The impact of network properties and mixing on control measures and disease-induced herd immunity in epidemic models: a mean-field model perspective

https://link.springer.com/article/10.1007/s11538-021-00947-8

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1st of November 2021

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Background

- In the simplest disease transmission model, pre-emptive vaccination of a $\left(1 - \frac{1}{R_0}\right)$ fraction of the population (**herd immunity threshold**) prevents an epidemic.

- However, if the epidemic is not controlled the final epidemic size will be much larger – the so-called '**overshoot**'.

- Implementing lockdown will result in an epidemic with a smaller R_0, however, we ask, what will happen when lifting the lockdown?

- We are interested in the existence of a '**sweet spot**' such that lifting the lockdown will not lead to a new epidemic – in other words, how many people need to become infected in the first wave in order to prevent a second wave?

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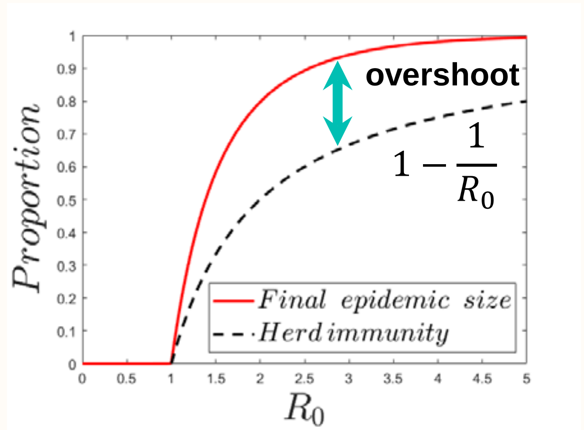
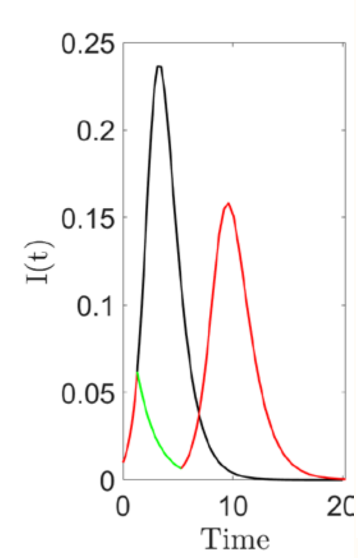
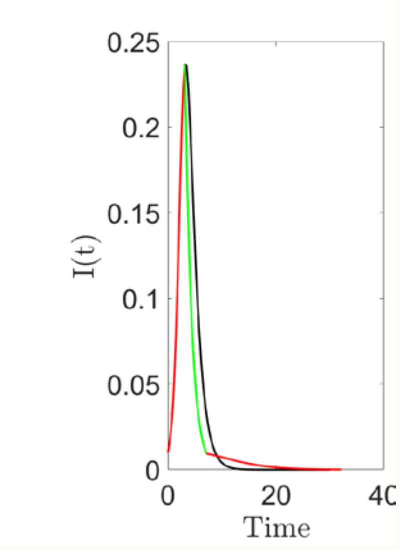


Herd immunity not achieved

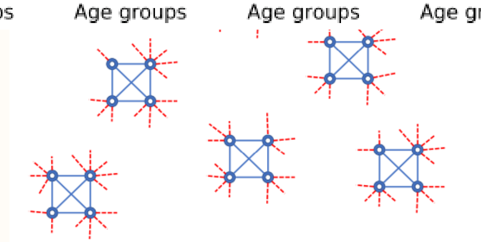


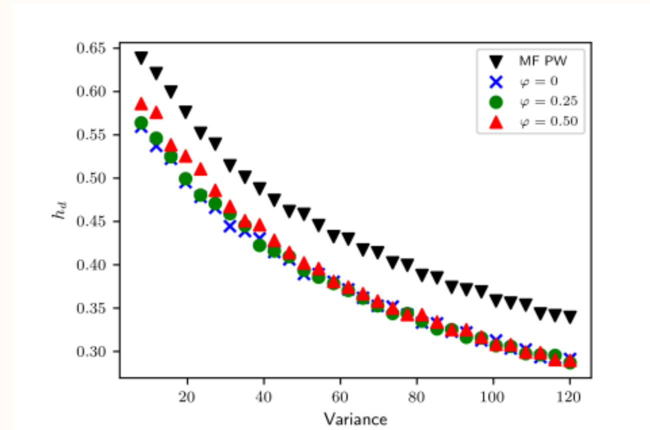


Herd immunity achieved

Herd immunity: some key observations

- In the presence of contact heterogeneity, a smaller but more targeted vaccination programme can stop an epidemic.
- When an epidemic spreads it typically finds the most vulnerable and the most highly connected individuals.
- If infection confers immunity, it means that as infection spreads it effectively `vaccinates' people.
- Lockdown can be implemented by:
  - Keeping contact structure and reducing rate
  - Changing contact structure and/or rates – **more likely in reality!**





- We can act on household/local and global contacts differently.
- Global contacts are likely to reduce and thus highly-connected nodes get 'hidden' and cannot be take out by first wave.
- Upon lifting lockdown then become re-activated and can generate a second wave.
- **Blanket lockdown strategies are unlikely to be successful and instead must consider contact heterogeneities – modelling and evaluating of selective interventions remain open questions.**

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