Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **3296** Type: **Oral Competition (Graduate Student) / Compétition orale (Étudiant(e) du 2e ou 3e cycle)**

(G*) The roles of secondary metabolite production in sustaining microbial diversity

Wednesday 8 June 2022 14:15 (15 minutes)

High diversity at steady state is theoretically difficult to be attained in well-mixed systems, in which there are only a small number of growth-limiting factors. Broadly speaking, it is related to degrees of freedom present in the system. To account for the rich diversity observed in nature, various mechanisms such as fluctuation and spatial heterogeneity have been proposed. A typical way that has been suggested to resolve this conundrum is to hypothesize the environment being modified by the production of an equally rich variety of secondary metabolites that are all growth-limiting. While this has been suggested by experiments to be a major mechanism in sustaining the coexistence of a small handful of strains in small systems, whether this explanation of diversity can be extended to very large systems with hundreds to thousands of species remains to be seen. Equally perplexing is the idea that secondary metabolites strengthen the coupling between species; In principle this should drive down diversity unless nontrivial structure is present in the community. It is therefore likely that increasing the number of growth-limiting factors is only one of several roles that secondary metabolite plays; Diversity is maintained by the combined effect of these roles. Here, I use a mechanistic model of resource competition involving chemostats, which is a continuous culture device that controls bacterial growth rate at steady state in a well-mixed environment, with one externally supplied resource and only one single secondary metabolite. In particular, I focus on how cross-feeding and toxin production, in conjunction with metabolic constraints, modify the environment as well as the effective interspecific couplings to support the coexistence of a large number of species. Naturally arise from the model are the concept of keystone species, in the absence of which will lead to collapse of the entire community, and the stabilizing effect through changing the environment to bring the system to coexistence. Transitions from coexistence at steady state to persistence with oscillatory trajectories is also studied, and that changes in topologies of interaction networks are predictive of these transitions. And finally, I illustrate the low-dimensional description of these large systems, which sheds light on how diversity is maintained by the structures of microbial communities.

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Session Classification: W2-3 Biophysics Outside the Box (DPMB) | Biophysique hors de la boîte (DPMB)

Track Classification: Technical Sessions / Sessions techniques: Physics in Medicine and Biology / Physique en médecine et en biologie (DPMB-DPMB)