Regimes and mechanisms of inflammation described by reaction-diffusion systems

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Inflammation is a physiological process aimed at protecting the organism from various external stimuli. It plays an important role in numerous diseases including cancer and cardiovascular diseases like atherosclerosis. Although each type of inflammatory disease has its own characteristic stimuli, the inflammatory response mechanism is generic.
In this work, we propose mathematical models of inflammation based on reaction–diffusion equations describing the spatiotemporal dynamics of healthy cells, inflamed cells, immune cells, and pro- and anti-inflammatory mediators. The models capture the main phases of the inflammatory process, initiation, progression, and resolution, using systems of reaction–diffusion and integro-differential equations, with and without time delay.
Our analysis shows that inflammation can propagate within tissue as a reaction–diffusion wave, and we characterize its propagation speed using both analytical and numerical approaches. Numerical simulations, performed using an implicit finite difference scheme, are used to investigate how anti-inflammatory mechanisms influence the global dynamics of the system and the resolution of inflammation. Finally, a sensitivity analysis of model parameters reveals biological phenomena and highlights conditions leading to either sustained or resolving inflammation.

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