Disease Modeling in Devil Facial Tumor Disease

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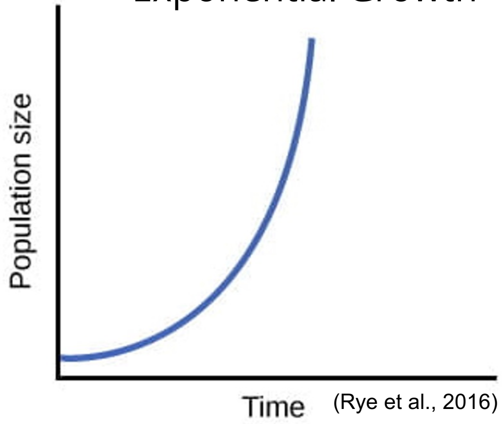
Group 3

(EVEcassandra, 2007)

Exponential Growth

- What is exponential growth?
    - A population's growth rate per individual remains the same disregarding population size (Avissar et al., 2016)
- Devil Face Tumor Disease (DFTD)
    - ~80% population decrease 5 years after first case reported
    - Transmits by the Devils fighting and biting (Dunlap, 2018)

Exponential Growth



(Rye et al., 2016)

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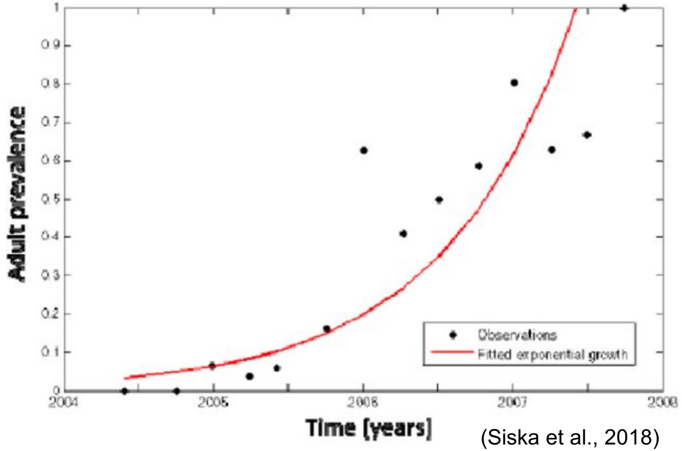


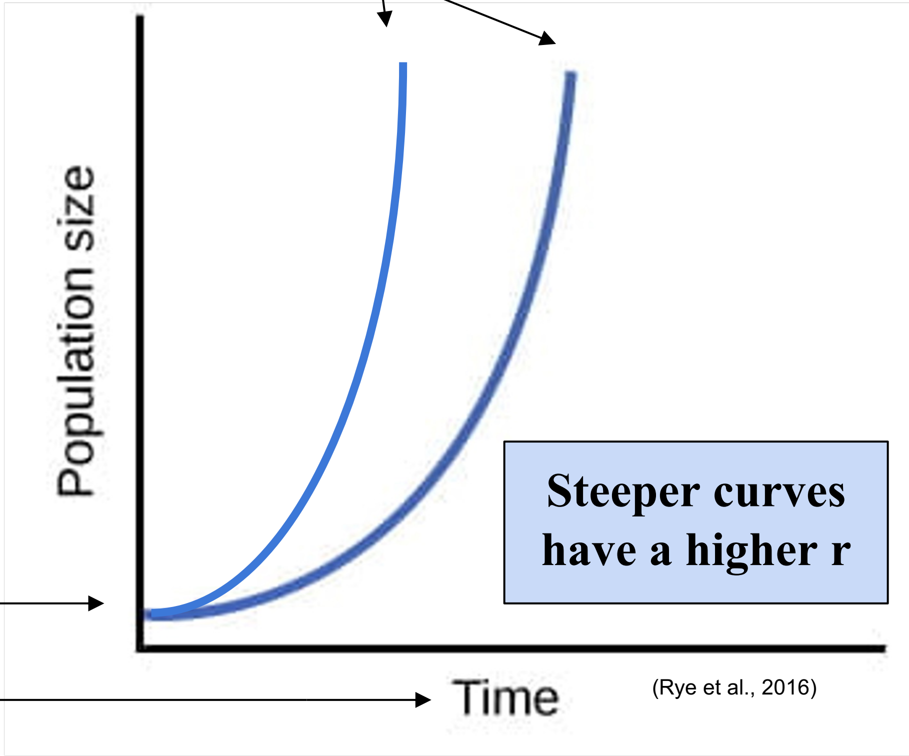
(Siska et al., 2018)

Tasmanian Devil with TDFD (Conroy, 2023)

Graphing Exponential Model of Infected

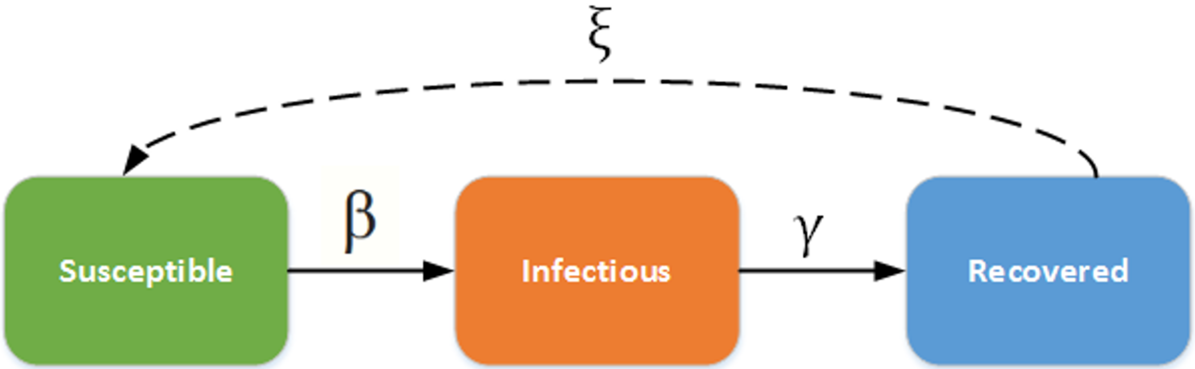
- $N_t = N_0e^{rt}$
- Growth rate: r
- Initial population: N_0
- Time: t

(CBC Radio, 2019)

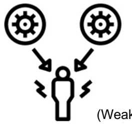


(Rye et al., 2016)

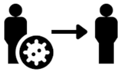
Using SIRS Model to Describe the Devil Facial Tumor Disease



(IDM, n.d.)



(Weak icons, n.d.)



(Geotah, n.d.)

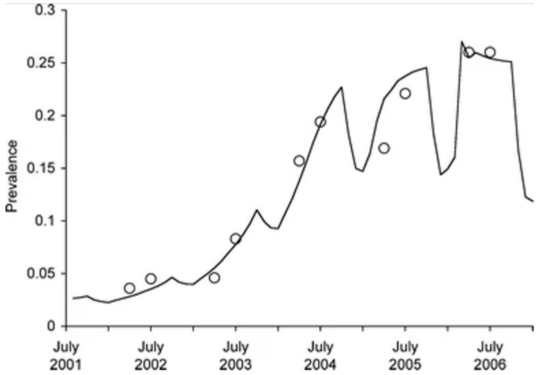
(Recovered, n.d.)

Where β is the rate of transmission, γ is the rate of recovery, and ξ is the rate of diminishing immunity.

- Susceptible individuals are the individuals in a population that could potentially be infected.
- Infectious individuals are the individuals in a population that are capable of spreading the disease.
- Recovered individuals are the individuals in a population that are immune to the disease.

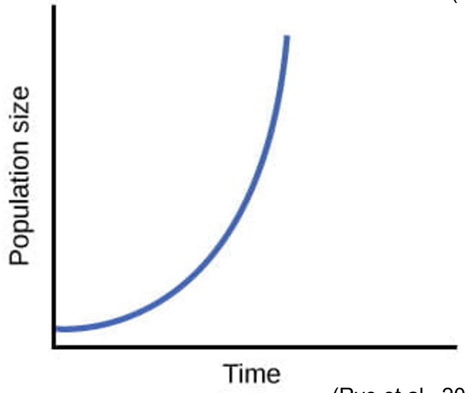
Using SIRS Model to Describe the Devil Facial Tumor Disease

- Rate of transmission (β) is affected by the proportion of susceptible individuals
  - Increasing rate of transmission early on
  - Decreasing rate of transmission after years



(McCallum et al., 2007)

- Rate of recovery (γ) is low
  - Anthropogenic vaccination hoping to increase proportion of “recovered” individuals (Woods et al. 2018)



(Rye et al., 2016)

Conclusion

- The exponential growth model depicts the growth rate per individual and remains unchanged by population size
  - Calculated using $N_t = N_0e^{rt}$
- The SIR model depicts a compartmental model used in infectious disease modelling
  - S = Susceptible
  - I = Infectious
  - R = Recovered

Tasmanian Devils Suffering From Cancer To Receive COVID-Inspired Jabs As the Vaccine Was Approved for Testing

Conelisa N. Hubilla Jun 30, 2023 10:53 AM EDT

In Australia, the large island southeast of the mainland is home to the Tasmanian devil (Sarcophilus harrisii), the world's largest carnivorous marsupial. Three decades ago, the devil facial tumor disease (DFTD) emerged on the island of Tasmania. Since then, it has killed up to 80% of Tasmanian devils, raising concerns that the disease could make the animals go extinct.

(Photo: Pexels/ Chaim Mehlman)

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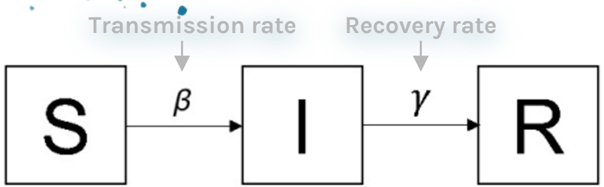
If one BIOL 150 student was infected with COVID-19 (Omicron), what proportion of the class would be infected after 2 weeks?



β = 0.103

γ = 1/6

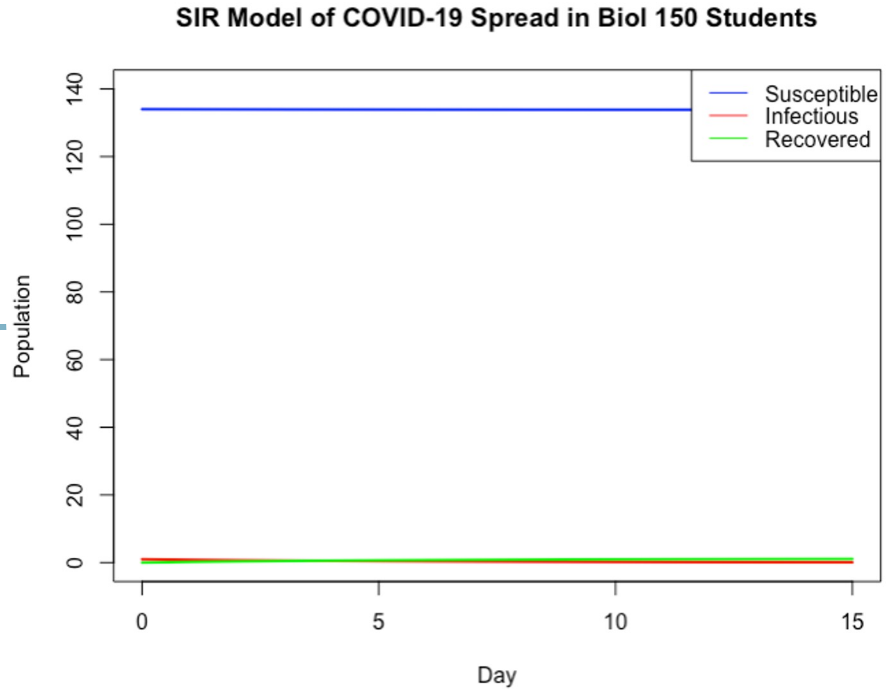
Population Size (N) = 135

Initial Conditions:

- **Infected** = 1
- **Susceptible** = 134

After 2 weeks, no one else in BIOL 150 would be infected with COVID-19.

Non-normal Distribution and Probability of Infection = 0.125



Which residence is safer?
UWP or MKV against Bacterial meningitis?

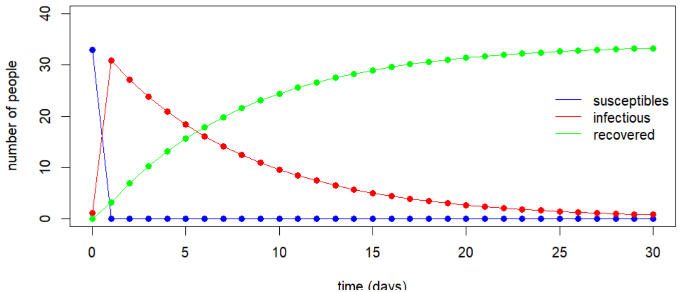
OUR CONSTANTS:

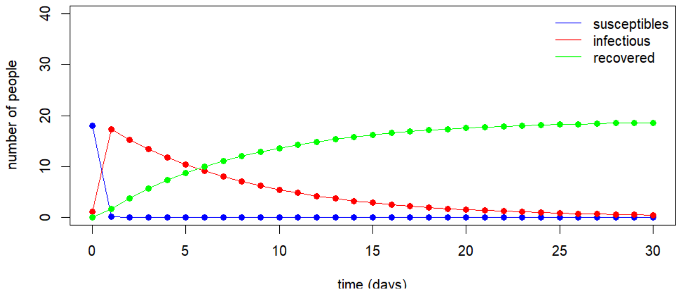
- Gamma: 0.13
- Beta_UWP: 0.103
- R_0_UWP: 26.83
- p_c_UWP: 96.27

- Beta_MKV: 0.129
- R_0_MKV: 18.87
- p_c_MKV: 94.70

OUR CONCLUSIONS:

UWP has a much **higher R_0** value, and so is a less safe residence. **MKV** is a little **safer** to avoid transmission and infection of *Bacterial meningitis*.





What is the required vaccination threshold for Biol 150 students to stop the spread of Measles?

- We used the anonymous data to find out how much contact was made between students

- We calculated the contact rate and basic reproductive number (Ro) with the data and literary values to find the vaccination threshold (Pc) that would prevent the exponential growth of Measles on campus

- Pc = (1 - 1/Ro)*100 = (1 - 1/36.66)*100 = **97.27%**

- 97% of the class needs to be vaccinated to stop the spread of Measles

Conclusions

Purpose: To determine the vaccination threshold of BIOL 150 students to stem the spread of chicken pox using data collected by the PeerLearn App.

- R0 < 1 = disease was dying out
- Vaccination likely not necessary
- **Limitations:**
    - Individuals were able to be infected multiple times
    - Most students appear to have used the app initially and then usage decreased
    - Infection duration of chicken pox is about 1 week – same as the duration of the study
- **Recommendations**
    - Have some sort of incentive to be able to have a reasonable amount of data to work with
    - Run the experiment for longer

$$R_0 = \frac{\beta}{\gamma}$$

Basic Reproduction Number

$$p_c = 1 - \frac{1}{R_0}$$

Vaccination Threshold

Virulence of Influenza (H1N1) in the BIOL 150 Class

Virulence: The probability that an individual will become infected, once exposed

$$\textbf{H1N1 Virulence} = \frac{R_0 * \gamma}{contacts} = 0.012$$

Probability of infection is <u>low</u>

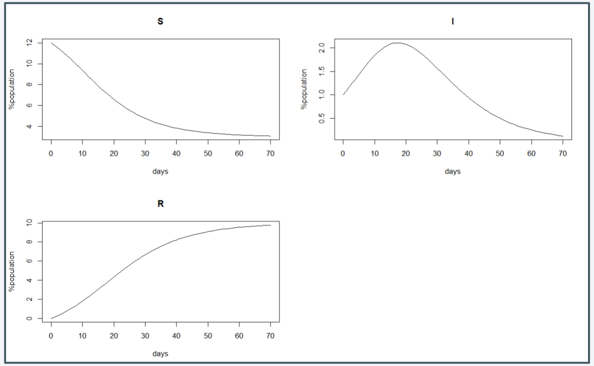


Figure 1. SIR Model for students that downloaded PeerLearn app

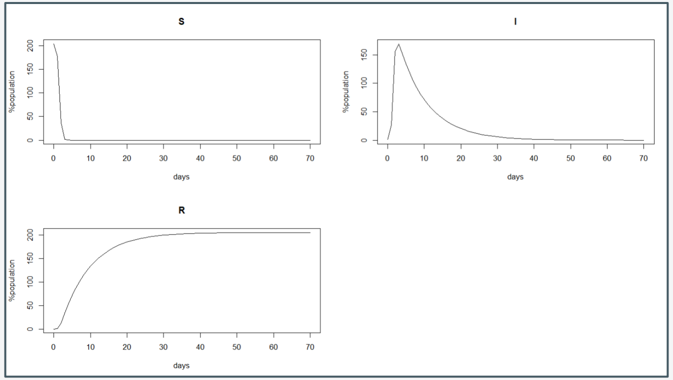
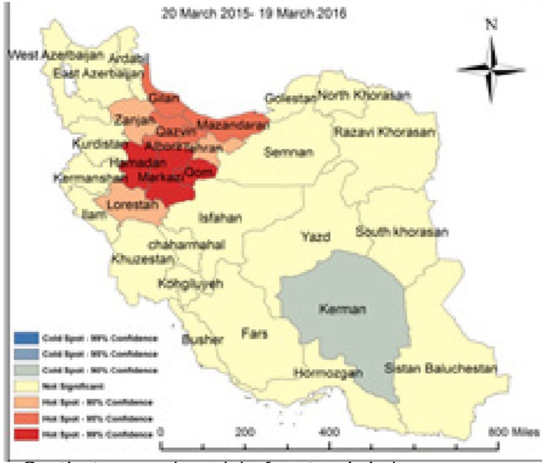


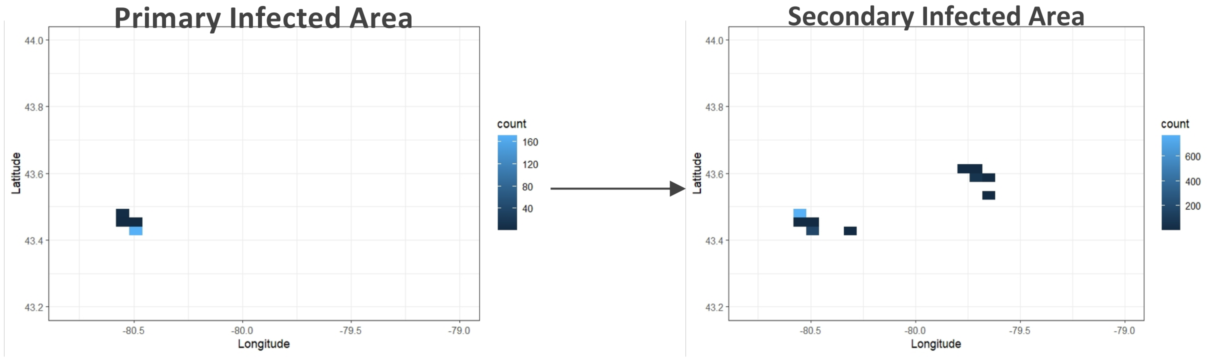
Figure 2. Scaled SIR Model for entire class

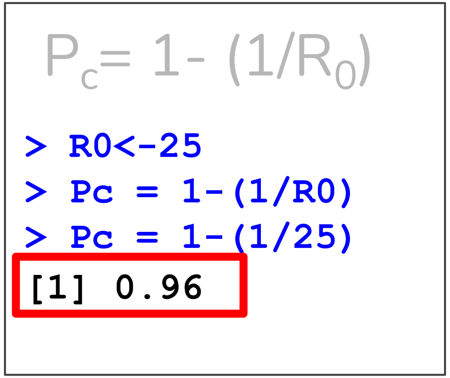
How can we use spatiotemporal data to calculate the critical vaccination threshold?

- A study by Alimohamadi et al. (2020) describes the use of spatio-temporal analysis to track the distribution of Pertussis
- Were able to identify hotspots of pertussis in northern parts of Iran
- This information was then used to implement vaccination programs in these areas
    - Herd immunity occurs at a vaccination fraction of 90-92% (McGirr et al., 2013)
- Based on our findings, close to the entire class of BIOL 150 students would need to be vaccinated to prevent the spread of Pertussis within the population
    - Targeting certain areas such as RCH could improve the results of any vaccination efforts



Spatio-temporal model of pertussis in Iran (Alimohamadi et al., 2020)






```
> R0<-25
> Pc = 1-(1/R0)
> Pc = 1-(1/25)
[1] 0.96
```

Calculation of herd immunity (Nayer, 2020)