

# 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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- ▶ How much does it matter?





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# Model goals

## ► Theoretical


7:32






←


Poster presentation




**[P2.154] When purpose matters: Four goals of mechanistic modeling for public health**




Wednesday, Nov 29th 2023



17:50 - 19:20



Saved



Note

**View Abstract (text only)**

**Background and study aims**


Models played a prominent role during the COVID-19 pandemic in orienting political decisions on public health interventions. This led to extensive media coverage of modeling outputs, sometimes in the form of intense controversies. The intensity of these debates can at least in part be attributed to confusion on what questions

Read all


**Poster sessions**

Nov  
29th  
17:50






Poster Session 2  
1:30h



**Speaker**



Justin Lessler










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




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# Modeling partial protection

## ► Biological

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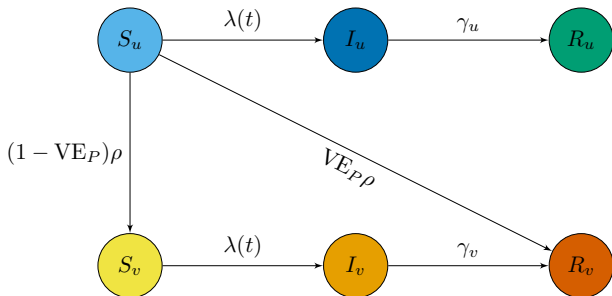
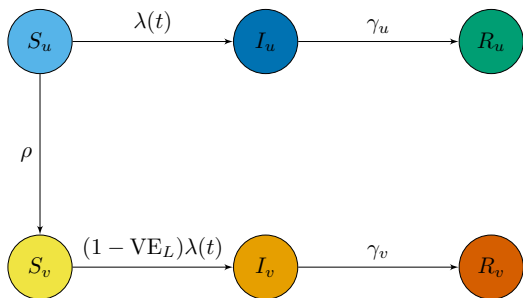
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# Modeling partial immunity



# Why does it matter?

► Prediction



# Why does it matter?

- ▶ Prediction
- ▶ Parameter estimation

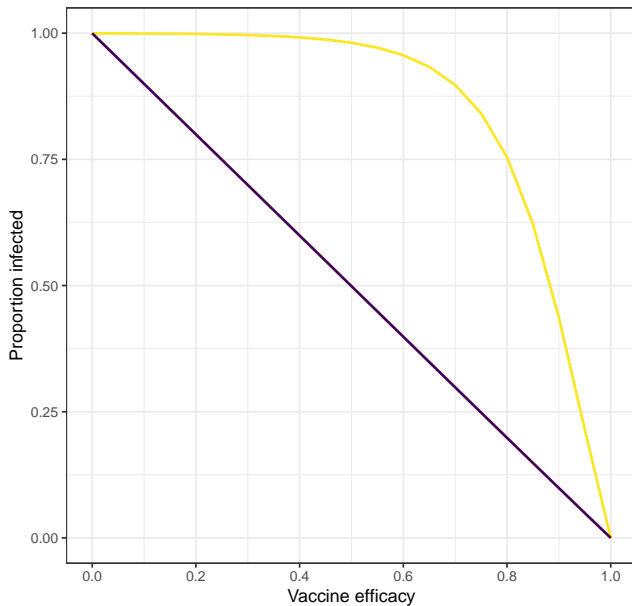
# Why does it matter?

- ▶ Prediction
- ▶ Parameter estimation
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- ▶ Parameter estimation
- ▶ Planning

Epidemic size






- ▶ Also known as “all or none”:


11:00




•





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


# [016.1] individual variation in vaccine immune response can produce bimodal distributions of protection

 Thursday, Nov 30th 2023

 17:10 - 17:30

 Save

 Note

## View Abstract (text only)

Background and Aims:

The ability for vaccines to protect against infectious diseases varies among individuals, but computational models employed to inform policy typically do not account for this variation. In such models, the effect of a vaccine on protection against infection or other outcomes is typically modelled in one of two ways. The “all-or-nothing” model


Read all

### Session


Nov 30th  
17:10

#### Session 16: Vaccination 2

Chair: Corey Peak  
1:20h



### Speaker



Cameron Zachreson

- ▶ Also known as “all or none”:
  - ▶ Assumes that a substantial proportion of the population is completely unprotected

11:00

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↗

1016.1

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## Polarized model

- ▶ Also known as “all or none”:
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- ▶ Can be seen as a limit of broad distribution of susceptibilities

11:00

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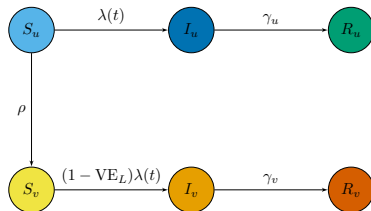


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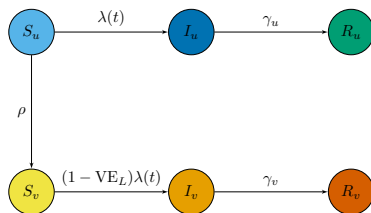
# Leaky model

- The problem of phantom challenges



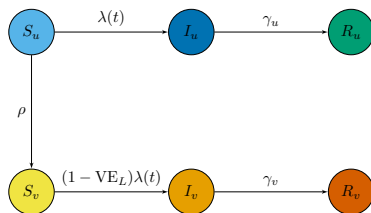
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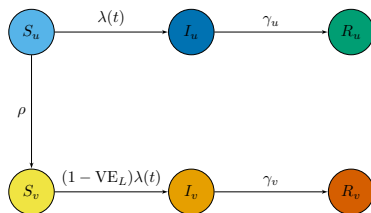
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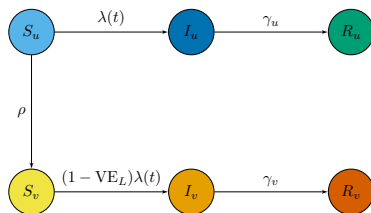
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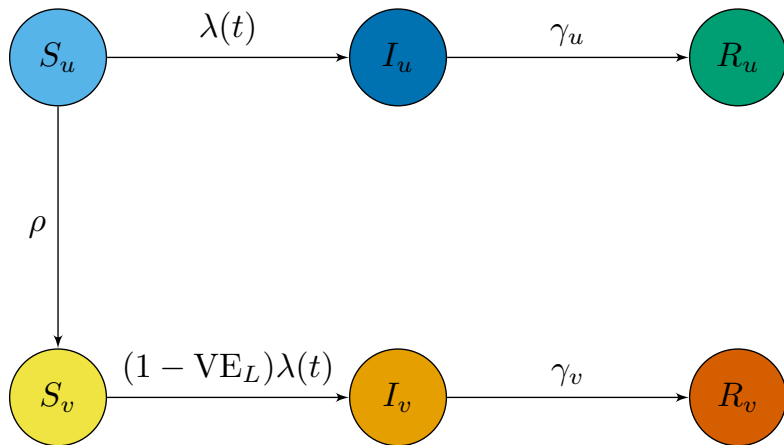


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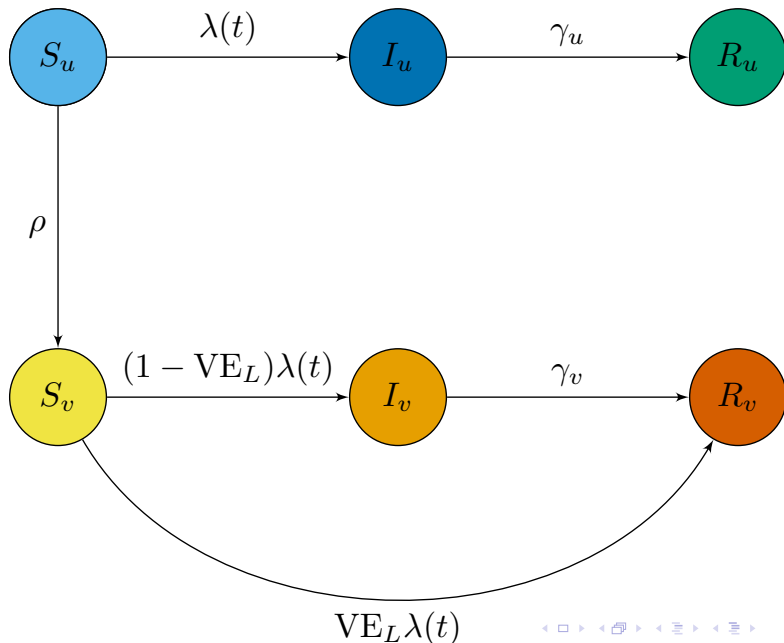
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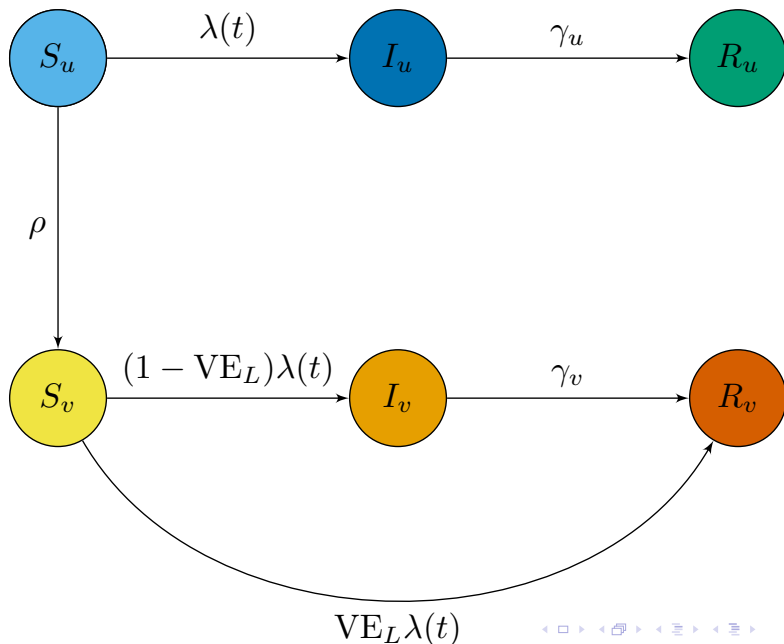
# Leaky



## Leaky with boosting



## Leaky with partial boosting





# The dynamicist's perspective

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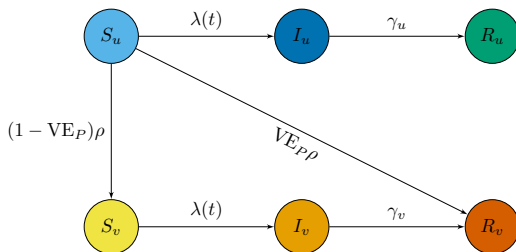
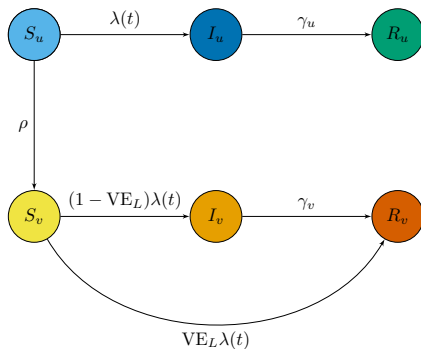
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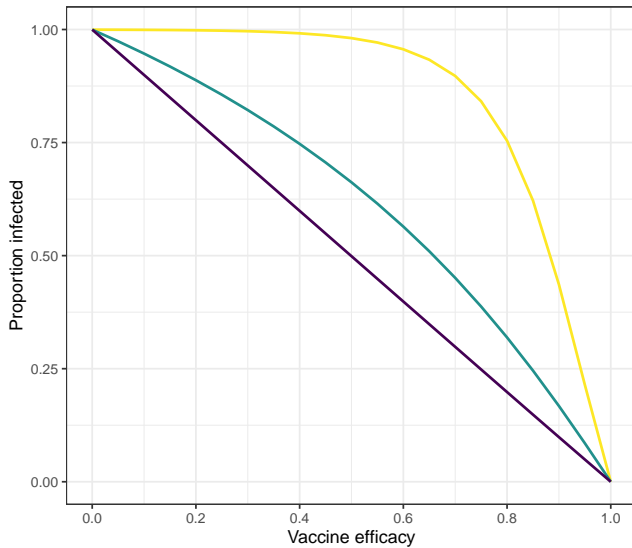
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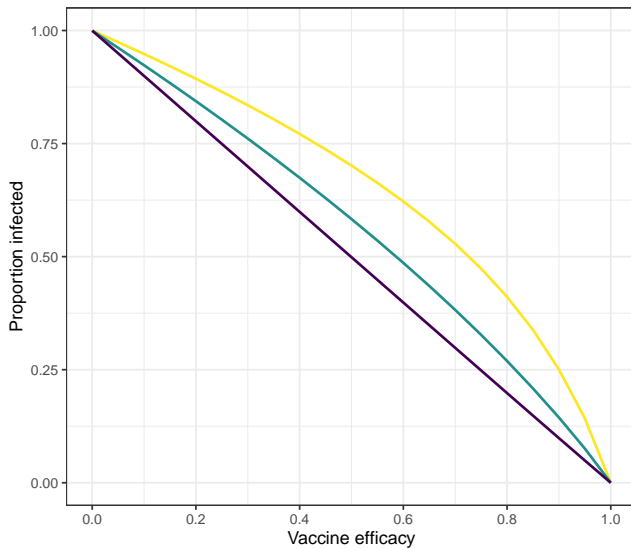


## Leaky



Boosting proportion — 0 — 0.5 — 1

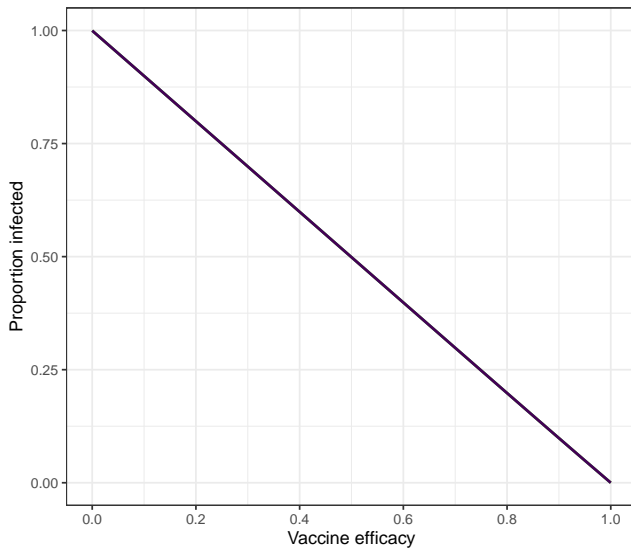
## Mixed



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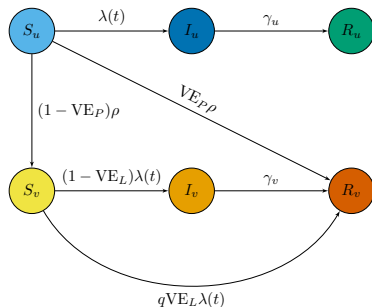


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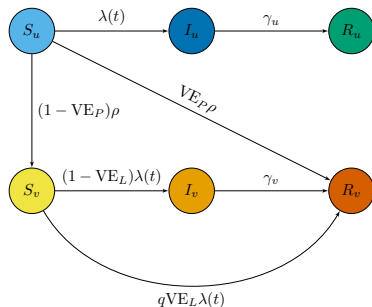
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# Transmission reduction



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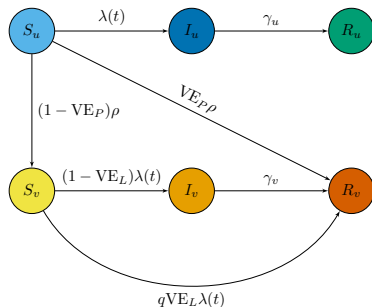
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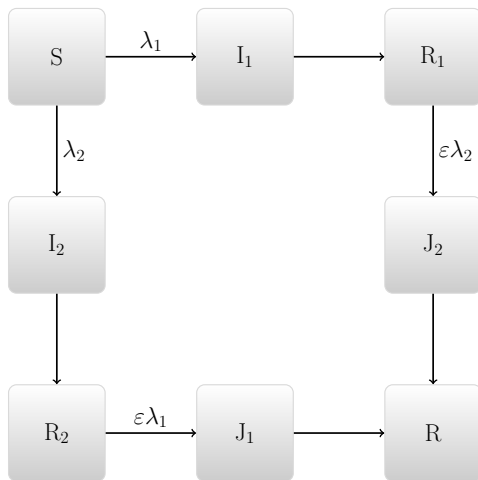
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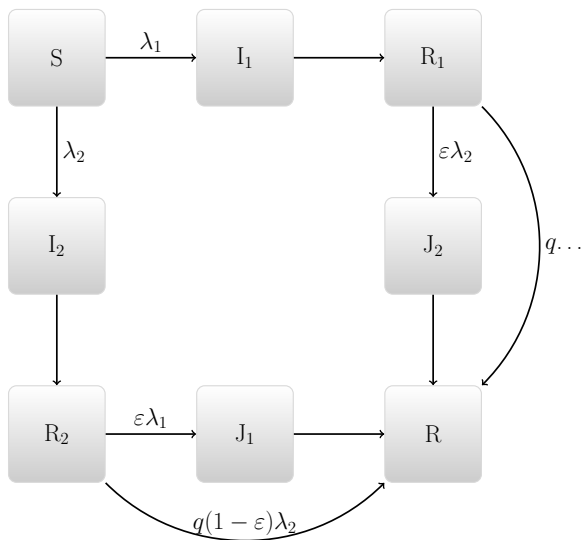


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## Interacting strains



## Interacting strains with boosting



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# Estimating parameters is practically hard

## ► Cobey presentation

11:06

← Presentation

→

Wednesday, Nov 29th 2023

09:10 - 09:50

Save

Note

**View Abstract (text only)**

Vaccination is a popular strategy to control pathogens, and yet vaccine performance remains difficult to explain. The less than stellar protection conferred by seasonal influenza vaccines is often attributed to the challenge of matching vaccine strains to strains that will be circulating after the vaccine is distributed. Evidence has been accumulating for decades that past infections and vaccinations also

Read all

**Session**

Nov  
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**[INV02] Impacts of vaccinating  
against influenza**

Chairs: Cecile Viboud, Joseph Wu,  
Katrina Lythgoe

0:40h

**Speaker**

Sarah Cobey  
University of Chicago, USA

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**Sarah Cobey**  
University of Chicago, USA

# Estimating parameters is practically hard

- ▶ Cobey presentation
  - ▶ Antigenic evolution is extremely complicated
  - ▶ Immune responses as well

11:06

← Presentation

→

Wednesday, Nov 29th 2023

09:10 - 09:50

Save

Note

**View Abstract (text only)**

Vaccination is a popular strategy to control pathogens, and yet vaccine performance remains difficult to explain. The less than stellar protection conferred by seasonal influenza vaccines is often attributed to the challenge of matching vaccine strains to strains that will be circulating after the vaccine is distributed. Evidence has been accumulating for decades that past infections and vaccinations also

Read all

**Session**

Nov 29th 09:10

**[INV02] Impacts of vaccinating against influenza**

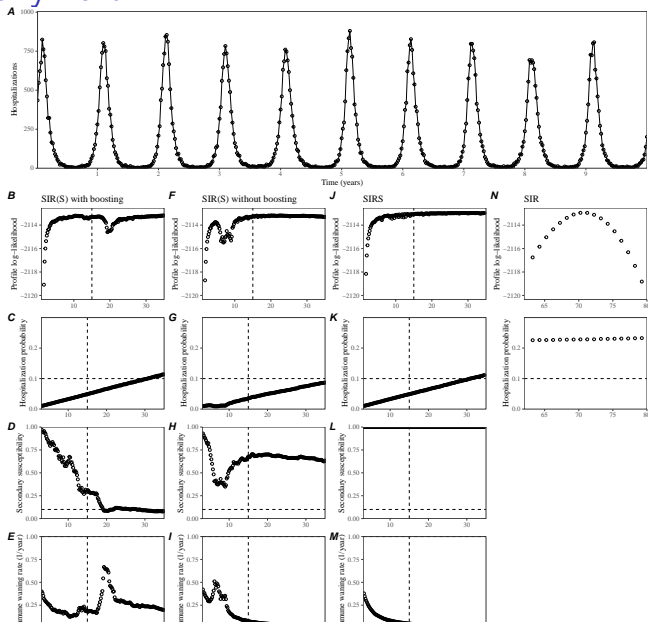
Chairs: Cecile Viboud, Joseph Wu, Katrina Lythgoe

0:40h

**Speaker**

**Sarah Cobey**  
University of Chicago, USA

# Estimating parameters from population-level data is intrinsically hard



# Individual-level inference depends on paradigm

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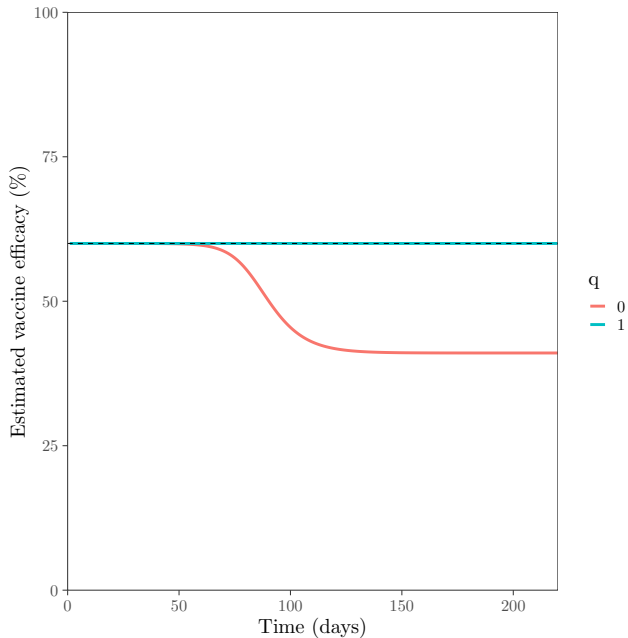
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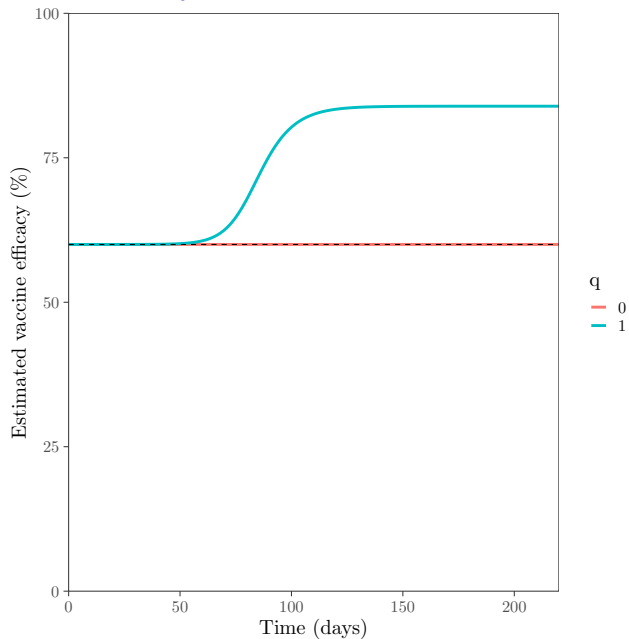
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# Incidence-based cross-protection



# Hazard-based cross-protection



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- ▶ Daniel, Mike and other collaborators

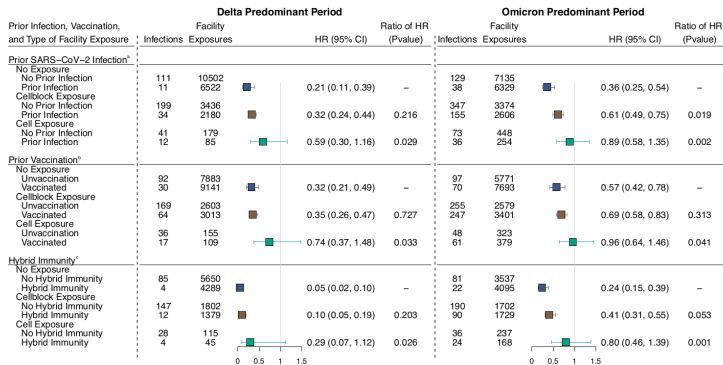
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# Connecticut correctional study



Lind et al., Nat Commun, 2023.

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

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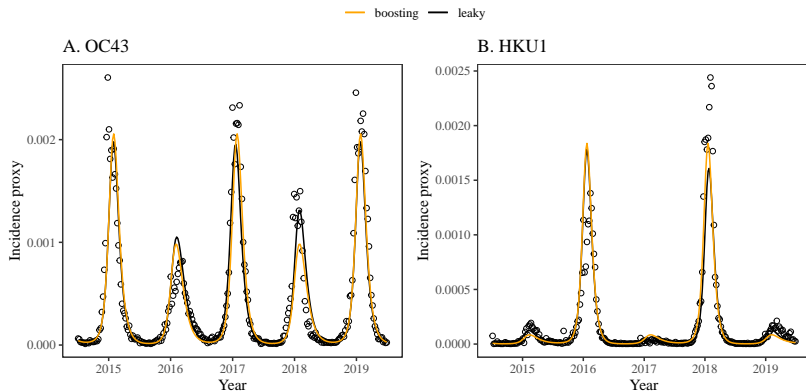
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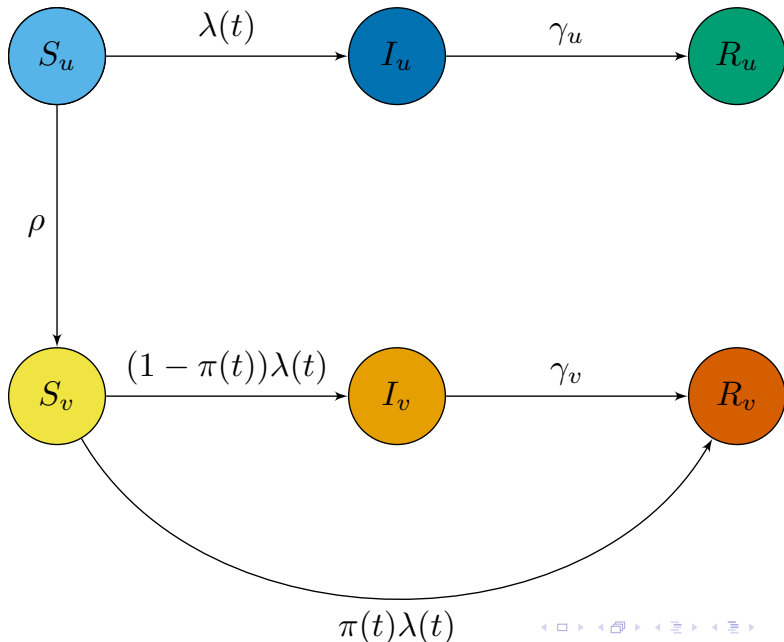
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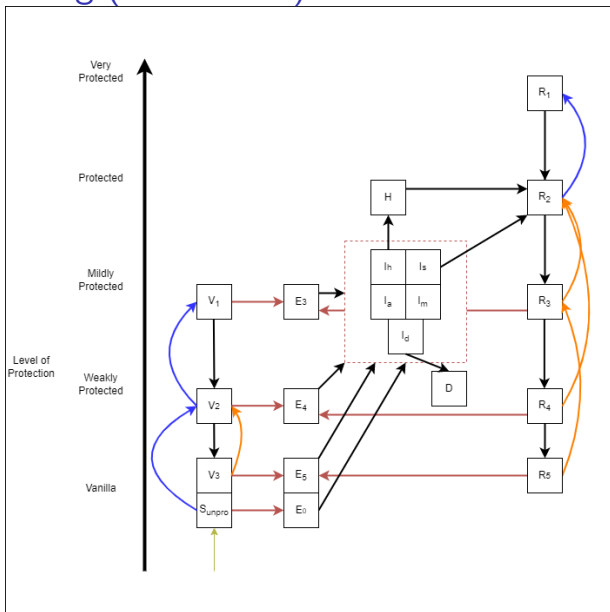
# Coronavirus fits



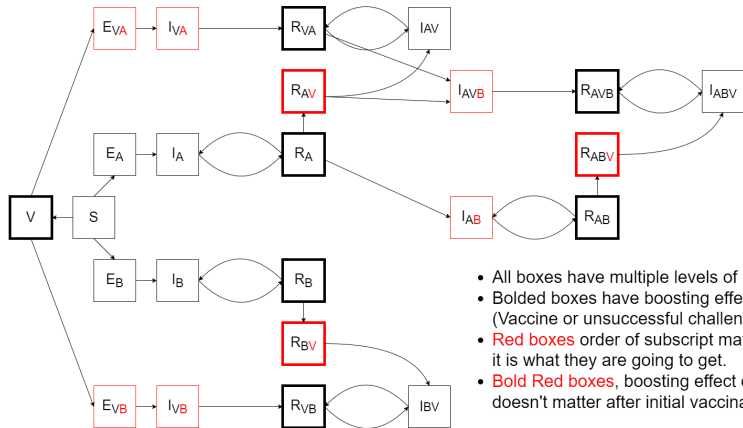
## Dose dependence



# 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