Modeling the impact of outbreak control interventions

MATHEMATICAL MODELING FOR INFECTIOUS DISEASE PLANNING IN AFRICA

(30 minutes)

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Learning Objectives

1. Understand the basic framework for evaluating the impact of interventions with a transmission model
2. Identify and interpret the impact of interventions based on model outputs

List some possible interventions

List possible interventions

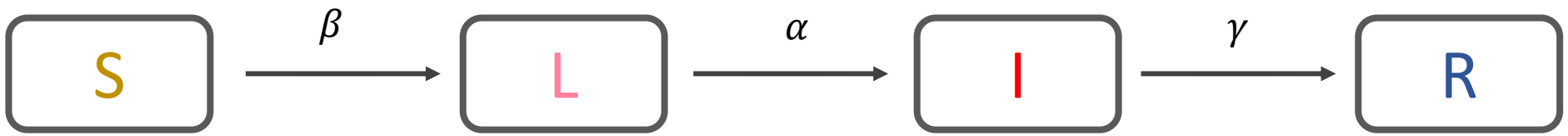
- Vaccination
- Social distancing
- Movement restrictions
- Test and isolate…

Accounting for interventions in transmission models

- Build the model such that it answers questions about “what-if” scenarios.
- Recall SLIR model: In what ways will the model structure change if we wanted to study <u>vaccination</u>?

Evaluating vaccination effects in SLIR model

- SLIR model

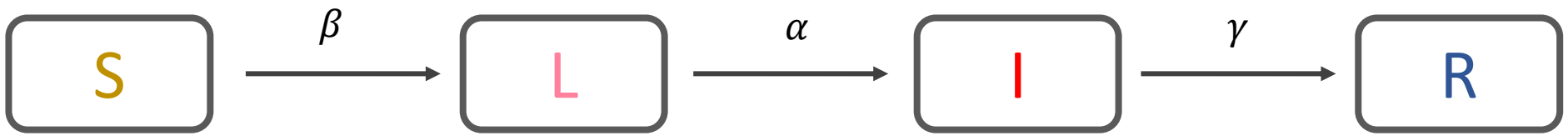


- SLIR model with vaccination (V)

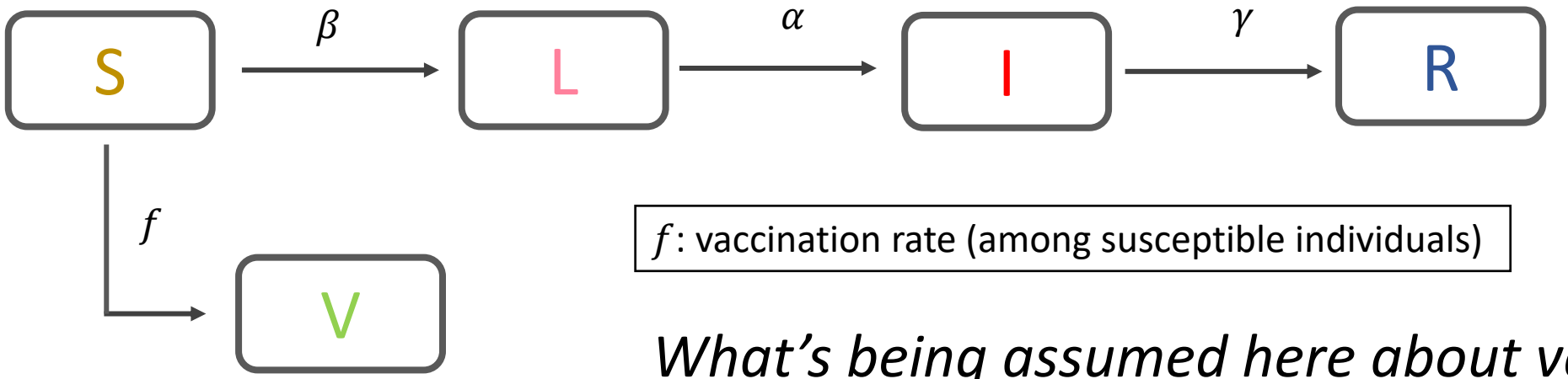
?

Evaluating vaccination effects in SLIR model

- SLIR model



- SLIR model with vaccination (V)



f: vaccination rate (among susceptible individuals)

What's being assumed here about vaccine efficacy?

Evaluating vaccination effects in SLIR model

- Model equations

$$\frac{dS}{dt} = \frac{-\beta SI}{N} - fS,$$

$$\boxed{\frac{dV}{dt} = fS,}$$

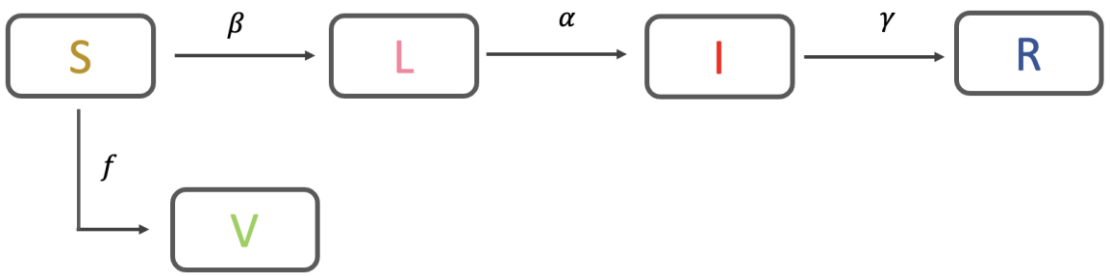
$$\frac{dL}{dt} = \frac{\beta SI}{N} - \alpha L,$$

$$\frac{dI}{dt} = \alpha L - \gamma \mathrm{I},$$

$$\frac{dR}{dt} = \gamma \mathrm{I},$$

$$N = S + V + L + I + R.$$

f: vaccination rate



Recall scenario

There are reports of an outbreak of a new emerging infectious disease that is transmitted from human to human. Not much is known about it, but we've been asked to create some initial models to analyze its spread.

- People have ~20% daily probability of getting infected upon contact with infected individuals
- People recover on average 10 days after infection
- After getting infected, it takes about 3 days before an individual become infectious.

Now, assume:

- A daily vaccination rate of 0.1% susceptible individuals ($f = ?$) starting day 1
- No vaccinees or immune individuals at the start of the outbreak

Evaluating vaccination effects in SLIR model

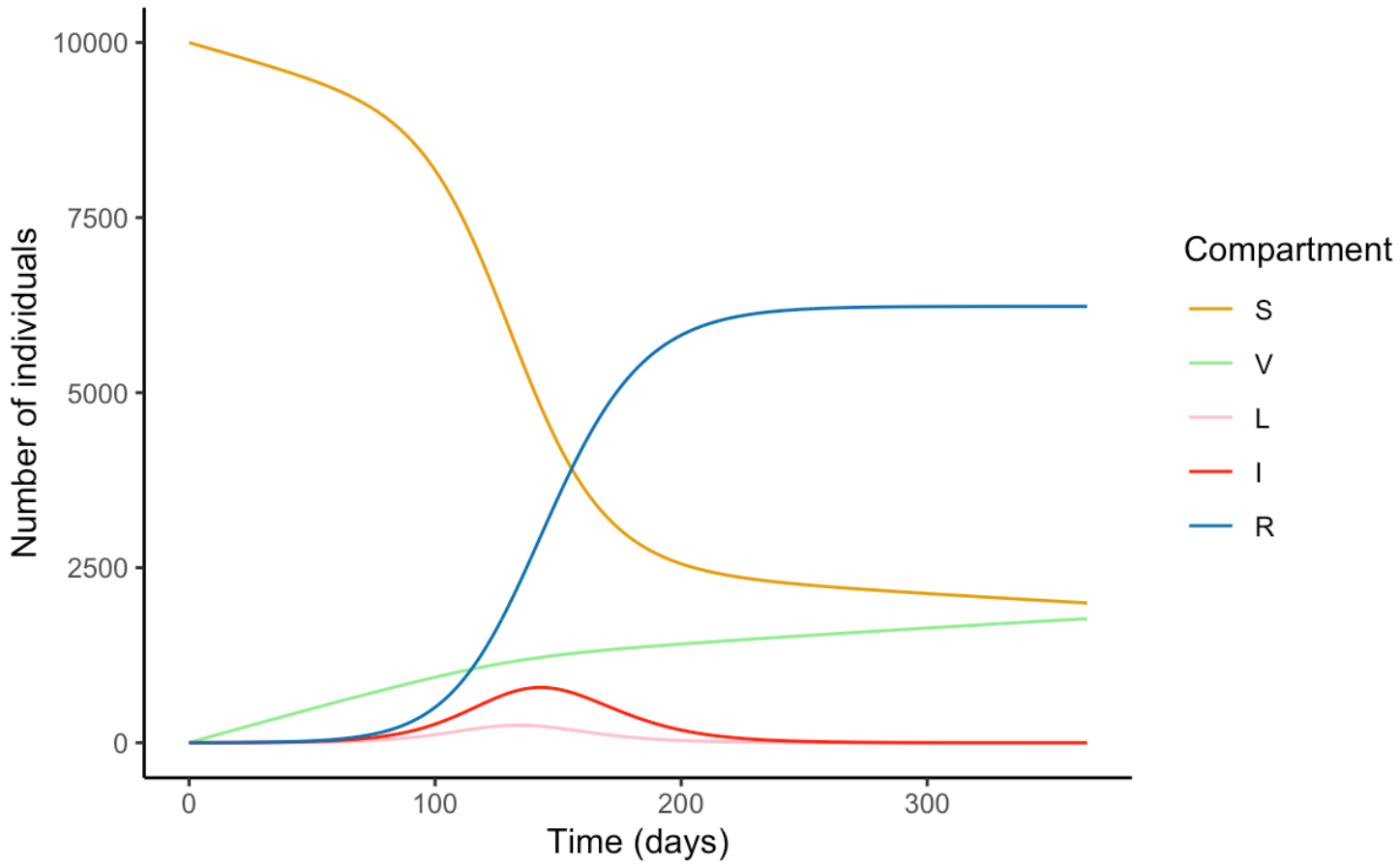
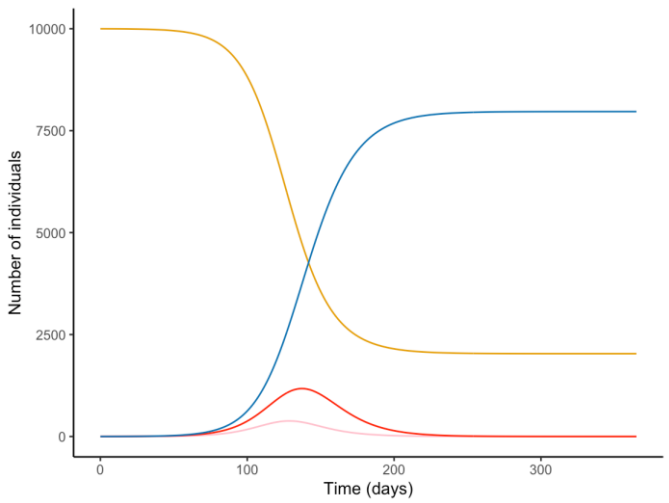


Figure: Dynamics of the number of susceptible (S), vaccinated (V), latently infected (L), infectious (I) and recovered (R) individuals in a population of 10,000 after the introduction of one infected individual. Parameters: $S(0) = 9998$, $V(0) = 0$, $L(0) = 1$, $I(0) = 1$, $R(0) = 0$, $\beta = 0.2$, $\alpha = 1/3$, $\gamma = 1/10$, $f = 0.1/100$

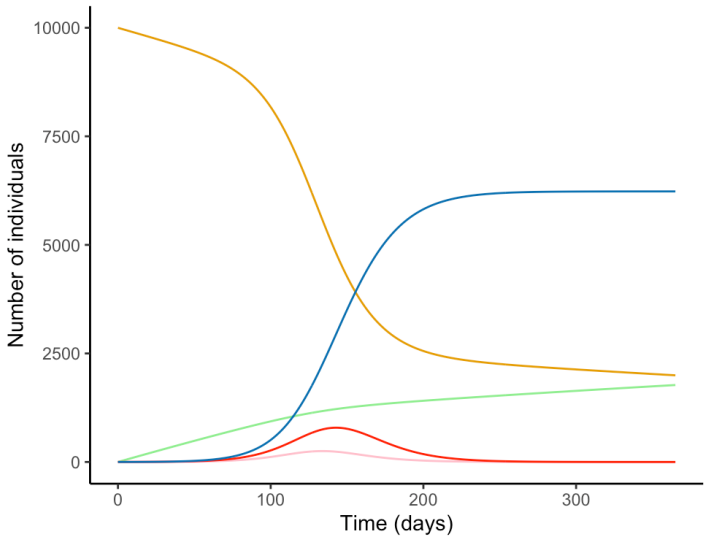
Evaluating vaccination effects in SLIR model

- *What is the impact of increasing vaccination coverage?*

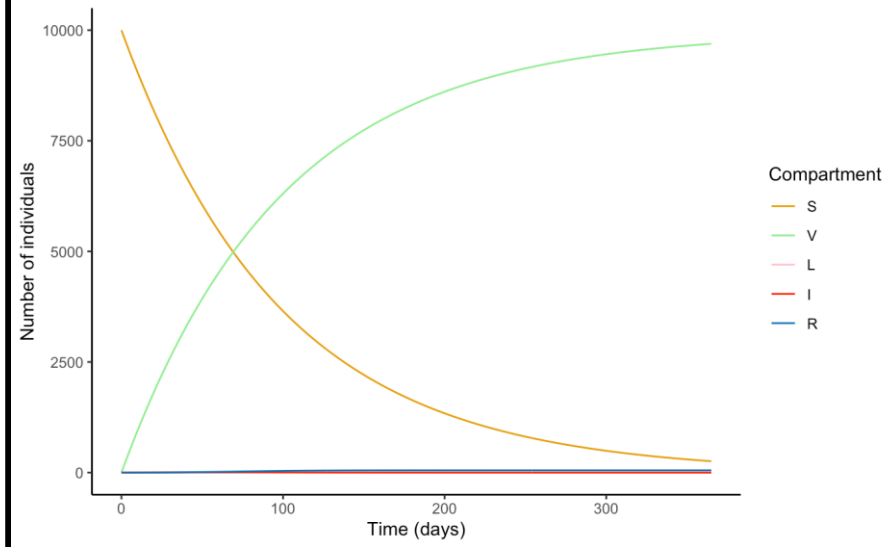
$f = 0\%$



$f = 0.1\%$



$f = 1\%$



Total # of infections by day 365

7968

6232

61

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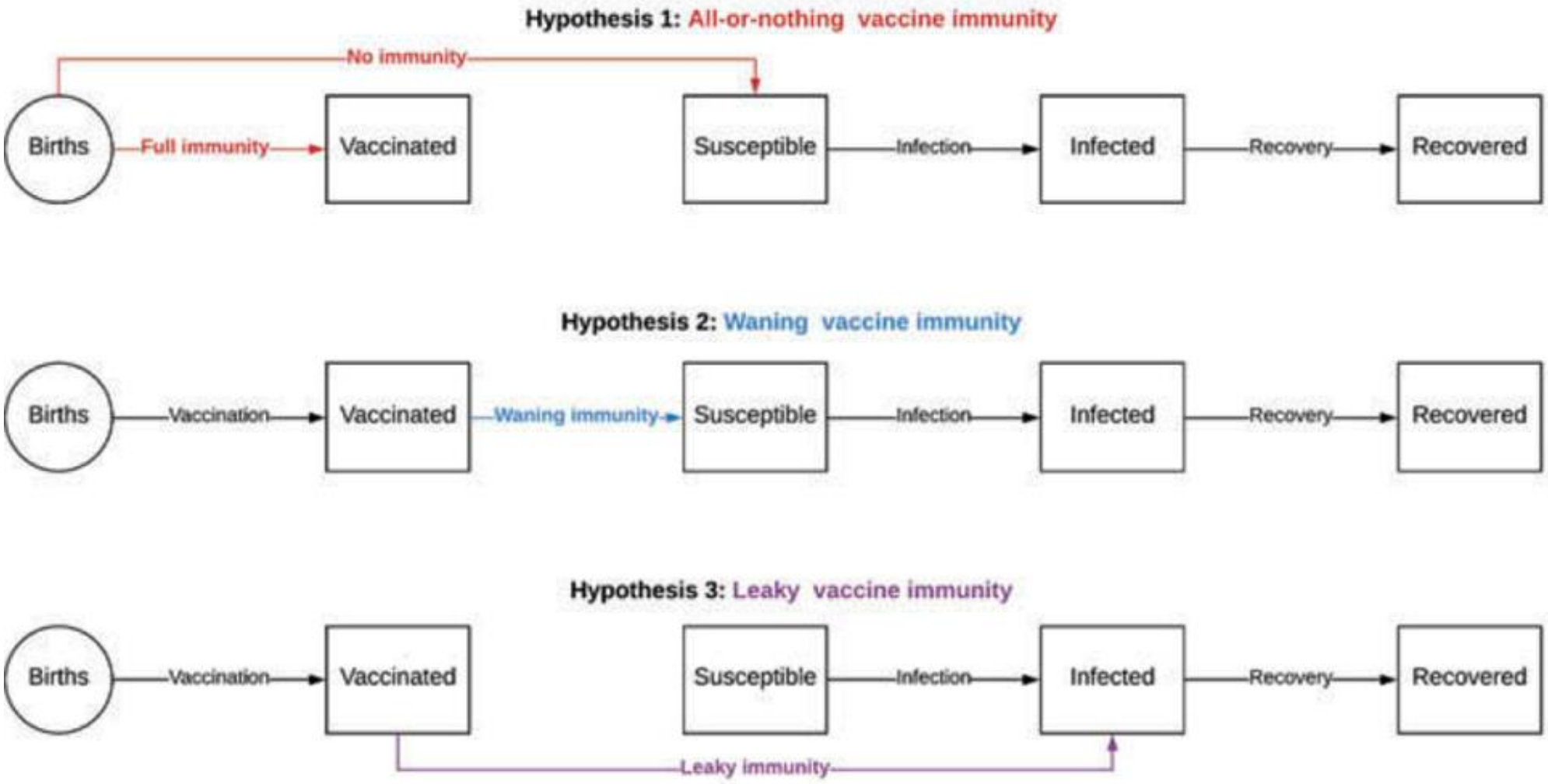
Other vaccination assumptions



Celes et al (2018) Human vaccines and immuntherapeutics

What’s next

- **Activity**: Opportunity to apply concepts discussed to evaluate vaccination impacts on COVID-19 transmission and later, on your disease of focus

How will model structure or assumptions change if we account for…

- **Social distancing?**

- **Test and isolate?**

How could model structure or assumptions be modified to account for…

- **Social distancing?** A reduction in contact rates

- **Test and isolate?** A reduction in contact rates or a reduction in the infectious period

- Depending on intervention, model modification could involve changing **rates**, **assumptions** or modifying **compartments**.