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Percolation in Excitable Media: Insights into Signal Propagation in Heart-like Systems

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Understanding how electrical signals propagate through biological tissues is central to the study of physiological function and pathological breakdown. In this work, we explore a model system inspired by cardiac tissue, using tools from percolation theory and statistical physics to investigate the emergence and failure of global signal propagation. Our model captures the interplay between structural connectivity and dynamic excitability, revealing critical thresholds beyond which the system loses its capacity to sustain coordinated activity.

We simulate a two-dimensional excitable medium, mimicking heart-like networks, where local inhomogeneities and quenched disorder lead to complex propagation patterns. Through percolation analysis, we identify how microscopic disruptions—whether due to blocked pathways or inactive nodes—can lead to macroscopic breakdowns in signal transmission. The results offer insight into phenomena such as conduction block and fibrillation, which are of clinical relevance.

While rooted in theoretical physics, our study bridges concepts between statistical mechanics and biological dynamics, emphasizing how simple models can offer deep understanding of complex physiological systems. This framework, although classical, lays the groundwork for further integration with data-driven or AI-enhanced models in biological tissue analysis.

Authors: MOLLA, Md Aquib (Vidyasagar College); Dr GOSWAMI, Sanchari (Vidyasagar College)

Presenter: MOLLA, Md Aquib (Vidyasagar College)