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Pairwise Network Models in Epidemiology: A Review of Approximations, Dynamics, and Applications

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In this review, we provide a comprehensive analysis of pairwise network models in epidemiological modeling, focusing on their ability to capture local interaction dynamics and network heterogeneity. We examine key approximation techniques, including moment closures for homogeneous and heterogeneous degree networks, and discuss their role in deriving epidemic thresholds, basic reproduction numbers R_0, and final outbreak sizes. Special emphasis is placed on clustering effects, rewiring mechanisms, and the interaction between network structure among homogeneous species and disease spread. The review highlights advances in pairwise models for SIS, SIR, and SEIR dynamics, comparing analytical results with stochastic simulations on complex network topologies such as Poisson, exponential, scale-free networks, etc. Finally, we identify emerging directions, such as two-community network models in zoonotic ecology, multi-pathogen interactions, and higher-order clustered networks such as 4-node square clusters and their impact on two-community models, offering insights for future research in network science and epidemiology.

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