gene threshold characteristics.

In this poster we specifically characterize the shape and speed of gene propagation fronts in one and two-dimensional spatial systems of gene carriers in various metastable environments. The shape and structure of the critical gene carrier nuclei or aggregations are also determined, and the intrinsic link with the gene carrier extinction probability is developed. We also demonstrate the applicability of these critical aggregation problems to gene propagation in unstable environments using the concept of practical stability. The dimensionality of the system is shown to have subtle effects on the gene propagation kinetics and the stability of the critical aggregations, and this effect is important in certain anisotropic environments. Also of interest is the relaxation time for waveform propagation to emerge from an initially localized gene carrier distribution. This relaxation time is important for the genetic substitution and control problems. We also show that the spherical traveling wave solutions of gene carrier frequency in isotropic media exhibit minimal energy dissipation and are therefore global attractors of gene invasion. In addition we show that this attraction property is intrinsic to systems displaying more general dispersion transport processes and stochasticity.

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