Using *NAADSM* 3.1

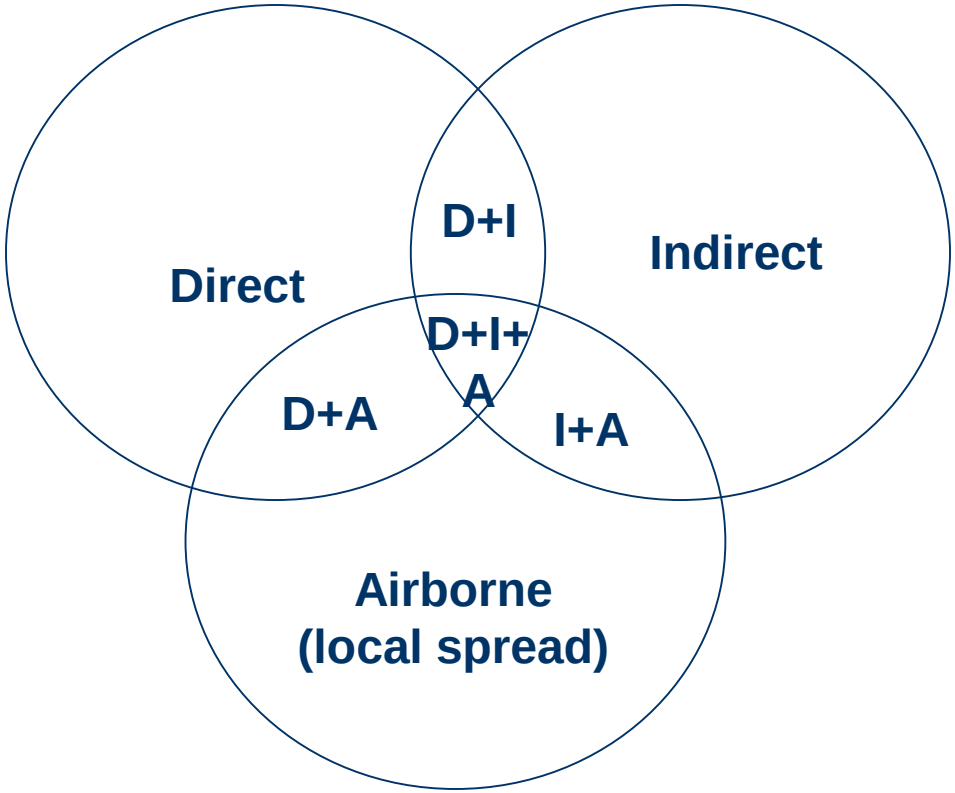
Part 2: Disease spread

NAADSM Development Team

http://www.naadsm.org

Mechanisms of disease spread

- Three mechanisms of disease spread are available in *NAADSM*:
  - Direct contact - movement of animals
  - Indirect contact - movement of people, equipment, vehicles, *etc*.
  - “Airborne” or local area spread
    - Based on proximity to infected farms
- Any subset of these can operate simultaneously



Disease state and disease spread (I)

- Transmission via direct contact can occur if infected unit is Latent, Infectious Subclinical or Infectious Clinical
  - The user has the option of simulating spread by direct contact from latent and/or subclinical units
- Transmission of disease via indirect contact can occur if infected unit is either Infectious Subclinical or Infectious Clinical
  - The user has the option of simulating spread by indirect contact from subclinical units
  - Latent units can never spread disease by indirect contact
- Transmission via airborne dispersion can occur when infected unit is Infectious Subclinical or Infectious Clinical

Disease state and disease spread (II)

- Recall that latent herds (units) are infected, but not yet shedding the disease agent
- What might happen if:
  - Animals from a latent herd are introduced into a susceptible herd?
    - Answer: This is direct contact. Infected animals are moved into a susceptible herd. The susceptible herd may become infected as a result.
      - Why might this make sense?
  - A feed truck visits a latent herd, and then later visits a susceptible herd without being washed?
    - Answer: This is indirect contact. In *NAADSM*, latent herds cannot spread disease by indirect contact.

Disease state and disease spread (III)

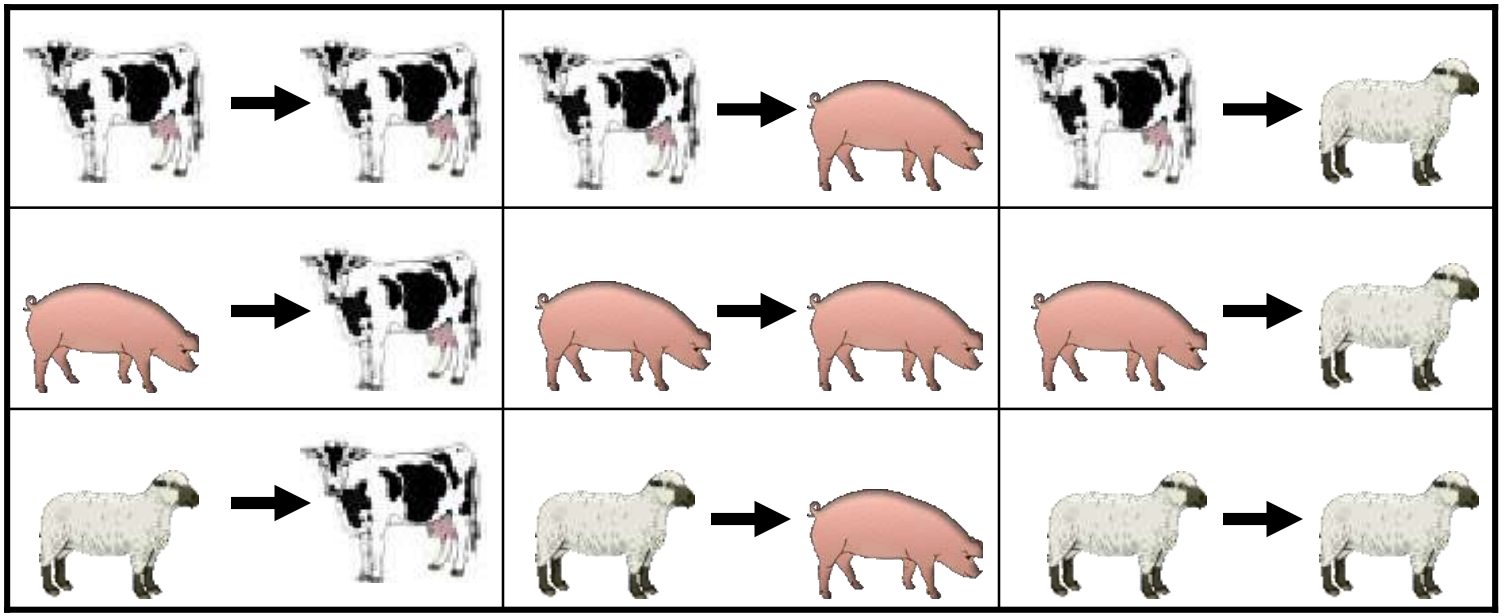
- Recall that subclinical herds are infected AND infectious (shedding the agent)
- What might happen if:
  - Animals from a subclinical herd are introduced into a susceptible herd?
    - Answer: Subclinical herds may transmit disease by direct contact.
  - A feed truck visits a subclinical herd, and then later visits a susceptible herd without being washed?
    - Answer: Subclinical herds may spread disease by indirect contact.

NAADSM demo (V): Disease spread

- Viewing "Spread options" window
  - Select the spread mechanism(s) suitable for your situation
  - Linear versus exponential decline for airborne spread will be discussed a little later

Who can spread to whom?

- Disease spread between units depends on:
  - The biology of the disease
  - The contact patterns among units of different production types

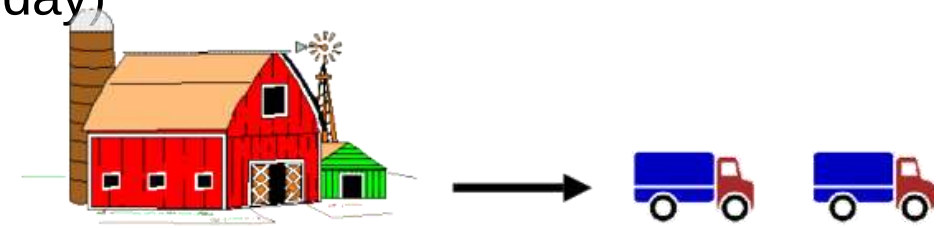


NAADSM demo (VI): Creating production type pairings

- Viewing the "Production type combinations" window
  - Adding or removing production type combinations

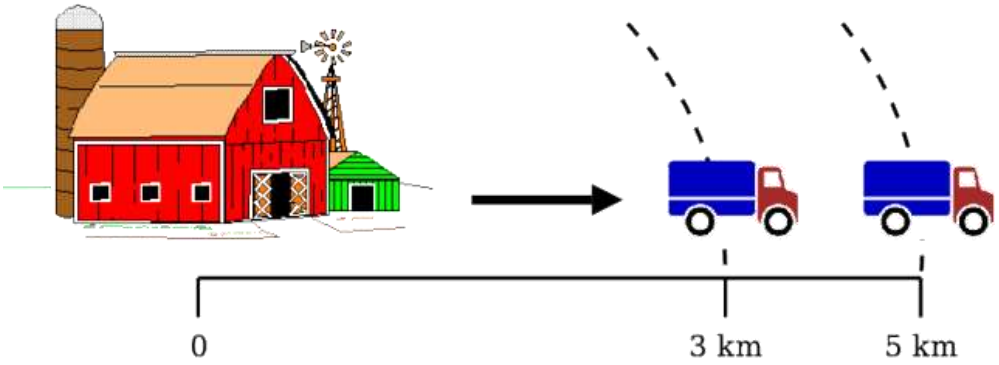
Parameters for contact spread: Contact rate

- The main parameter for contact spread is the *contact* rate, or the mean number of *outgoing* contacts per day from a unit
  - Contact rates are specified independently for each pairing of production types
  - For each unit that can infect others, the model simulates a number of outgoing shipments using EITHER:
    - A stochastic, Poisson distribution, defined by its mean
    - OR a fixed movement rate, if the user wants to specify contact frequencies more exactly (*e.g.*, exactly one contact every other day)



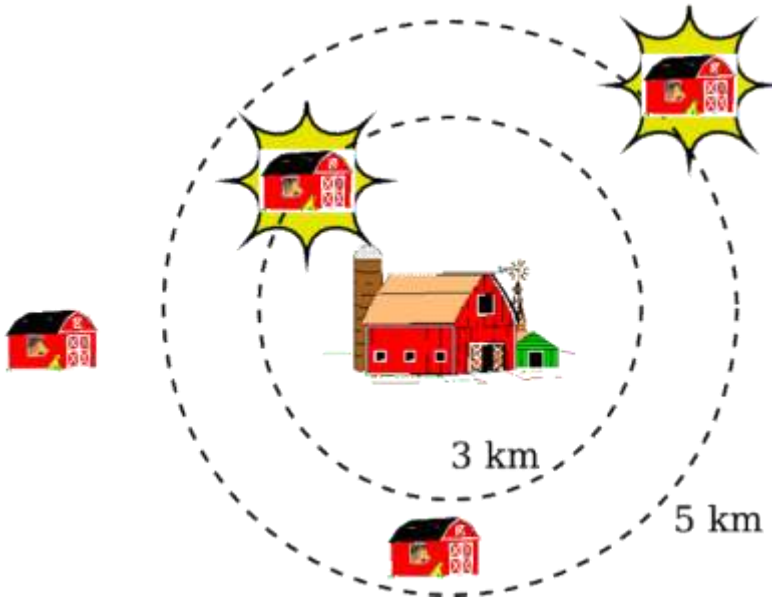
Parameters for contact spread: Movement distance

- From a probability density function of movement distances, a distance is chosen for each shipment
  - This parameter is specified independently for each pairing of production types



Parameters for contact spread: Selecting a recipient of contact (I)

- The model chooses as potential destinations the units where distance from the source best matches the distance selected from the probability density function
  - Direction is not considered
  - Production types are considered
  - Status of recipient units is considered
    - Quarantined units cannot be the recipients of direct contact
    - Quarantined units can be the recipients of indirect contact
    - (Quarantine will be discussed in more detail later)



Parameters for contact spread: Selecting a recipient of contact (II)

- If two destinations are the same distance from the source, choose one randomly
  - This choice is weighted by size: a unit twice as large is twice as likely to be chosen

Things to know about contacts & movements

- If NO suitable destinations exist at the appropriate distance, *NAADSM* will search outside of input distribution to find a destination
- If ANY suitable destinations exist in the database, the movement will occur
  - This is especially important in small populations, near the edges of the population, when movements are not restricted
- If an appropriate destination has been QUARANTINED it cannot accept an incoming direct contact

Quiz #1

- A shipment occurs from a beef farm to a dairy farm
- A distance of 30 km is selected from the input distribution
- Potential recipients:
  - Unit 1, swine, susceptible, not quarantined, 25 km away
  - Unit 2, dairy, susceptible, not quarantined, 40 km away
  - Unit 3, dairy, susceptible, not quarantined, 300 km away
- Which unit is selected as the recipient?

Quiz #2

- Small change:
  - Unit 1, swine, susceptible, not quarantined, 25 km away
  - Unit 2, dairy, clinically infectious, not quarantined, 40 km away
  - Unit 3, dairy, susceptible, not quarantined, 300 km away
- Which is selected?

Quiz #3

- Time passes:
  - Unit 1, swine, susceptible, not quarantined, 25 km away
  - Unit 2, dairy, destroyed, 40 km away
  - Unit 3, dairy, susceptible, not quarantined, 300 km away
- Now which is selected?

Quiz #4

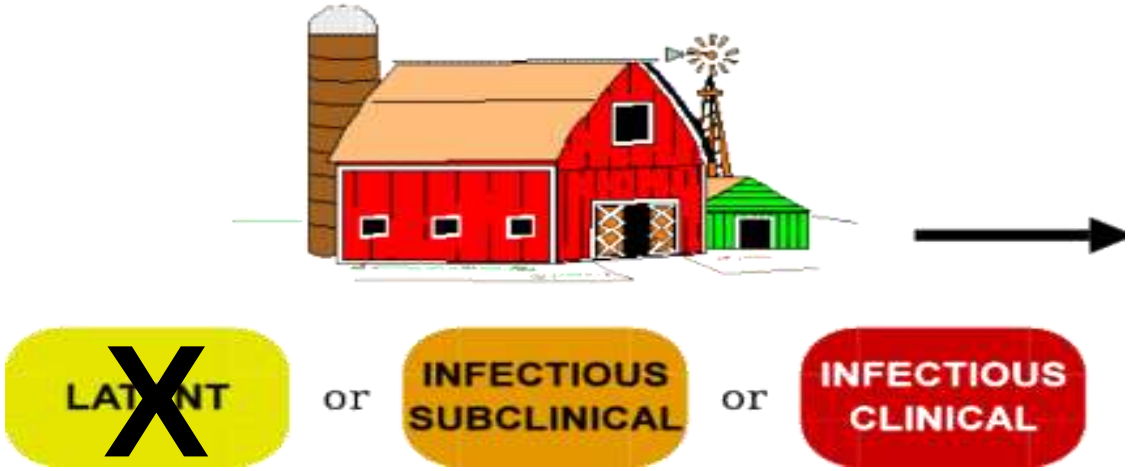
- Things get worse:
  - Unit 1, swine, susceptible, not quarantined, 25 km away
  - Unit 2, dairy, destroyed, 40 km away
  - Unit 3, dairy, susceptible, quarantined, 300 km away
- Now which is selected?

Parameters for contact spread: Probability of infection transfer

- The probability of infection transfer is the probability that, if a contact occurs, it will be adequate
  - Recall the definition of adequate contact from earlier
    - What is the difference between adequate and effective contact?
  - This concept is directly analogous to "*h*" that we used in our Reed-Frost models

Notes on indirect contact

- Indirect contact works like direct contact, except:
  - Latent units cannot be a source of infection



Quiz #5

- Can the following contacts in *NAADSM* be adequate, effective, both, or neither?
  - Movement of animals from a latent herd (unit) to a susceptible herd
  - Movement of animals from a clinical herd to a susceptible herd
  - Movement of animals from a clinical herd to a vaccine immune herd
  - Movement of animals from a clinical herd to a latent herd
  - Movement of a truck from a latent herd to a susceptible herd
  - Movement of a truck from a clinical herd to a naturally immune herd

NAADSM demo (VII): Contact spread

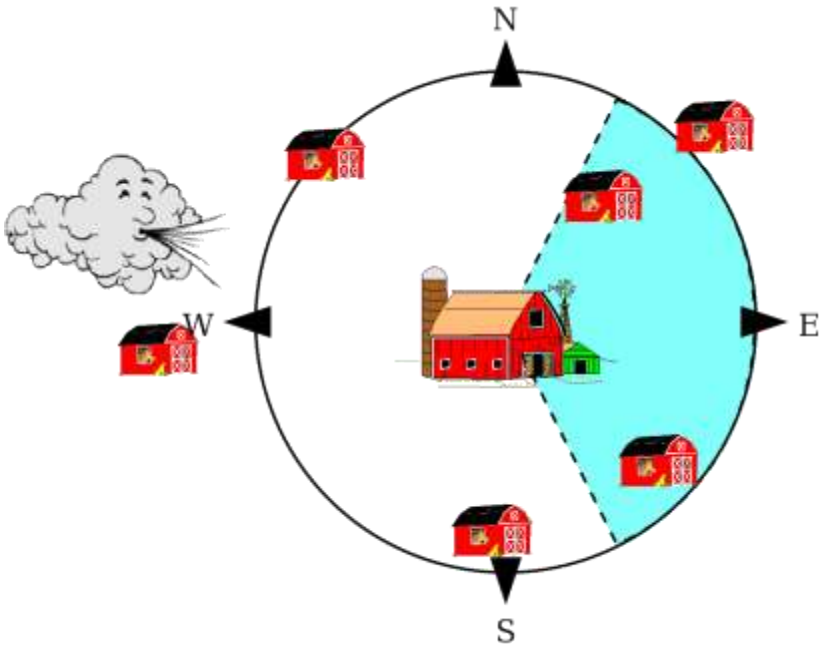
- Viewing the "Contact spread" window
  - Options for direct and indirect contact spread
    - Production type pairings
      - Transmission
      - Contact rate
        - Remember: this represents outgoing shipments
      - Probability of infection transfer
      - Distance distribution
      - Shipping delay
        - Be careful! Long shipping delays can produce odd results
        - May miss shipments if tracing occurs before shipment arrives

“Airborne” or local-area spread

- Parameters:
  - Wind direction (0-360 degrees)
  - Rate of spread declines linearly or exponentially
  - Probability of infection at 1 km from source
  - Maximum distance of spread
- As with direct and indirect contact spread, the parameters are specified independently for each pairing of production types

Directionality of airborne spread

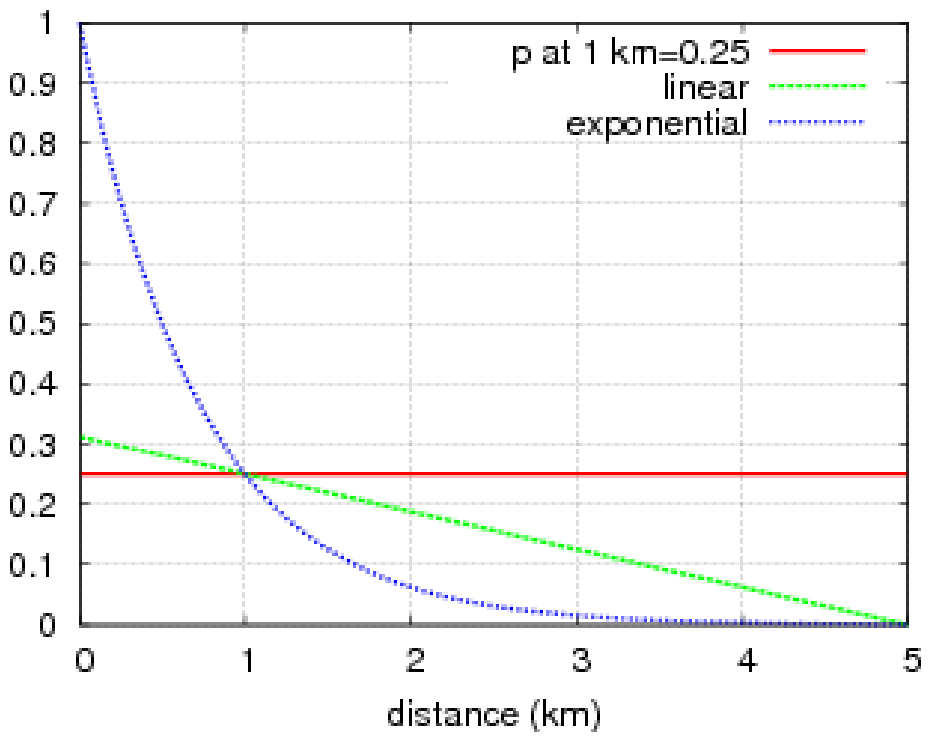
- Consider all possible target units given wind direction and maximum distance of spread



- This mechanism can be used in a nondirectional way (*i.e.*, 360 degrees) to simulate “local area” spread
  - Spread that cannot be attributed to any particular source, but is observed to occur in the area surrounding an infected premises

Airborne spread: Linear versus exponential decline

- A probability that disease transfer will occur between units 1 km apart is required for airborne/local area spread
  - (How might values for this parameter be obtained?)
- The red line in the plot shows a constant probability of disease spread, regardless of distance
  - *(NAADSM* does not actually support this, but it's a useful example)
- The green line shows a probability that declines linearly
  - A maximum distance of spread is also required
- The blue line shows a probability that declines exponentially
  - A maximum distance of spread is not required



NAADSM demo (VIII): Airborne spread

- Viewing “airborne spread” window
  - Production type combinations
    - Probability of spread/day at 1 km
    - Range of wind direction
    - Transport delay

Summary

- Three mechanisms of disease spread are simulated in *NAADSM*
- The production types of the source and recipient units influence the frequency of contact and the probability that disease spread will occur by any of these mechanisms
- The disease state of a source unit determines whether contact can be adequate
- The disease state of a recipient unit determines whether an adequate contact will be effective
- The airborne spread mechanism in *NAADSM* can be used to simulate otherwise uncharacterizable local-area spread

Questions?

The *NAADSM* development team (past and present)

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  - Mark A. Schoenbaum
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Recommended reading

- Harvey, N., Reeves, A., Schoenbaum, M.A., Zagmutt-Vergara, F.J., Dubé, C., Hill, A.E., Corso, B.A., McNab, W.B., Cartwright, C.I., Salman, M.D., 2007. The North American Animal Disease Spread Model: A simulation model to assist decision making in evaluating animal disease incursions. *Preventive Veterinary Medicine* 82: 176–197.
- Hill, A., and Reeves, A. 2006. User's Guide for the *North American Animal Disease Spread Model*, 2nd ed. Fort Collins, Colorado: Animal Population Health Institute, Colorado State University. Available at *http://wwww.naadsm.org*