LMS/LadHyX Seminar

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Mechanical adaptation and morphogenesis of fire ant swarms: From simple interactions to emerging complexity

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ABSTRACT

A majority of soft materials such as adhesives, entangled biopolymers, but also most living matter owe their complex mechanical behavior to an underlying network structure. Despite this inherent complexity, the physical structure of these materials can often be conceptualized as dynamic physical networks, where nodes and connections are governed by simple rules. An advantage of such a network representation resides in its well-defined mathematical structure, enabling the use of the powerful machinery of statistical mechanics. This statistical approach, or transient network theory (TNT), provides a bridge to connect (simple) "network rules" to emerging (complex) "continuum response". In dynamic polymer networks, topological bond rearrangement combined with chain elasticity is sufficient to explain the emerging elasticity, rheology, and time-dependent fracture of the material. Applying this approach to living materials is tempting but is challenging because of the diversity of mechanisms involved (cell signaling, reaction, diffusion, growth, ...) and issues with direct observations and measurements. This presentation will discuss our recent work on a biological yet simplified mechanical network (the raft) that solenopsis invicta (better known as fire ants) make with their own body to escape flooding. Like cellular systems, these networks are highly dynamic and active. As such, they are not only capable of adapting their viscoelastic response to load to avoid premature failure, but also display collective morphogenesis with the stochastic emergence of long protrusions from the raft's edge. Employing experimental characterization and our dynamic network model, we unveil a set of local rules that reproduces the emergence of these instabilities in the absence of external factors. Results suggest that collective morphogenesis in fire ant swarms emerge from a reduced set of rules at the network level. To conclude, we discuss the potential of the concept of dynamics network to better understanding active and living materials, and discuss potential applications to the development of decentralized, autonomous active matter and synthetic swarms.

BIOGRAPHY

Franck Vernerey is a professor in the Department of Mechanical Engineering at the University of Colorado, Boulder and currently an invited faculty at Ecole Polytechnique (LMS). He received his Ph.D. from Northwestern University in 2006 in the field of theoretical and applied mechanics. His interests are in developing statistical mechanics approaches to understand the emerging response of network- like materials in biology and their synthetic analog. These networks span several orders of magnitude, from the molecular scale (polymers) to the micron scale (cell networks) and the macroscale (insect aggregations and entangled filaments). Although theoretical, this research has applications in the mechanical characterization of living materials, the computational design of biopolymers for regenerative medicine as well as the development of bio- inspired functional soft materials. Dr. Vernerey is the author of more than 100 scientific publications in peer- reviewed journals and book chapters. He is also the recipient of the NSF career award in 2014 and the Presidential Early Career Award for Scientists and Engineers (PECASE) in 2017.