Conceptual models of cross-immunity, and practical applications

Jonathan Dushoff, McMaster University

Epidemics9, Nov 2023

Conceptual talk with practical goals

- How should we incorporate partial immunity into population-level modeling?

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- Why does it matter?

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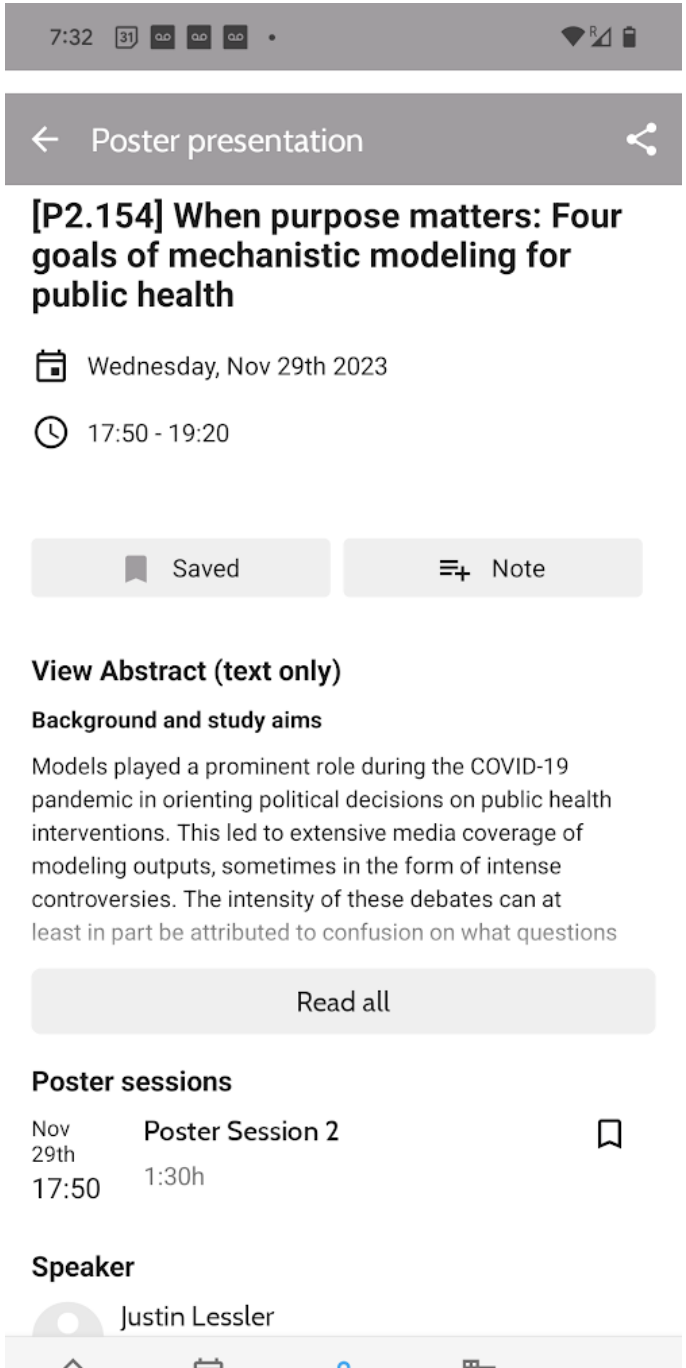
Model goals

- Theoretical



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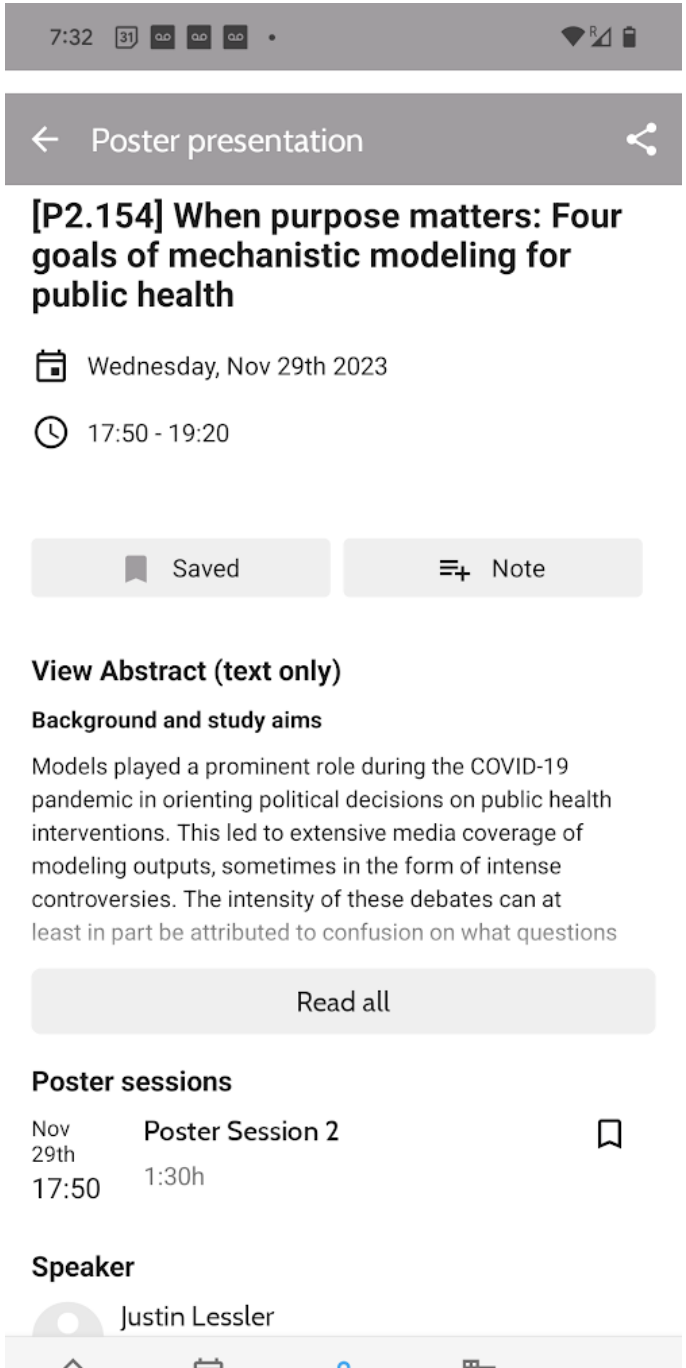

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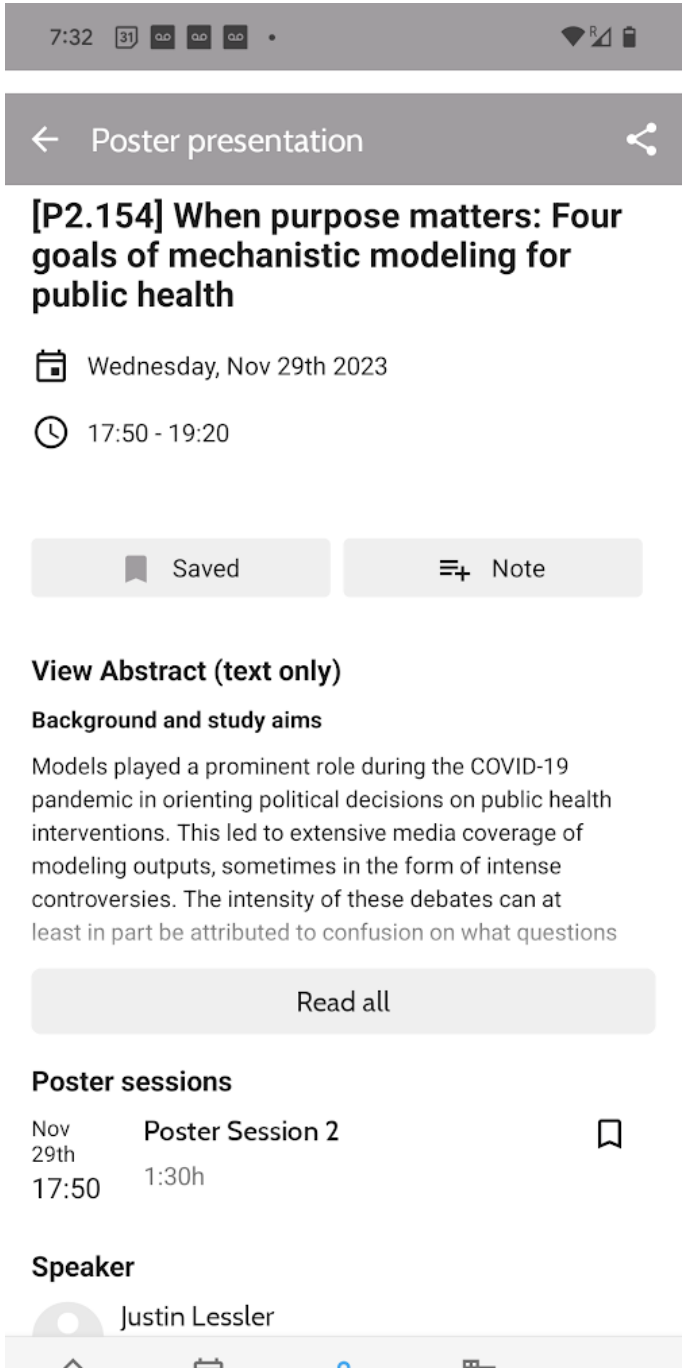

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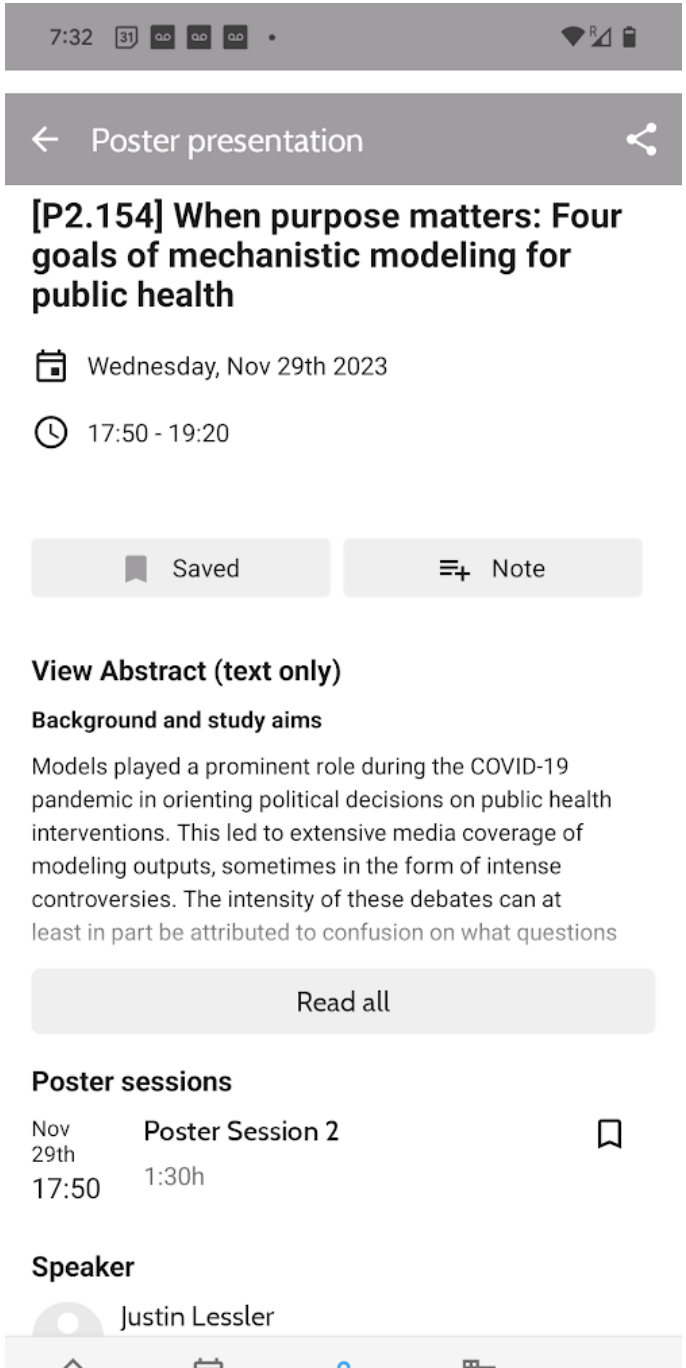

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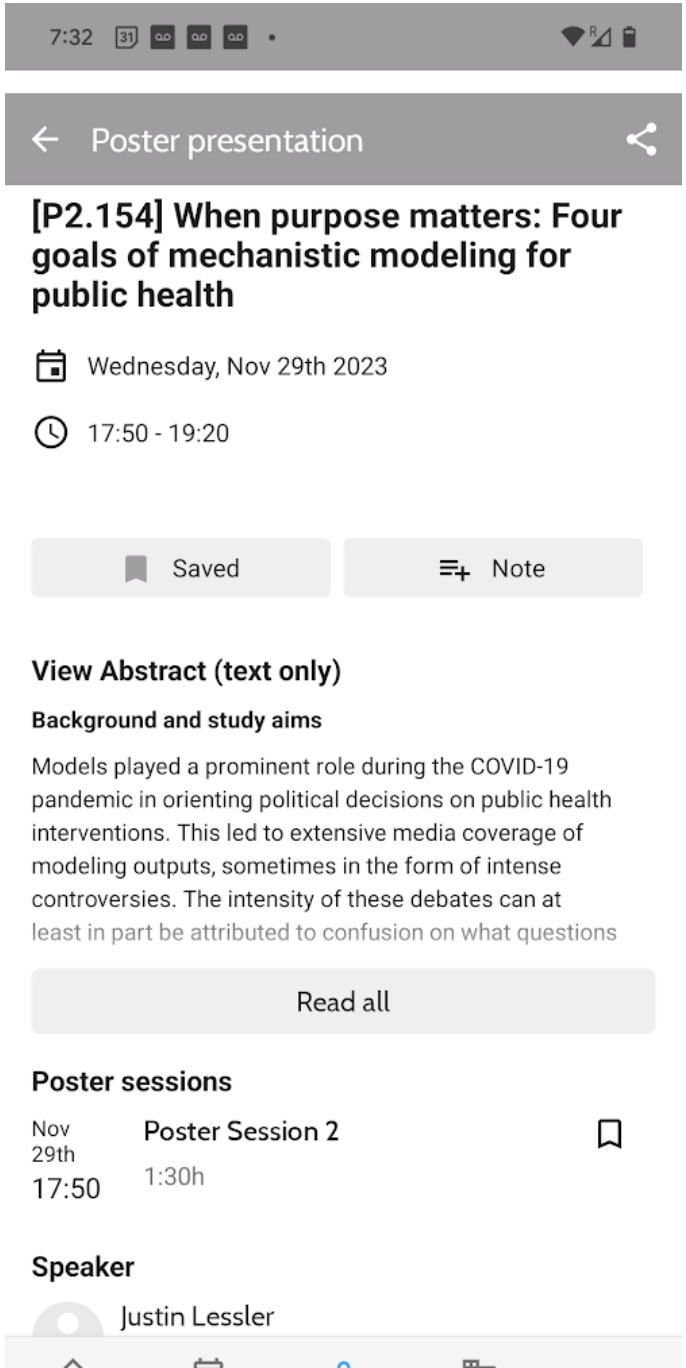

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Modeling partial protection

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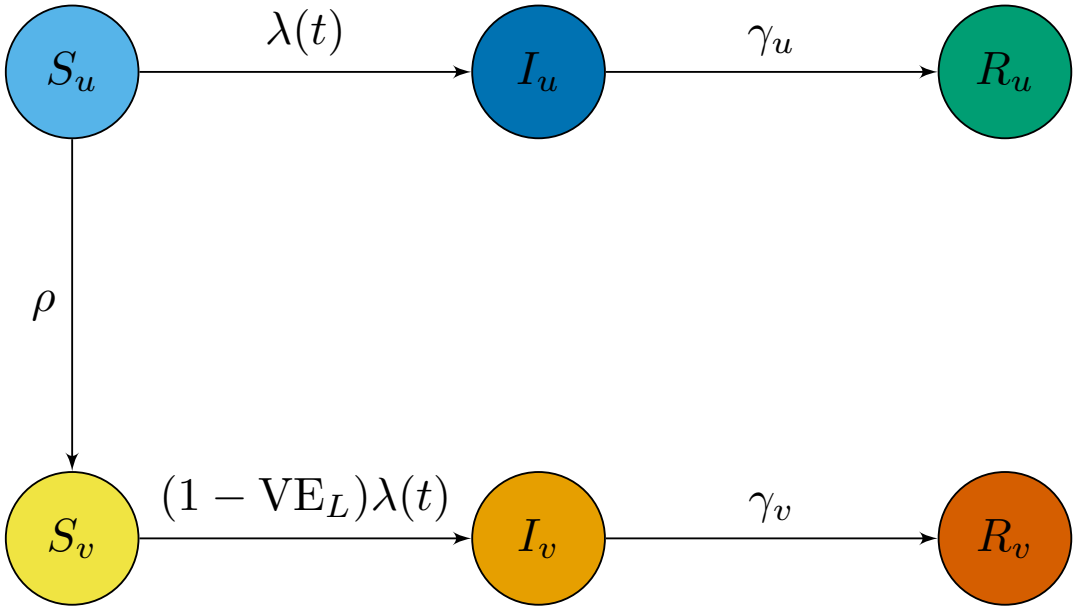
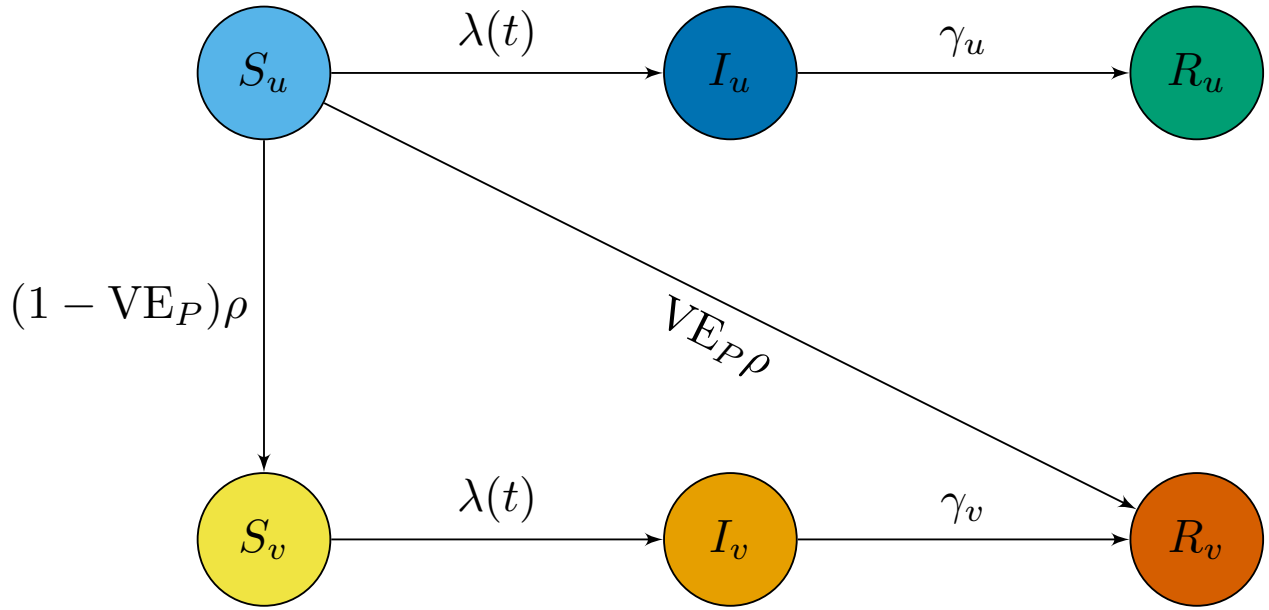
Modeling partial immunity





Why does it matter?

- Prediction

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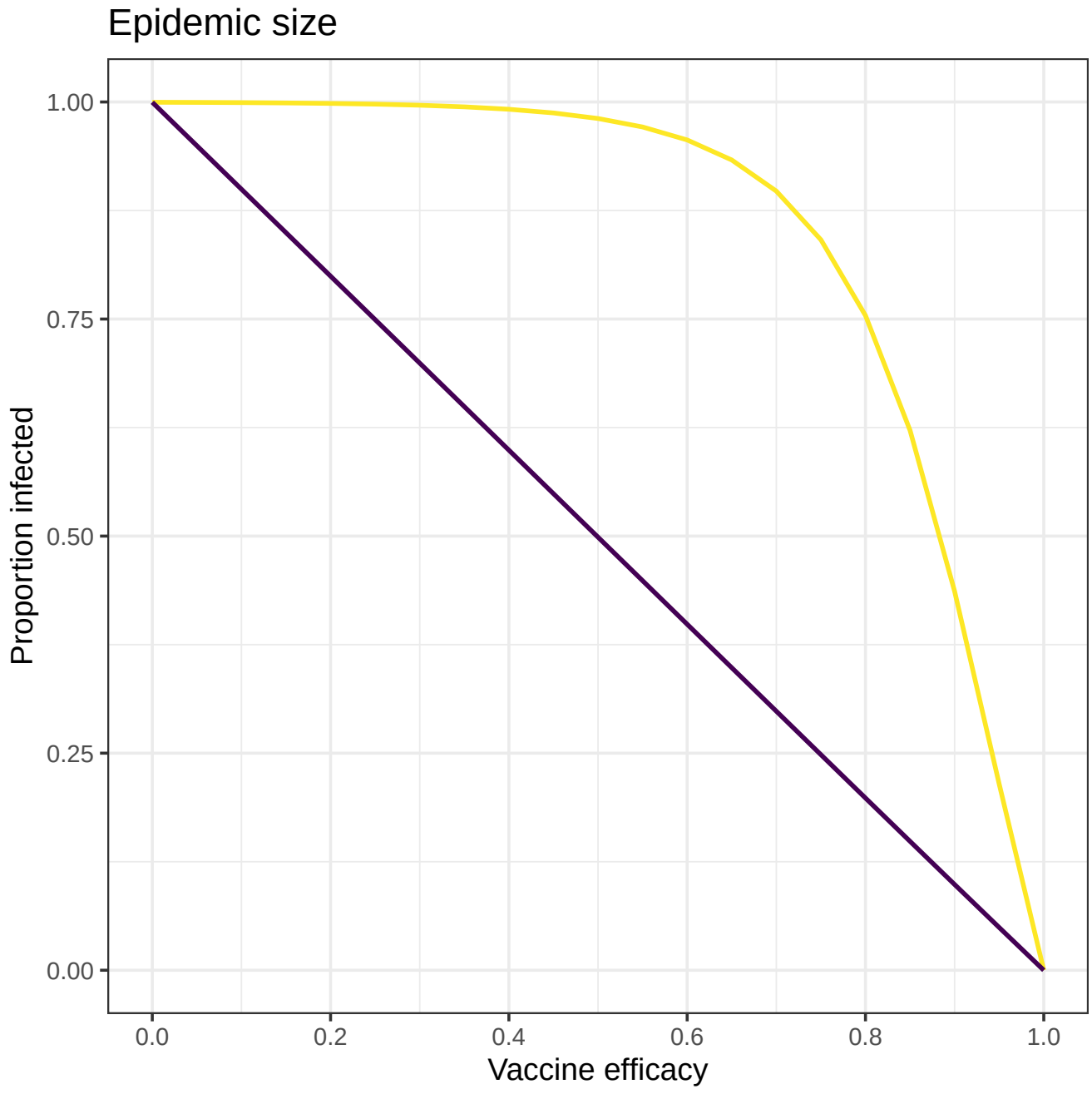
Epidemic size
Proportion infected
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0.50
0.25
0.00
0.0
0.2
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0.8
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Vaccine efficacy

Polarized model

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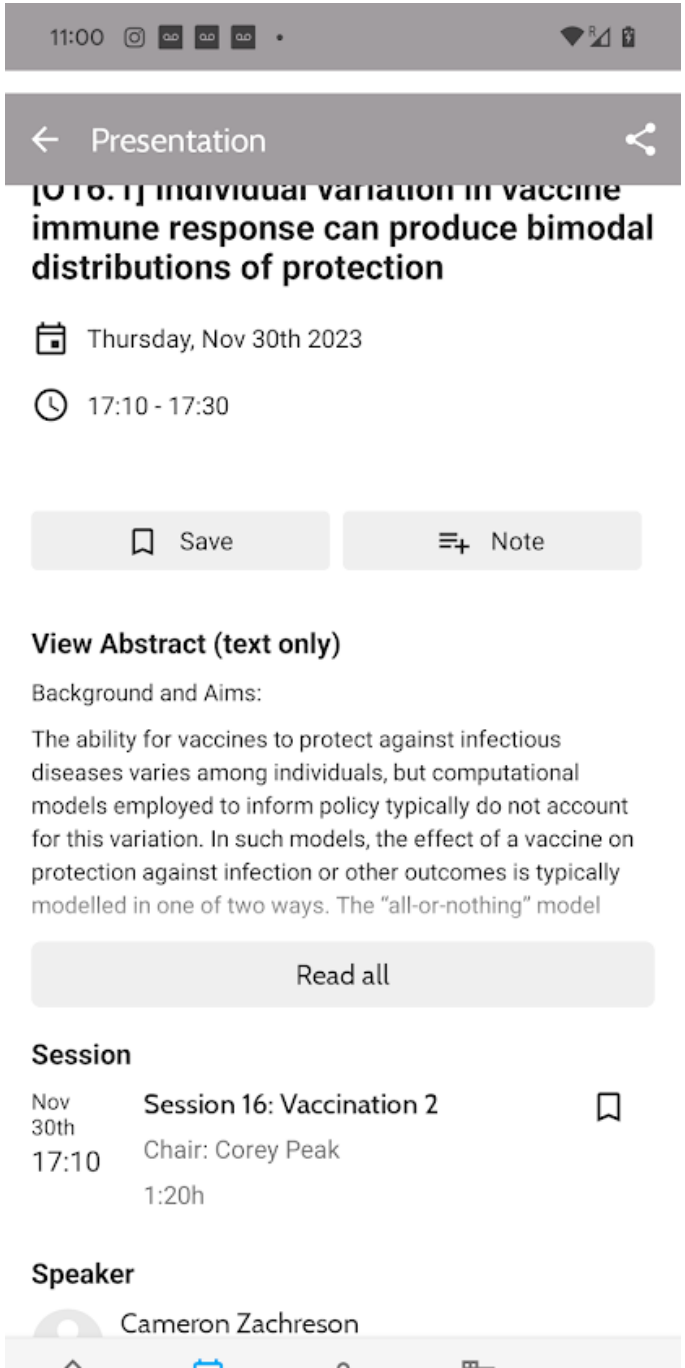

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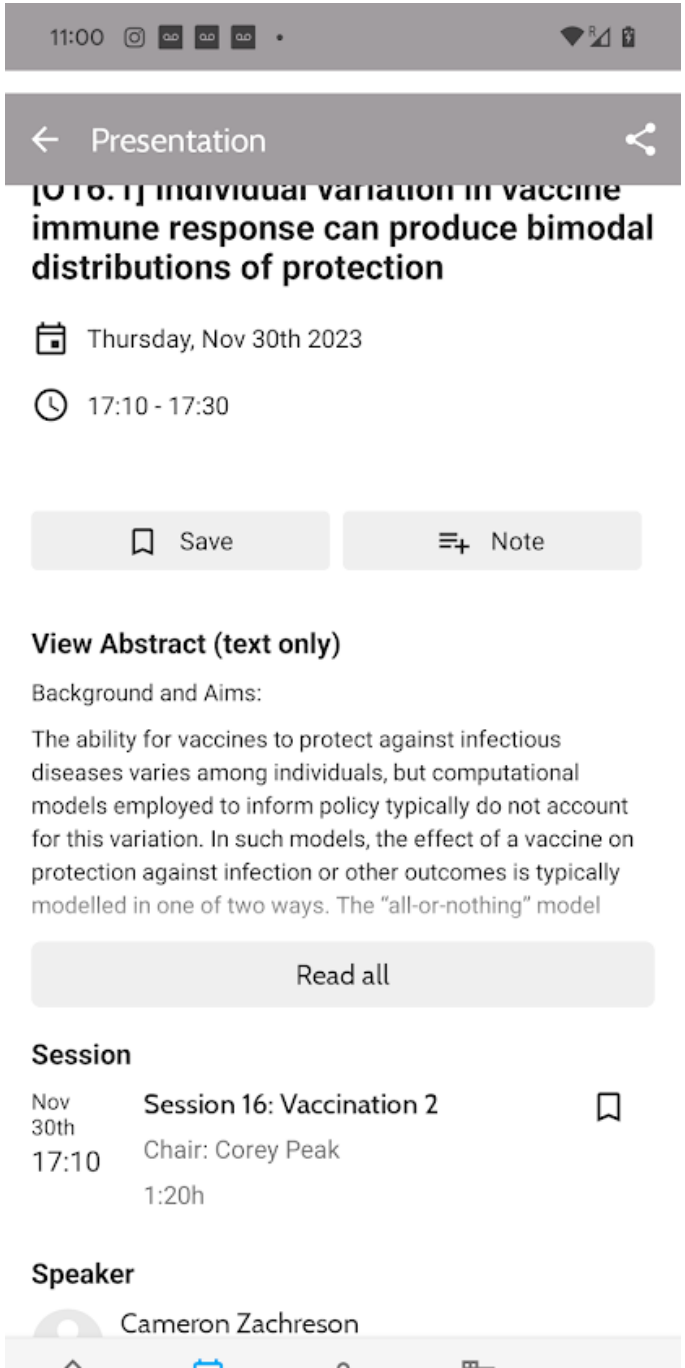

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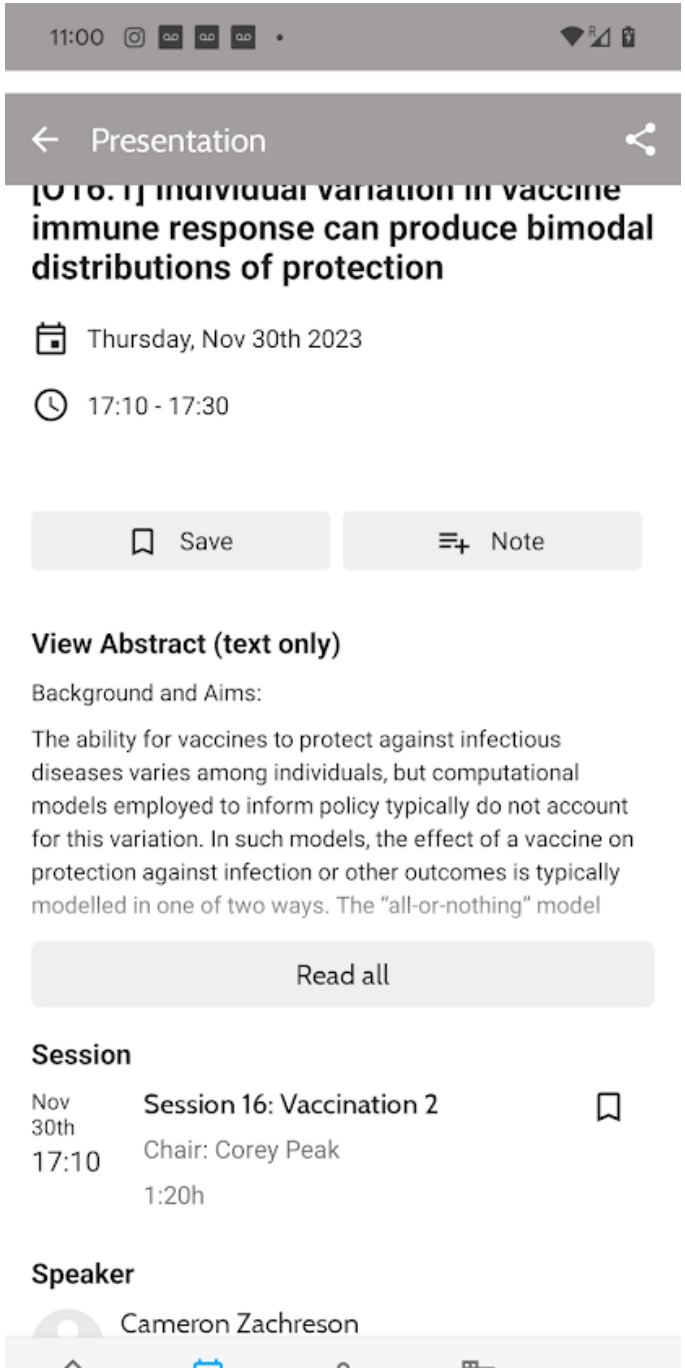

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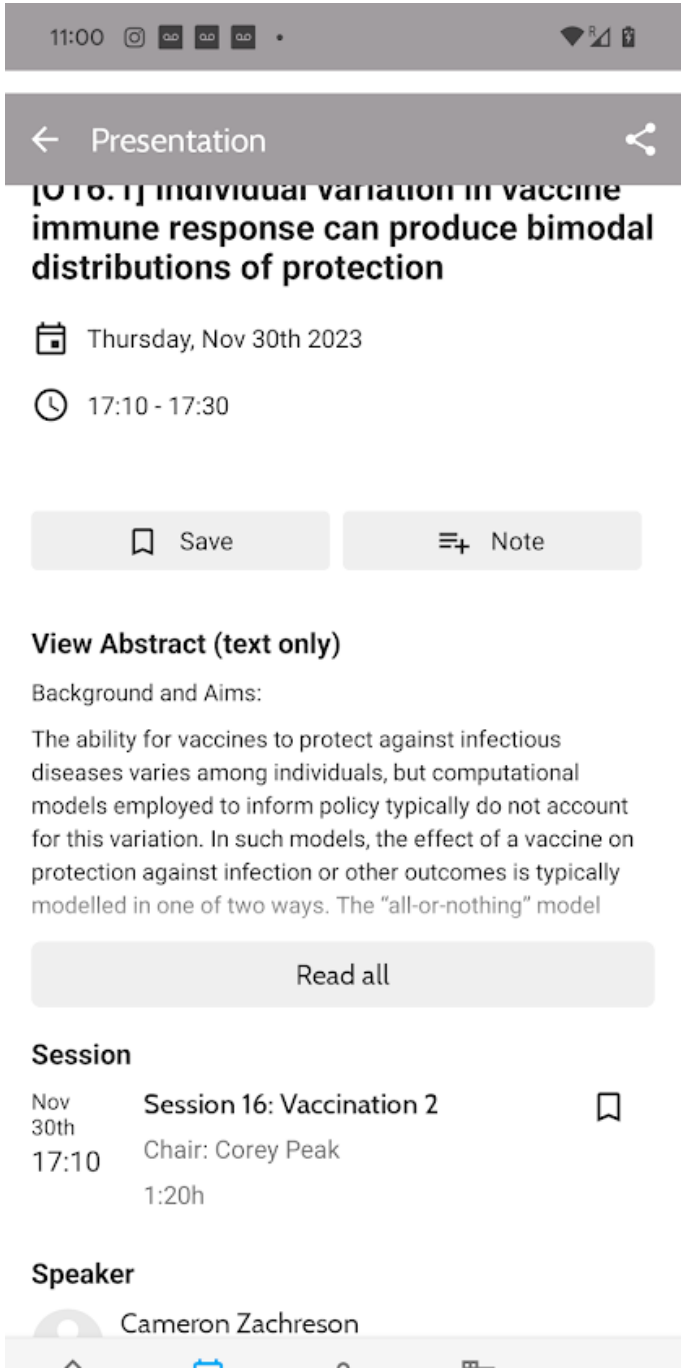

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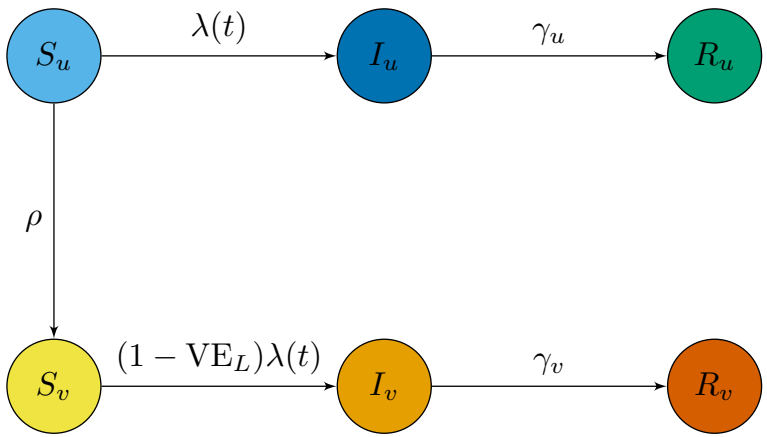

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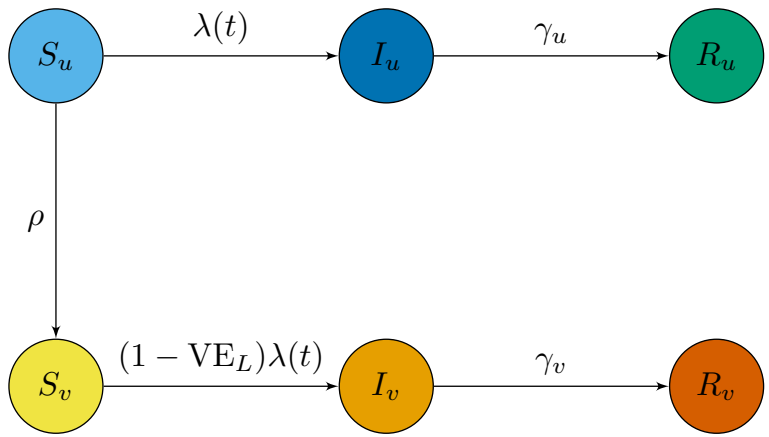

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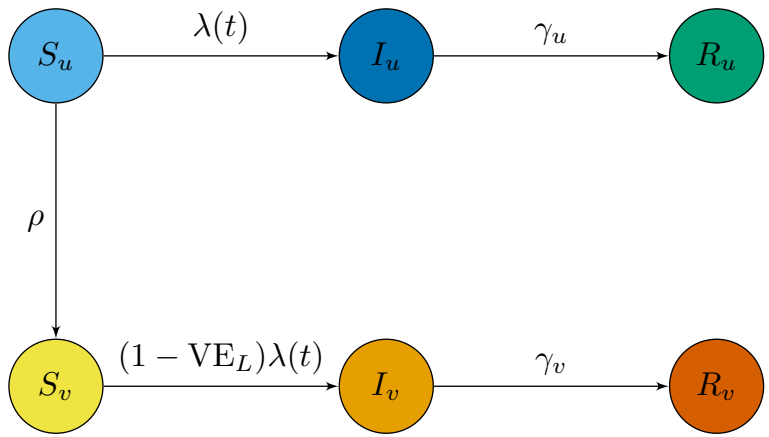
- I actively resist the flu, and then succumb to the same challenge next week!



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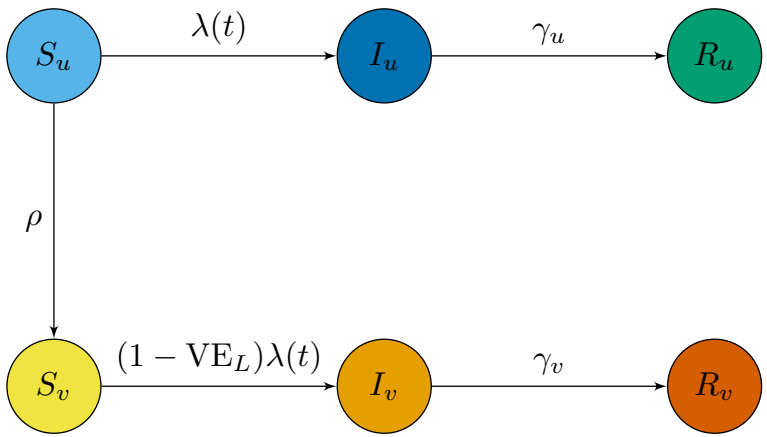

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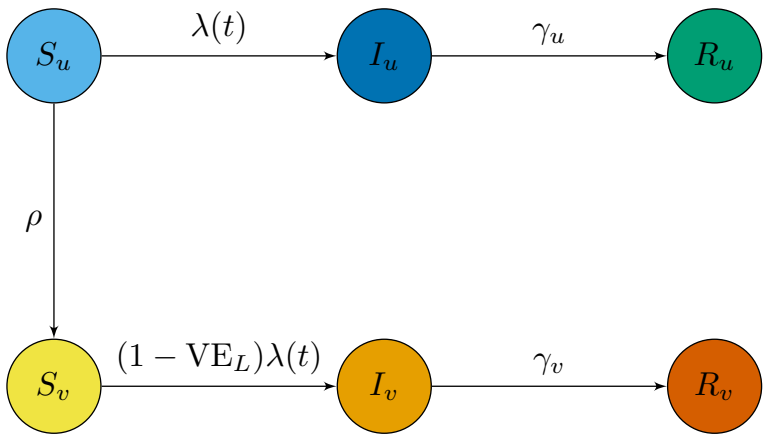

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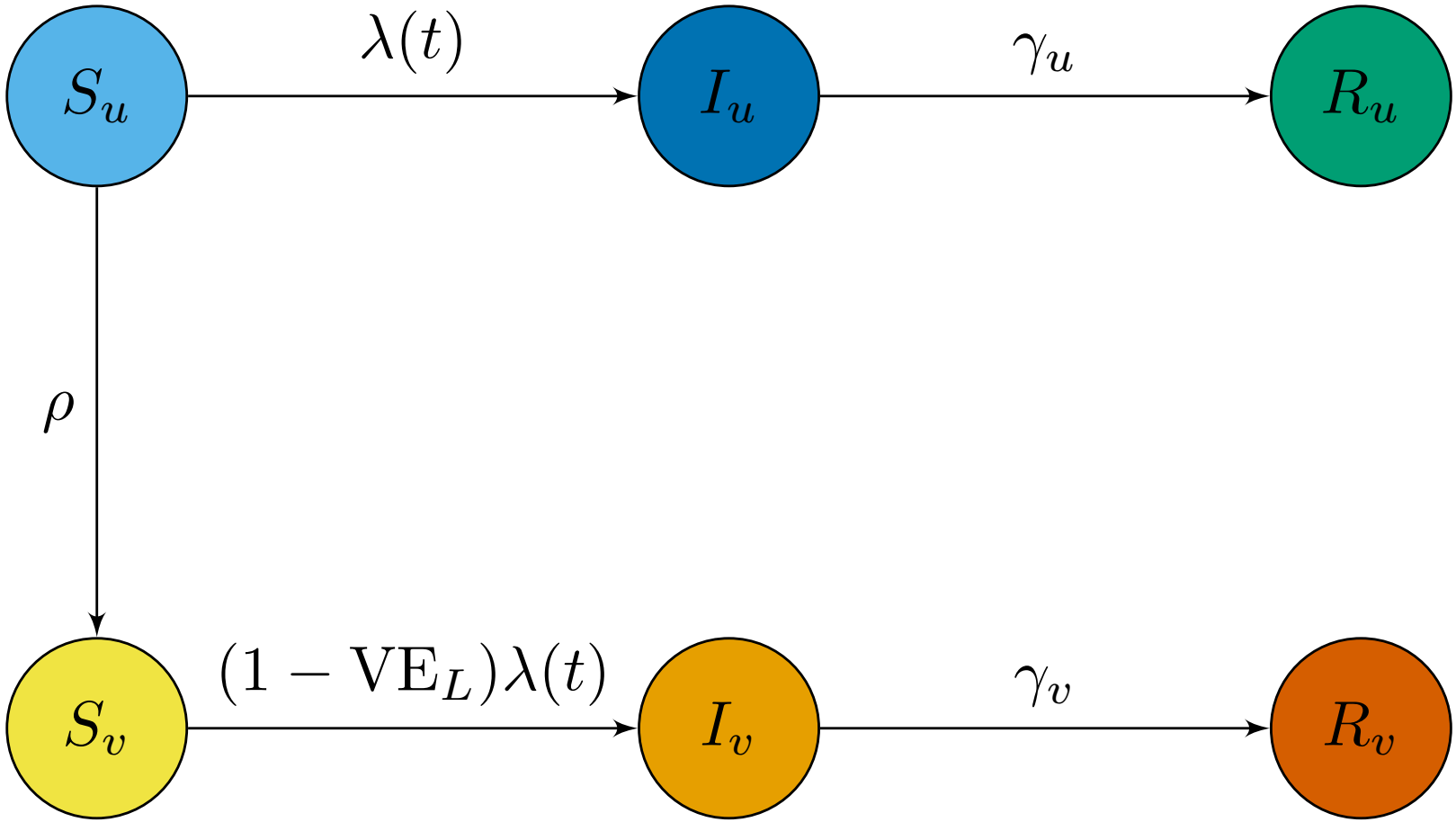
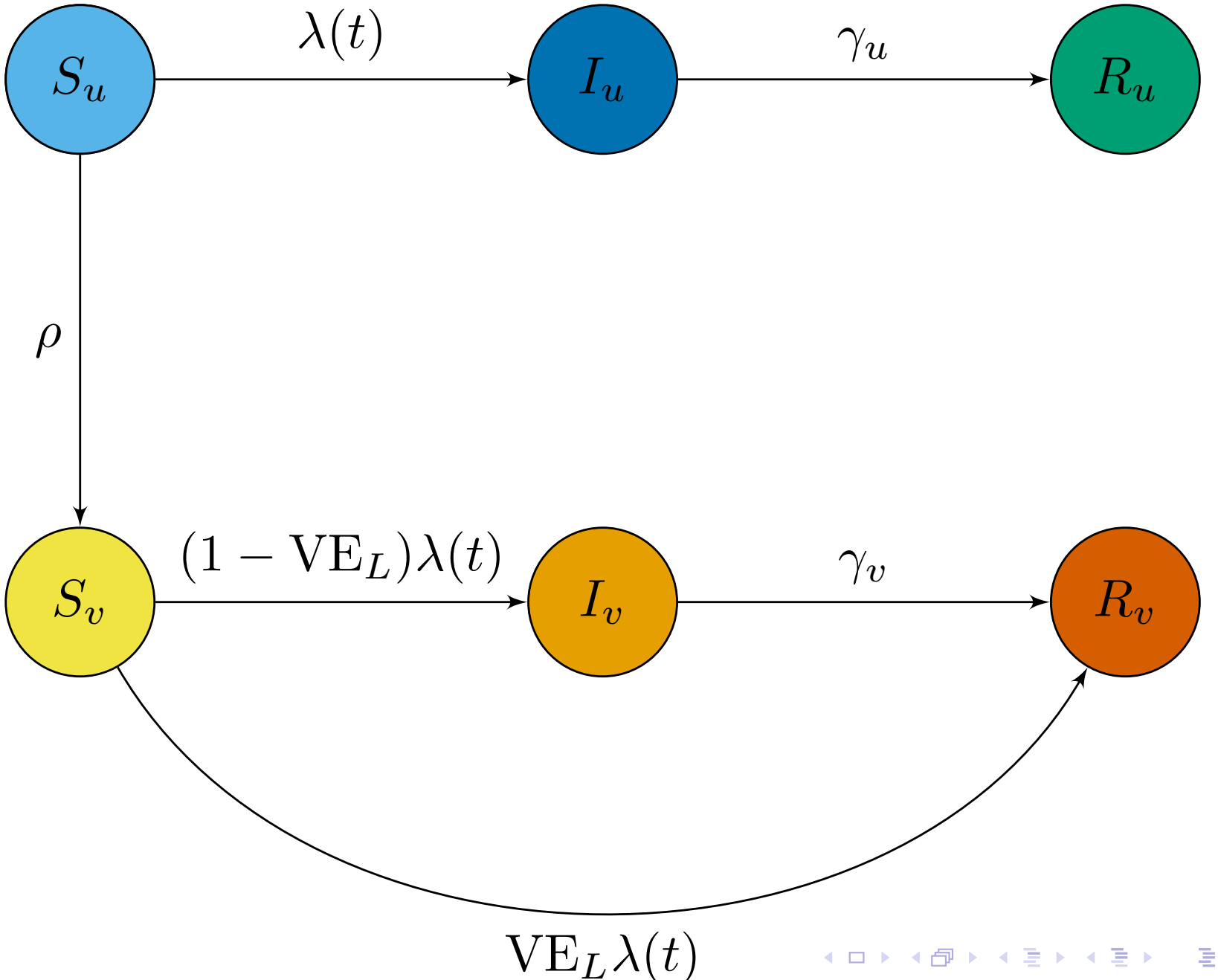
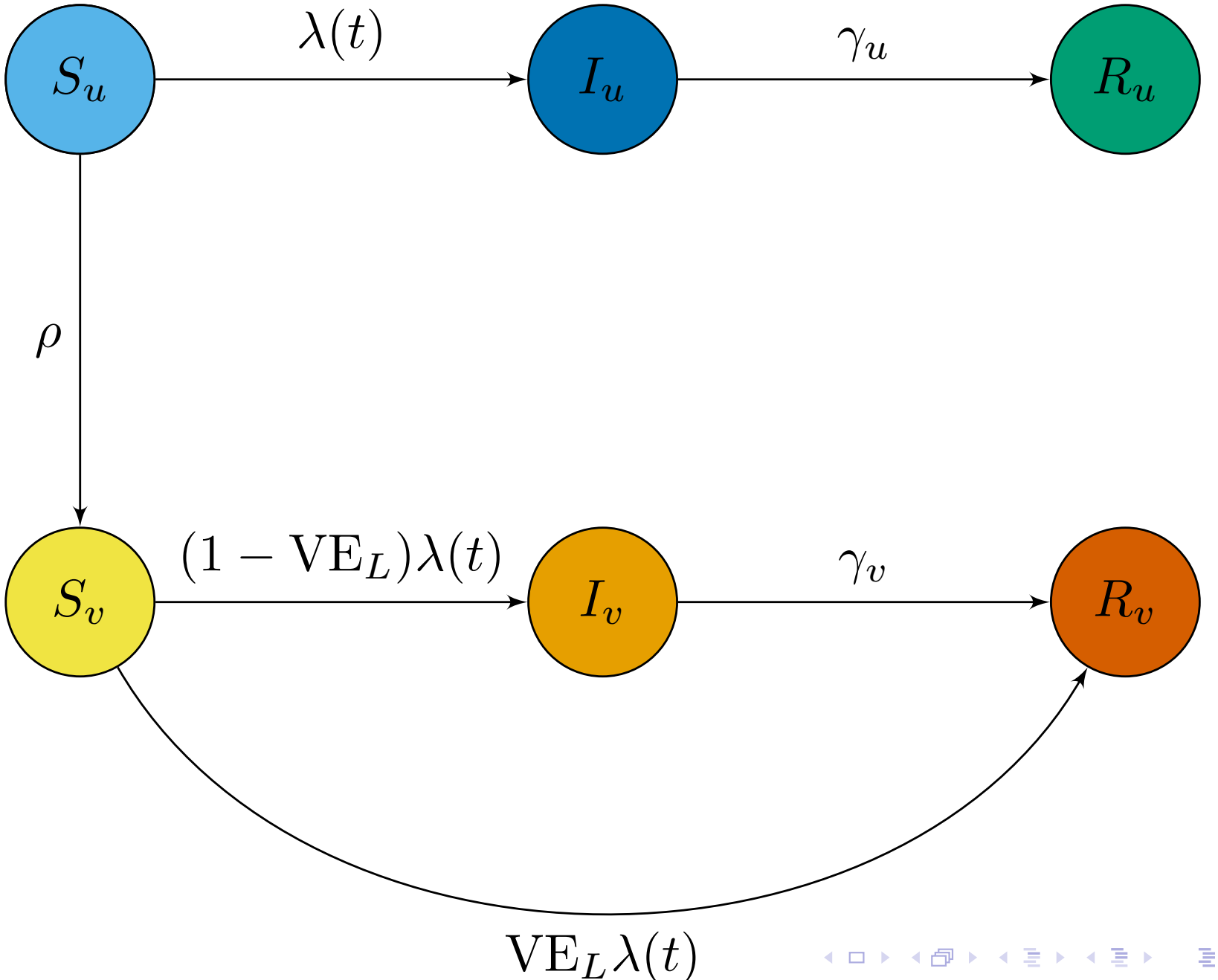

S_u
$\lambda(t)$
I_u
γ_u
R_u
ρ
S_v
$(1 - \mathrm{VE}_L)\lambda(t)$
I_v
γ_v
R_v

Leaky with boosting



Leaky with partial boosting



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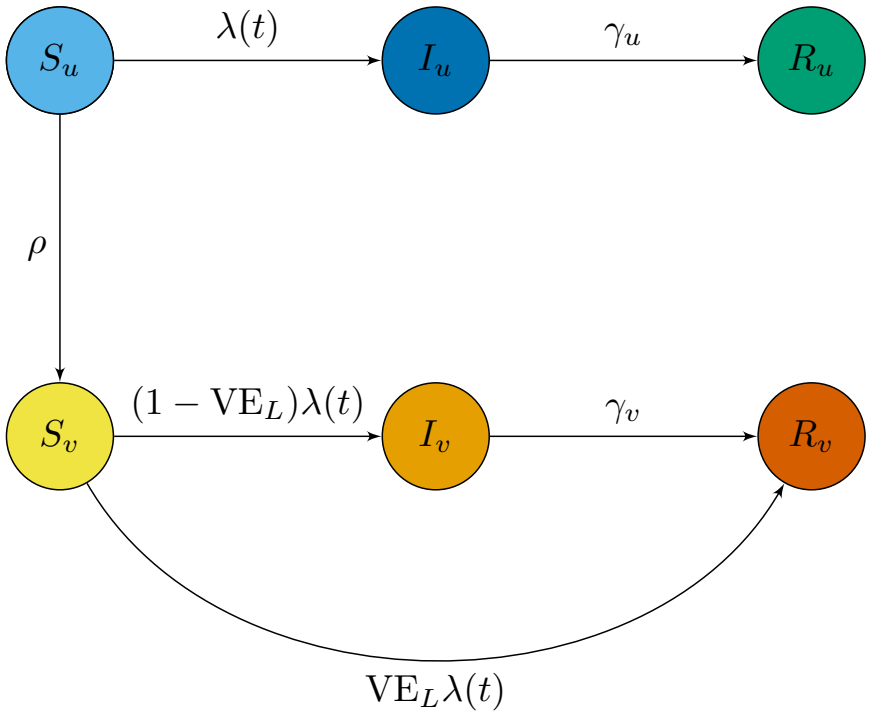
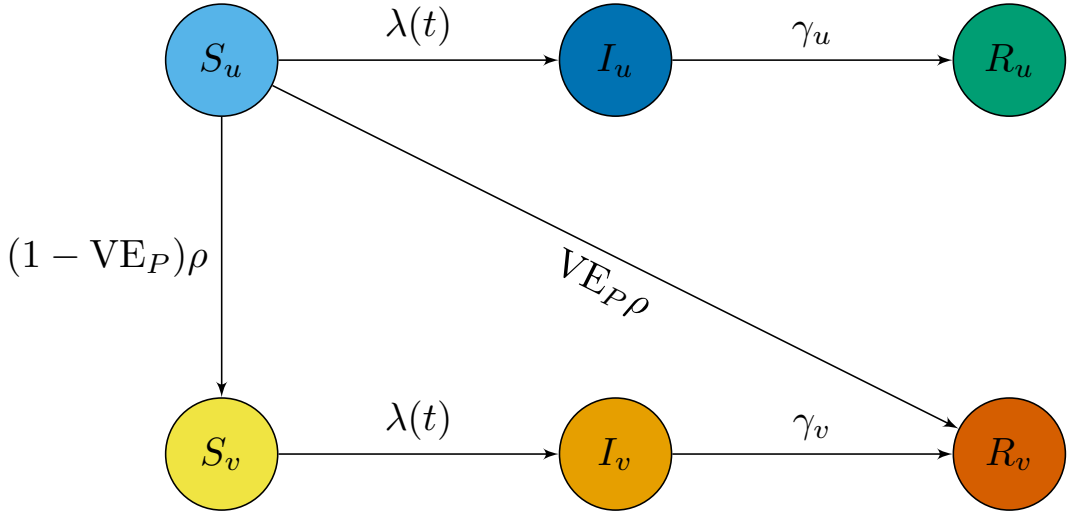
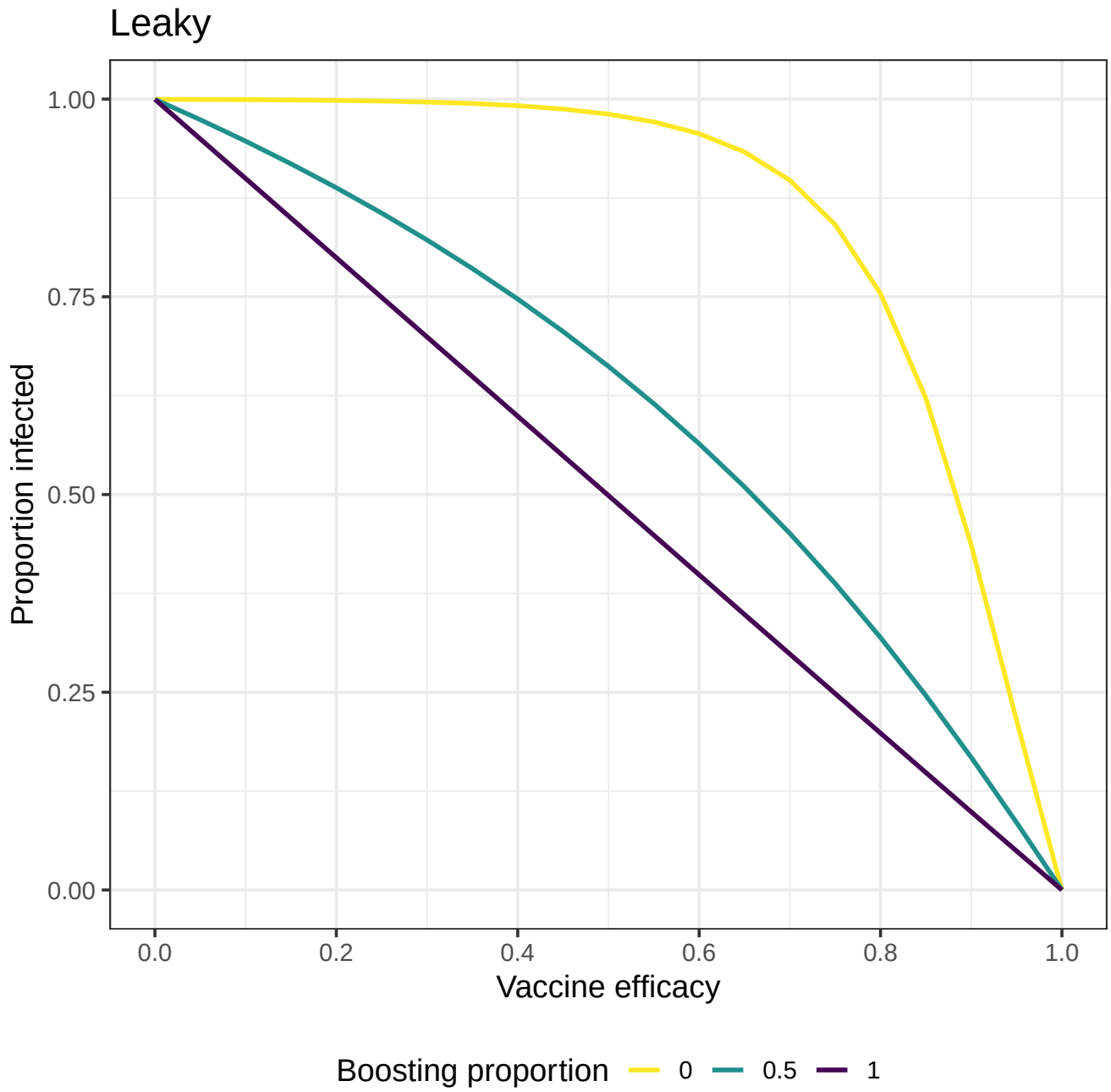
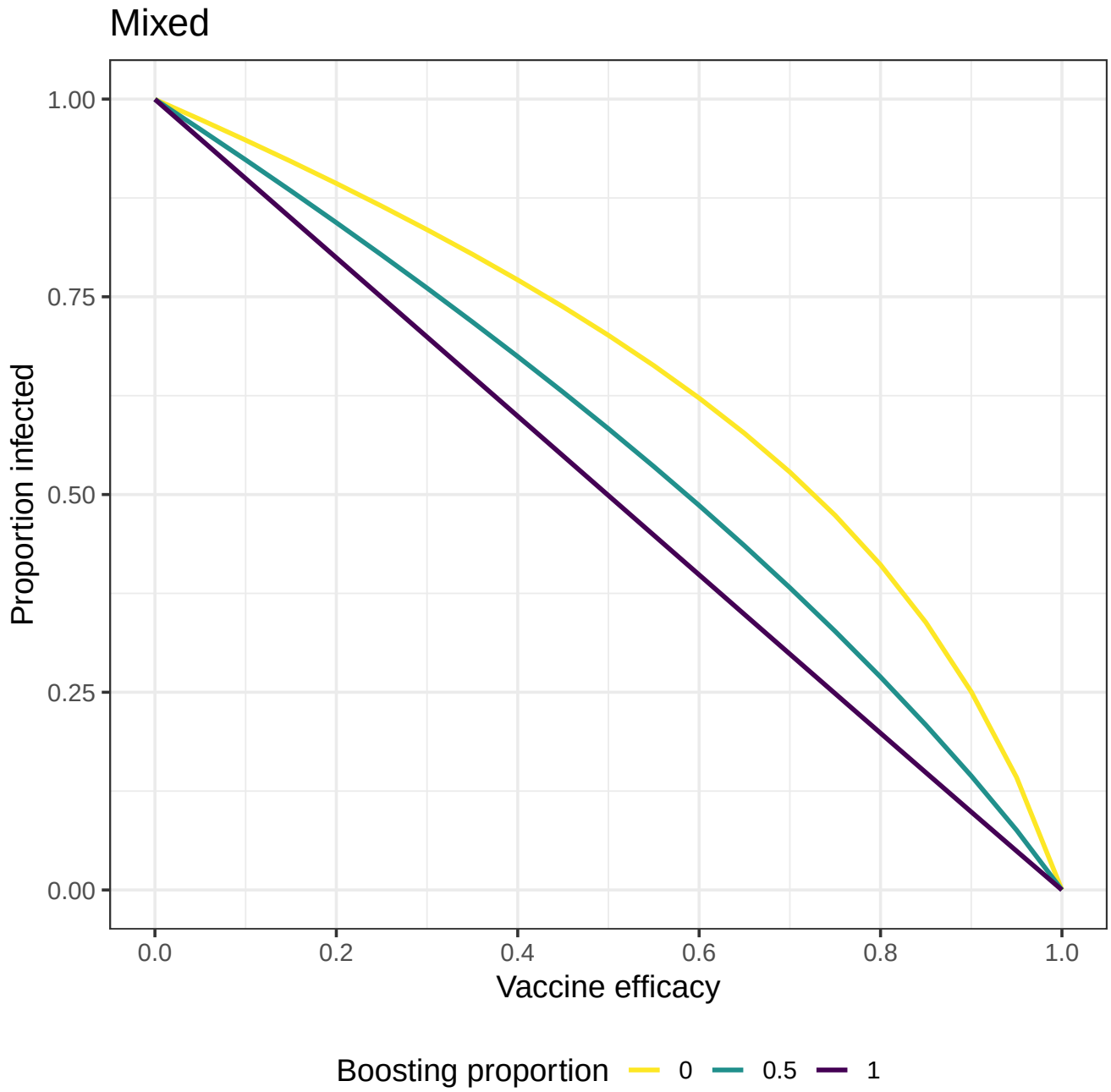
Leaky with boosting v. polarized






Leaky
1.00
0.75
0.50
0.25
0.00
Proportion infected
0.0
0.2
0.4
0.6
0.8
1.0
Vaccine efficacy
Boosting proportion
0
0.5
1


Mixed
1.00
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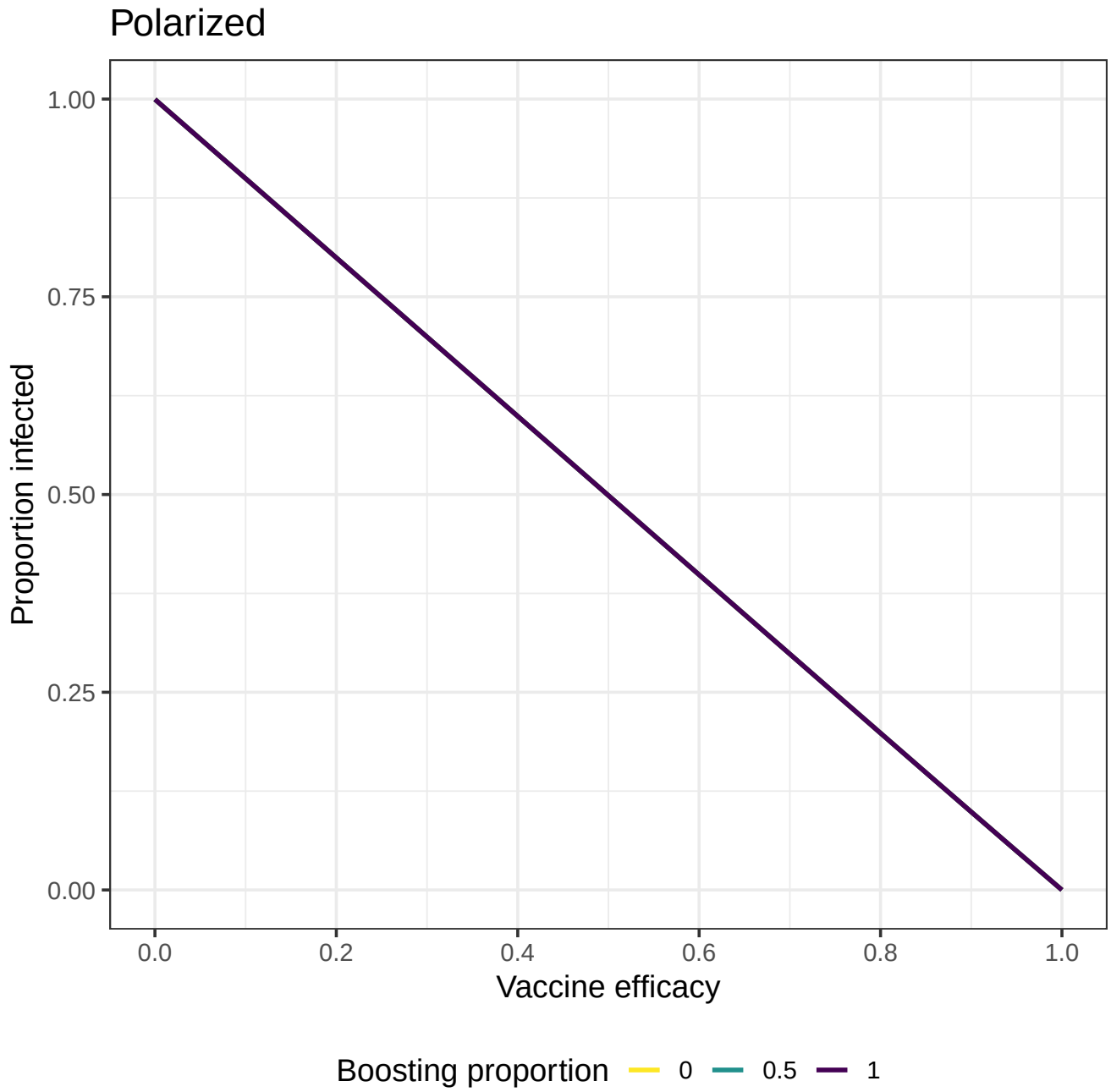
Polarized
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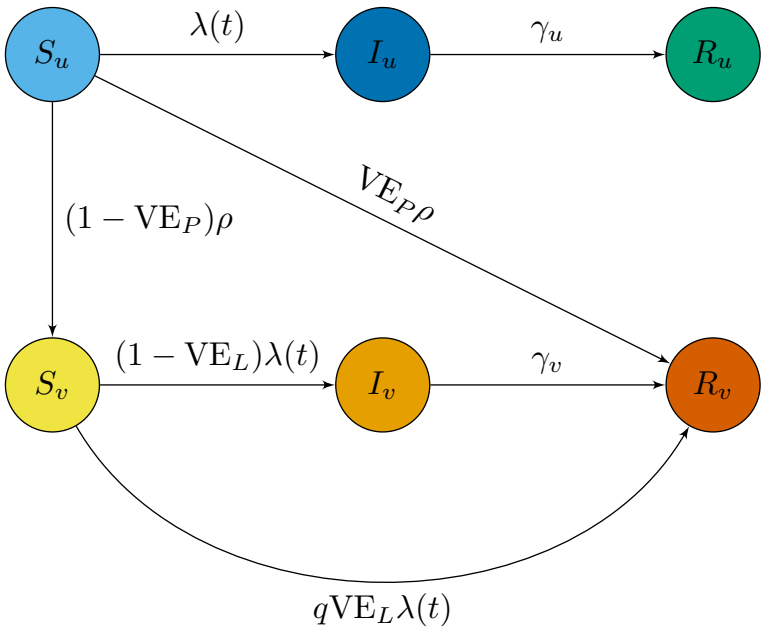
Transmission reduction



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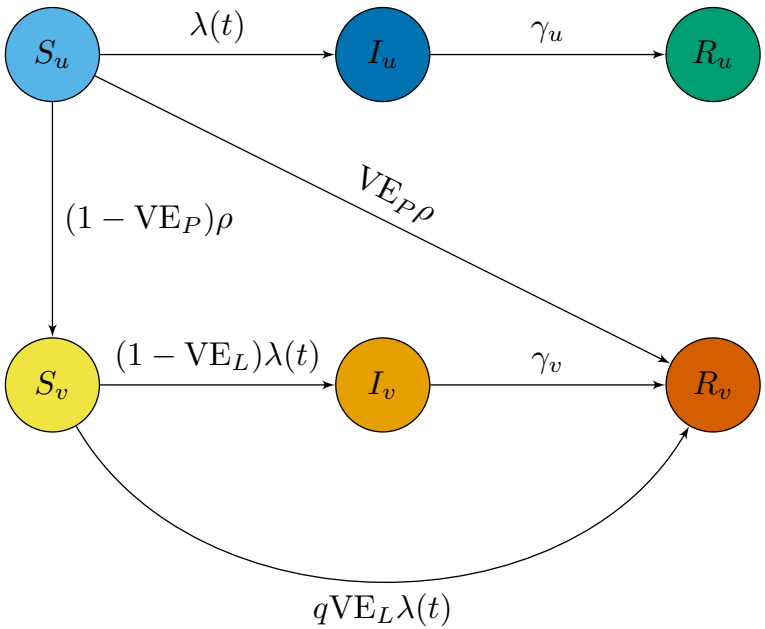

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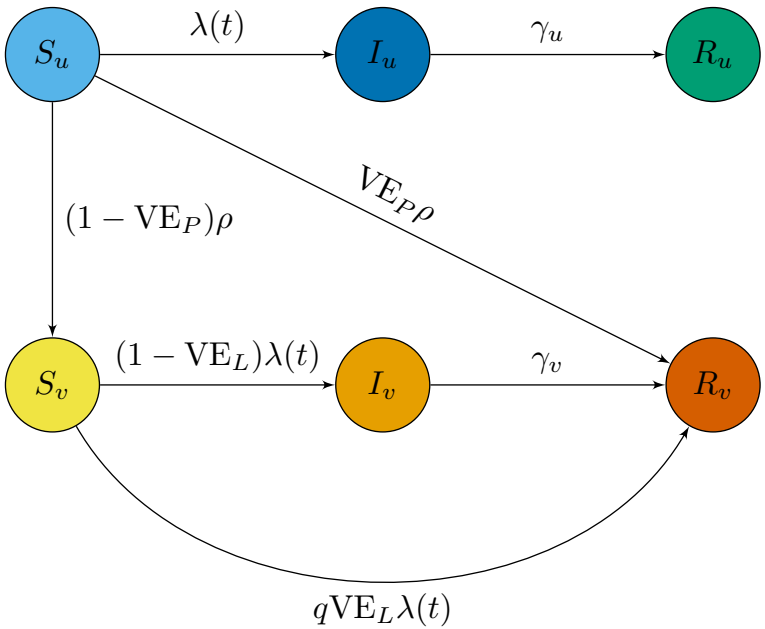

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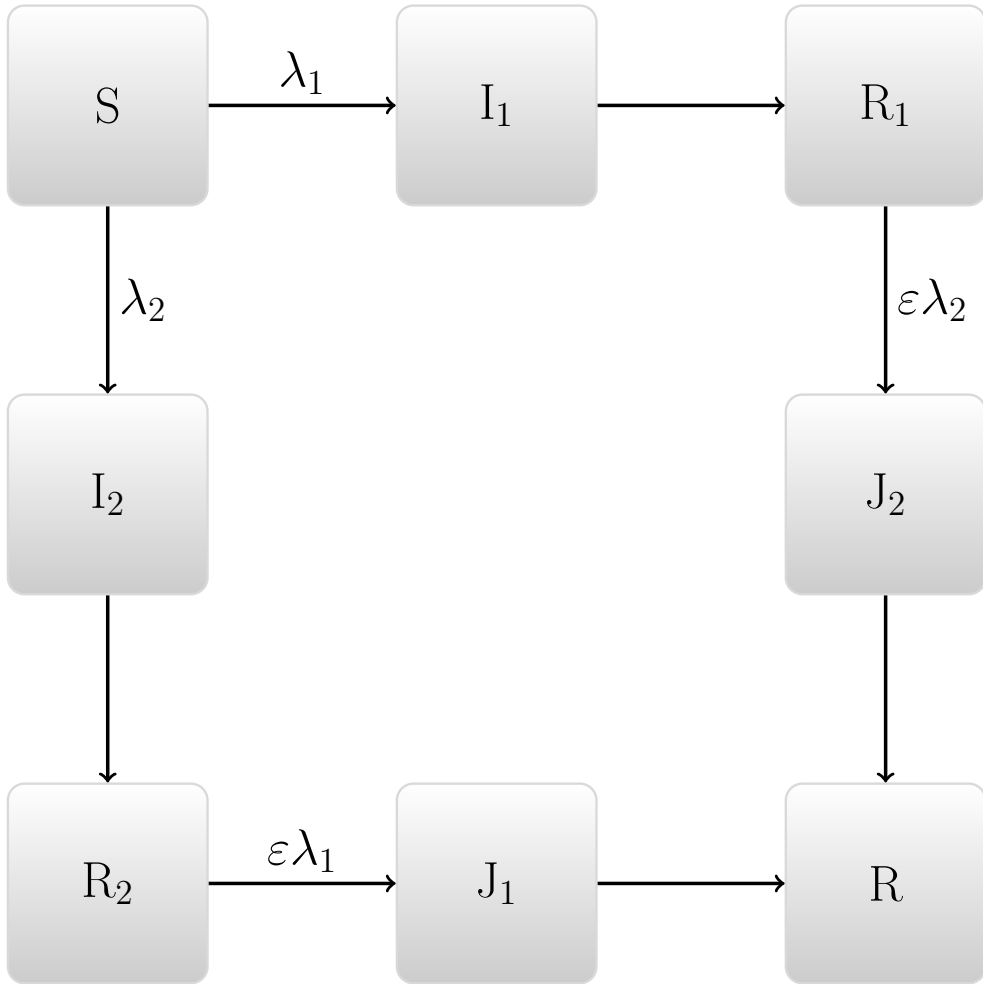
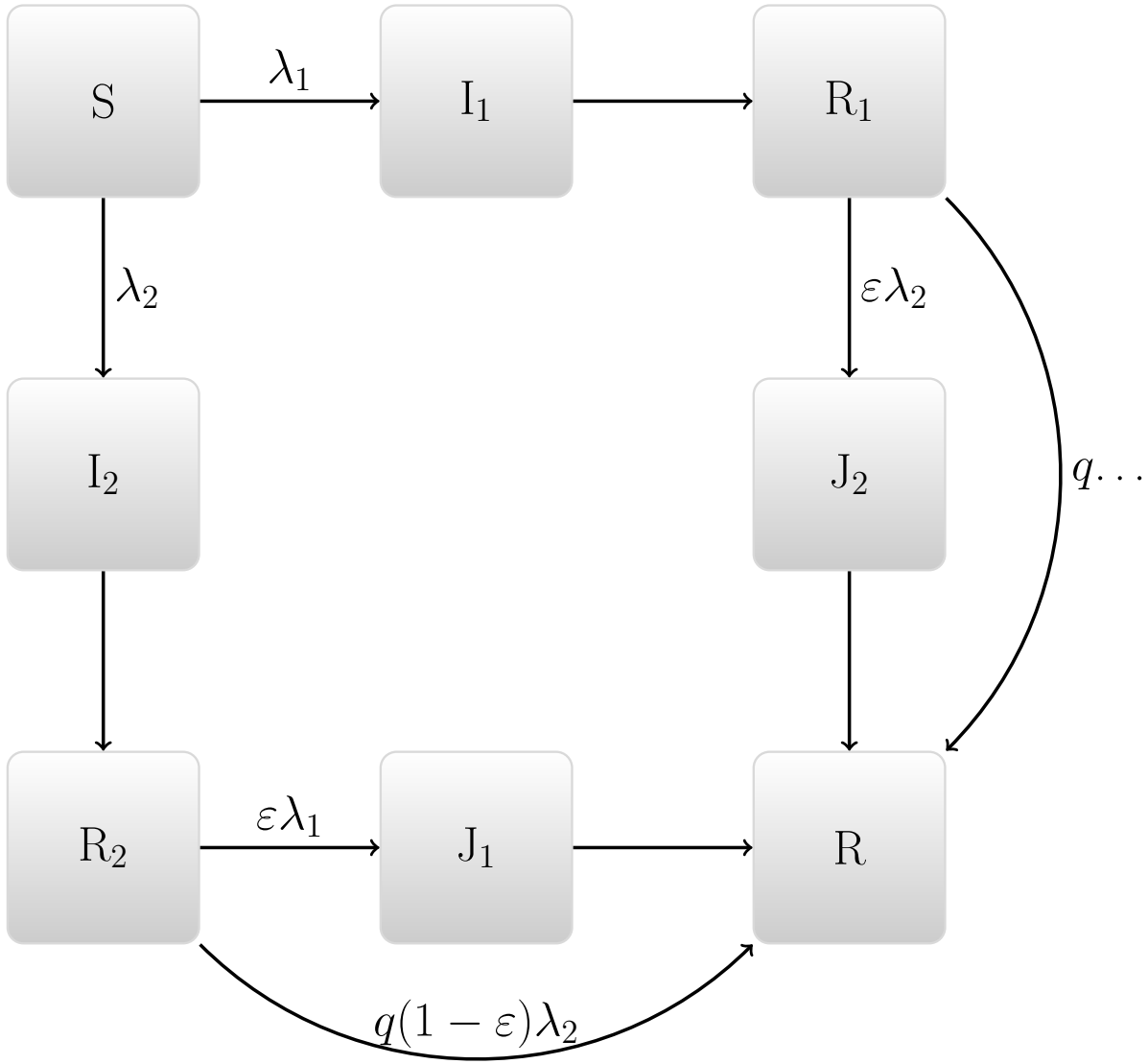


Interacting strains with boosting



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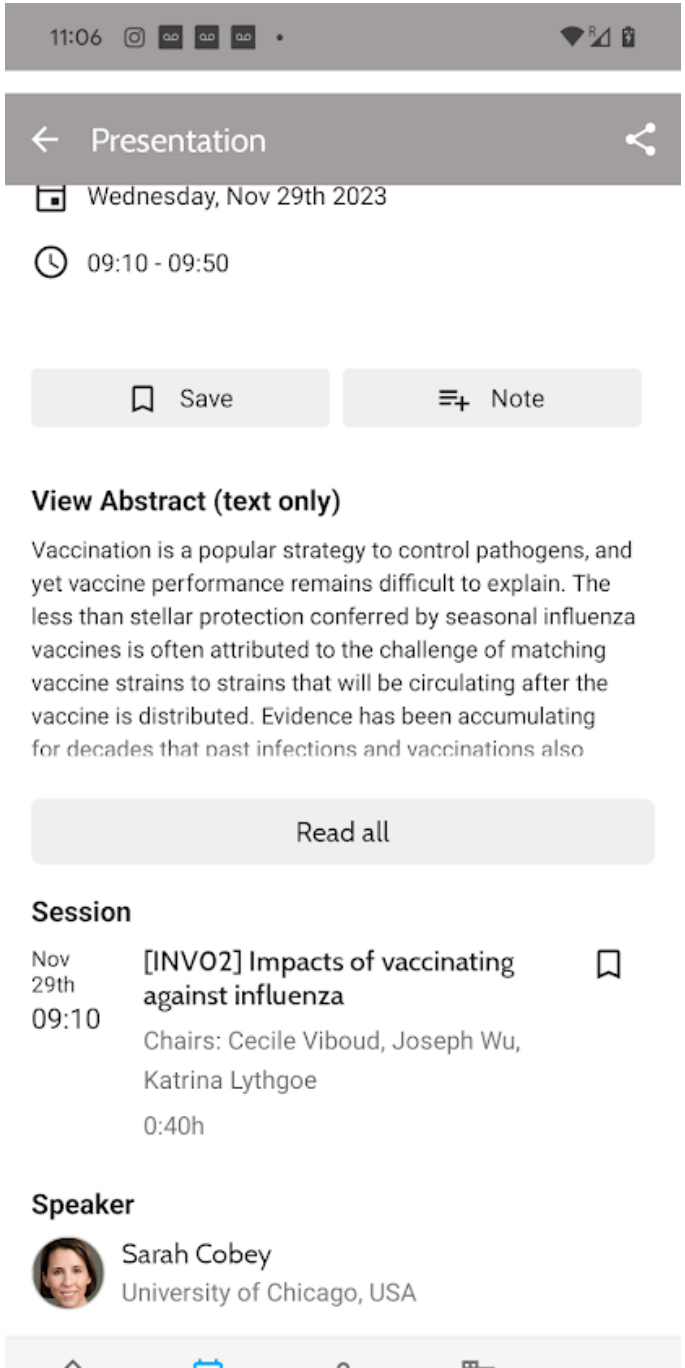

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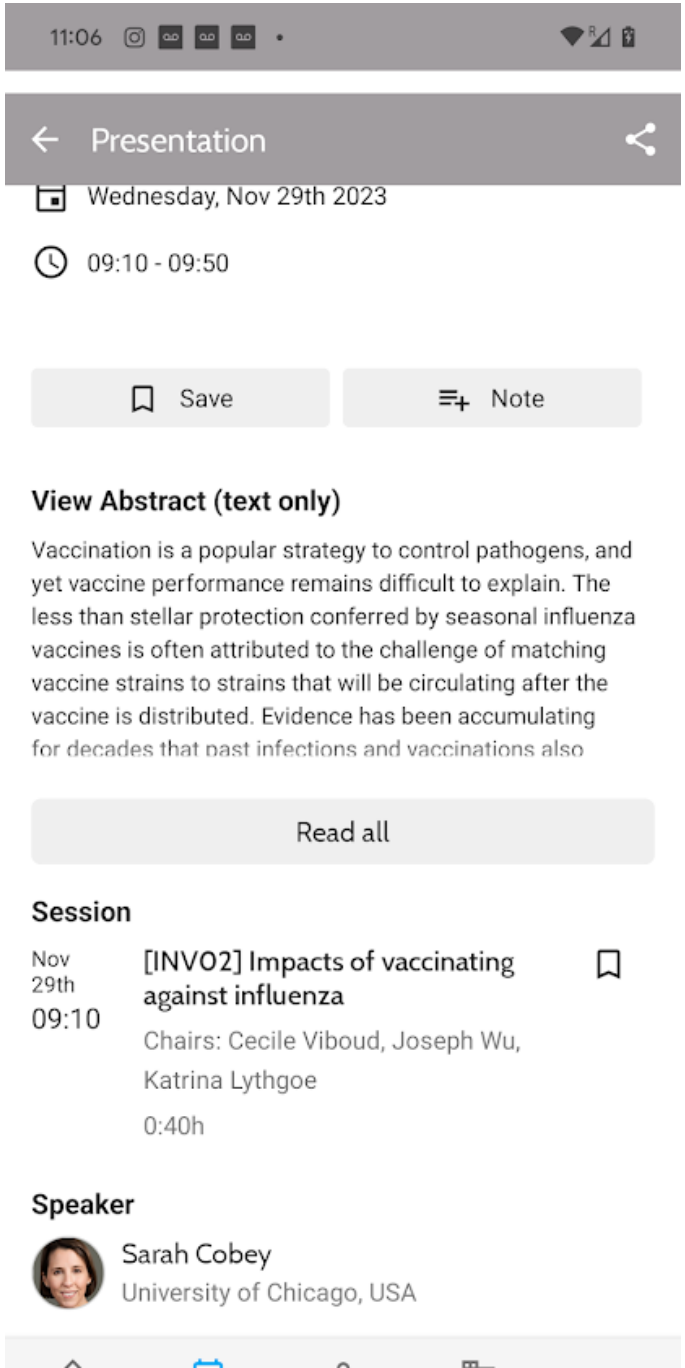

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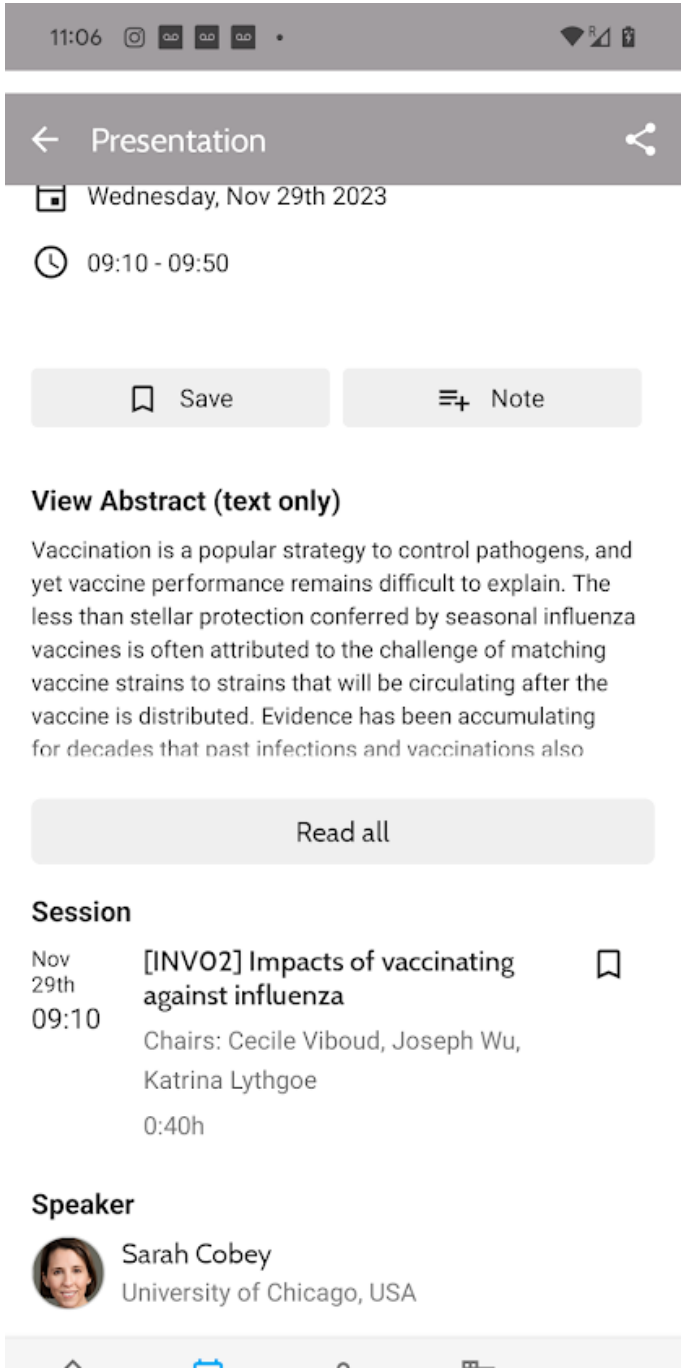

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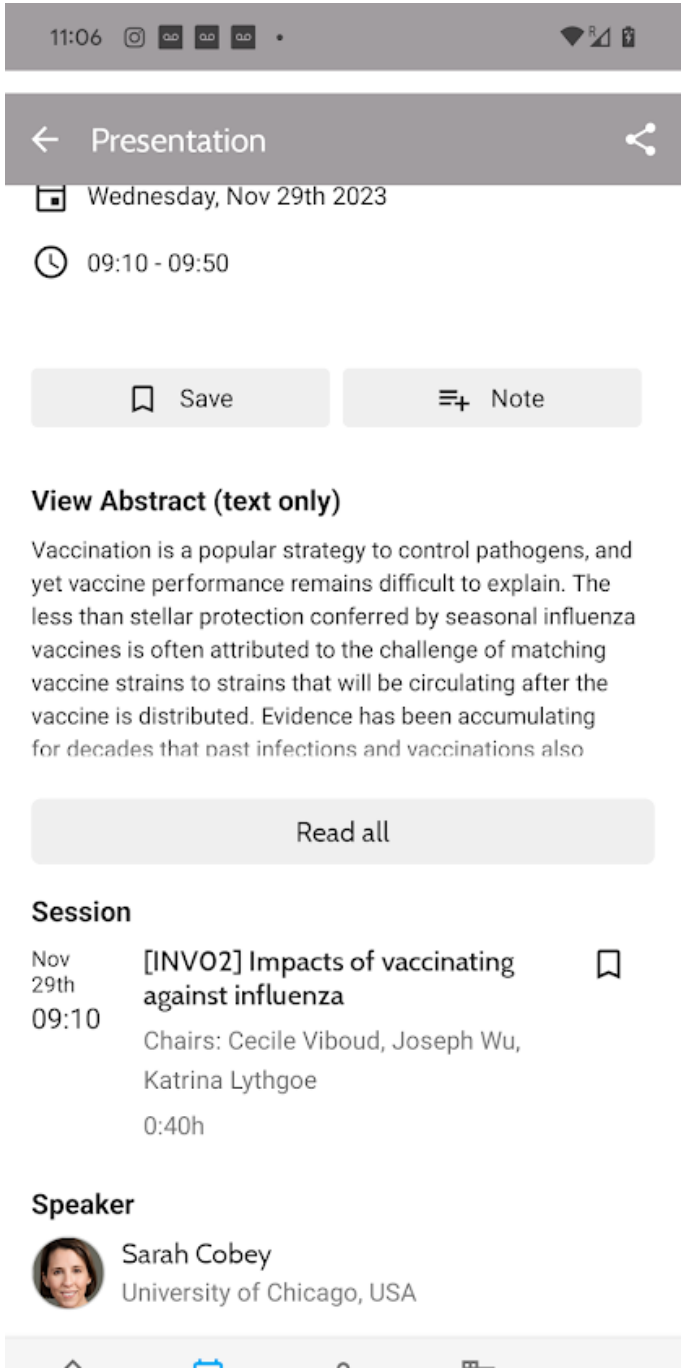
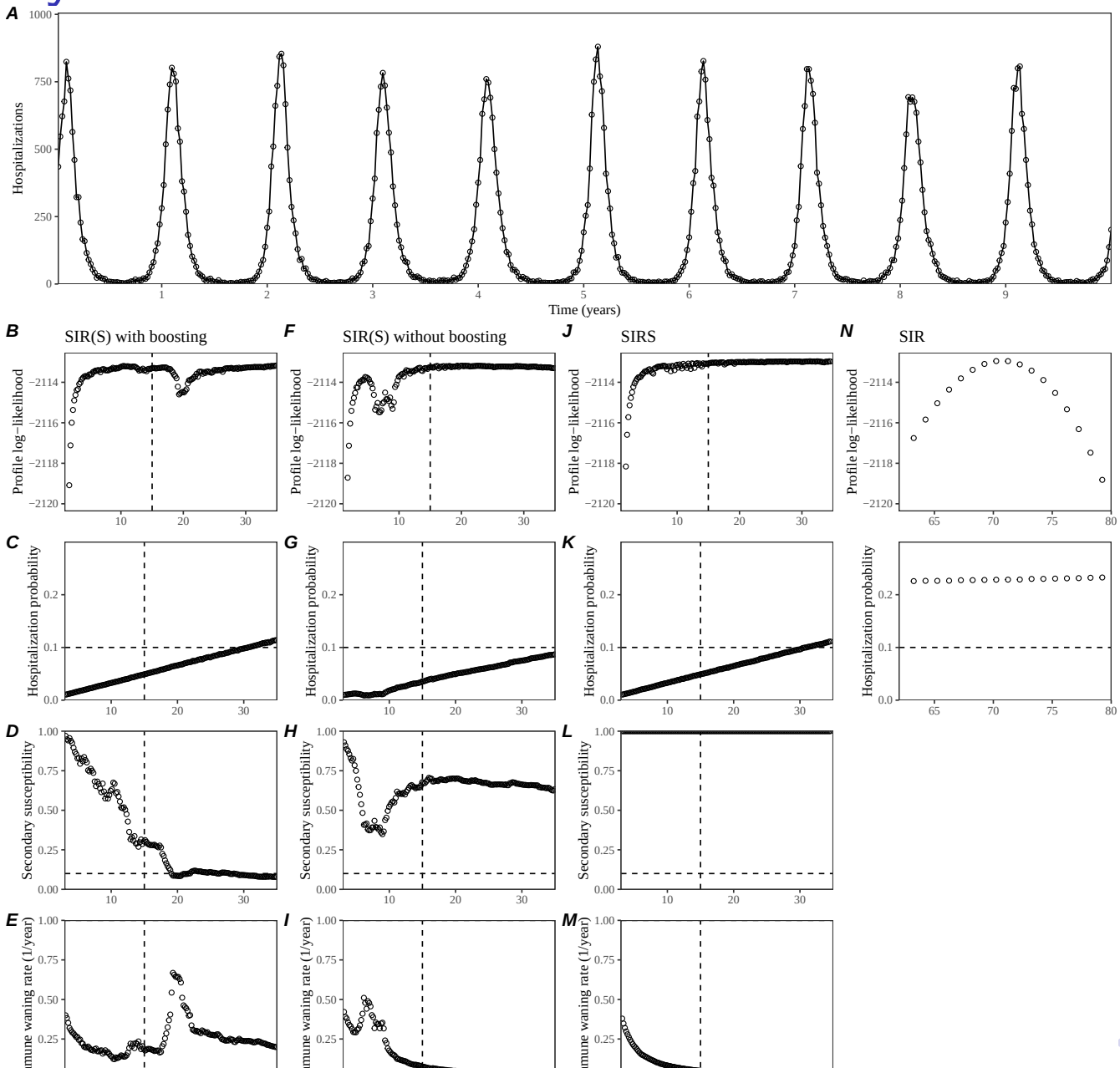


Estimating parameters from population-level data is intrinsically hard



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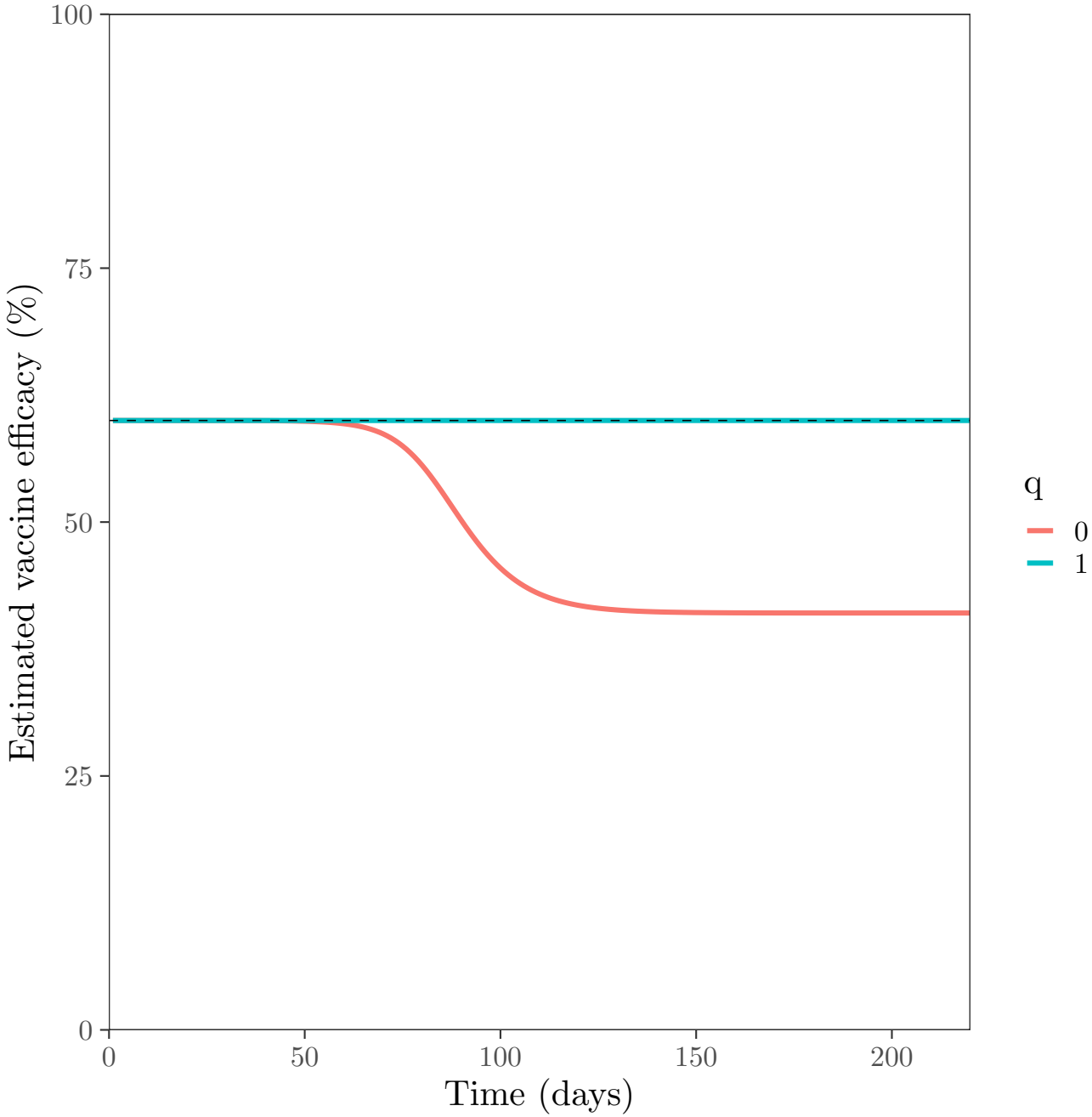
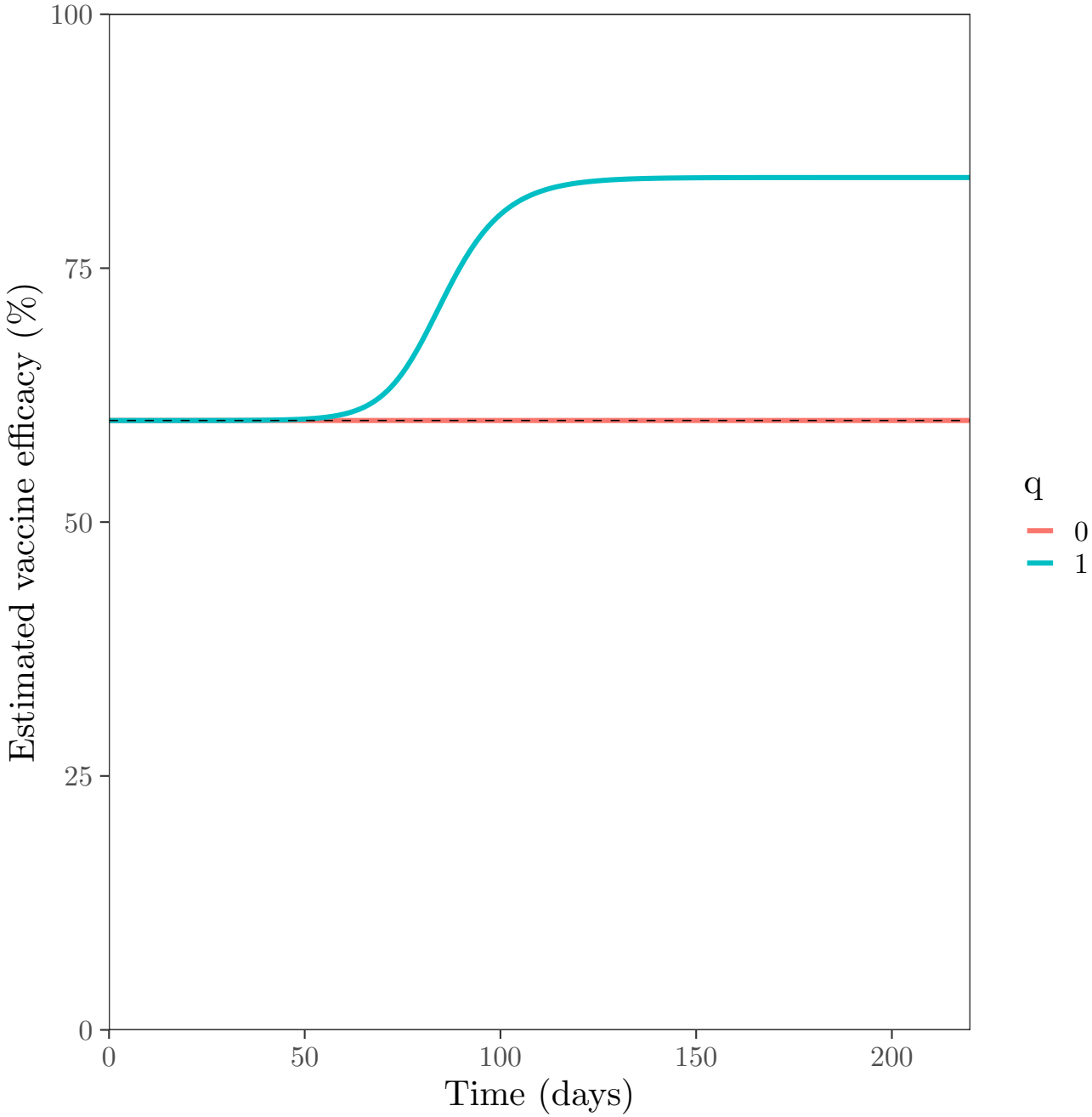
Incidence-based cross-protection



Hazard-based cross-protection



Skimming the surface

- Relationship to serology

Skimming the surface

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- Different outcomes (severe illness)

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Thanks

- Organizers and audience

Thanks

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- Daniel, Mike and other collaborators

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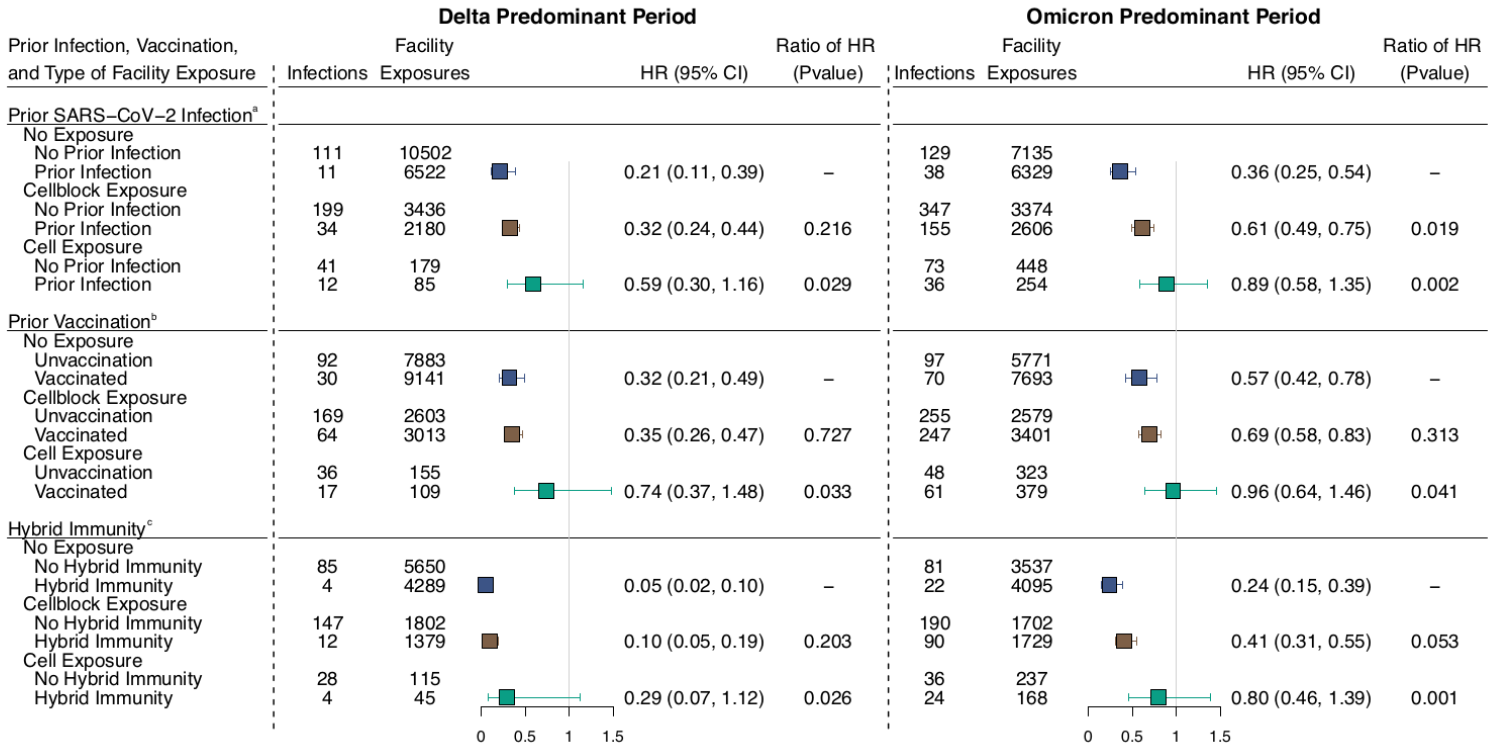
Connecticut correctional study



Lind et al., Nat Commun, 2023.

https://doi.org/10.1038/s41467-023-40750-8

Time scales of challenge

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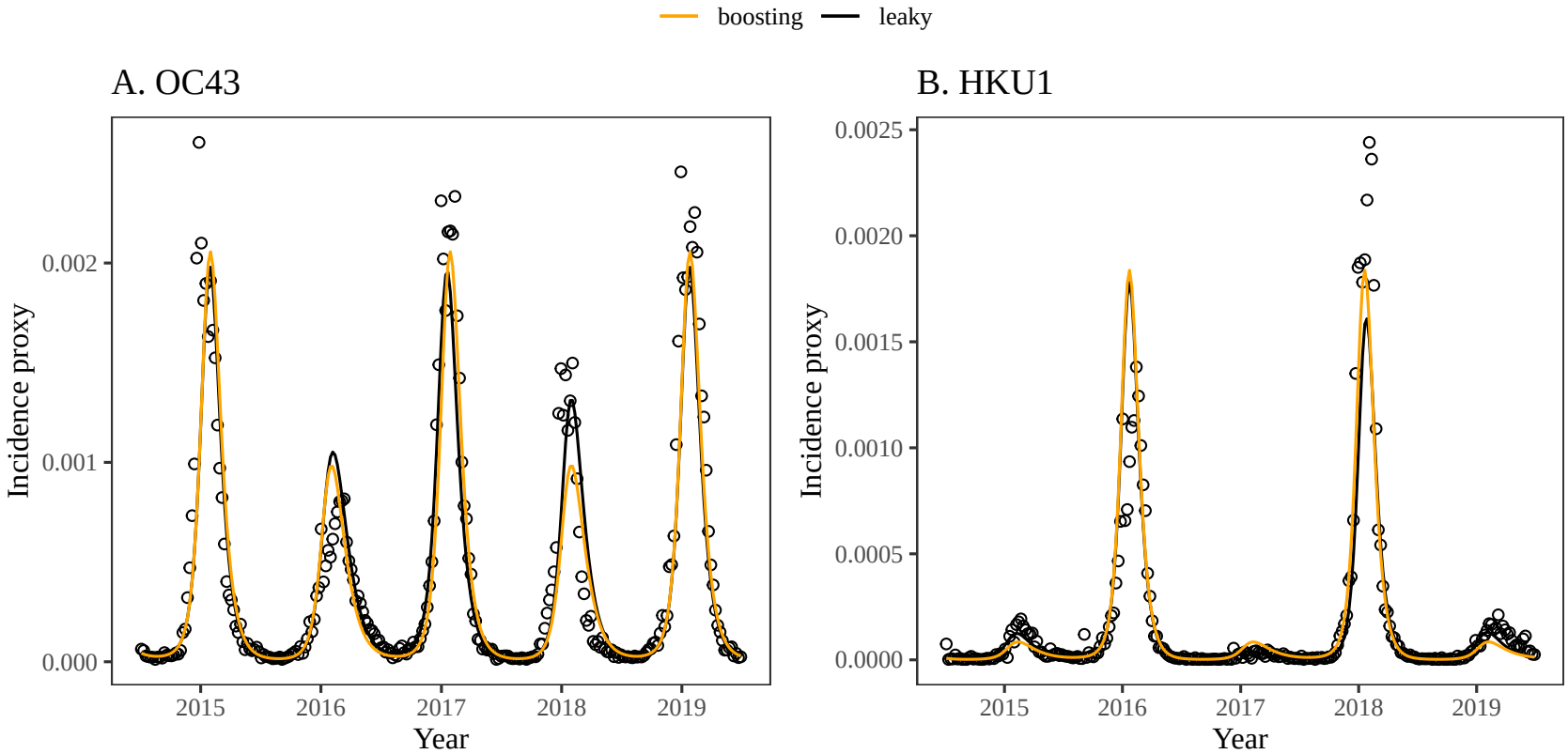
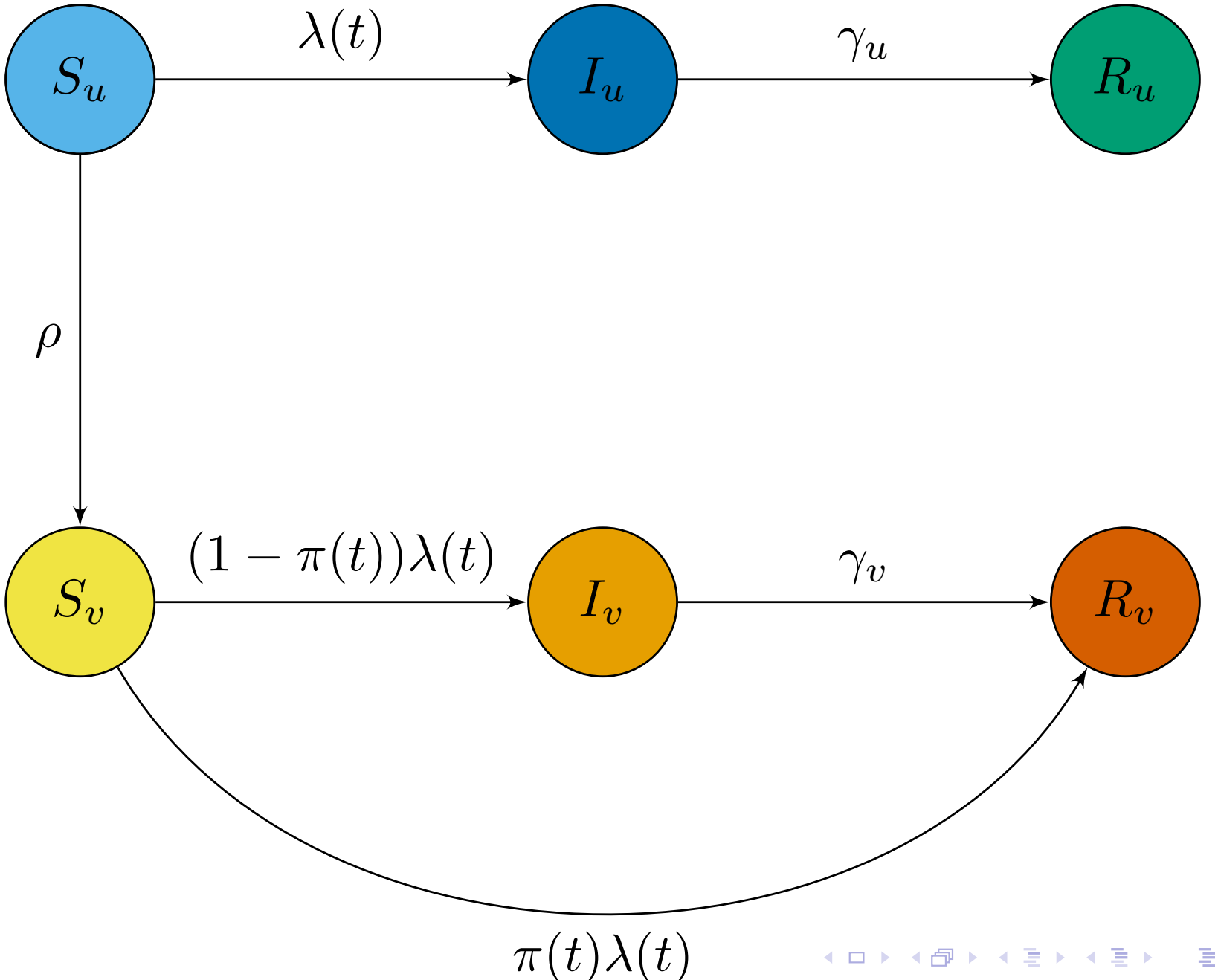
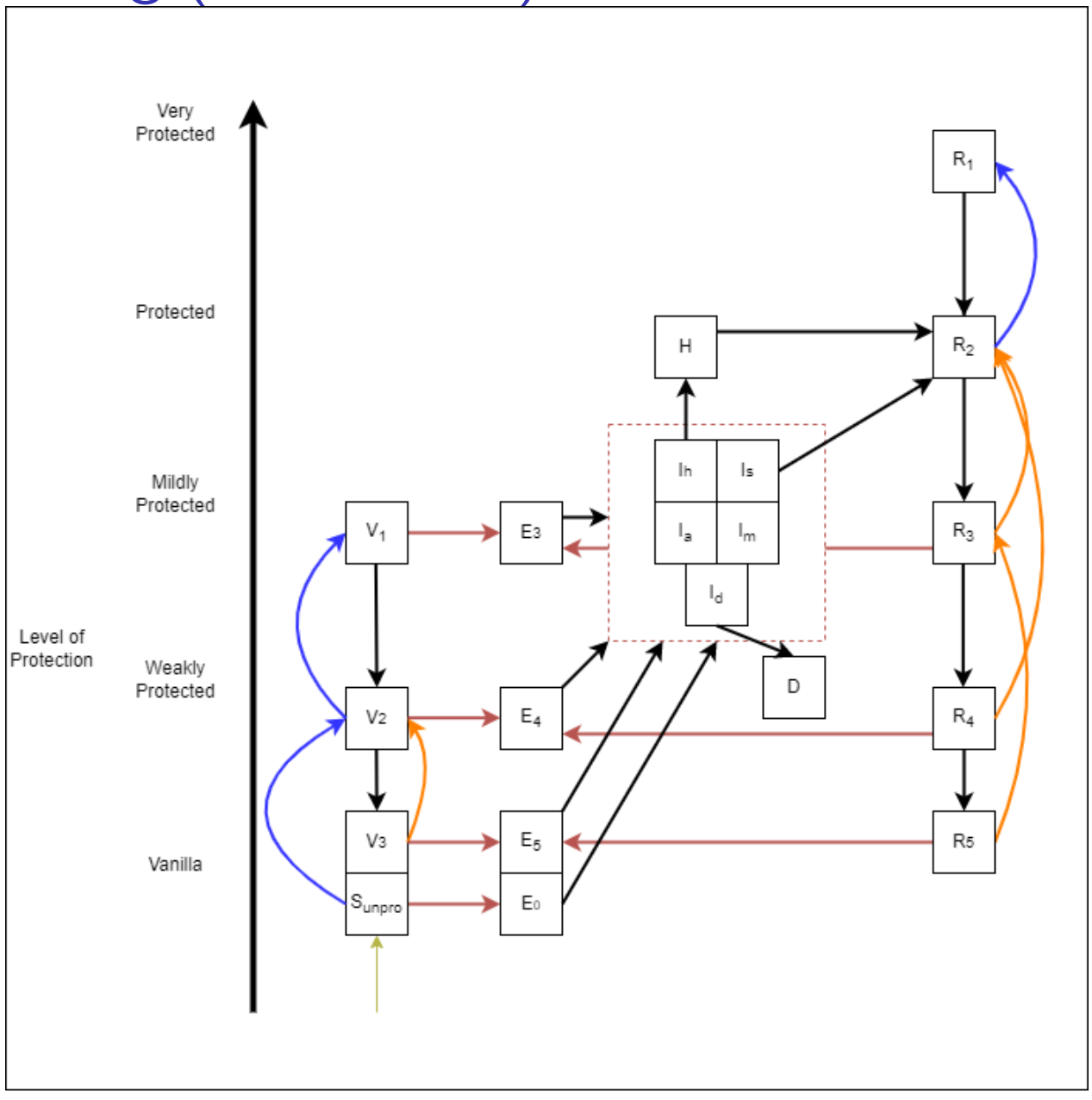
Coronavirus fits



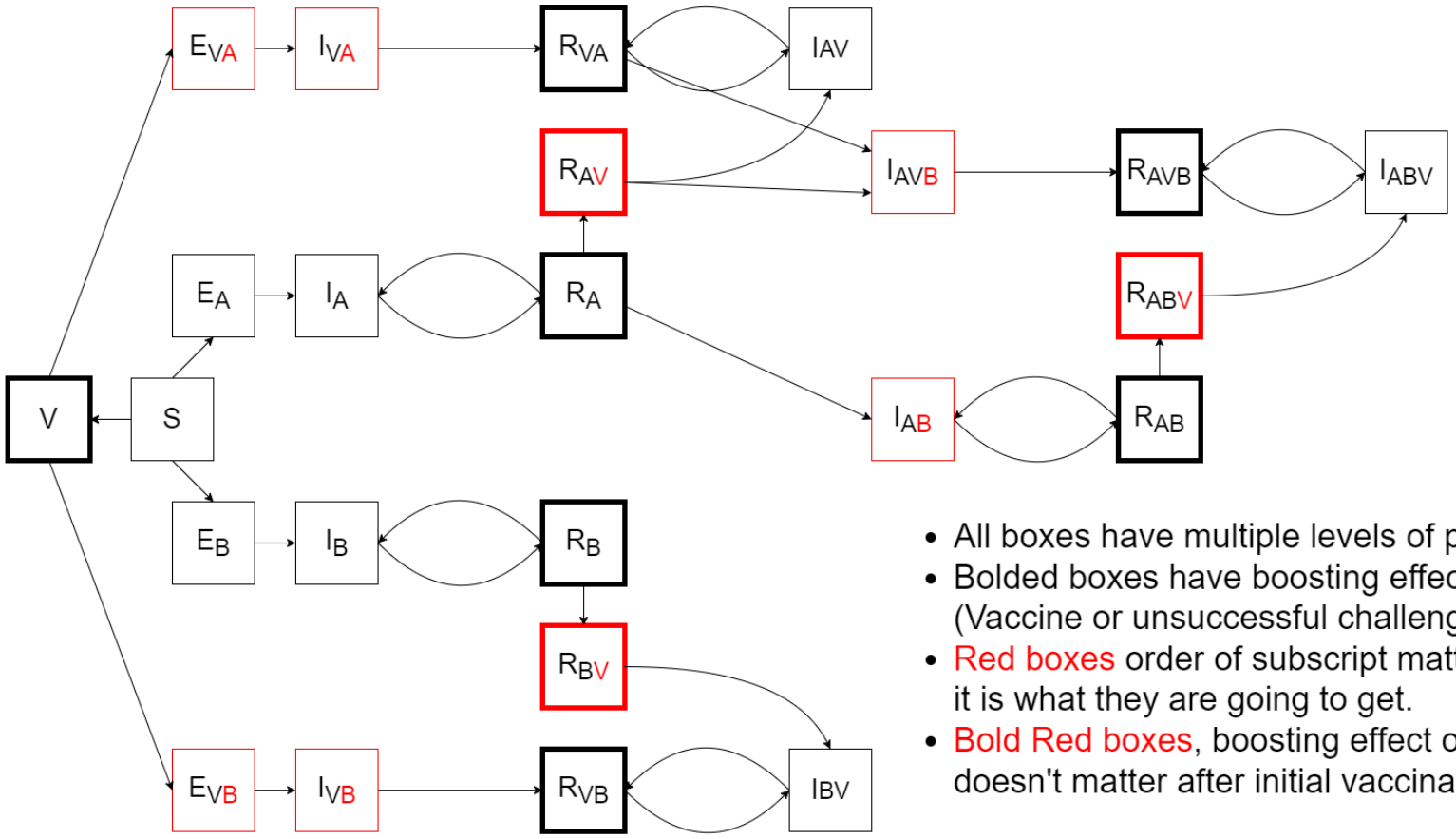
Dose dependence



Immune waning (whiteboard)



Cross immunity (whiteboard)



- All boxes have multiple levels of protection
- Bolded boxes have boosting effect (Vaccine or unsuccessful challenge)
- Red boxes order of subscript matters and it is what they are going to get.
- Bold Red boxes, boosting effect order doesn't matter after initial vaccination.

Michael WZ Li, PHAC