Infectious Disease Models

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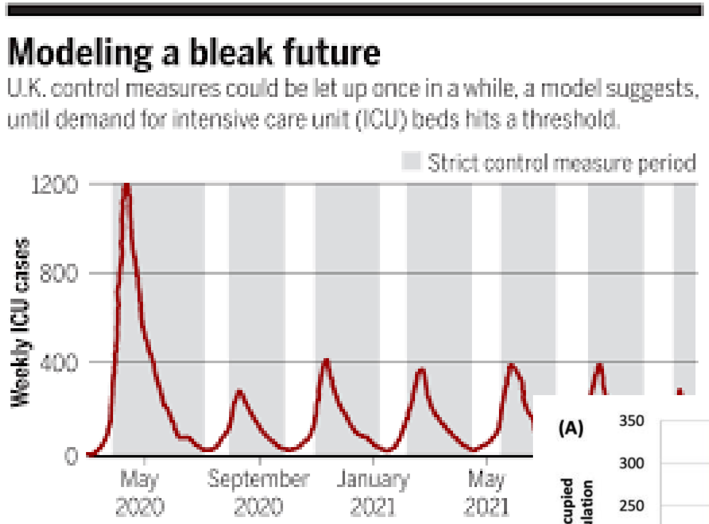
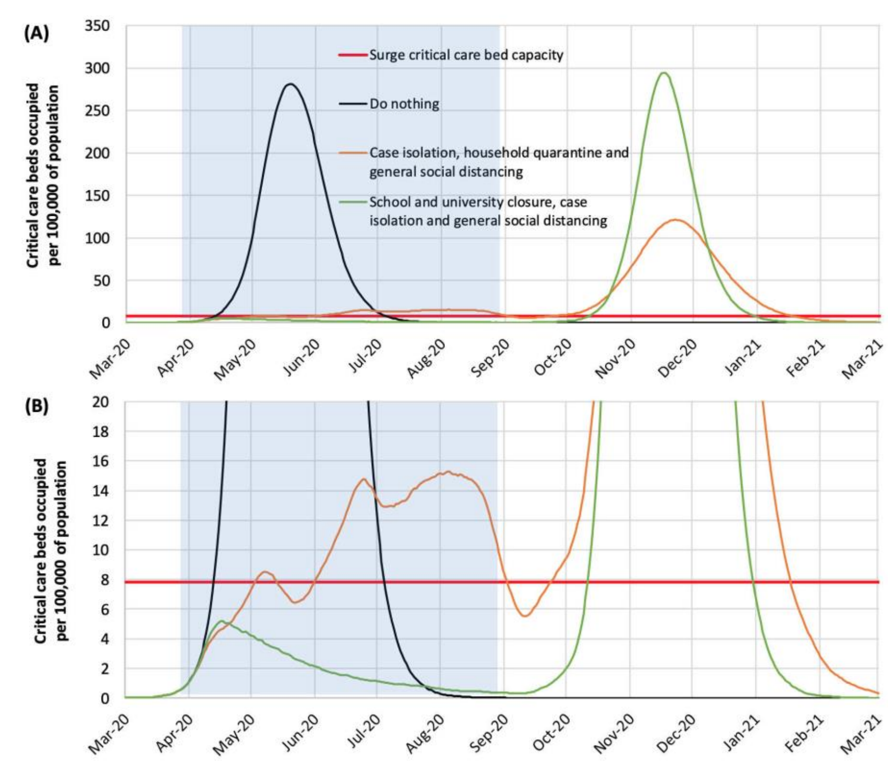
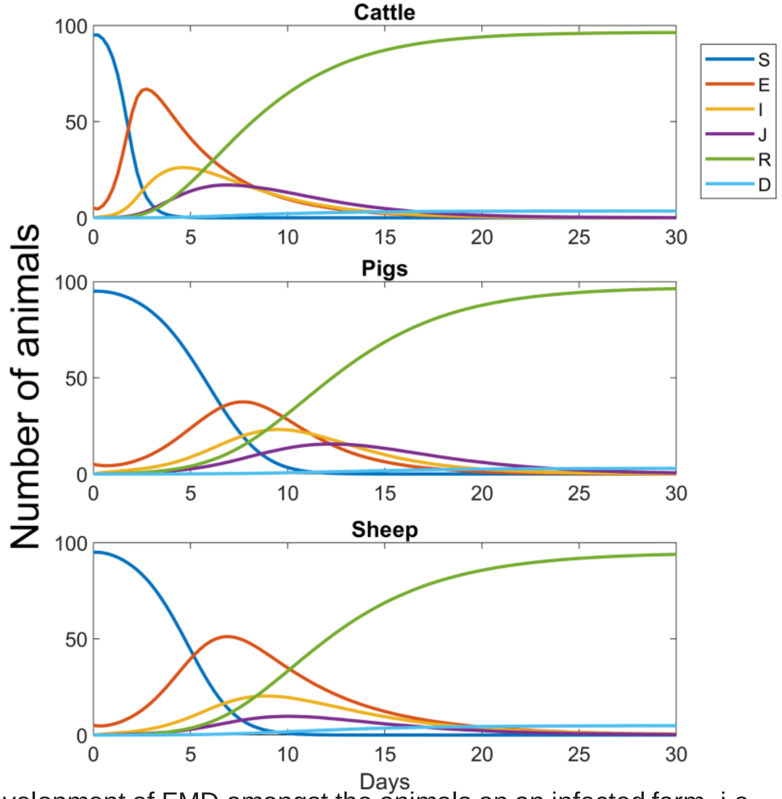
OIE

Infectious disease models provide information that can be used to understand transmission and compare controls options.







The development of FMD amongst the animals on an infected farm, i.e. intrafarm disease spread. The disease is initiated with 5 infected and 95 uninfected animals in all cases. The disease develop quickest in the case with cattle and slowest for pigs.

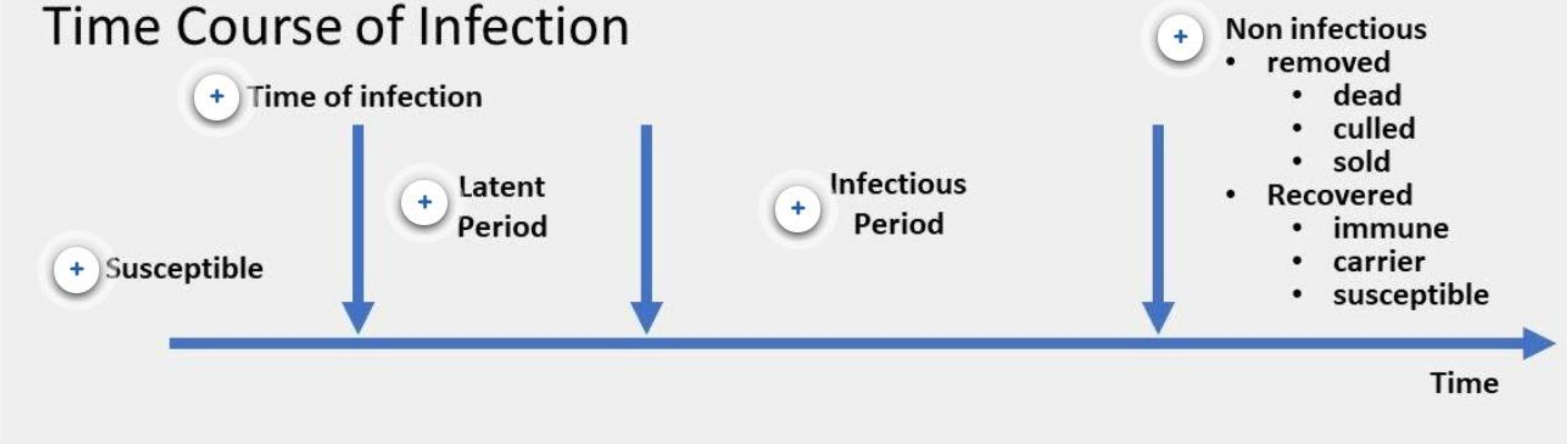
Objectives

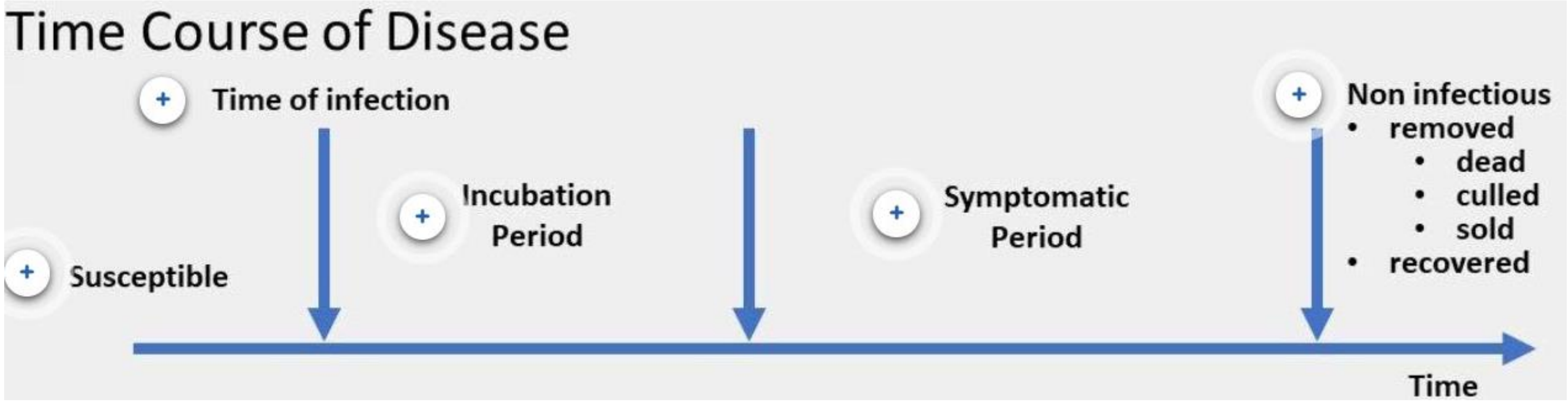
- Focus is on building a conceptual understanding of infectious disease modelling and its practical application
- We won’t be covering how to build sophisticated models.
- At the completion of the course, participants will be able to:
    1. Build, analyse, and explain a simple infectious model and consider intervention scenarios.
    2. List the data requirements to build a disease model.
    3. Use the outputs from a model to support recommendations for the control and management of infectious diseases.

Review and Summary

Infectious disease

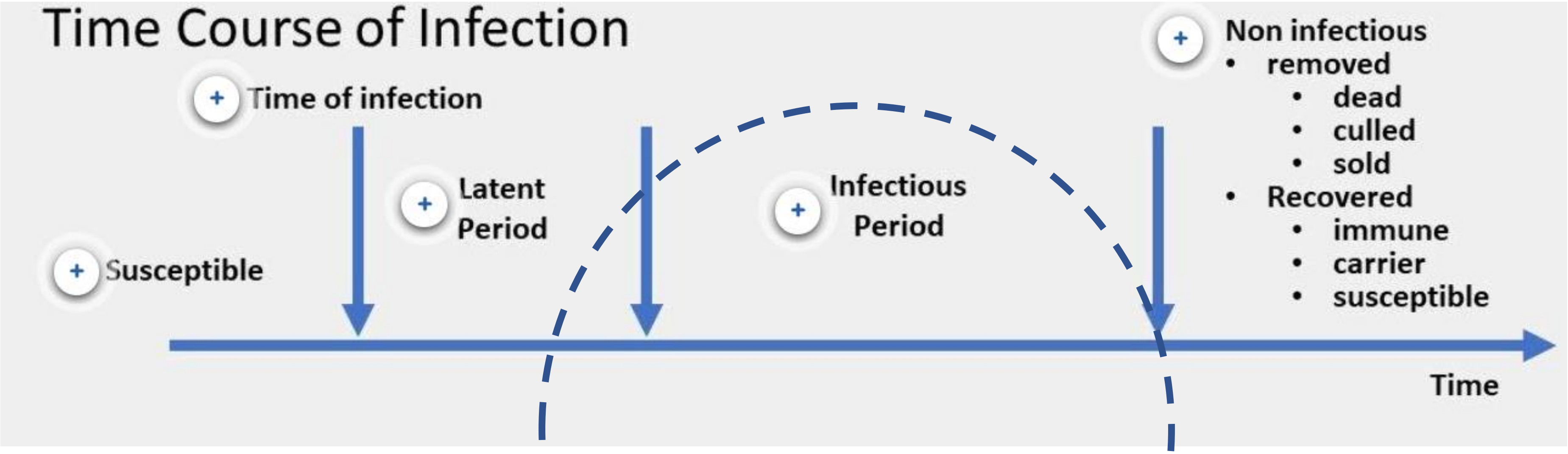
- Infection and Disease

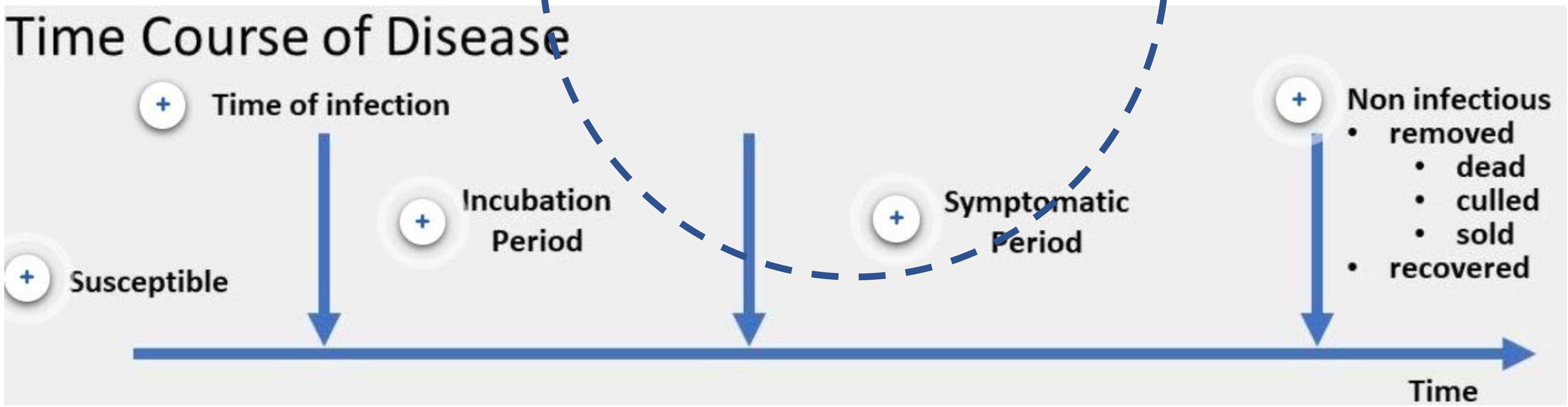




Infectious disease

- Infection and Disease

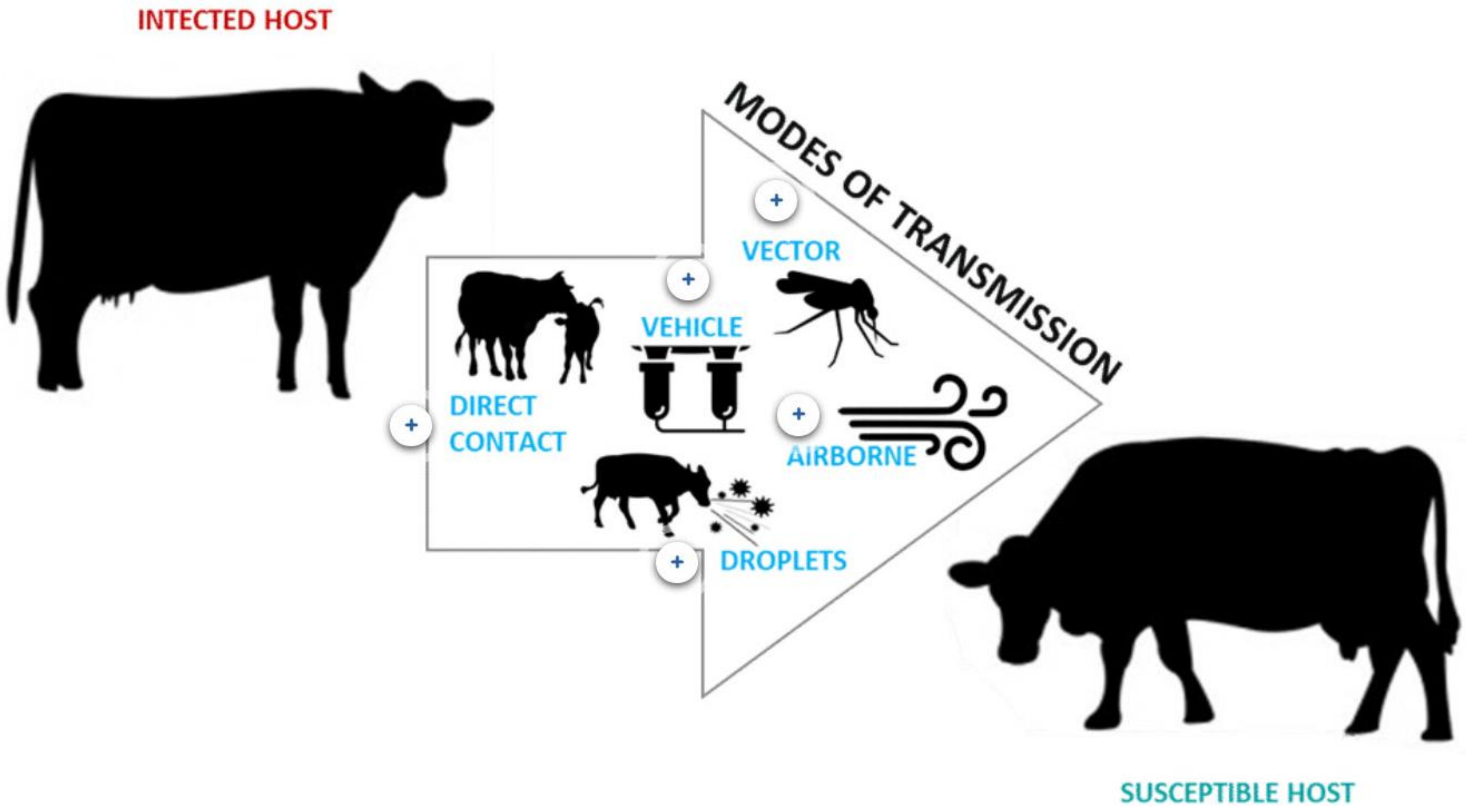




We are particularly interest in when the infectious period occurs relative to the appearance of symptoms

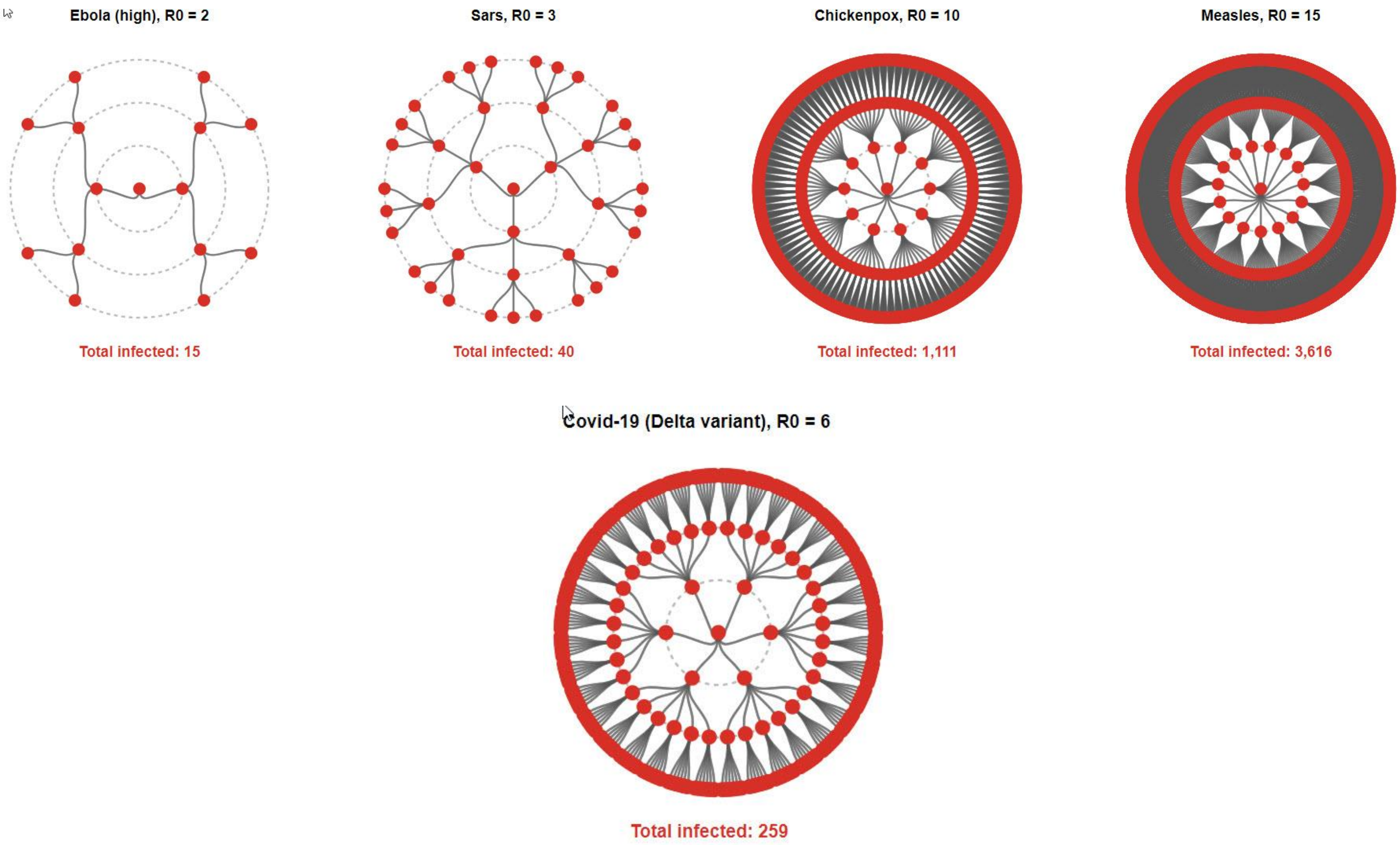
Infectious disease

- <u>Transmission</u>



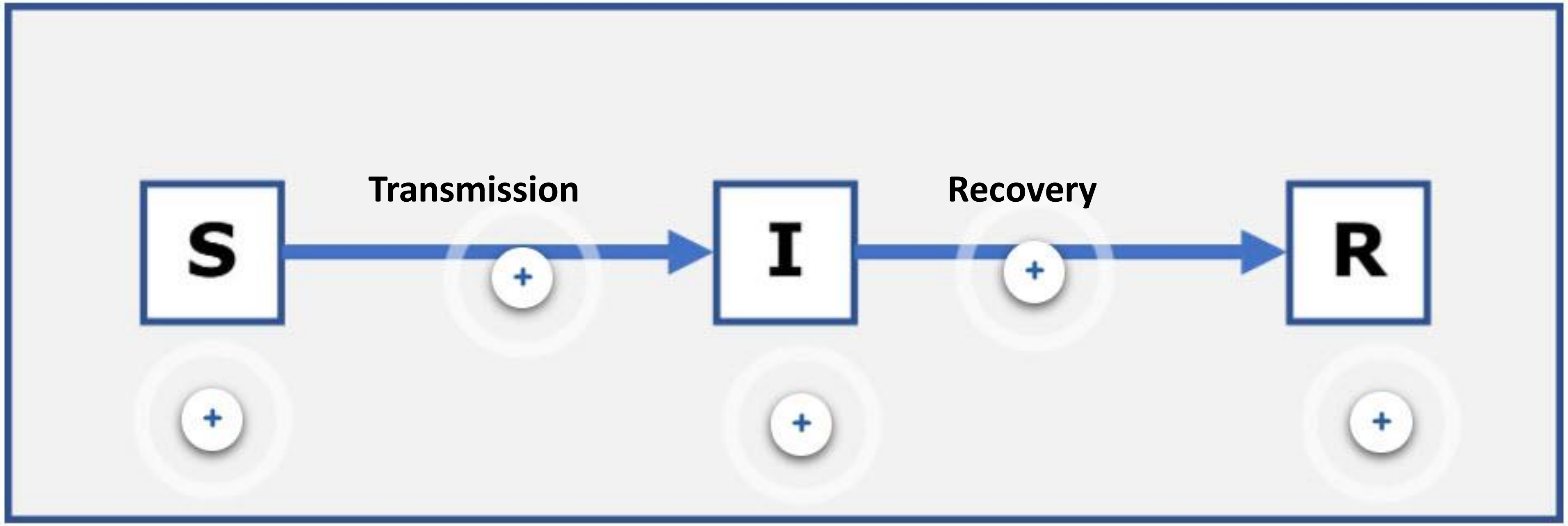
Infectious Disease

- <u>Reproductive Number (R_0)</u>
  - Number of new infections that one infected individual can cause
    - $R_0 > 1$ means outbreak will grow
    - $R_0 = 1$ numbers will remain constant
    - $R_0 < 1$ means outbreak should die out


Ebola (high), R0 = 2
Total infected: 15
Sars, R0 = 3
Total infected: 40
Chickenpox, R0 = 10
Total infected: 1,111
Measles, R0 = 15
Total infected: 3,616
Covid-19 (Delta variant), R0 = 6
Total infected: 259

Infectious Disease Models

- Use mathematics to describe transmission and evaluate controls



Infectious Disease Models

- Transmission is determined by:
  - Contact Rate
  - Probability of transmission
  - Level of infection (i.e. what proportion of contacts will be with infectious animals)
- Recovery is determined by the duration an animal is infectious

Infectious Disease Model

- To sum up the key concepts:
  - SIR models classify animals according to their current status (e.g. susceptible, infectious and recovered)
  - We use mathematical formulas to determine how many animals will be susceptible, infectious, and recovered each day.
  - SIR models have parameters that are fixed for a given scenario but can vary among scenarios.

Stochastic Process = Chance

- Imagine rolling a die the probability of rolling a six would be 1/6
- Probability theory says if we roll the die six times we should expect to have one 6
- But will we?
- No because of chance

Breakout Rooms

Question 1 to 3

Question 1

Note down the day with the maximum number of new infectious occurred and the day with the maximum number of infected farms occurred.

- Why is there are lag between these days?

Question 1

- Max Number new infections = Day 1
- Max Number infections = Day 11
- The model is built in such a way, so the highest incidence occurs when the number of susceptible populations is highest. The number of infected farms accumulate each day over the infectious period (despite recovery and culling activities), hence there is a lag.

Question 2

Note down the maximum number of infectious properties and the day that occurred.

To see what would have happened if the government had not started a cull program change the number if change B7 to 0.

- Now what was the maximum number of infected properties and which day did it occur?

Question 2

Day 85 is when the maximum number of infectious properties occurred.

Question 3

Change the number in cell B7 back to 0.4 and increase the number of farms infected at the beginning of the outbreak from 2 to 10 (i.e. change cell B3 to 10).

- Now what was the maximum number of infected properties and which day did it occur?
- Was the day the same as when there were only two infected farms at the beginning?
- Why might this be?

Question 3

- If the initial number of infected increases from 2 to 10, the max number of infected properties also increases from 18 to 87. The peak day also changes from day 11 to day 8.
- An epidemic would peak earlier if there was a higher number of infectious in the population, because there is a greater infection force.

Extension Question

- The model assumes that transmission rate was constant across the outbreak. Do you think that is reasonable?

Return to Main Room

Breakout Rooms

Question 4 to 5

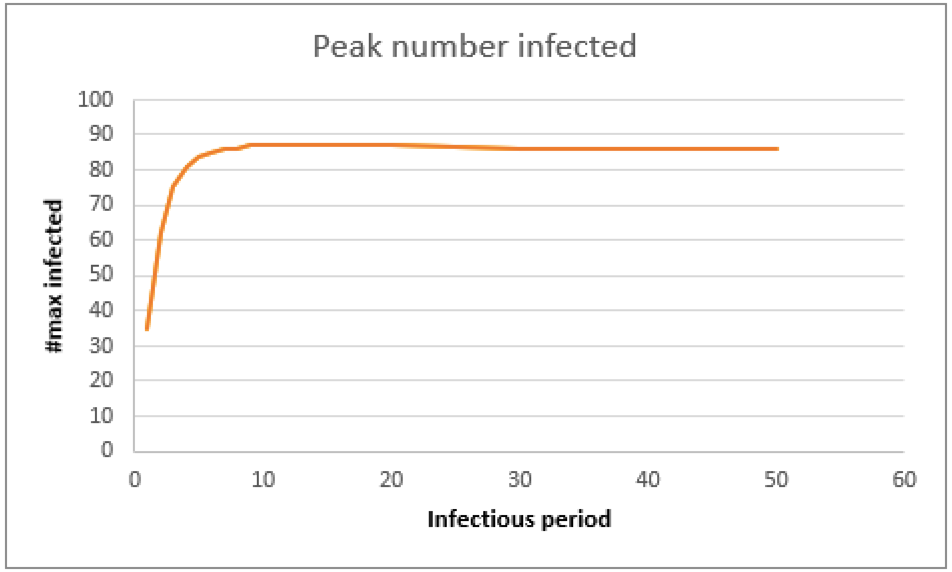
Question 4

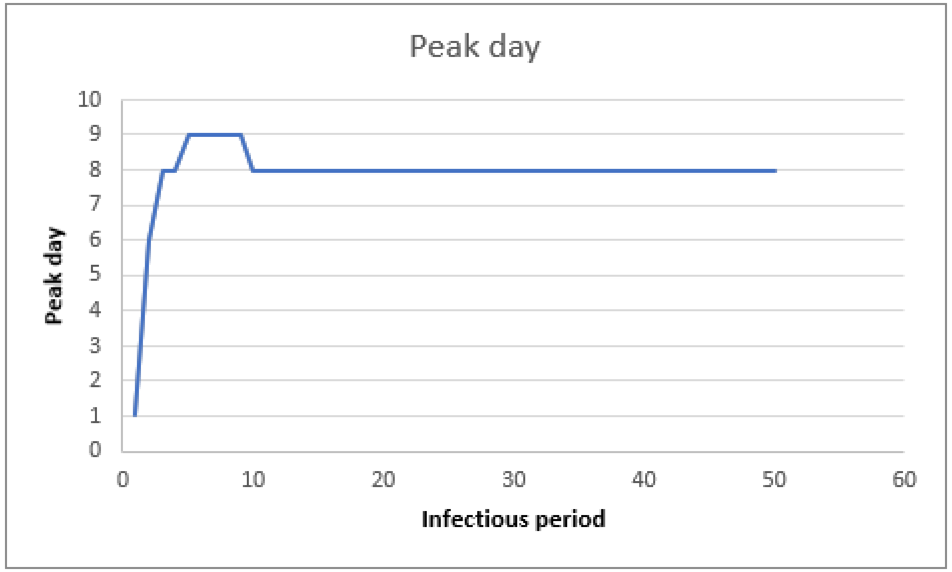
Leave the number of infected properties at the beginning at 10 and then increase and decrease the number of days a farm remains infectious.

- How does this change how the outbreak progresses?

Question 4

- The model is insensitive to change in infectious period > 5 days





Extension Question

- Does that seem biologically plausible?
- Why might this be happening in this model?

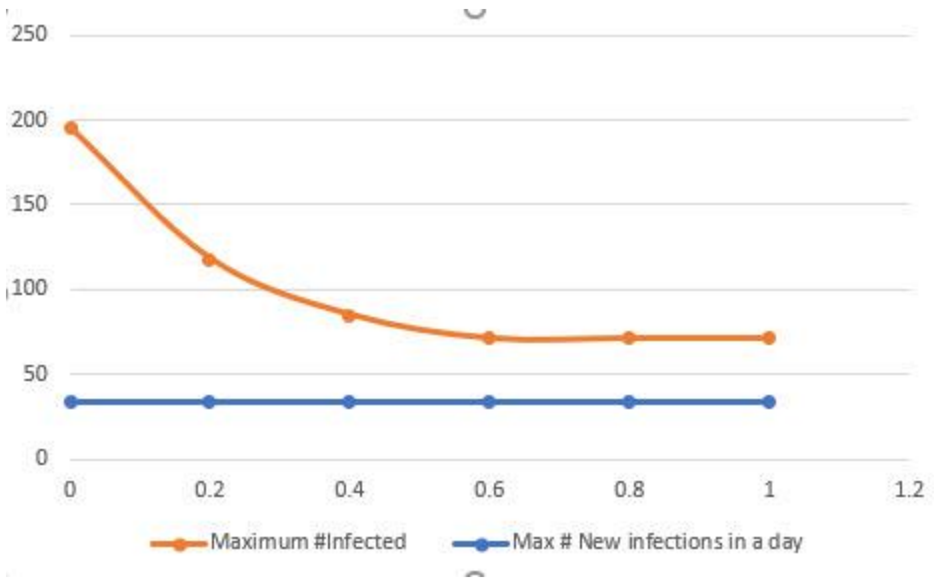
Extension Question

- No, it is not biologically plausible.

- Part of the reason it occurs here is we have assumed that the transmission rate is a constant and does not change over time. Therefore, increasing or decreasing the duration of time a farm is infectious will not alter the number of new infections ‘just’ the rate of recovery.

Question 5

- Return the input parameter to those in the initial scenario. Now record the maximum number of infected farms when the probability a farm is culled is 0, 0.2, 0.4, 0.6 and 0.8. What does this graph tell us about the effectiveness of culling?



Question 5

- With an increase of the culling efficiency up to 40%, the number of max infected properties decreases (i.e. the this control is more successful in controlling the epidemic). If the culling efficiency is over 60%, the increase in the culling efficiency does not change the number of max infected. This means culling has reached its maximum capacity in controlling the epidemic. When we have 60% culling on and we want to control this epidemic even better, we should spend resource in some other control methods.

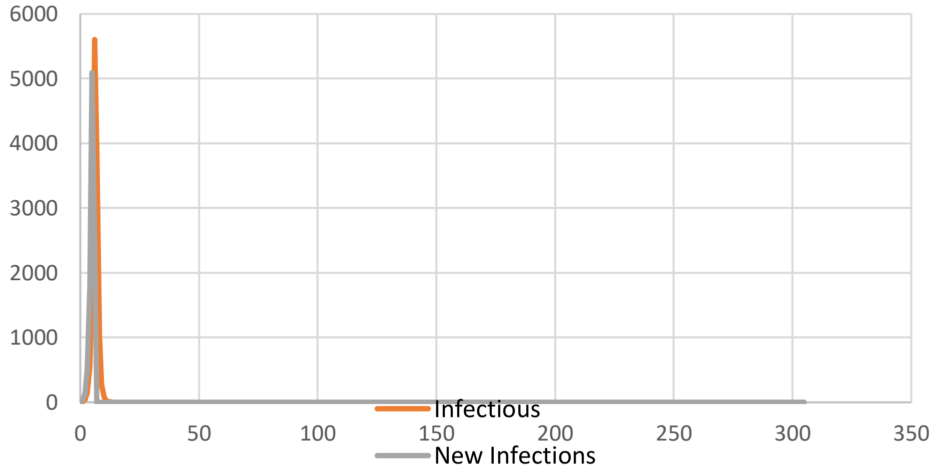
- Does this make biological sense?

Return to Main Room

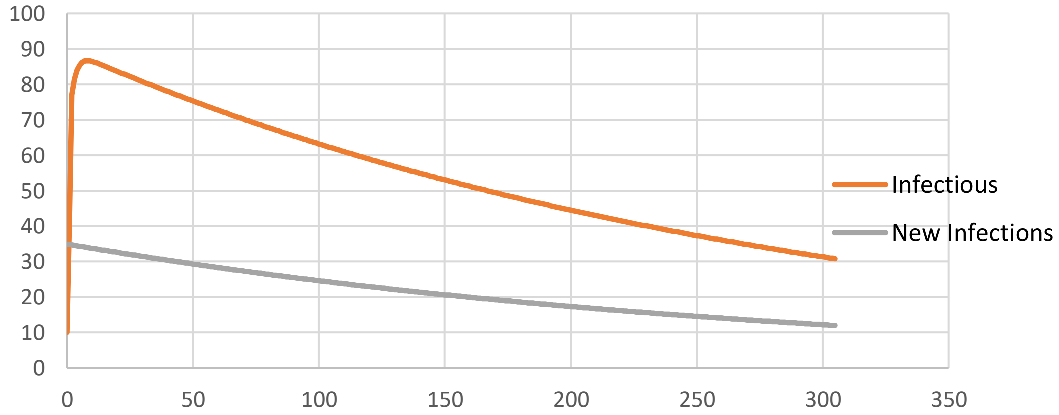
Did our model behave as we expected?

- Not really discuss….

Transmission rate determined by number of infectious farms



Transmission rate constant

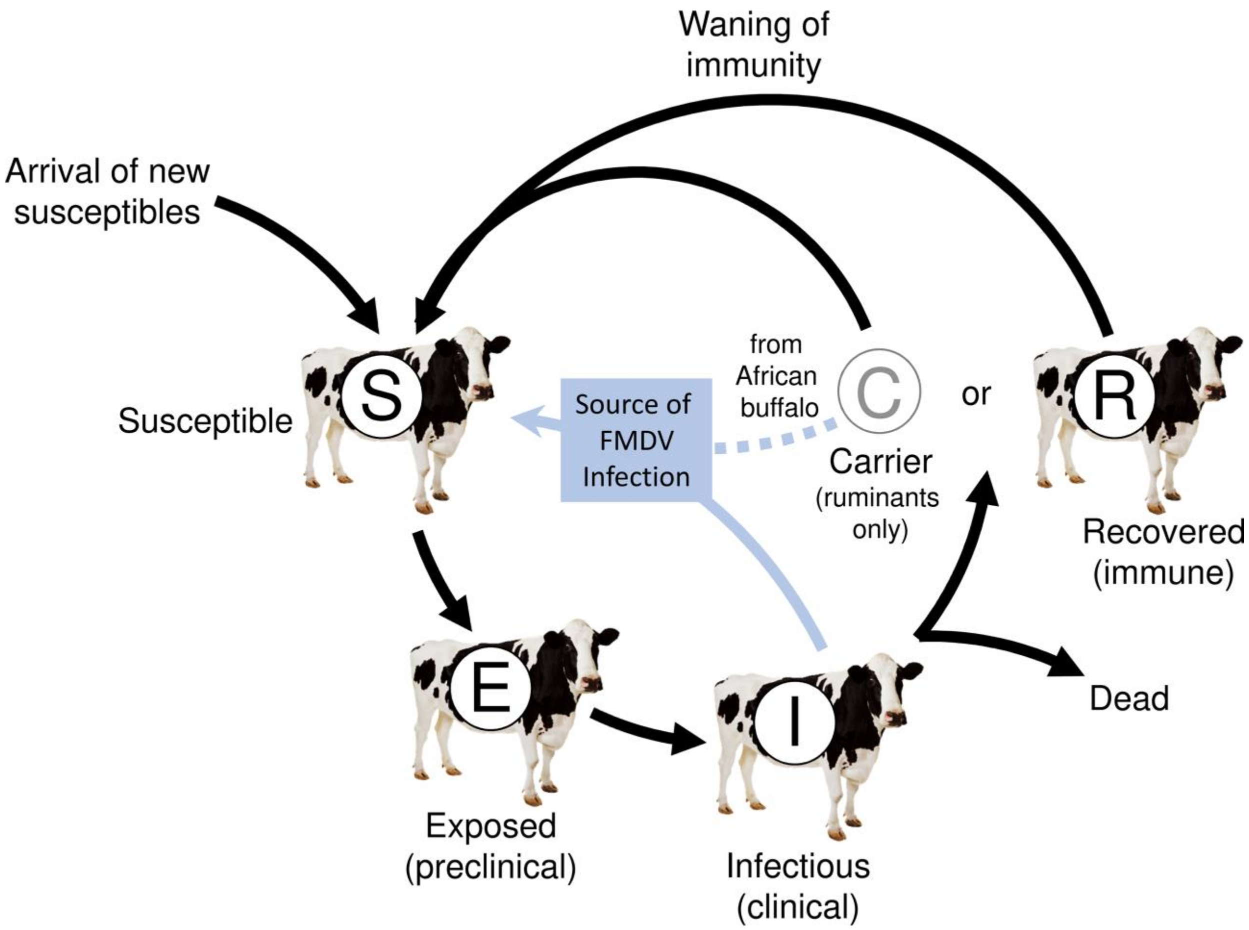


[Link to spreadsheet]

Conclusion

- All models are a simplification of the world and all models are wrong but some models are useful.
  - A good modeller will be clear about the assumptions and evaluate the impacts of the assumptions
- We can increase the complexity of the model by:
  - Adding states to the SIR model

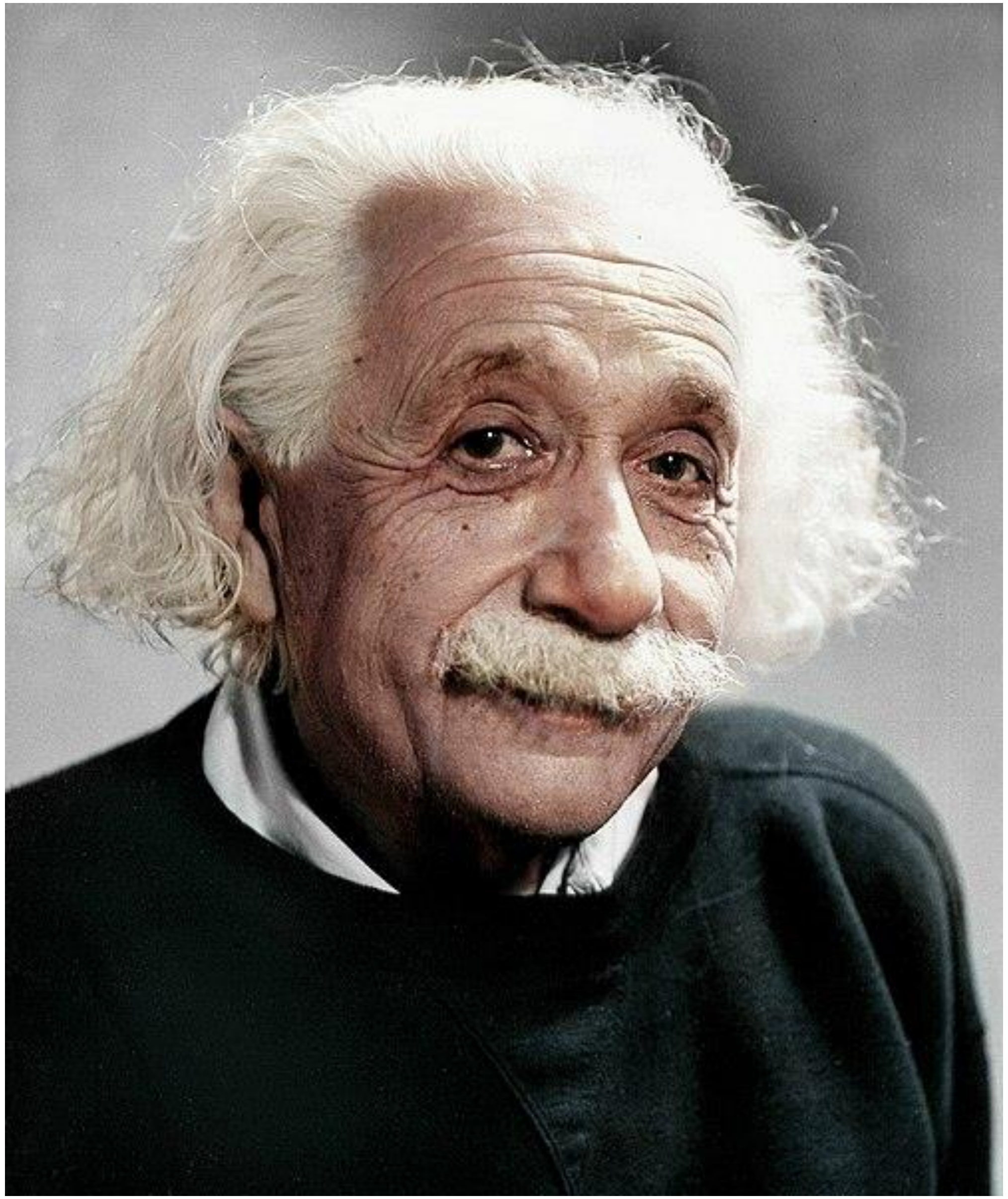
Moving on from SIR models



Conclusion

- All models are a simplification of the world and all models are wrong but some models are useful.
  - A good modeller will be clear about the assumptions and evaluate the impacts of the assumptions

- We can increase the complexity of the model by
  - Adding states to the SIR model
  - Incorporating stochastic processes
  - Allow for different values across the population (e.g. different contact rates for different types of farms)



It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender

Conclusion

- Increasing complexity:
  - Could give more realistic results (but remember it is a representation and not guarantee)
  - Will increase the data requirements
  - Could make it harder to interpret and translate for decision makers

- Coming next: What are the data requirements for more sophisticated models?