Critical weaknesses in shielding strategies for COVID-19

University of Bath
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Outline

Background

The model

Results

Conclusions

Background

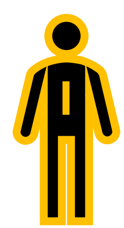
UNIVERSITY OF BATH

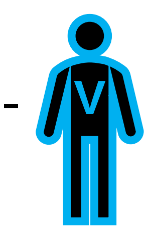
How does an epidemic die out?

"When a sufficiently large fraction of people are immune to an infectious disease – a fraction above the herd immunity threshold – the entire population can be protected from an epidemic. In principle, herd immunity could be established naturally by infection or artificially by vaccination."

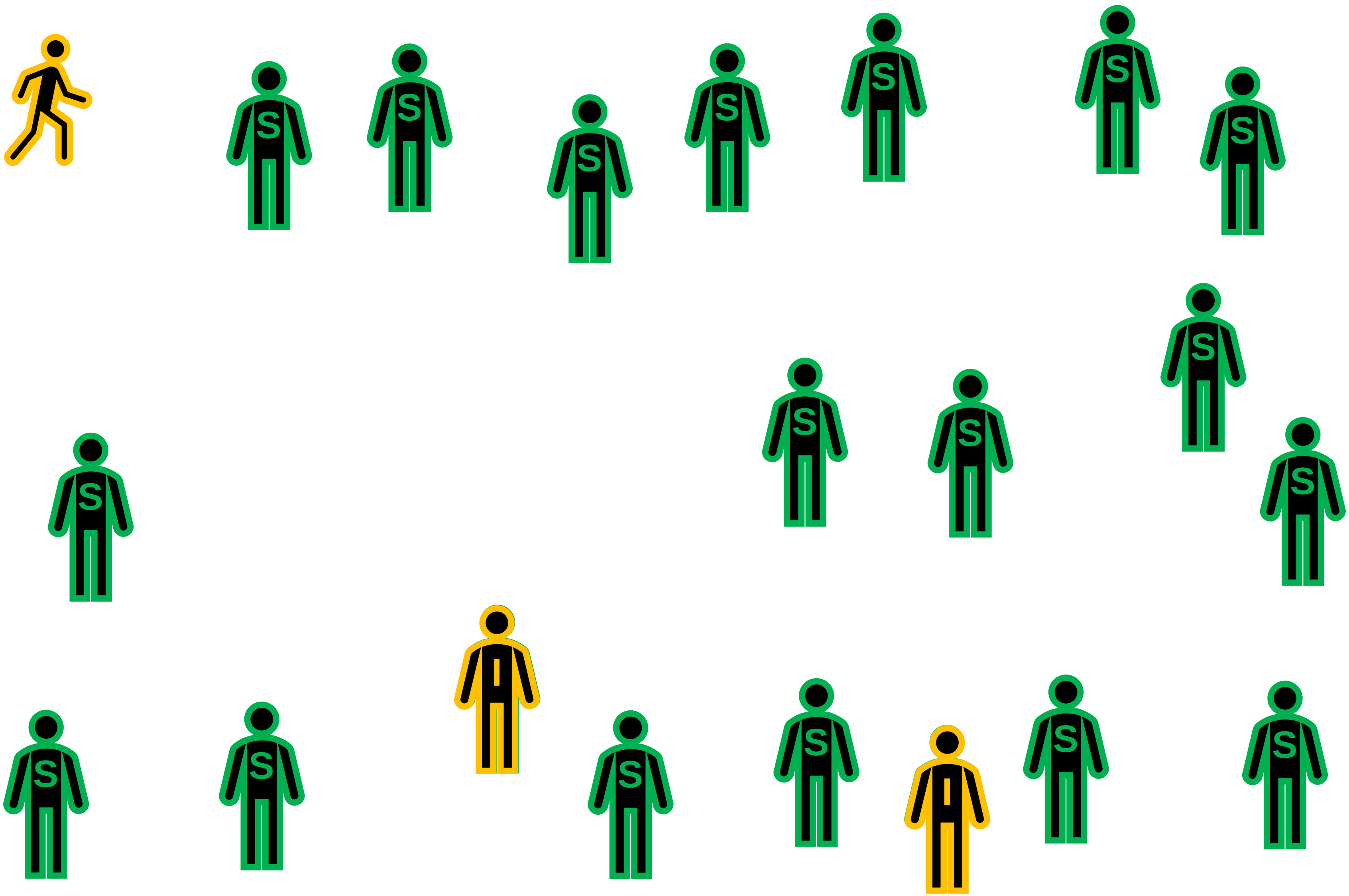
From: "Herd immunity in the epidemiology and control of COVID-19"
https://royalsociety.org/-/media/policy/projects/set-c/set-c-herd-immunity.pdf

Susceptible -


Infected -


Vaccinated -


Basic reproduction number – R_0



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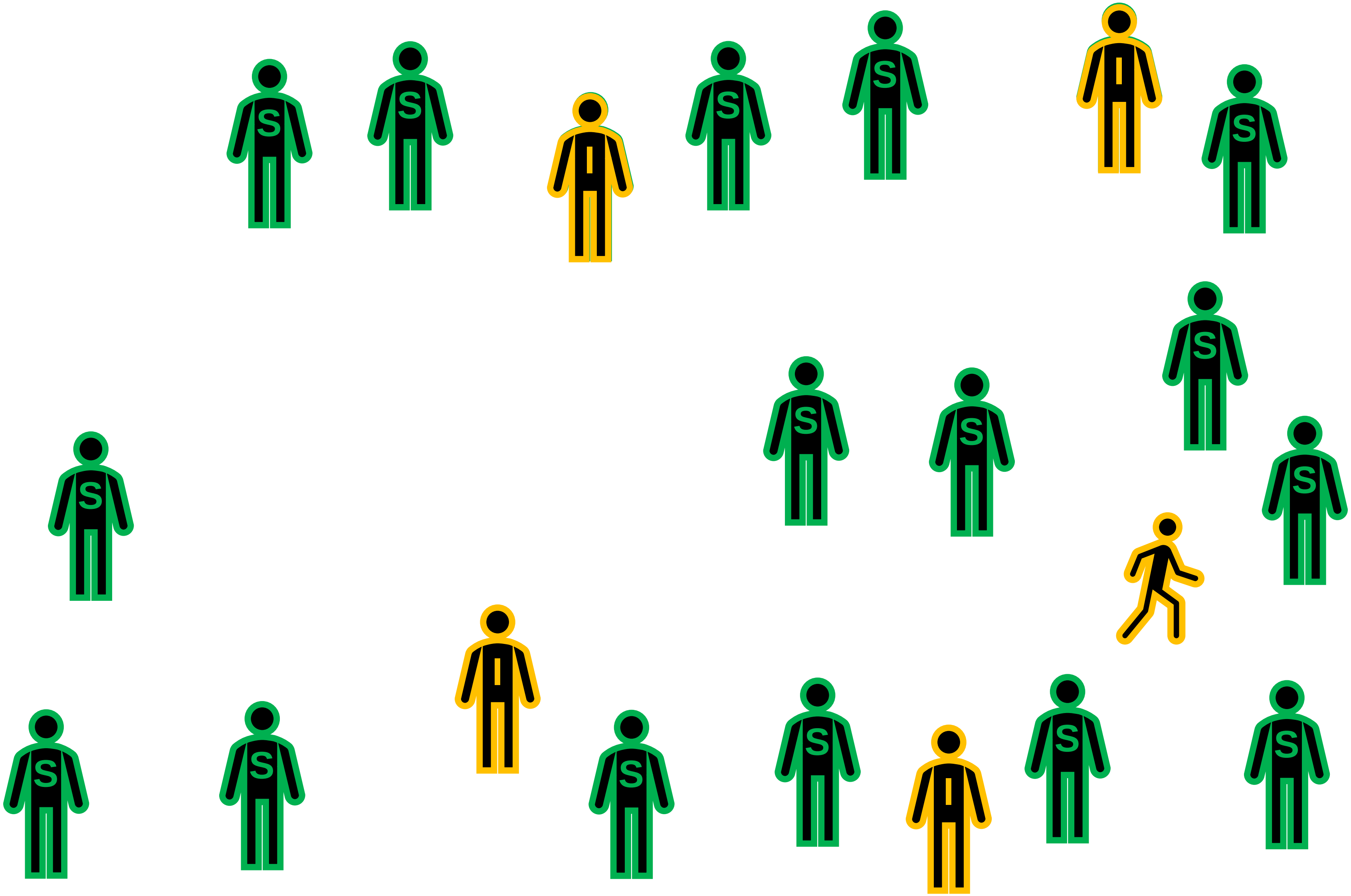

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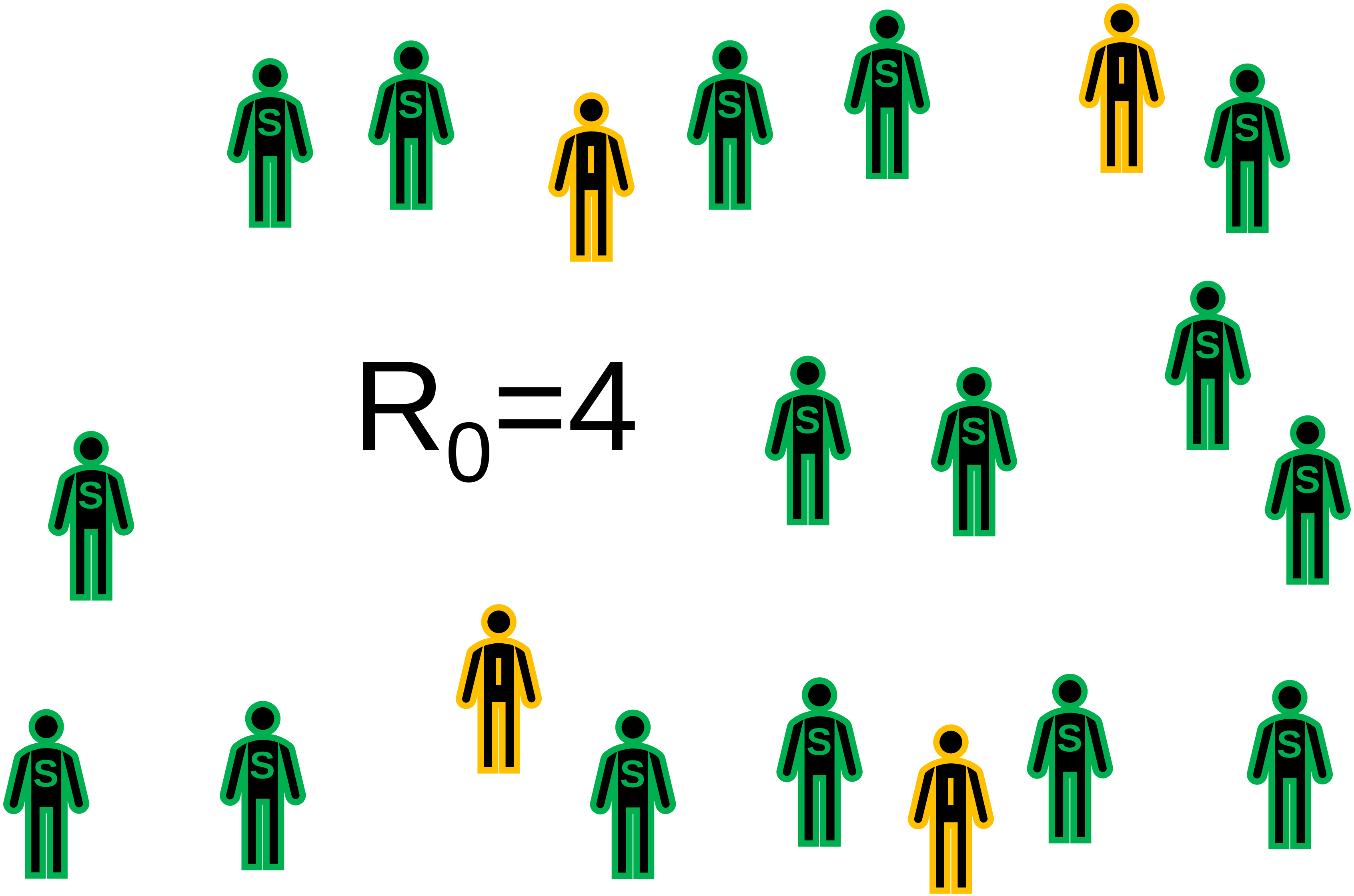
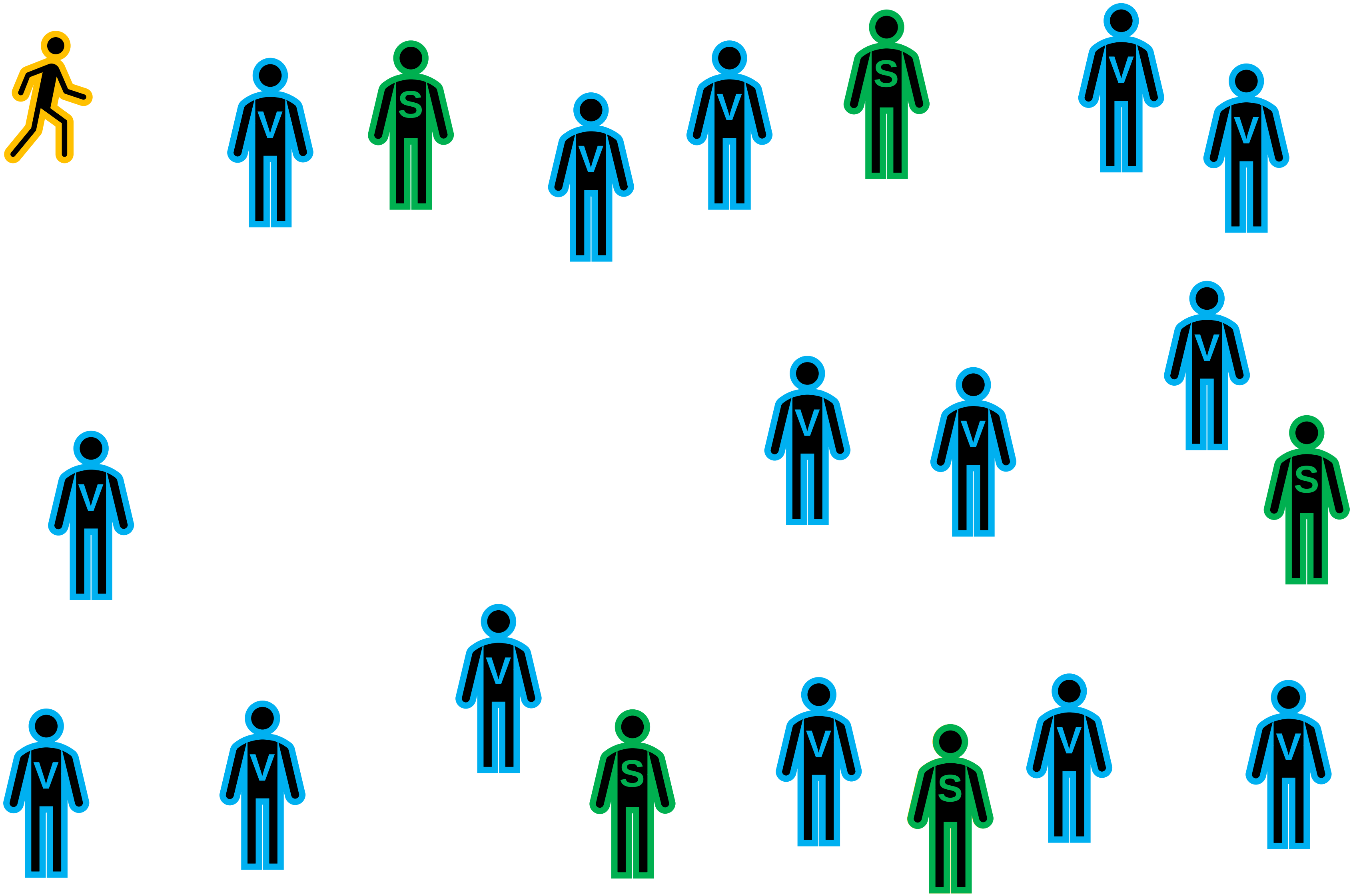


$$R_0=4$$

Herd immunity threshold



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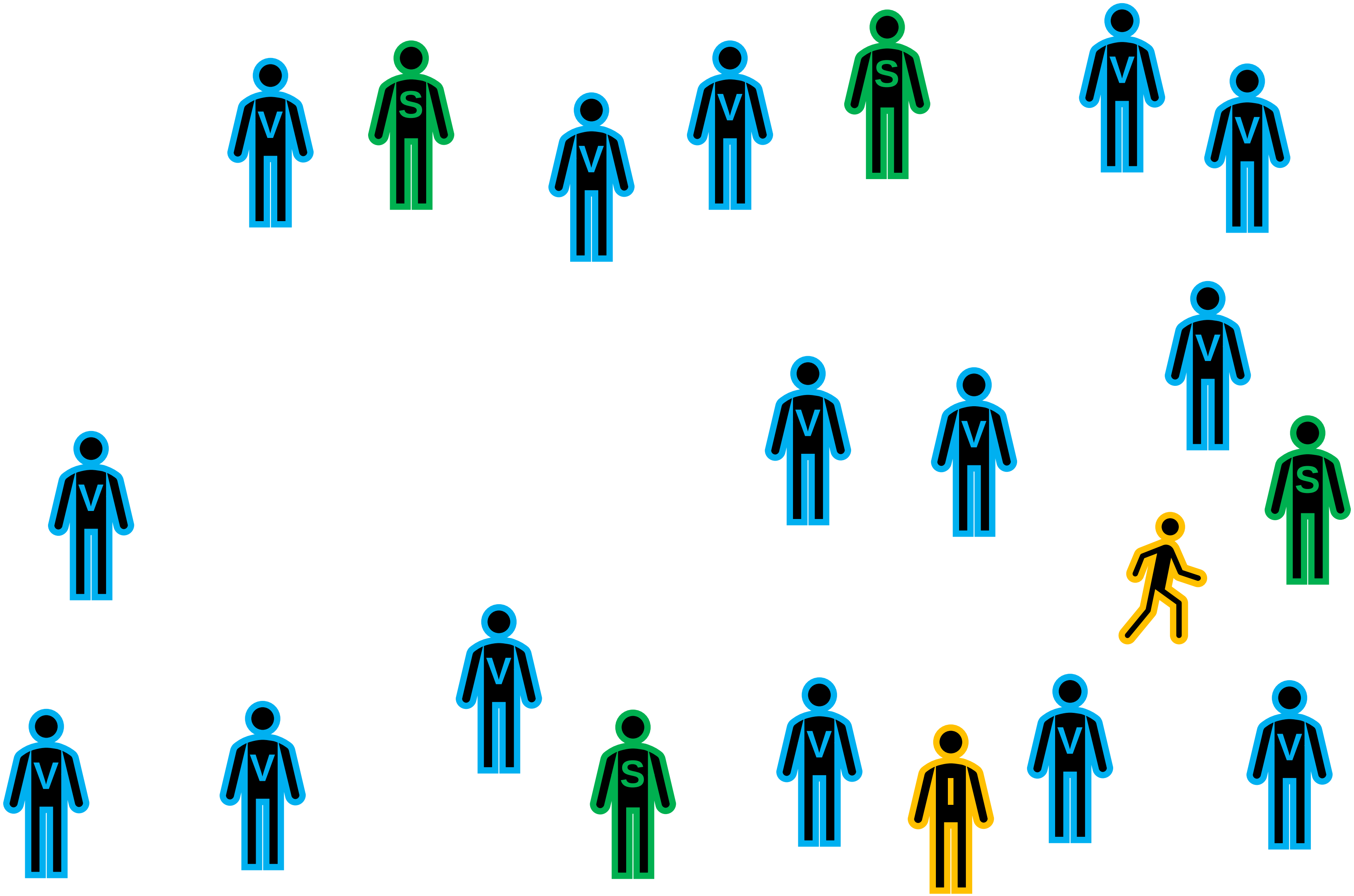
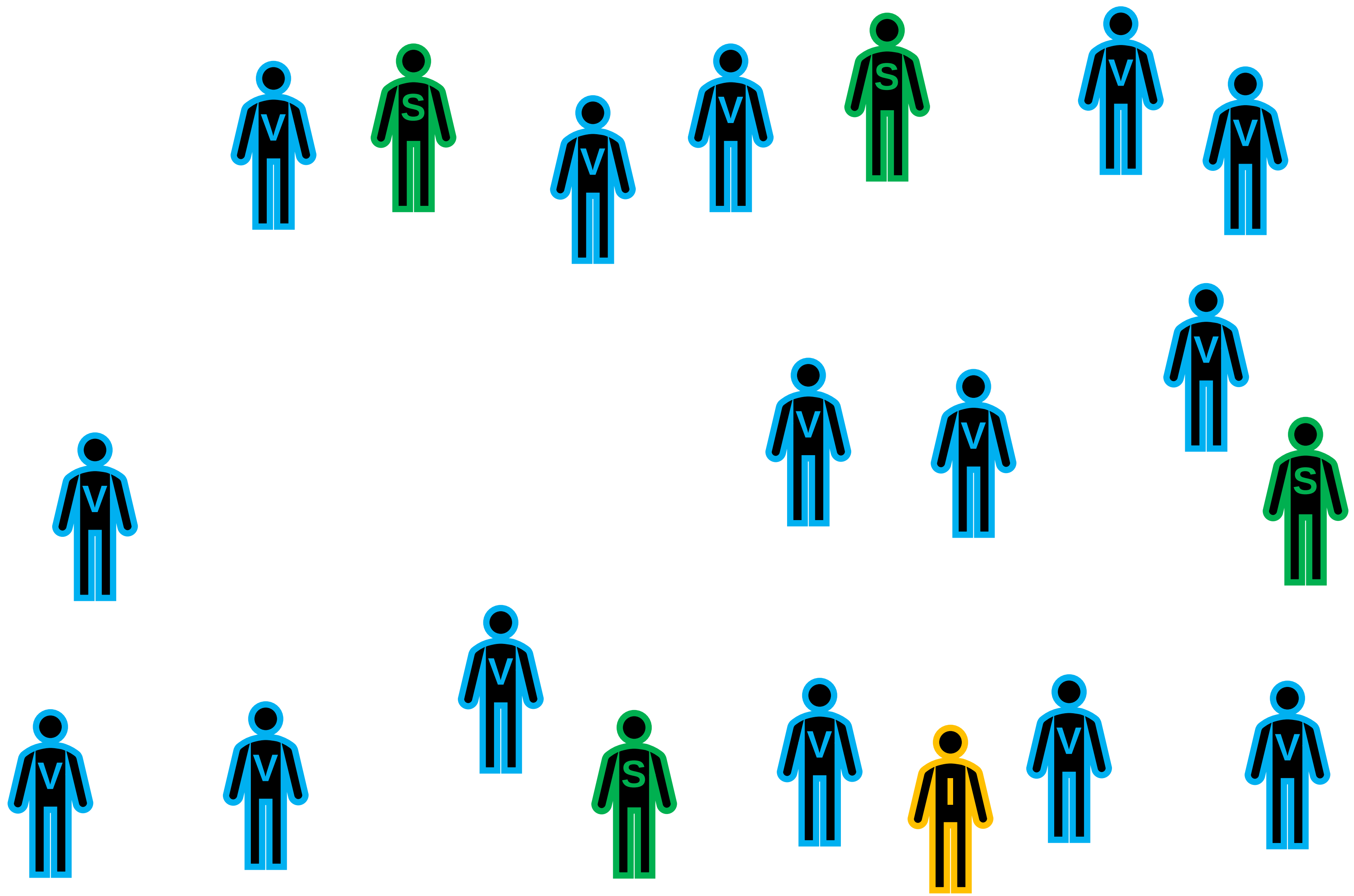


Herd immunity threshold



Herd immunity through natural infection…

“Our aim is to try to reduce the peak, broaden the peak, not suppress it completely; also, because the vast majority of people get a mild illness, to build up some kind of herd immunity so more people are immune to this disease and we reduce the transmission, at the same time we protect those who are most vulnerable to it.”

Patrick Vallance (13th March, 2020)

… is a bad idea

“But herd immunity acquired by natural infection has several disadvantages as a means of COVID-19 control”

(1) The build-up of herd immunity would be associated with a high burden of illness and death;
(2) While infection is spreading through a population, it is not yet clear that the most vulnerable can be protected from severe and fatal COVID-19; and
(3) It may not be possible to achieve herd immunity by natural infection if protection against reinfection is partial and transient.

The preferred route to herd immunity is not through natural infection but by vaccination.”

From: “Herd immunity in the epidemiology and control of COVID-19” https://royalsociety.org/-/media/policy/projects/set-c/set-c-herd-immunity.pdf

The idea persists

Coronavirus: can herd immunity really protect us?

March 13, 2020 2.12pm GMT

Coronavirus: could it be burning out after 20% of a population is infected?

June 29, 2020 1.59pm BST

Herd immunity call backed by British academics

Coronavirus latest: How Sweden could achieve 'herd immunity' by next month

Martin Kulldorff and Jay Bhattacharya

Lockdown isn't working

2 November 2020, 2:00pm

NEWS FEATURE · 21 OCTOBER 2020

The false promise of herd immunity for COVID-19

Why proposals to largely let the virus run its course – embraced by Donald Trump's administration and others – could bring "untold death and suffering".

Herd immunity is within reach. So why won't ministers talk about it?

NEWS

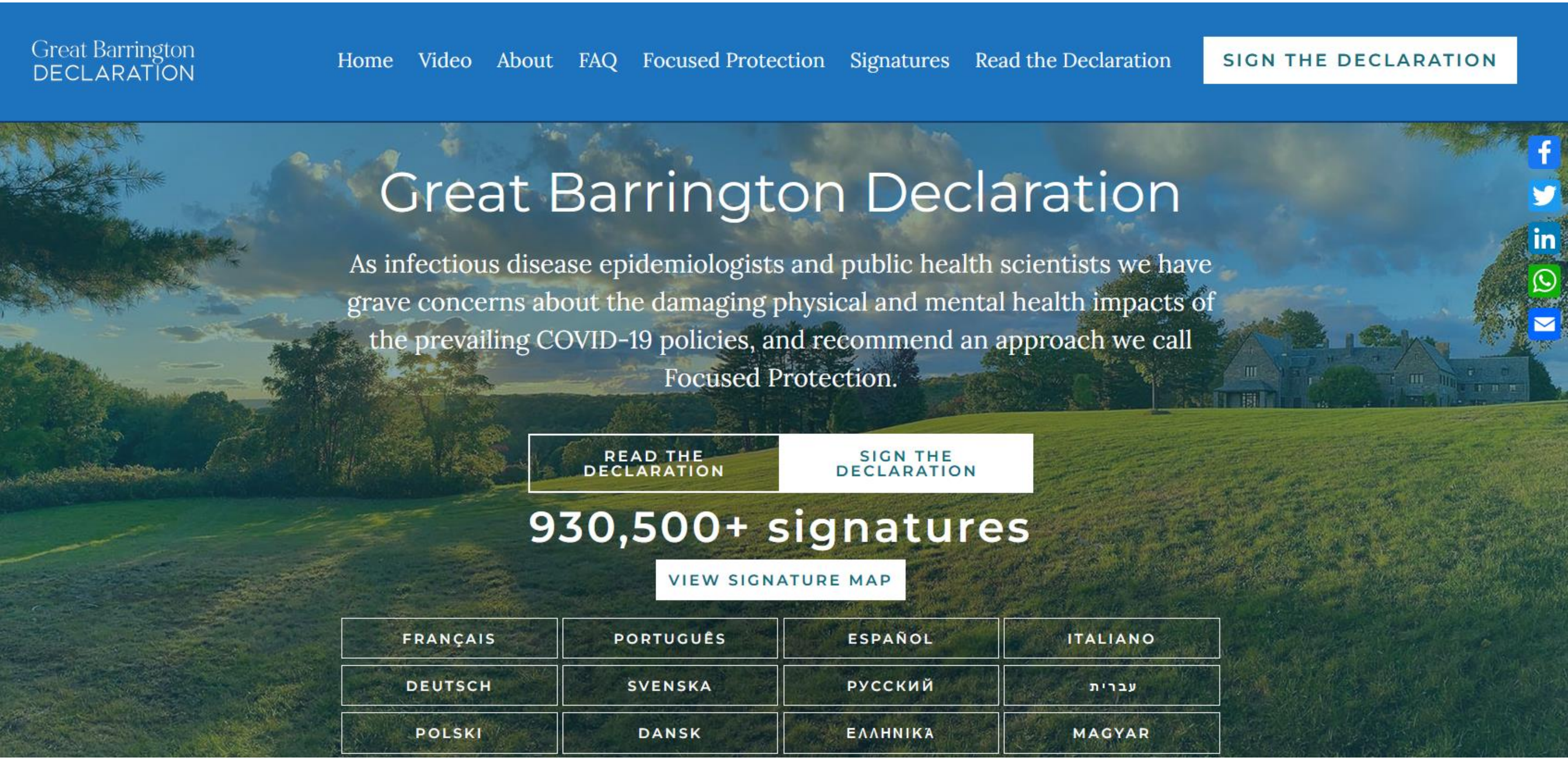
Covid-19: Experts debate merits of lockdowns versus "focused protection"

Coronavirus breakthrough: London has achieved 'herd immunity', claims former Pfizer chief

Britain will pass threshold for Covid herd immunity on MONDAY when more than 74 per cent of people will have protection against the virus, scientists say

Herd immunity and shielding: should we let Covid spread through the young?

The Great Barrington Declaration



The Great Barrington Declaration

The Great Barrington Declaration

As infectious disease epidemiologists and public health scientists we have grave concerns about the damaging physical, and mental health impacts of the prevailing COVID-19 policies and recommend an approach we call Focused Protection.

Coming from both the left and right, and around the world, we have devoted our careers to protecting people. Current lockdown policies are producing devastating effects on short and long-term public health. The results (to name a few) include lower childhood vaccination rates, worsening cardiovascular disease outcomes, fewer cancer screenings and deteriorating mental health - leading to greater excess mortality in years to come, with the working class and younger members of society carrying the heaviest burden. Keeping students out of school is a grave injustice.

Keeping these measures in place until a vaccine is available will cause irreparable damage, with the underprivileged disproportionately harmed.

Fortunately, our understanding of the virus is growing. We know that vulnerability to death from COVID-19 is more than a thousand-fold higher in the old and infirm than the young. Indeed, for children, COVID-19 is less dangerous than many other harms, including influenza.

As immunity builds in the population, the risk of infection to all - including the vulnerable - falls. We know that all populations will eventually reach herd immunity – i.e. the point at which the rate of new infections is stable – and that this can be assisted by (but is not dependent upon) a vaccine. Our goal should therefore be to minimize mortality and social harm until we reach herd immunity.

The most compassionate approach that balances the risks and benefits of reaching herd immunity, is to allow those who are at minimal risk of death to live their lives normally to build up immunity to the virus through natural infection, while better protecting those who are at highest risk. We call this Focused Protection.

Adopting measures to protect the vulnerable should be the central aim of public health responses to COVID-19. By way of example, nursing homes should use staff with acquired immunity and perform frequent PCR testing of other staff and all visitors. Staff rotation should be minimized. Retired people living at home should have groceries and other essentials delivered to their home. When possible, they should meet family members outside rather than inside. A comprehensive and detailed list of measures, including approaches to multi-generational households, can be implemented, and is well within the scope and capability of public health professionals.

Those who are not vulnerable should immediately be allowed to resume life as normal. Simple hygiene measures, such as hand washing and staying home when sick should be practiced by everyone to reduce the herd immunity threshold. Schools and universities should be open for in-person teaching. Extracurricular activities, such as sports, should be resumed. Young low-risk adults should work normally, rather than from home. Restaurants and other businesses should open. Arts, music, sport and other cultural activities should resume. People who are more at risk may participate if they wish, while society as a whole enjoys the protection conferred upon the vulnerable by those who have built up herd immunity.

On October 4, 2020, this declaration was authored and signed in Great Barrington, United States, by:

Dr. Jay Bhattacharya, professor at Stanford University Medical School, a physician, epidemiologist, health economist, and public health policy expert focusing on infectious diseases and vulnerable populations.

Dr. Sunetra Gupta, professor at Oxford University, an epidemiologist with expertise in immunology, vaccine development, and mathematical modeling of infectious diseases.

Dr. Martin Kulldorff, professor of medicine at Harvard University, a biostatistician, and epidemiologist with expertise in detecting and monitoring of infectious disease outbreaks and vaccine safety evaluations.

The Great Barrington Declaration

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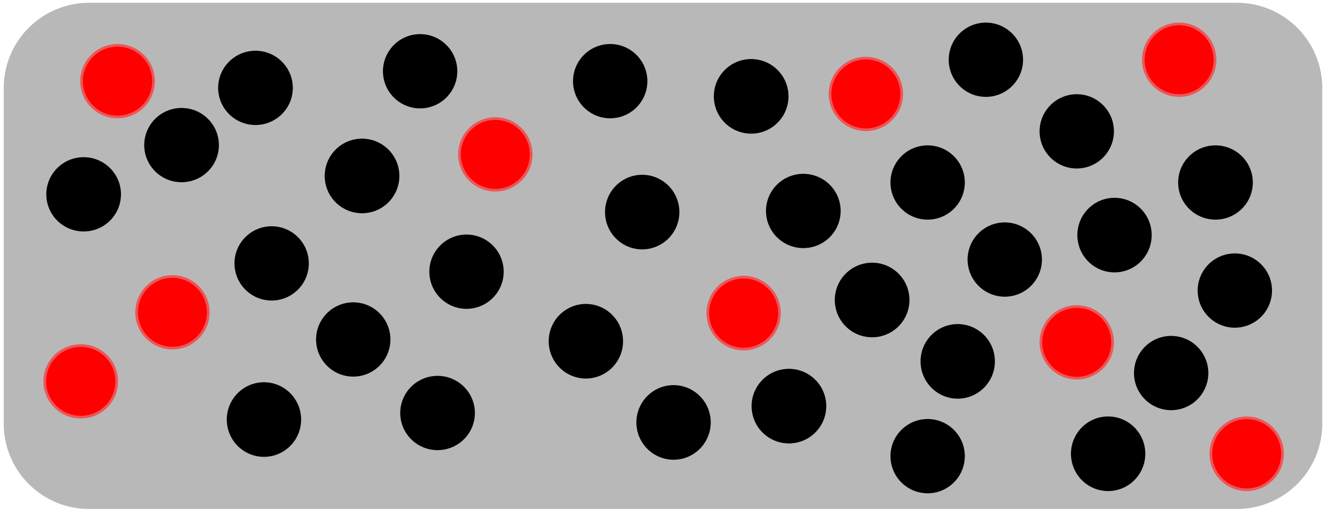
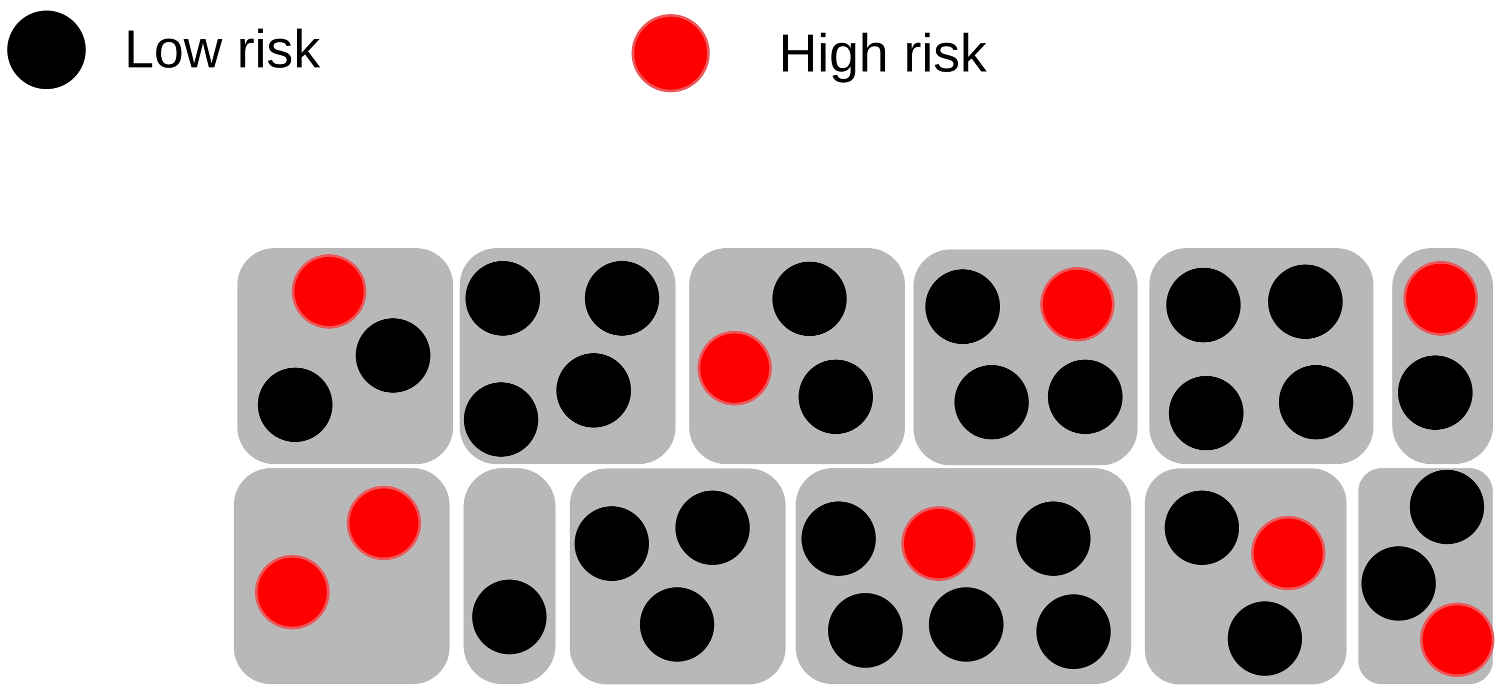
No mitigations

Low risk

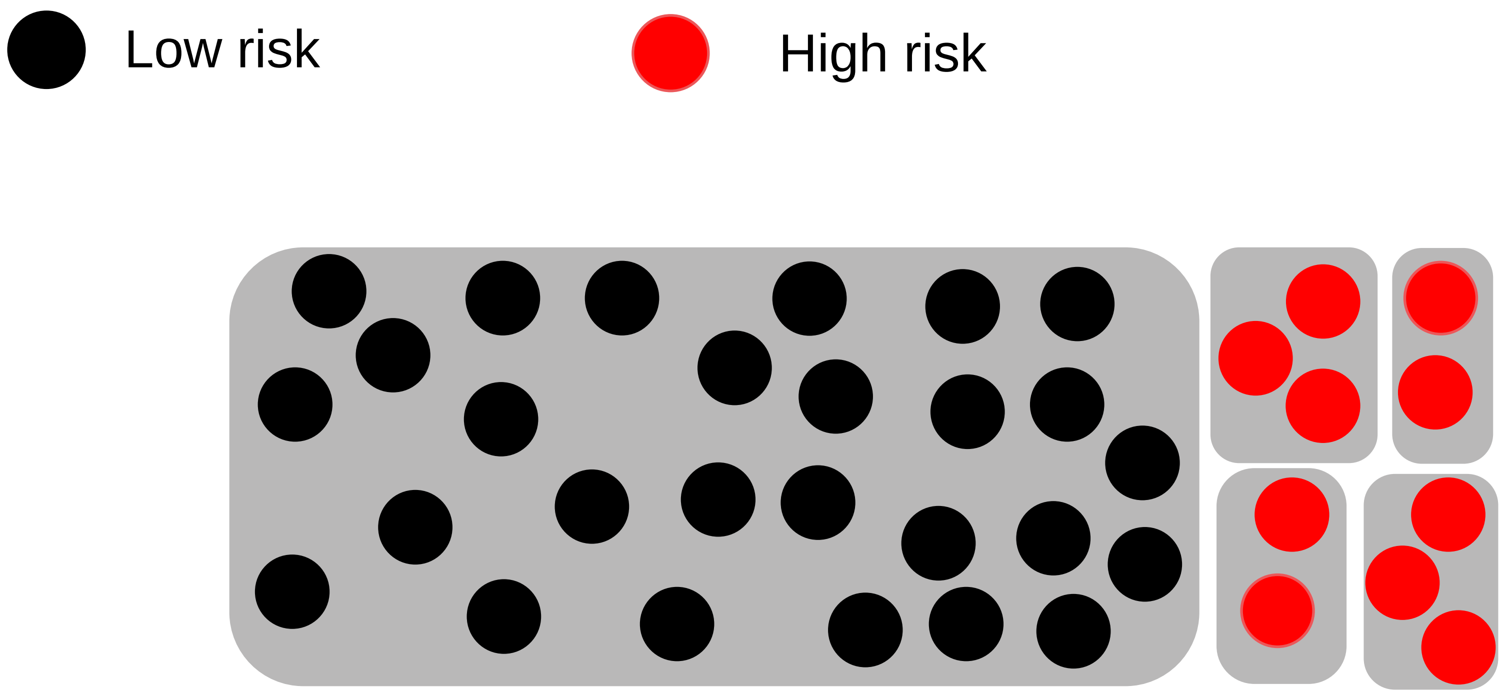
High risk



Lockdown



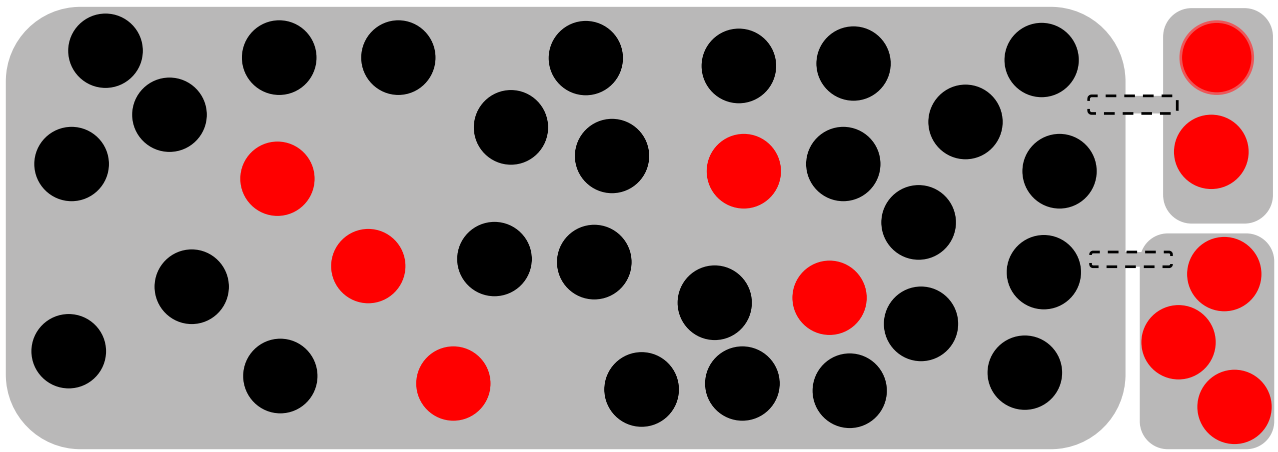
Focussed protection - theory



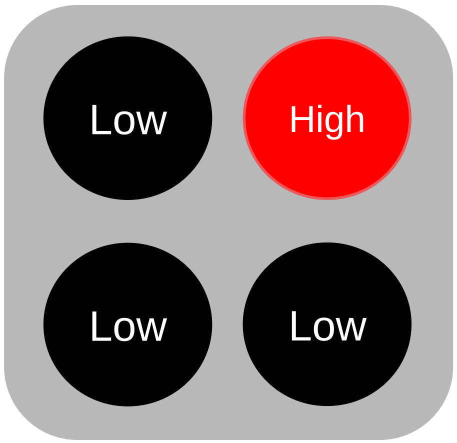
Focussed protection - practice

Low risk

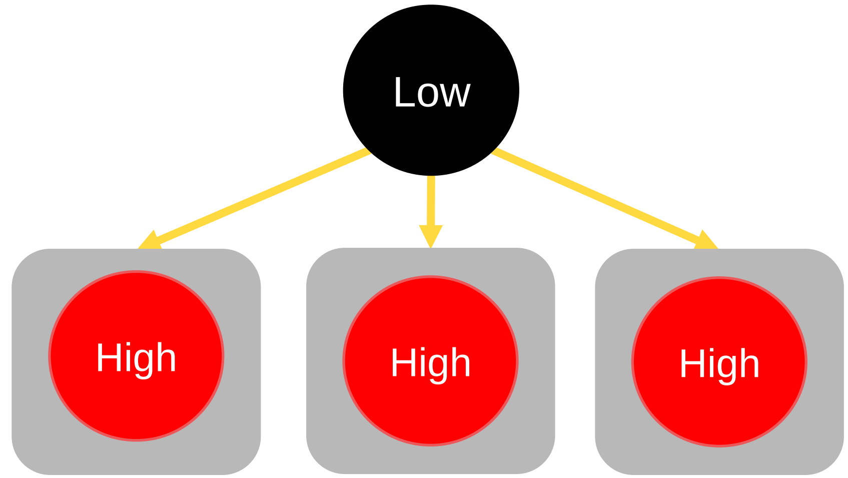
High risk



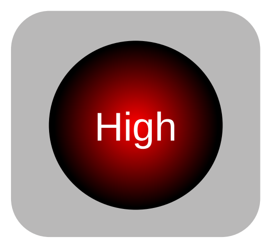
Imperfect shielding



Multi-risk households

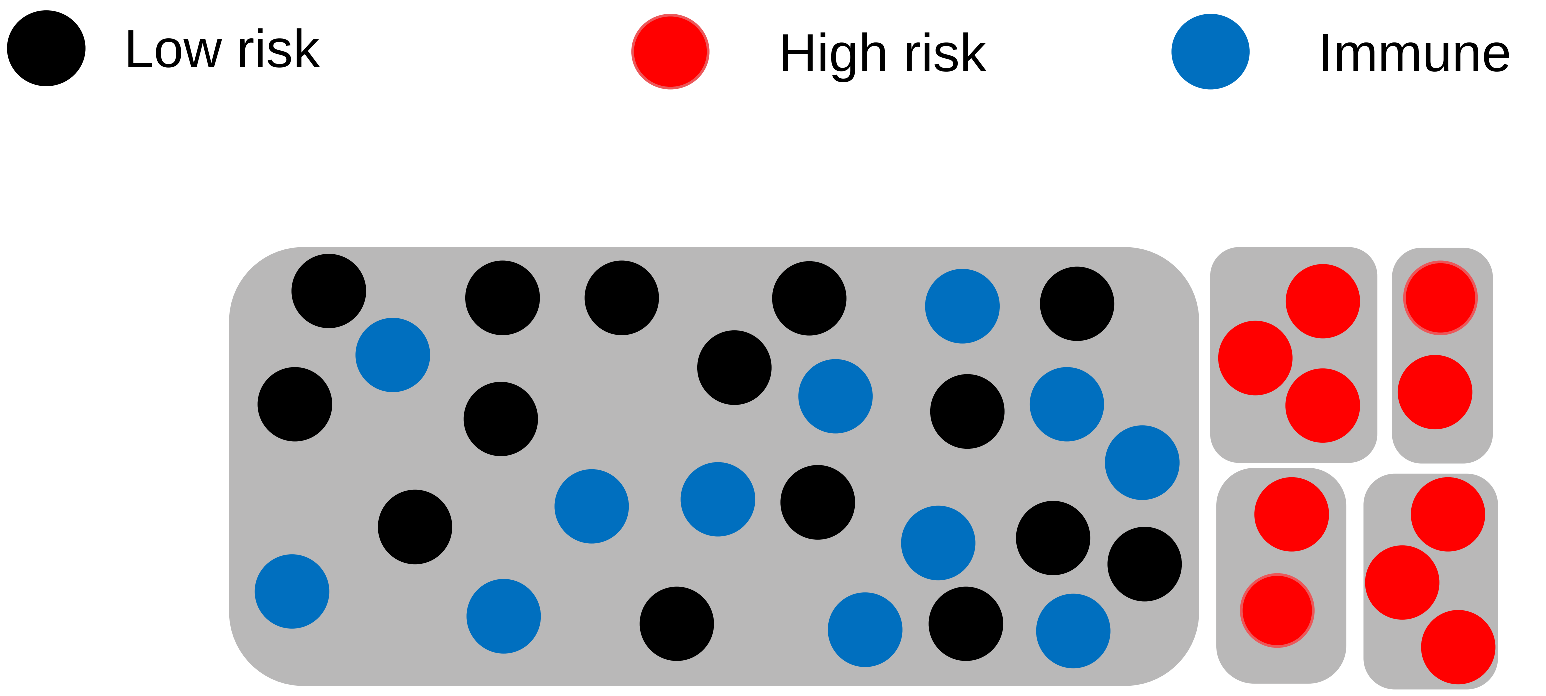


Residential care



Misdiagnosed or undiagnosed risk

Uneven distribution of immunity



Potential weaknesses with shielding strategies

- Inability to effectively shield higher-risk individuals (imperfect shielding)
- Uneven distribution of immunity
- People may voluntarily change their behaviour (reduced contact)
- Inability to identify many people at higher-risk (or to self-identify risk)
- If shielding fails then it may be difficult to bring cases under control
- Unnecessary mortality and morbidity (such as Long covid)
- Potential for overwhelming healthcare capacity
- Unknown duration or efficacy of naturally acquired immunity
- Increased mutation supply, potentially leading to new variants (which evade immunity)
- Ethical implications for the prolonged isolation of higher-risk individuals with reduced access to health and social care

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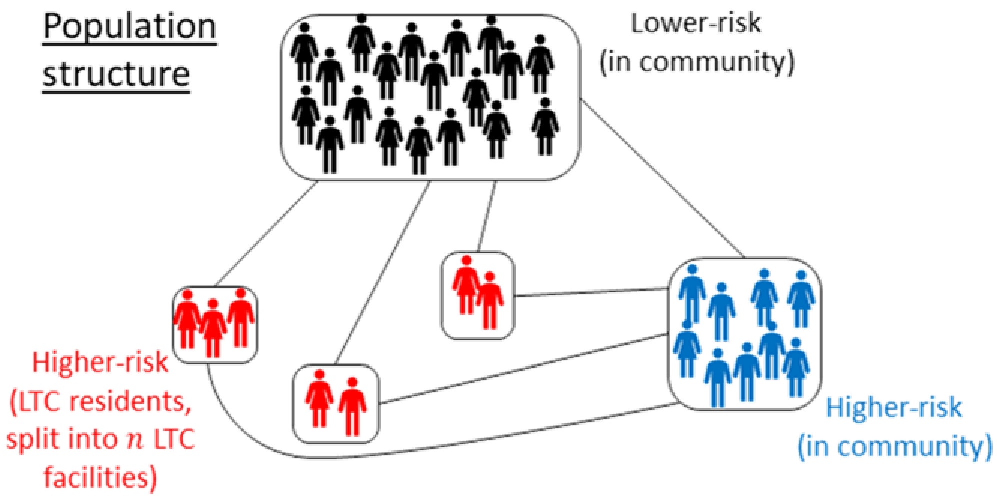
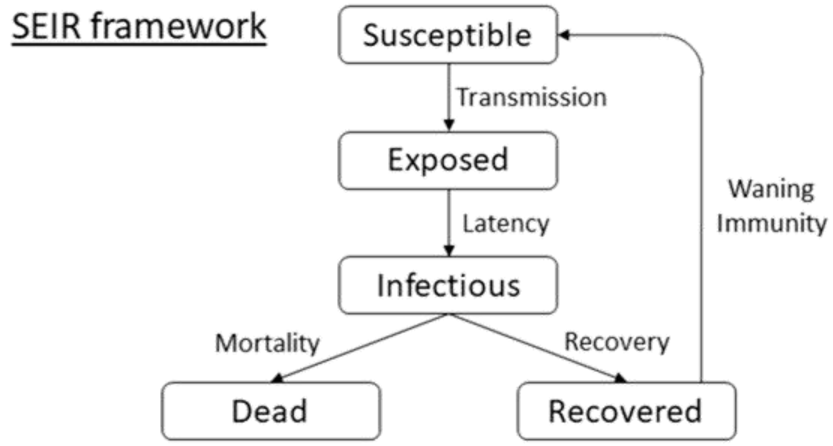
The model

Model structure





Shielding scenarios

No shielding (NS): No difference in contact rates between higher- and lower-risk individuals.

Perfect shielding (PS): Contact rates for higher-risk individuals set to 0 during the shielding phase.

Imperfect shielding (IS): Contact rates for higher-risk individuals reduced by 80% during the shielding phase.

Modifiers

Reduce contact (RC): A 50% reduction in contact rates, either permanently for all individuals in the absence of shielding (NS+RC), or during the shielding phase by the lower-risk population (PS+RC, IS+RC).

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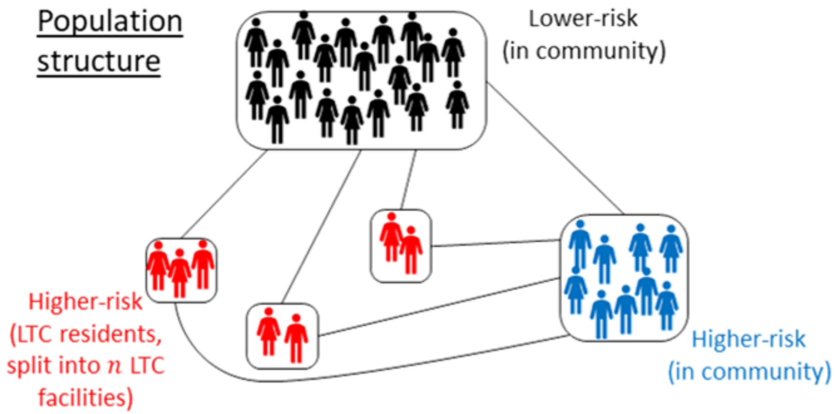
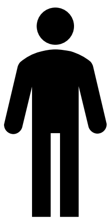
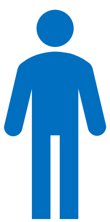
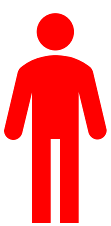




93% of the population
Part of the community
Lower IFR
Can be externally infected

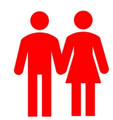


6.3% of the population
Part of the community
Higher IFR
Can be externally infected

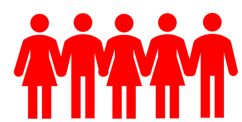


0.7% of the population
Split into LTC facilities
Higher IFR
Can't be externally infected

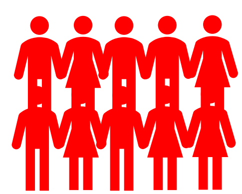
LTC Facilities:



Small:
- 20 residents each
- 120 facilities



Medium:
- 50 residents each
- 48 facilities



Large:
- 100 residents each
- 24 facilities

Model structure

Let $i, j \in \mathcal{C} := \{L, H_C, H_F^1, \ldots, H_F^n\}$.

$S_i \to E_i$	Rate: $\eta_i(t) S_i$
$S_i + I_j \to E_i + I_j$	Rate: $\beta_0 r p_{ij} q_{ij} S_i \frac{I_j}{N_j}$
$E_i \to I_i$	Rate: σE_i
$I_i \to R_i$	Rate: $\Gamma(1-\alpha_i) I_i$
$I_i \to D_i$	Rate: $\Gamma \alpha_i I_i$
$R_i \to S_i$	Rate: νR_i

External infection:

$$\eta_i(t) = \begin{cases} 10^{-3}, & i \in \{L, H_C\} \text{ and } t > t_s, \\ 0, & \text{otherwise.} \end{cases}$$

Intervention matrix:

$$Q = \begin{bmatrix} q_1 & q_4 & q_5 \mathbf{1}_n^T \\ q_4 & q_2 & q_6 \mathbf{1}_n^T \\ q_5 \mathbf{1}_n & q_6 \mathbf{1}_n & q_3 I_n \end{bmatrix}$$

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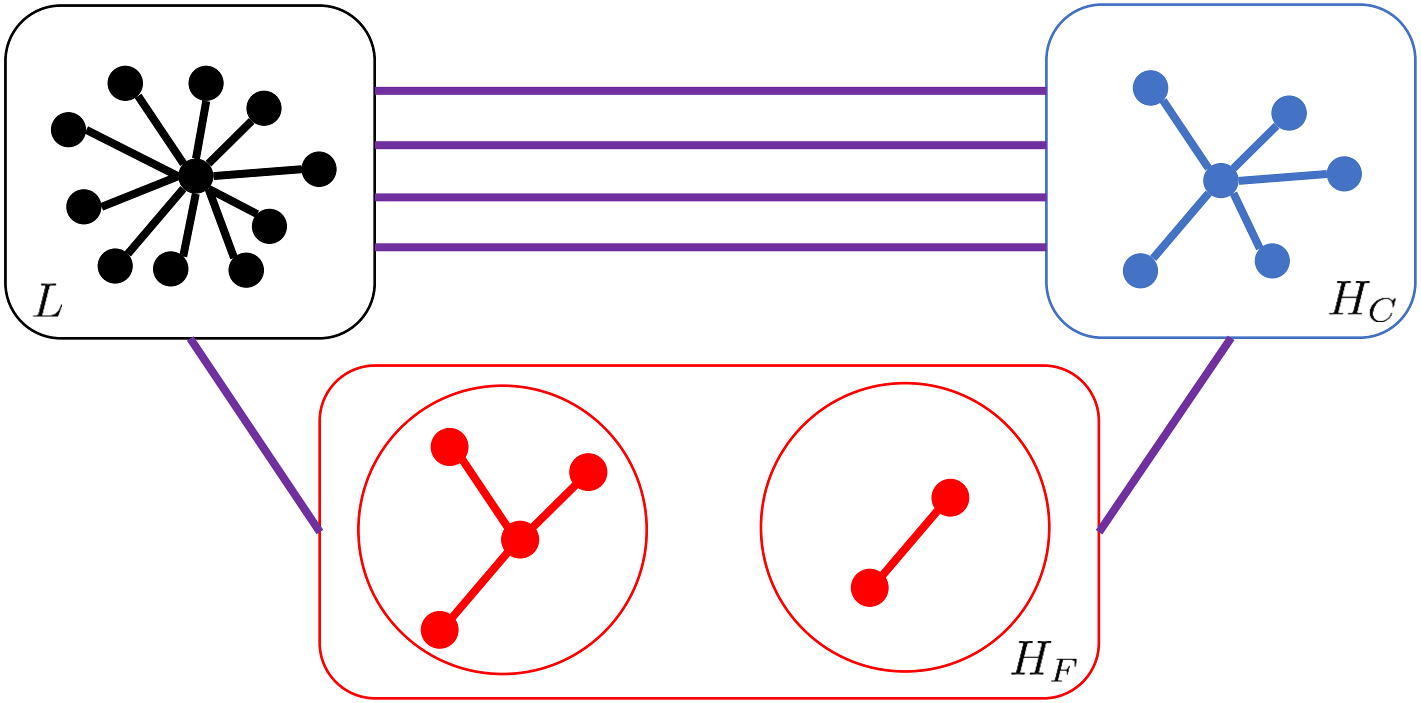

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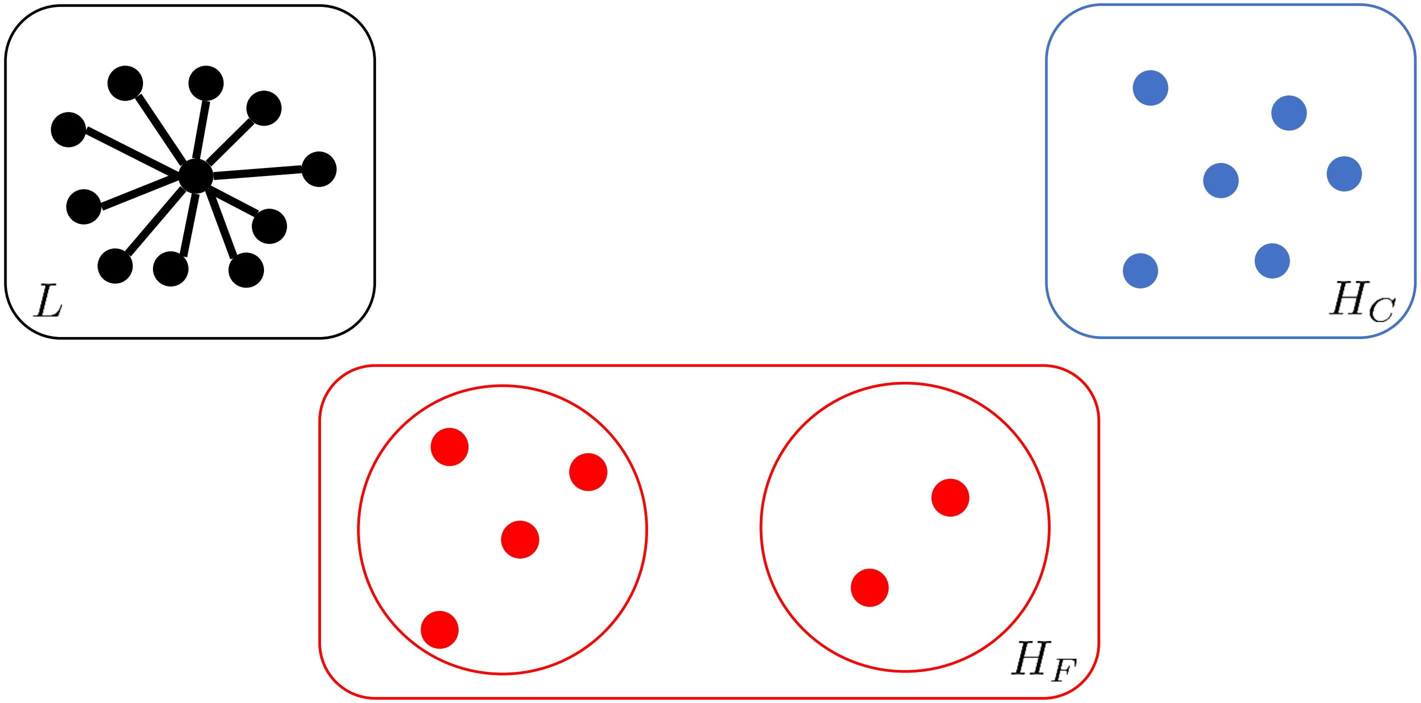

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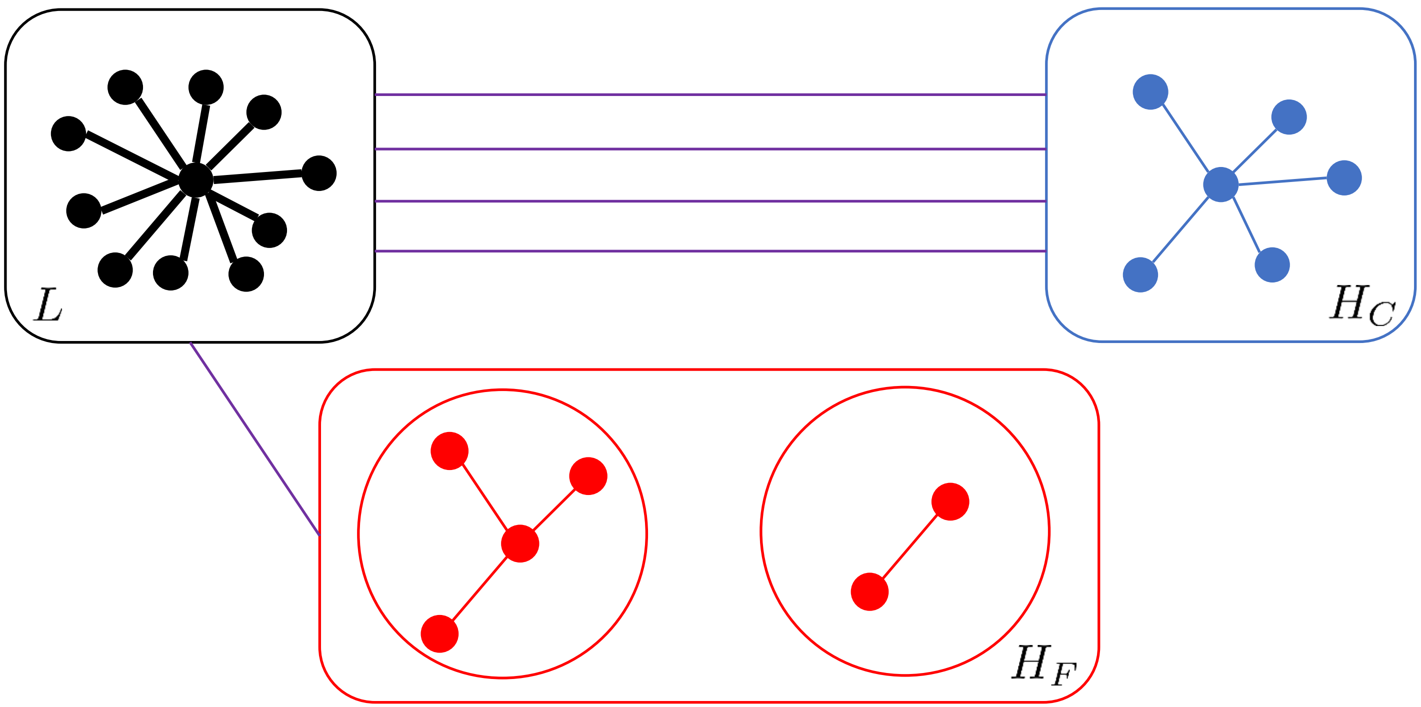

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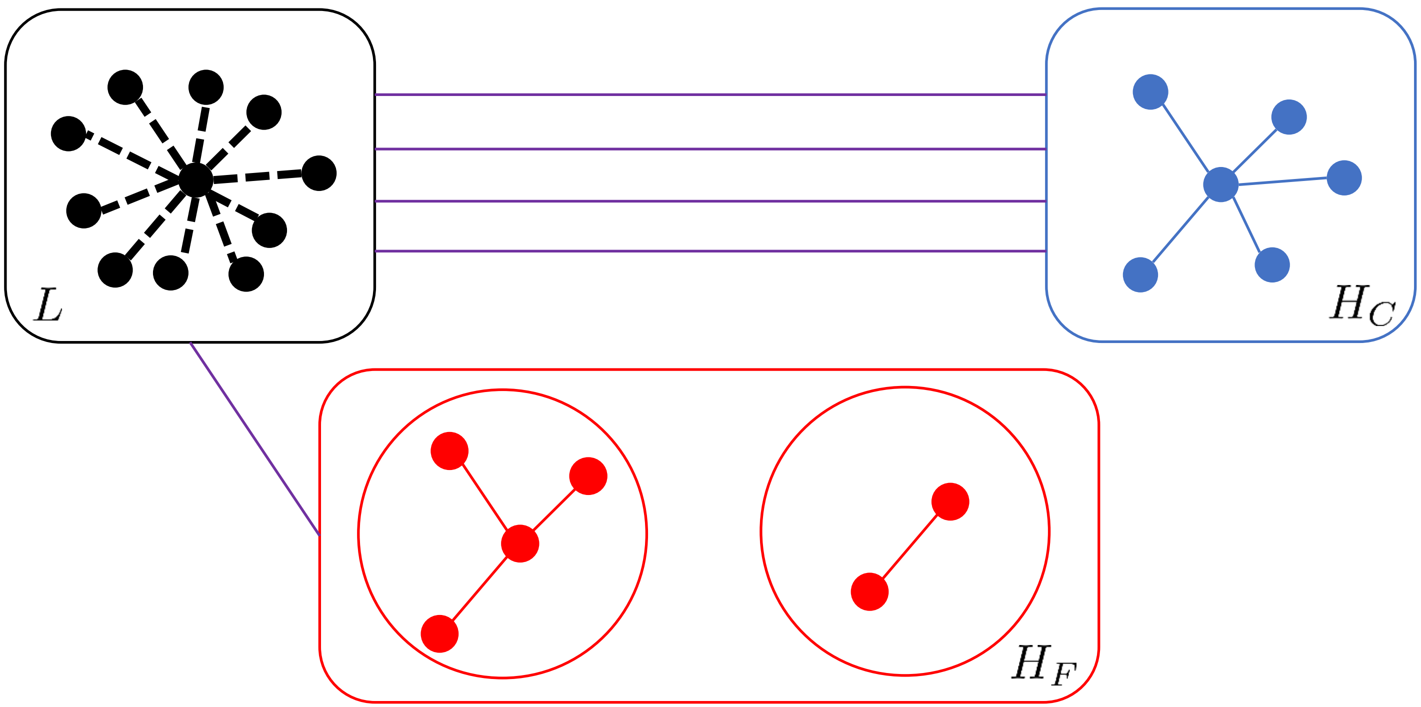

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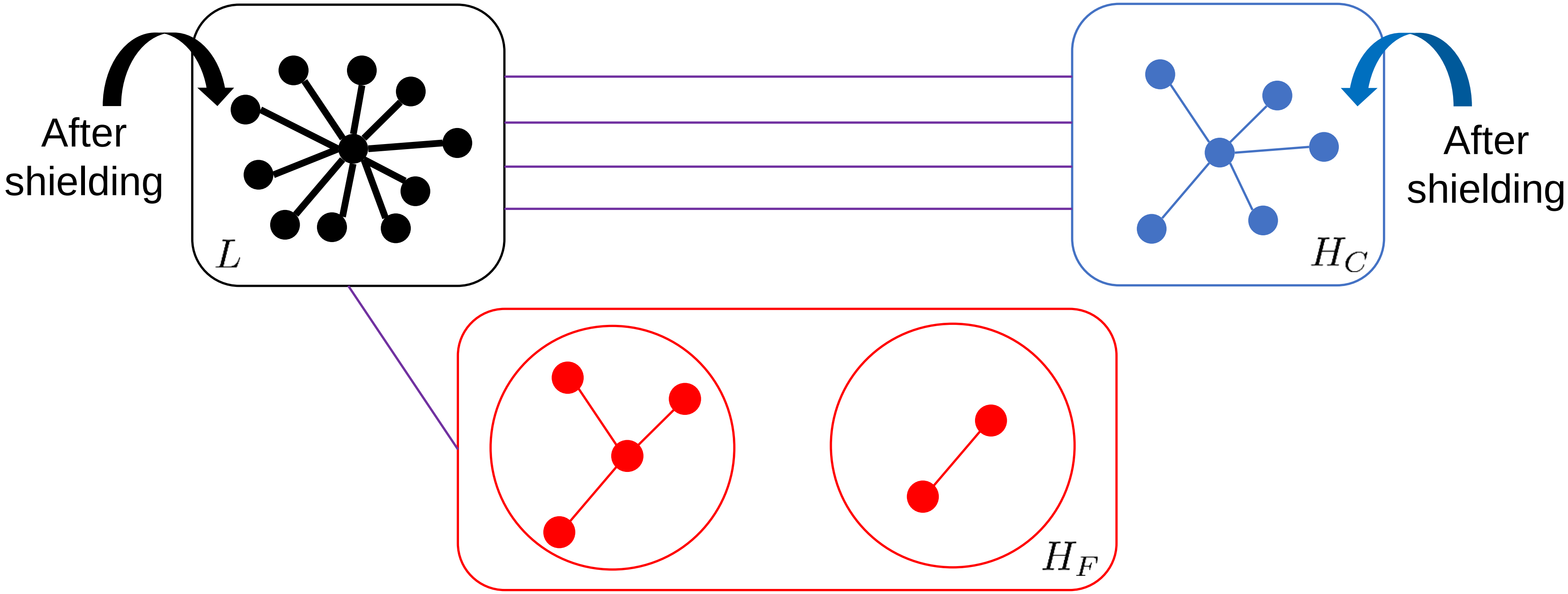

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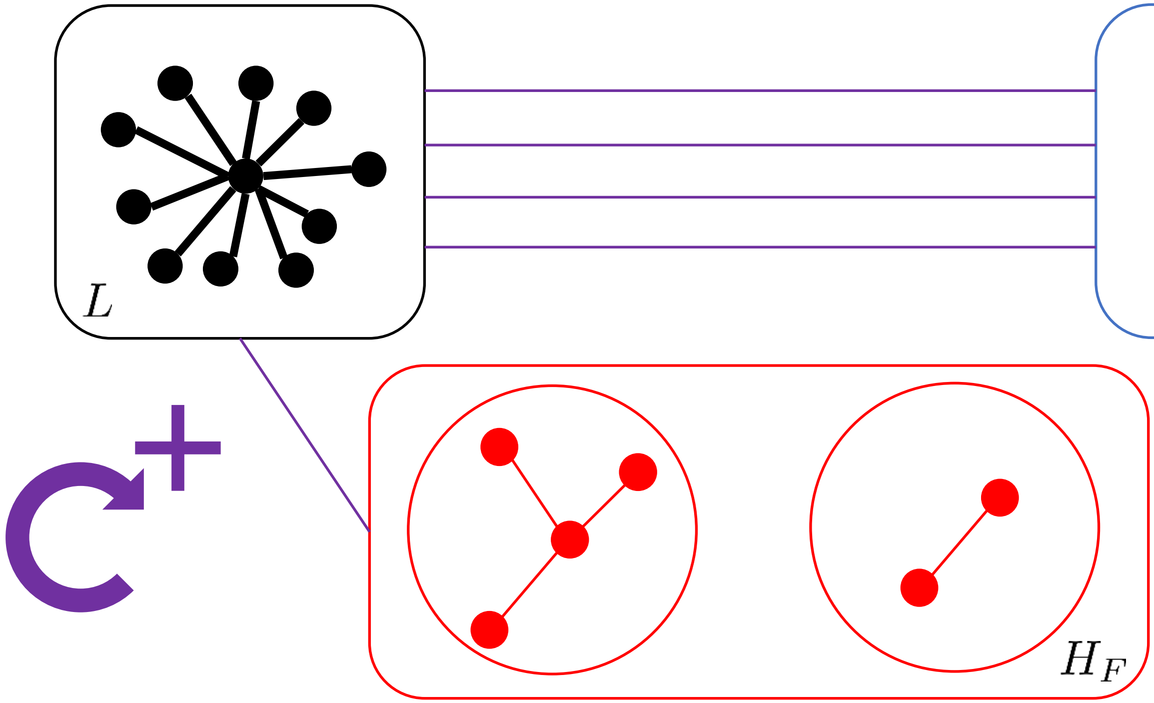
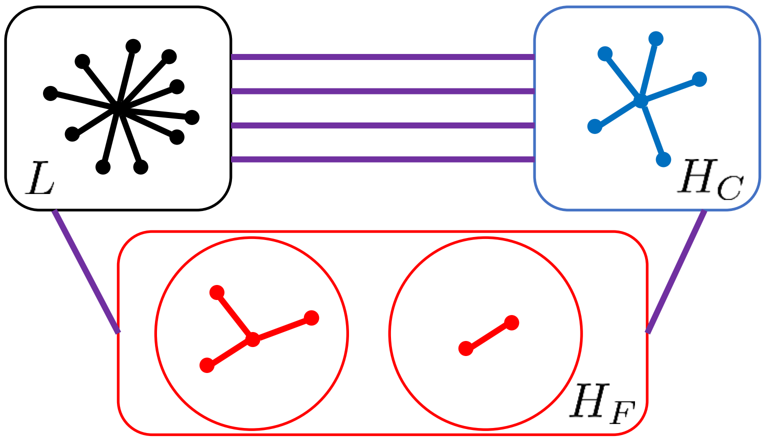


Results

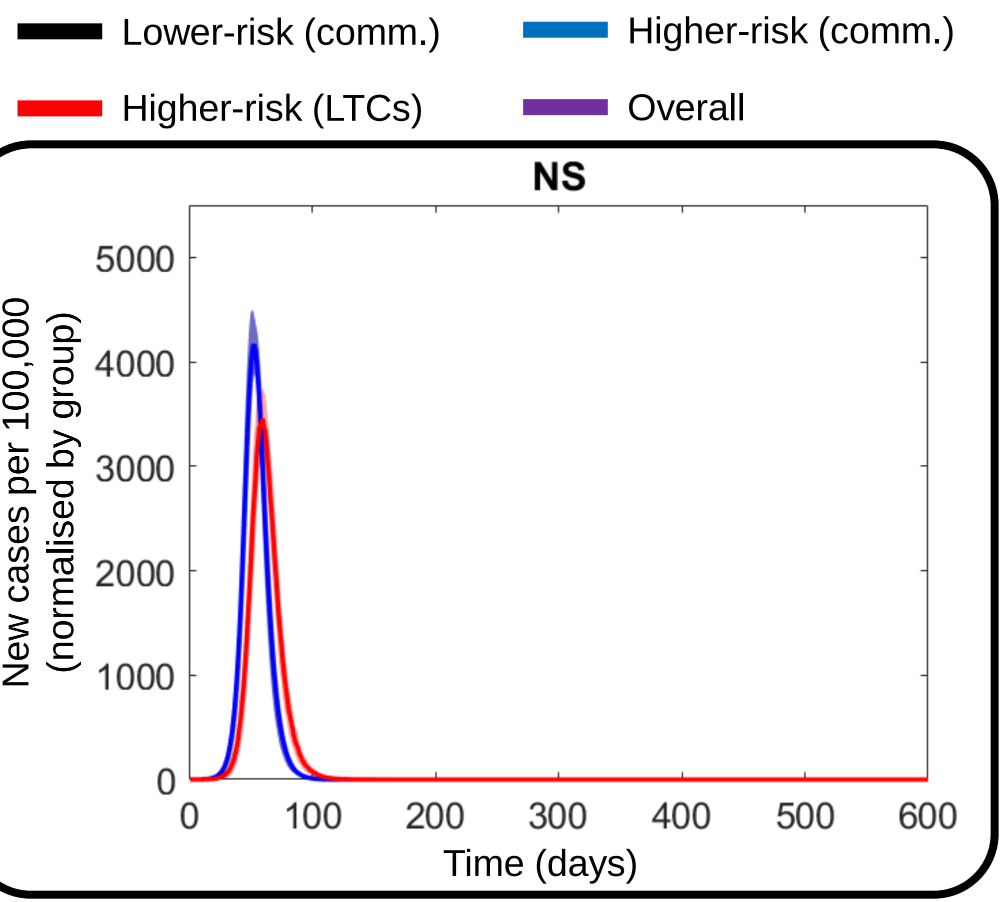
Results: No shielding

Scenario



Intervention matrix

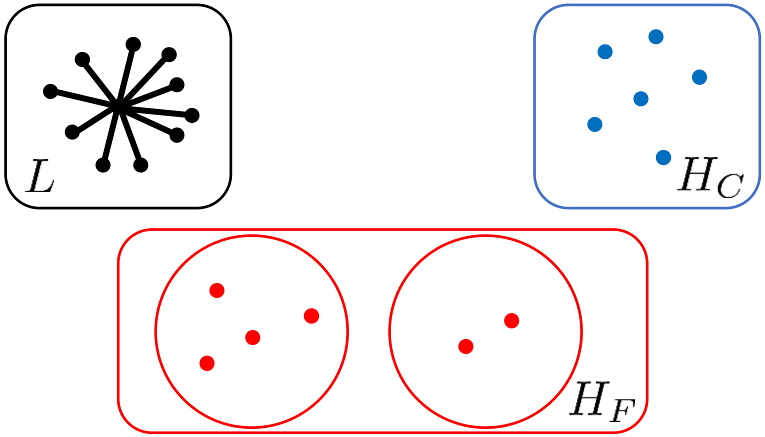
$q_1 = 1\ (L \leftrightarrow L)$	$q_4 = 1\ (L \leftrightarrow H_C)$
$q_2 = 1\ (H_C \leftrightarrow H_C)$	$q_5 = 1\ (L \leftrightarrow H_F)$
$q_3 = 1\ (H_F \leftrightarrow H_F)$	$q_6 = 1\ (H_C \leftrightarrow H_F)$

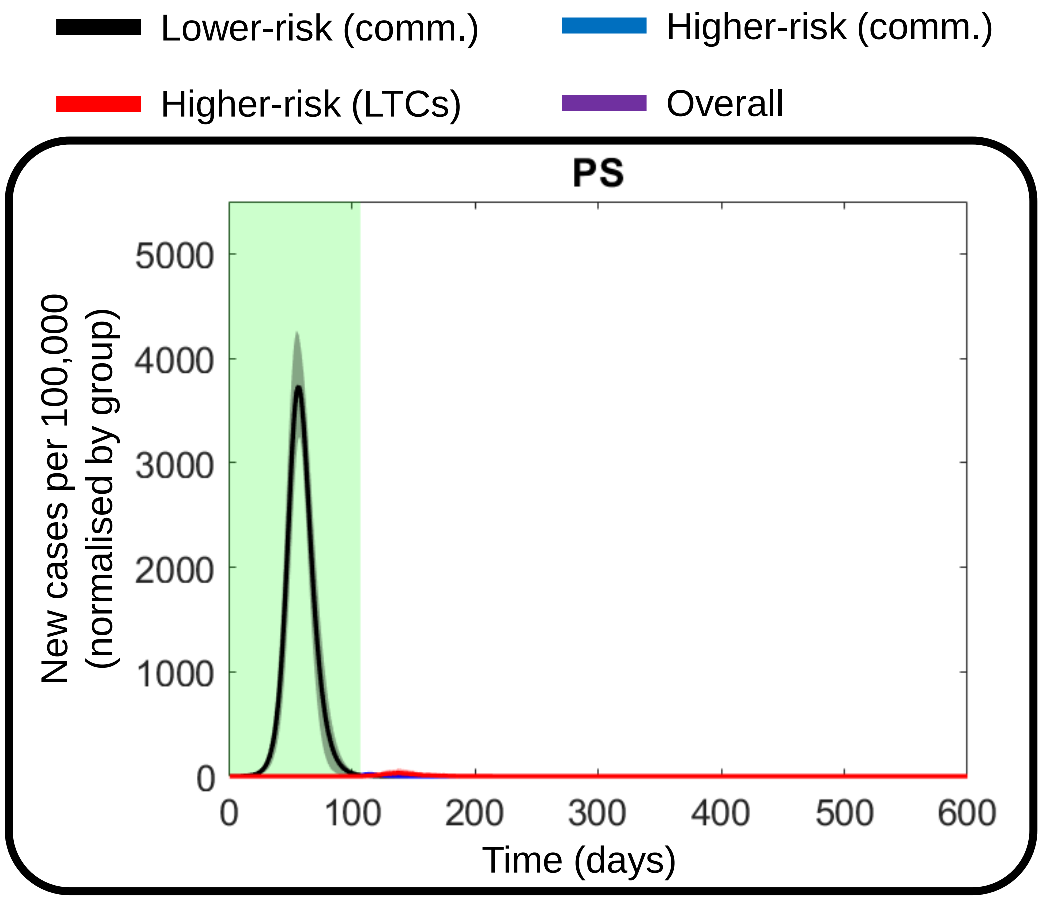


Deaths per 100,000 (normalised by group)	Low-risk Community	High-risk Community	High-risk LTCs	Overall
	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)

Results: Perfect shielding

Scenario





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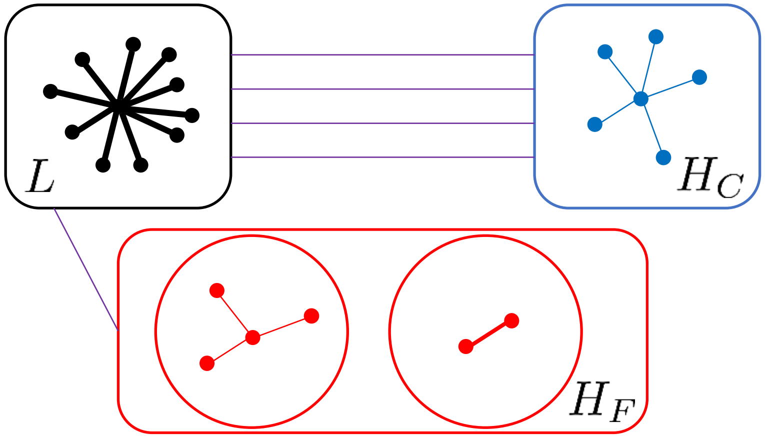
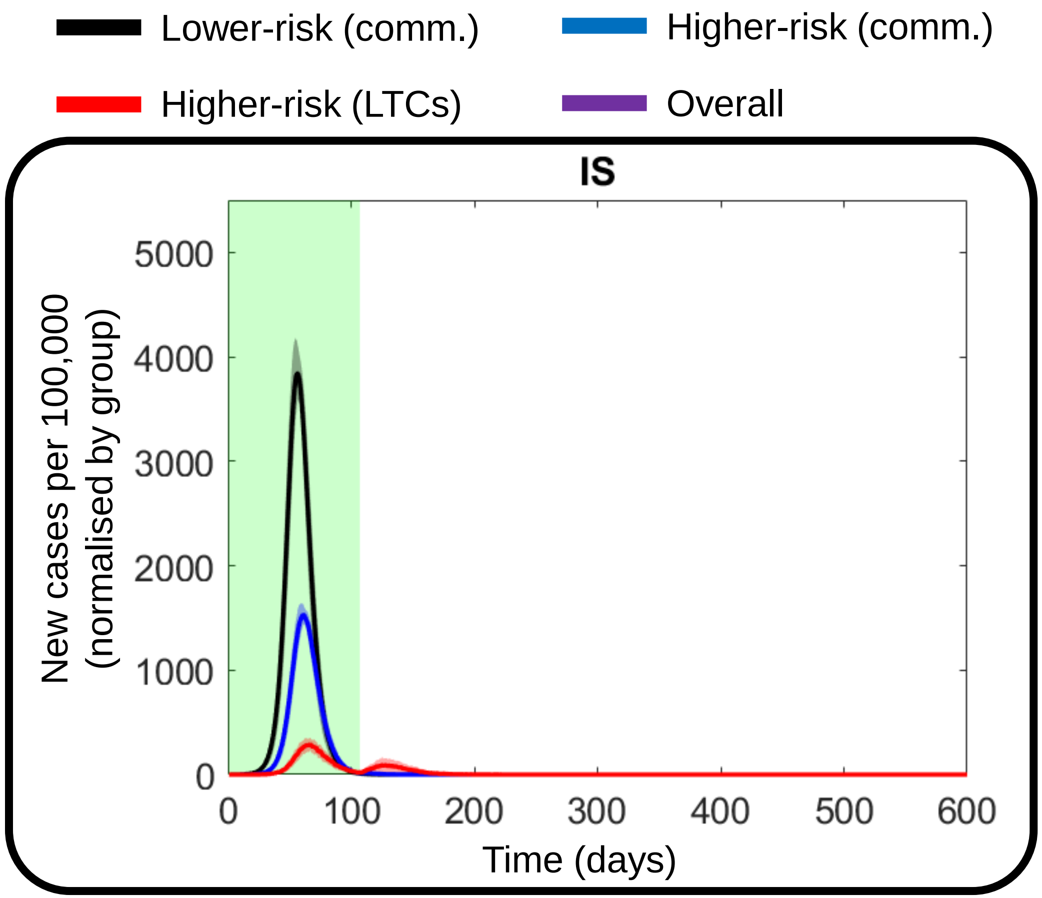
$q_3 = 0\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	92·5 (89·4, 95·7)	18·6 (0·0, 38·3)	54·3 (0·0, 123·3)	87·6 (84·2, 91·1)

Results: Imperfect shielding

Scenario



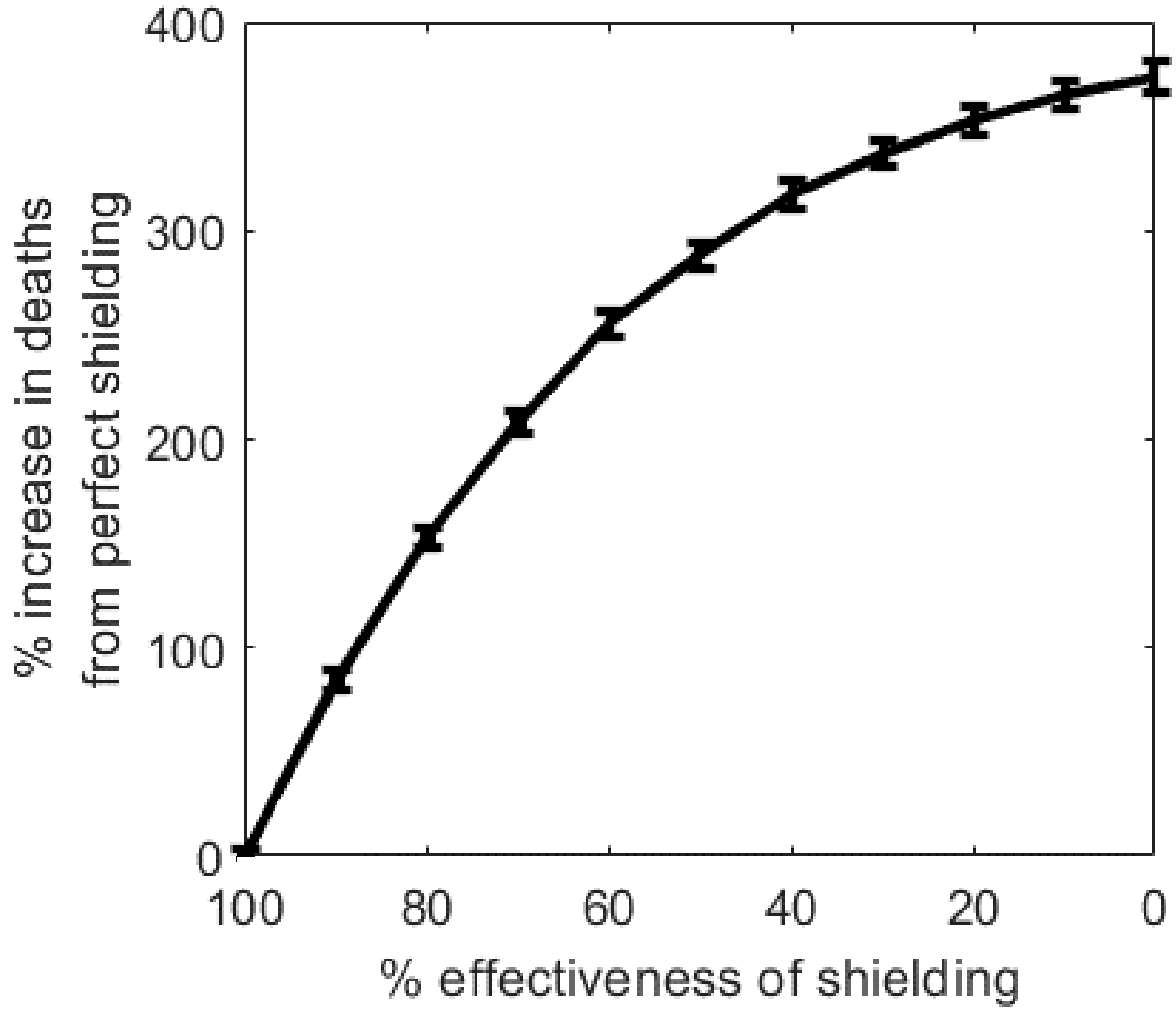


Intervention matrix

$q_1 = 1\ (L \leftrightarrow L)$	$q_4 = 0.2\ (L \leftrightarrow H_C)$
$q_2 = 0.2\ (H_C \leftrightarrow H_C)$	$q_5 = 0.2\ (L \leftrightarrow H_F)$
$q_3 = 0.2\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

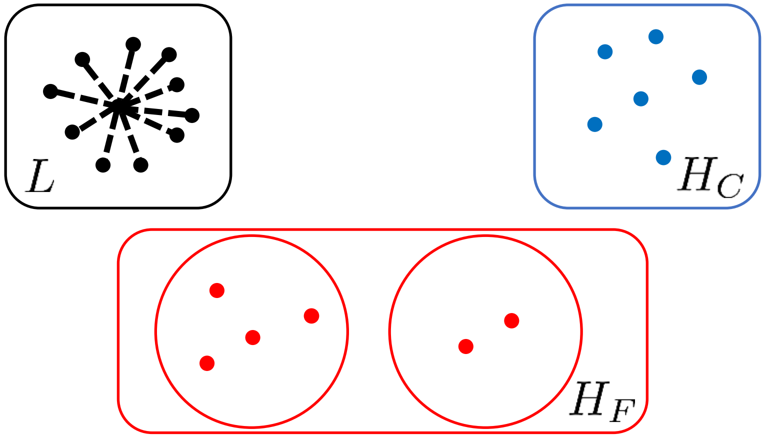
Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	92·4 (89·4, 95·5)	2090·9 (2038·0, 2143·8)	613·6 (478·4, 748·8)	221·7 (217·8, 225·5)

Results: Imperfection levels



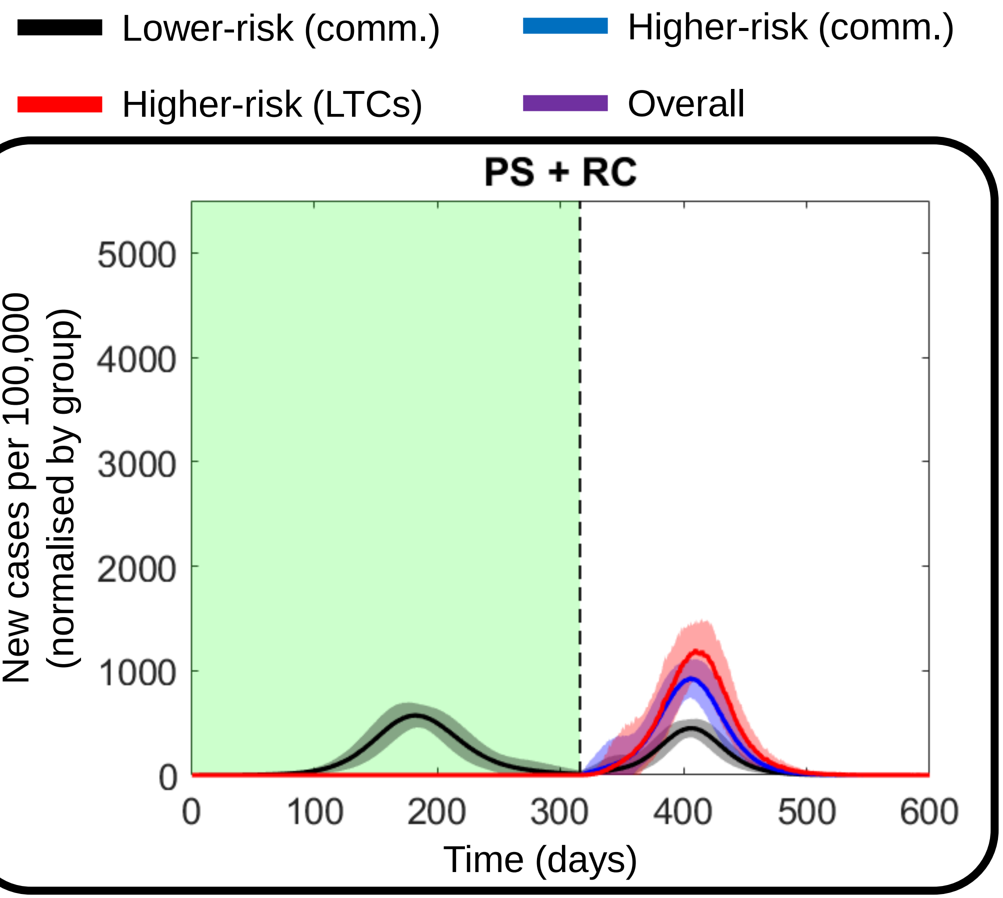
Results: Perfect shielding + reduced contact

Scenario



Intervention matrix

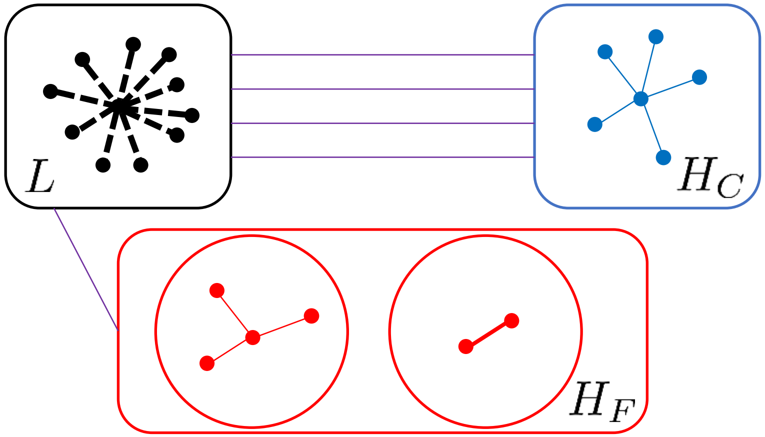
$q_1 = 0.5\ (L \leftrightarrow L)$	$q_4 = 0\ (L \leftrightarrow H_C)$
$q_2 = 0\ (H_C \leftrightarrow H_C)$	$q_5 = 0\ (L \leftrightarrow H_F)$
$q_3 = 0\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

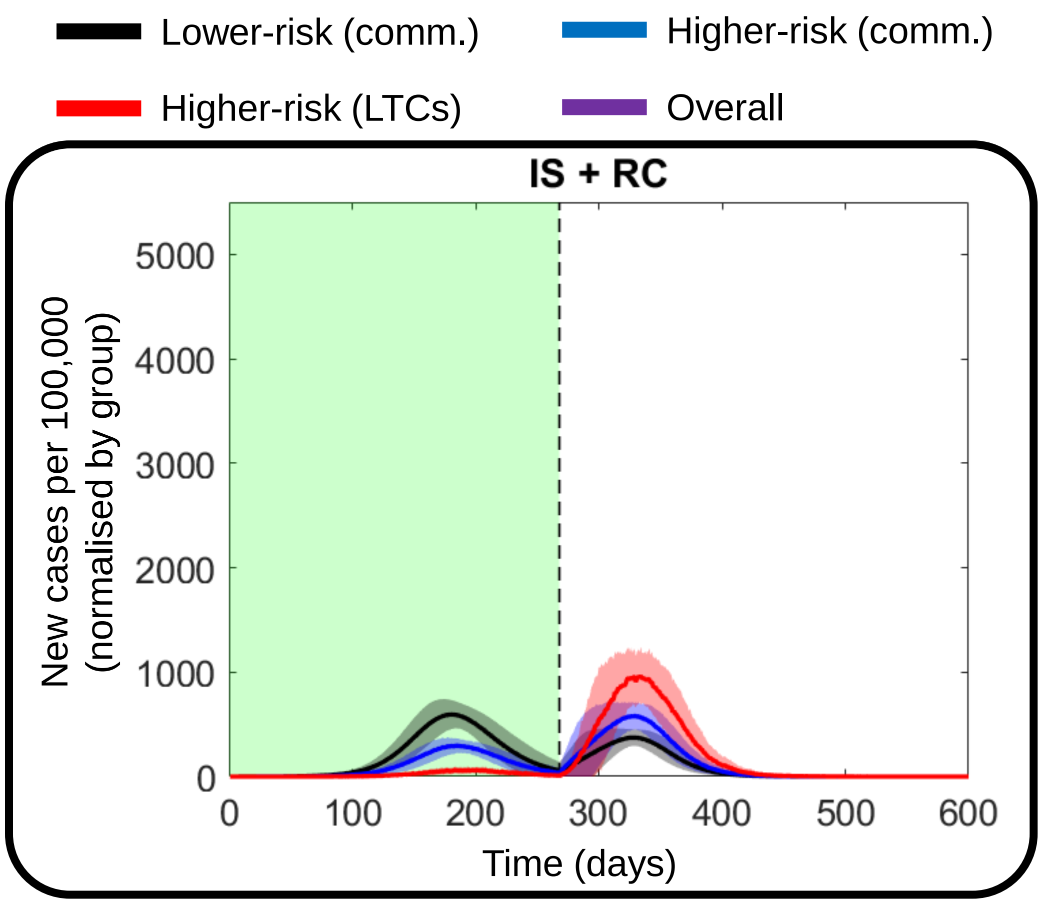


Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	81·2 (78·2, 84·3)	3114·4 (3010·8, 3218·0)	3944·2 (3695·7, 4192·6)	299·5 (292·0, 307·1)

Results: Imperfect shielding + reduced contact

Scenario





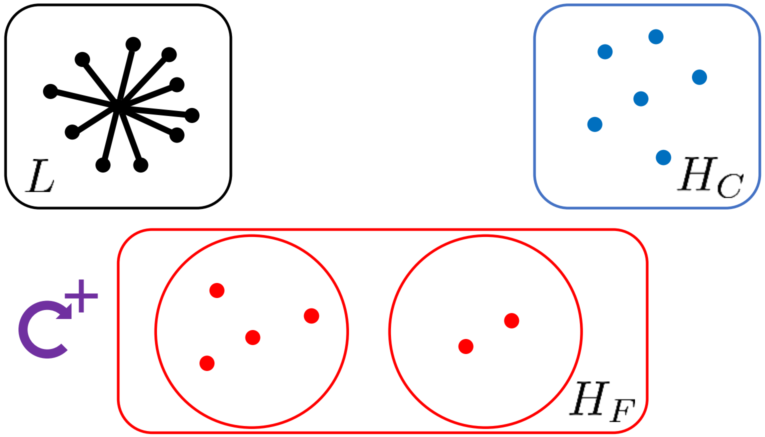
Intervention matrix

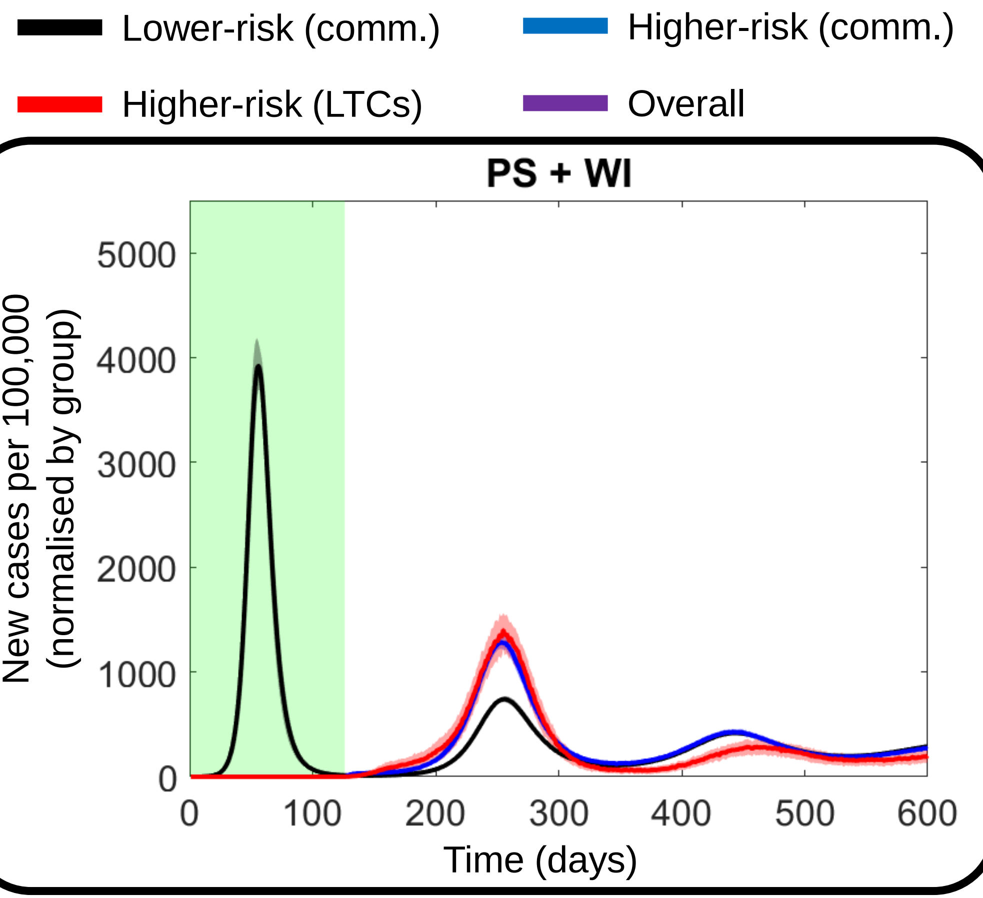
$q_1 = 0.5\ (L \leftrightarrow L)$	$q_4 = 0.2\ (L \leftrightarrow H_C)$
$q_2 = 0.2\ (H_C \leftrightarrow H_C)$	$q_5 = 0.2\ (L \leftrightarrow H_F)$
$q_3 = 0.2\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	80·3 (77·4, 83·3)	3491·5 (3337·7, 3645·3)	3783·7 (3516·2, 4051·2)	321·2 (309·7, 332·7)

Results: Perfect shielding + waning immunity

Scenario





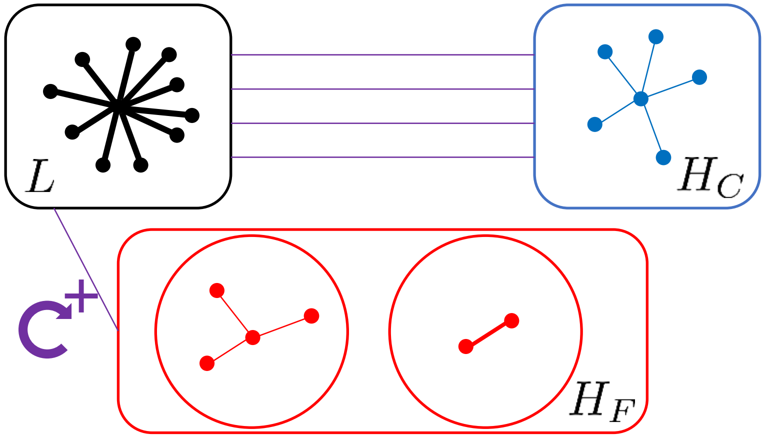
Intervention matrix

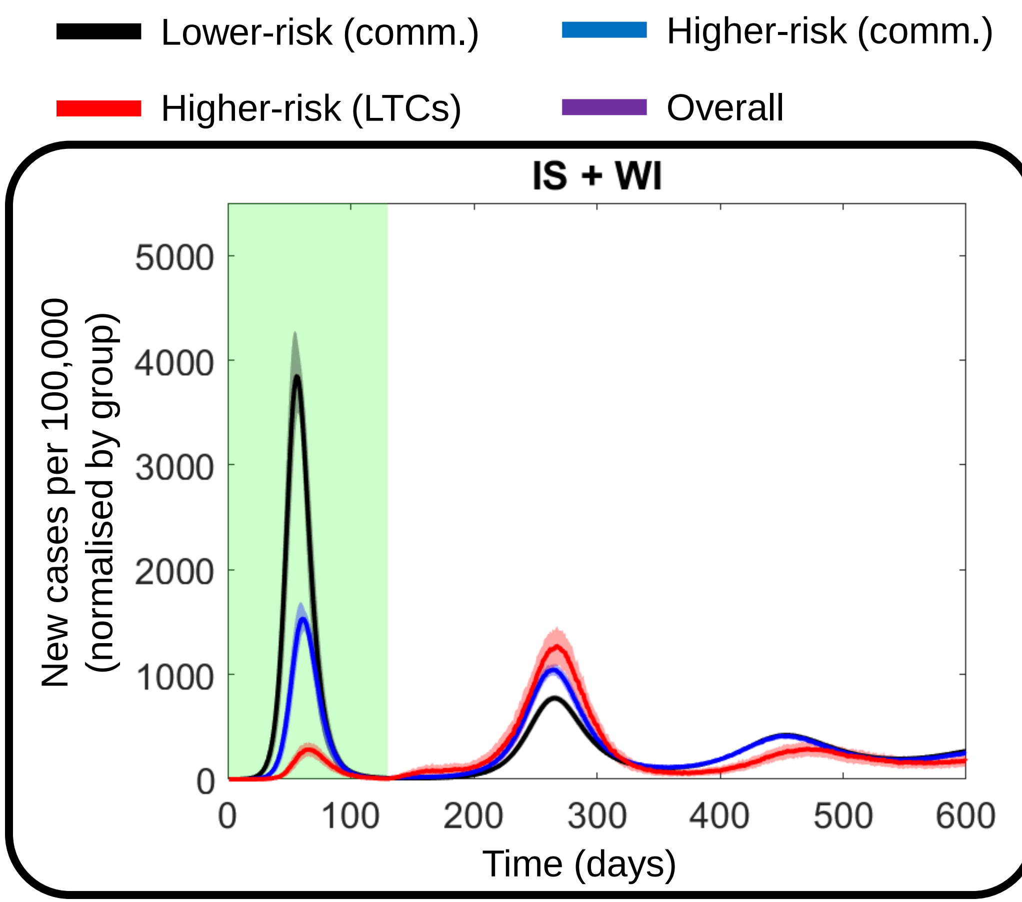
$q_1 = 1\ (L \leftrightarrow L)$	$q_4 = 0\ (L \leftrightarrow H_C)$
$q_2 = 0\ (H_C \leftrightarrow H_C)$	$q_5 = 0\ (L \leftrightarrow H_F)$
$q_3 = 0\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	213.5 (208.5, 218.5)	7533.2 (7423.5, 7642.8)	6740.6 (6445.8, 7035.3)	720.1 (711.4, 728.8)

Results: Imperfect shielding + waning immunity

Scenario





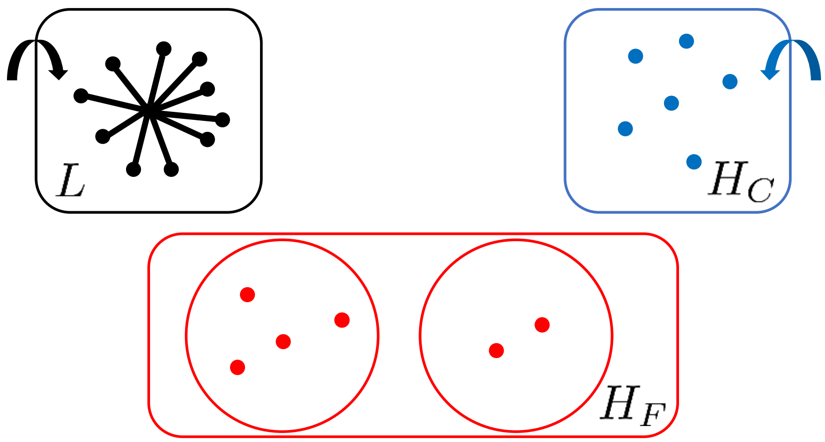
Intervention matrix

$q_1 = 1\ (L \leftrightarrow L)$	$q_4 = 0.2\ (L \leftrightarrow H_C)$
$q_2 = 0.2\ (H_C \leftrightarrow H_C)$	$q_5 = 0.2\ (L \leftrightarrow H_F)$
$q_3 = 0.2\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	212.2 (206.9, 217.5)	8641.1 (8546.4, 8735.7)	6879.4 (6596.7, 7162.2)	789.5 (781.4, 797.5)

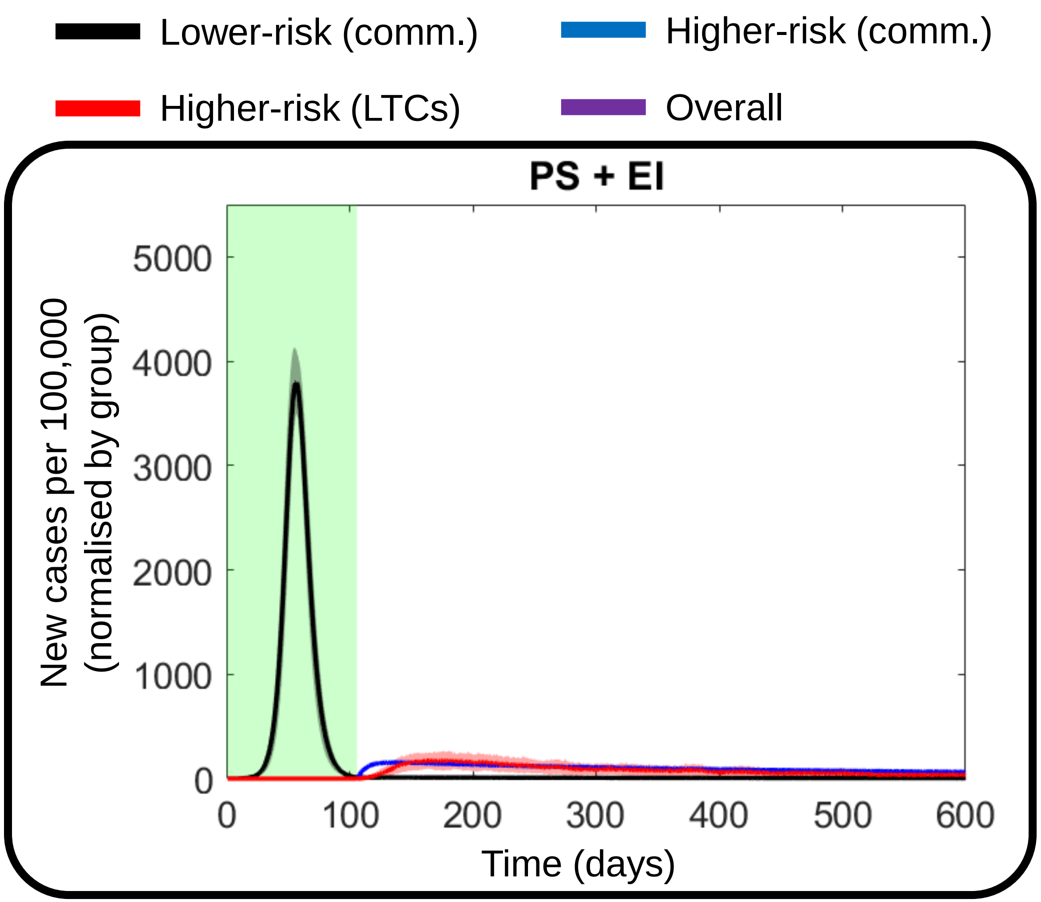
Results: Perfect shielding + external infection

Scenario



Intervention matrix

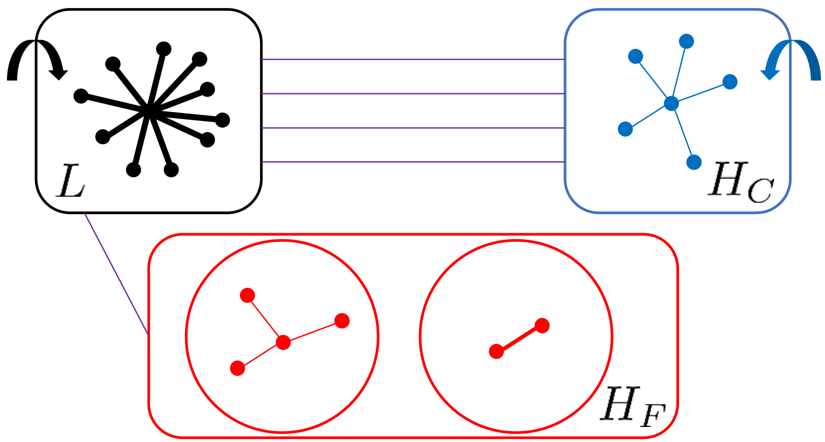
$q_1 = 1\ (L \leftrightarrow L)$	$q_4 = 0\ (L \leftrightarrow H_C)$
$q_2 = 0\ (H_C \leftrightarrow H_C)$	$q_5 = 0\ (L \leftrightarrow H_F)$
$q_3 = 0\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

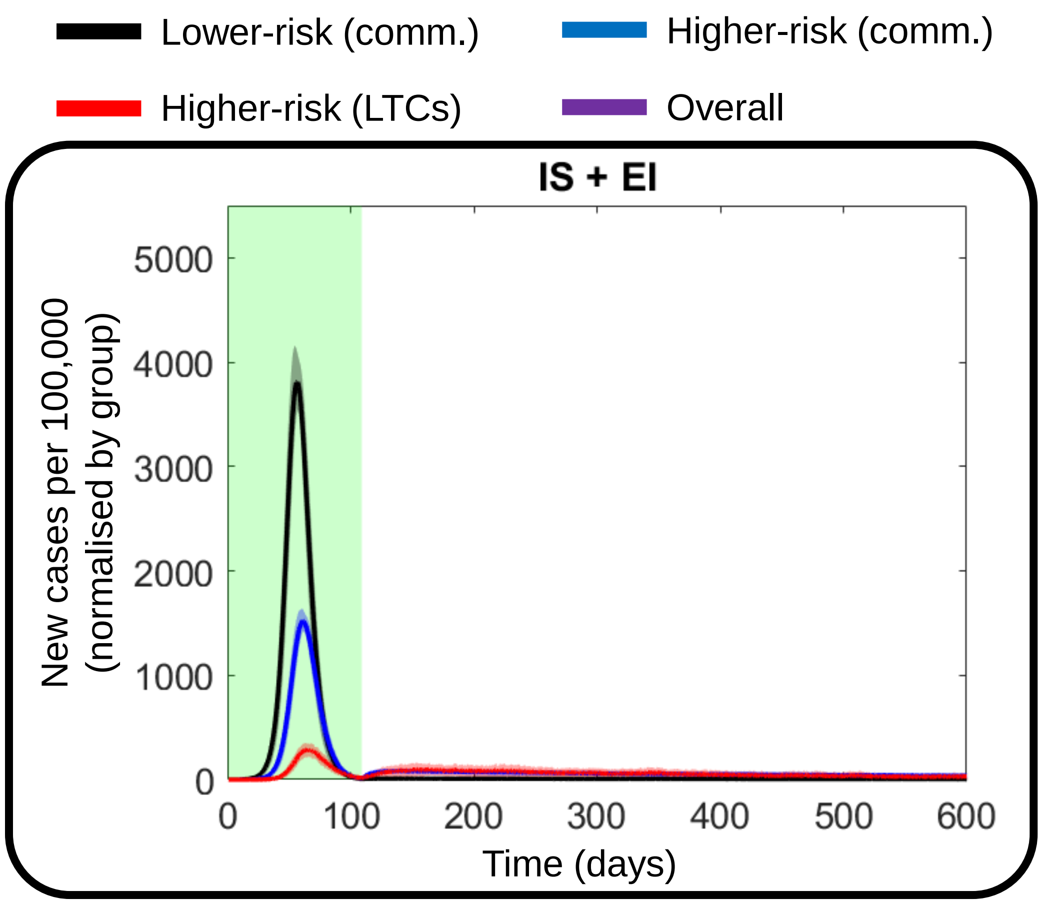


Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	96·3 (93·4, 99·2)	2487·2 (2426·7, 2547·7)	2023·9 (1756·9, 2290·9)	260·3 (255·2, 265·5)

Results: Imperfect shielding + external infection

Scenario





Intervention matrix

$q_1 = 1\ (L \leftrightarrow L)$	$q_4 = 0.2\ (L \leftrightarrow H_C)$
$q_2 = 0.2\ (H_C \leftrightarrow H_C)$	$q_5 = 0.2\ (L \leftrightarrow H_F)$
$q_3 = 0.2\ (H_F \leftrightarrow H_F)$	$q_6 = 0\ (H_C \leftrightarrow H_F)$

Deaths per 100,000 (normalised by group)	93.7 (90.3, 97.1)	4702.1 (4615.9, 4788.3)	4532.6 (4280.0, 4785.2)	415.1 (408.5, 421.6)
	96·3 (92·8, 99·8)	3450·5 (3376·0, 3524·9)	1868·5 (1654·2, 2082·7)	319·7 (313·5, 325·9)

Results: Summary

Average deaths per 100,000 (normalised by group)

	Lower-risk (Community)	Higher-risk (Community)	Higher-risk (LTCs)	Overall
NS	93.7	4702.1	4532.6	415.1
PS	92.5	18.6	54.3	87.6
IS	92.4	2090.9	613.6	221.7
NS + RC	74.2	3712.8	3336.5	326.2
PS + RC	81.2	3114.4	3944.2	299.5
IS + RC	80.3	3491.5	3783.7	321.2
NS + WI	211.9	10214.1	8732.4	901.3
PS + WI	213.5	7533.2	6740.6	720.1
IS + WI	212.2	8641.1	6879.4	789.5
NS + EI	96.8	4849.3	4612.9	427.8
PS + EI	96.3	2487.2	2023.9	260.3
IS + EI	96.3	3450.5	1868.5	319.7

Results: Summary

Average deaths per 100,000 (normalised by group)

PS	92.5	18.6	54.3	87.6
IS	92.4	2090.9	613.6	221.7

PS + RC	81.2	3114.4	3944.2	299.5
IS + RC	80.3	3491.5	3783.7	321.2

Results: Summary

PS	92.5	18.6	54.3	87.6
IS	92.4	2090.9	613.6	221.7
PS + RC	81.2	3114.4	3944.2	299.5
IS + RC	80.3	3491.5	3783.7	321.2

Uneven distribution of immunity:

<u>Perfect shielding</u>

During shielding, LTCs cannot gain any immunity.

Most infections into any given LTC result in outbreak.

<u>Imperfect shielding</u>

During shielding, some LTCs gain immunity.

Some infections into a given LTC will not outbreak.

Results: Summary

Average deaths per 100,000 (normalised by group)

	Lower-risk (Community)	Higher-risk (Community)	Higher-risk (LTCs)	Overall
NS	93.7	4702.1	4532.6	415.1
PS	92.5	18.6	54.3	87.6
IS	92.4	2090.9	613.6	221.7
NS + RC	74.2	3712.8	3336.5	326.2
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PS + EI	96.3	2487.2	2023.9	260.3
IS + EI	96.3	3450.5	1868.5	319.7

Conclusions

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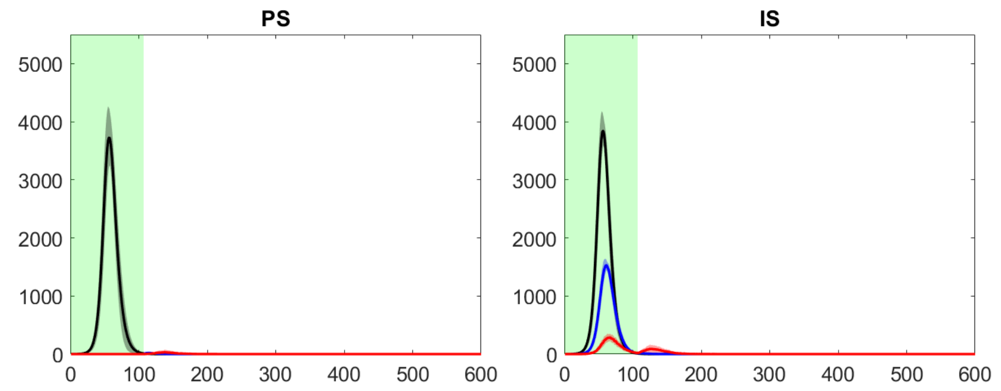
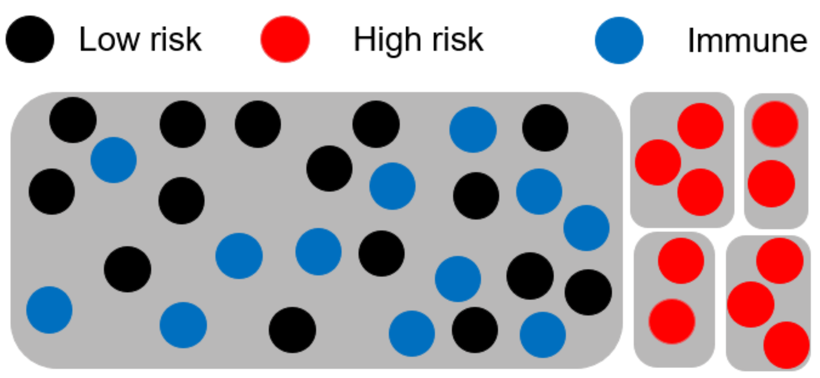
Conclusions and reflections

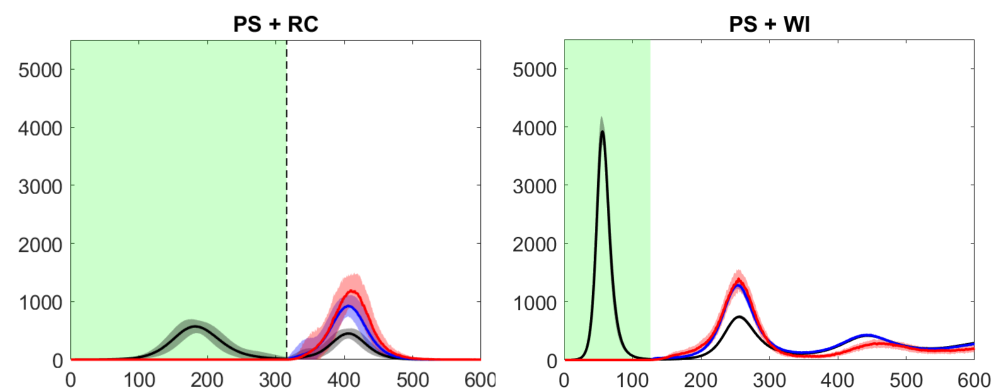
Shielding can “work” in theory, but will fail in practice.





Most problems caused by the uneven distribution of immunity during shielding.

Any additional realism, such as contact reduction and waning immunity render shielding untenable.



Thank you for listening.

This is joint work with Ben Ashby, currently at SFU, Canada.

This work was supported by NERC grants NE/V003909/1 (CAS, BA) and NE/N014979/1 (BA).

UKRI Natural Environment Research Council

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