Mathematics of infectious diseases

supervised by

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Infectious diseases have affected the humankind on many different ways either by diseases spreading within livestock (bovine tuberculosis), from animal hosts to humans (malaria), ingestion of contaminated food or water (typhoid fever), or by direct human to human interactions (influenza). The foundations of the state-of-the-art mathematical epidemiology of infectious diseases, employing the idea of population compartmentalisation, were laid in the seminal work of Kermack and McKenderick, [1]. The idea of partitioning a population according to disease progression has been used extensively in modelling the time-evolution, and in understanding and forecasting, and then controlling and preventing the spread of communicable diseases both in deterministic and non-deterministic settings [2].

The project will employ a deterministic modelling approach and use state-of-the-art mathematical tools to obtain information, in terms of system parameters about the characteristics of the modelled disease, such as the basic reproduction number, $\mathcal{R}_0$, conditions on multiple outbreaks, the final size of epidemic, etc. In addition, similarly to [3, 4], by fitting models to empirical data and performing numerical simulations, the project will obtain estimates of the system parameters to assign meaningful numerical values to epidemiological properties of the disease in question. The derived information will be used in investigating the impact of the flux of travel and the spatial heterogeneity on the spread of infection when spatially distant but connected communities are considered, and the effects of pathogen variants and different vaccination strategies.

The student should have some understanding of differential equations and some knowledge of scientific programming languages (e.g., Matlab, Python, R).

References

[1] W. O. Kermack and A. G. McKendrick. A contribution to the mathematical theory of epidemics. *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character*, 115(772):700–721, 1927.

[2] M. Martcheva. *An introduction to mathematical epidemiology*, volume 61. Springer, 2015.

[3] G. Kiss, D. Corken, R. Hall, A. Ibrahim, S. Moutari, F. Kee, G. Armstrong, D. Bradley, M. Middleton, L. Patterson, and others, "Mathematical Modelling of Gonorrhoea Spread in Northern Ireland between 2012 and 2022," *Acta Microbiologica Hellenica*, vol. 69, no. 2, pp. 114–141, 2024.

[4] G. Kiss, S. Moutari, C. McTaggart, L. Patterson, F. Kee, and F. Lamrock, "Deterministic modelling of asymptomatic spread and disease stage progression in vaccine preventable infectious diseases," *Quantitative Biology*, Wiley Online Library, 2024.