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Multi-scale mathematical models of disease

Multi-scale mathematical and computational modeling has emerged as a key technology in many areas of engineering, manufacturing, and business. It also holds great promise for biomedicine, with a wide range of potential applications. For instance, well-validated mathematical models could help limit the use of animal experiments for drug discovery or develop better-optimized treatment protocols for patients. Unique challenges arise in this context, however, such as the existence of feedback loops between scales, e.g., the bidirectional interplay between processes at the organism and intracellular levels, or the lack of knowledge about physical or biochemical principles underlying disease mechanisms. In particular, this raises challenging mathematical problems, such as analysis and validation of the dynamics of complex hybrid models. It also complicates the application of optimal control techniques, which is of particular importance, since most problems in biomedicine ultimately are about control. These issues will be illustrated through two ongoing case studies, metabolic drivers of tumor growth and the immune response to respiratory fungal infections.