North American Animal Disease SpreadModel

Disease Control

Barbara Corso, DVM, MS, Dipl ACVPM
Epidemiologist,
USDA, Animal and Plant Health Inspection Service, Veterinary Services
Centers for Epidemiology and Animal Health

- Uses slides from presentations by:
  - Mark A. Schoenbaum
  - Neil Harvey
  - Francisco Zagmutt Vergara
- Additional material from
  - Neil Harvey, Aaron Reeves
  - Other colleagues
- As well as my own

Disease Control

- How does NAADSM allow us to attempt disease control?
- What are the input parameters?
- Examples
- Order of actions

How does NAADSM allow us to try to control disease?

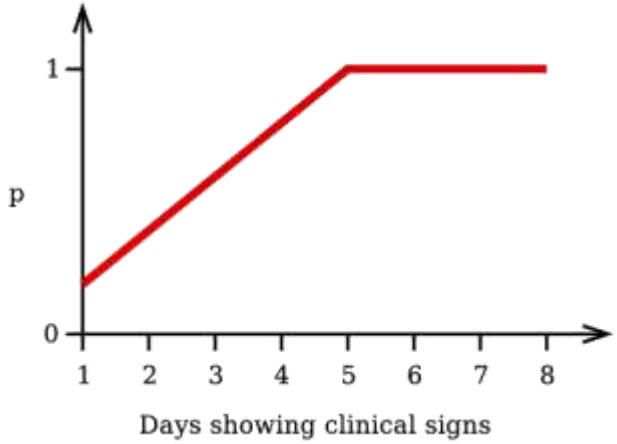
- Detection
- Tracing forward
- Quarantine
- Movement controls
- Destruction
- Vaccination
- Zones

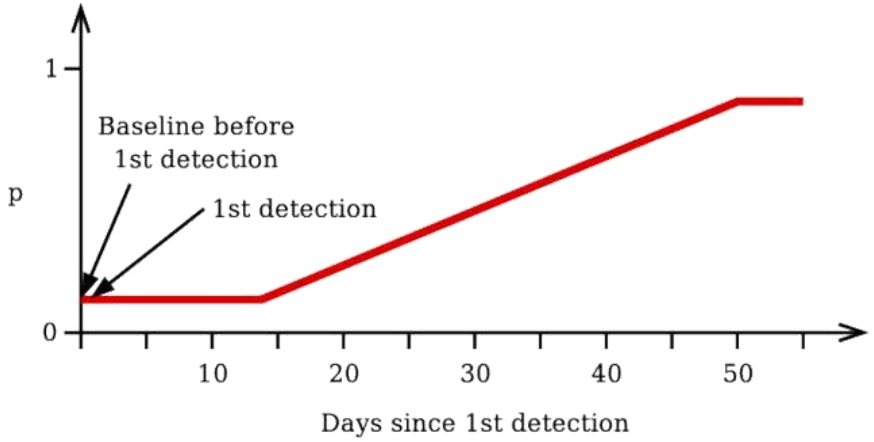
Detection

- Two independent factors in detection of diseased units
  - Daily probability of detection given the number of days animals have been showing clinical signs in particular unit
  - Daily probability of reporting given the number of days since first detection of the disease in the overall population (community awareness)

Detection

- Two charts provide the probabilities
- Probability of detection and reporting on a given day = $p_1 \times p_2$





Detection

- No false positives (100% specific)
- Different detection parameters may be specified for each production-type
- If zone option is selected, can alter the probability of detection within zones
- Detected units are quarantined the following day, automatically

Detection

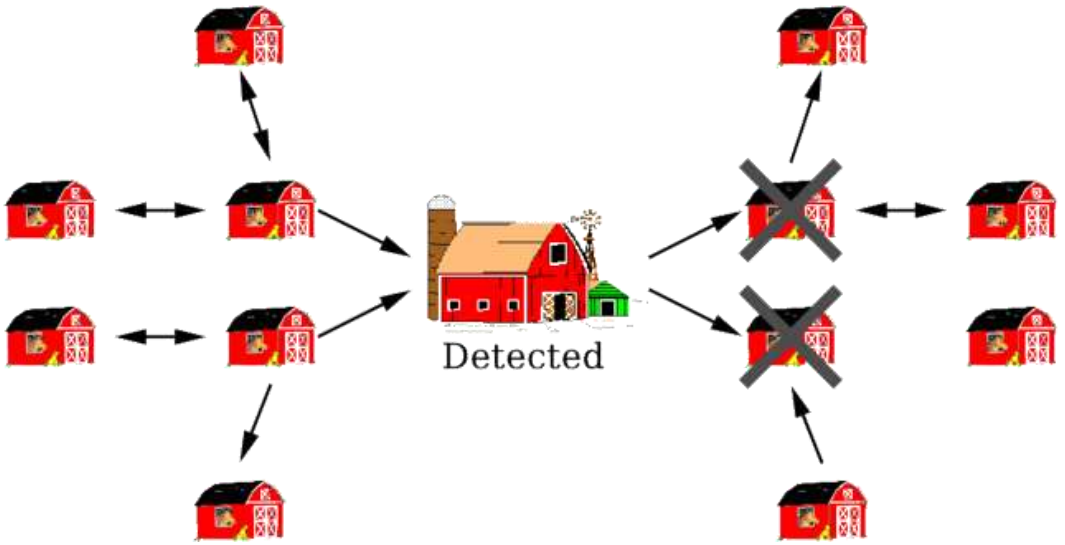
- Global Parameters
  - Include Detection (yes/no)
- Production type specific
  - Probability of detection vs. days unit has been showing clinical signs 
  - Probability of detection vs. days since the first detection of the disease in the overall population 

Tracing

- Units that have had direct or indirect contact with an infected premises before it is detected can be identified
- NAADSM tracks all movements out of infected premises
- Only traces forward from detected premises, not backward
- Direct or indirect contact may be traced
- Successful traces completed next day

Trace

- Trace goes 1 step forward
- Does not trace back to units that were the source of a contact with the detected unit



Tracing

- For each production type that will be traced, enter
  - How many days before detection to trace back
    - But remember, only records movements from infected
    - So no direct information on unnecessary traces
    - Can calculate if that information is wanted
  - How effective tracing is
    - What proportion of traces are completed successfully

Quarantine

- A unit is “quarantined”
  - When it is detected as diseased
  - When it has been designated to be destroyed but not yet been destroyed
- No direct contacts allowed
- Indirect contacts and airborne spread can still occur

Movement control

- To simulate overall movement control during the course of an outbreak
- Defined by production type
- Adjustments of movement rates for direct and indirect contact
  - Entered when contact is defined
  - Change over the course of the outbreak
- Zones also affect movement

Destruction

- Destruction eliminates the unit
- Destruction program is triggered by the first detection
  - But it may be several days before decisions are made and the program is “set up” and ready to destroy units
  - That delay in days is specified in parameters

Destruction

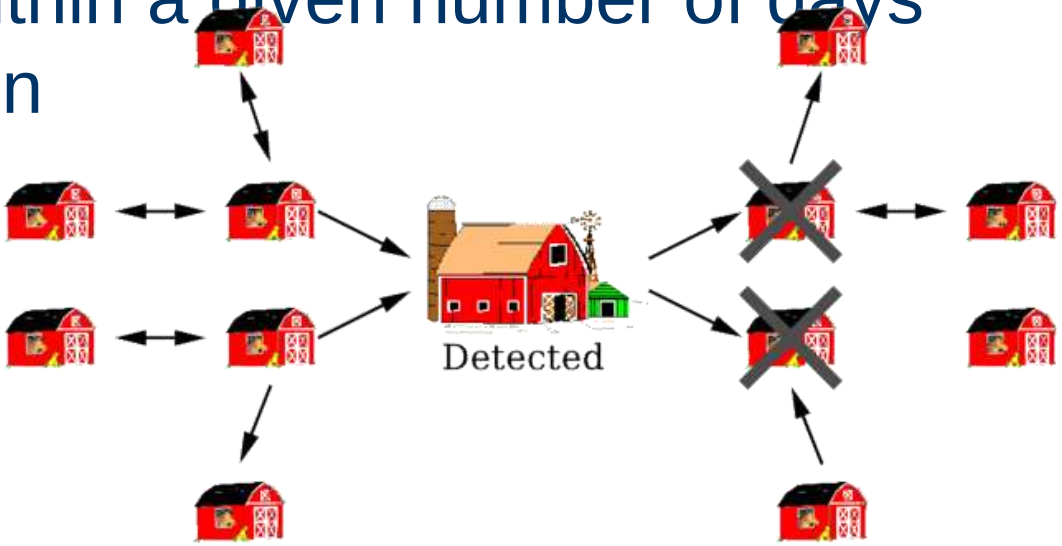
- Basic option: destroy all units detected as diseased
- Additional options:
  - Ring destruction
  - Destruction of traced units
    - Direct contact
    - Indirect contact

Destruction

- Ring destruction
- Destroy all units within a given distance of a detected unit

Destruction

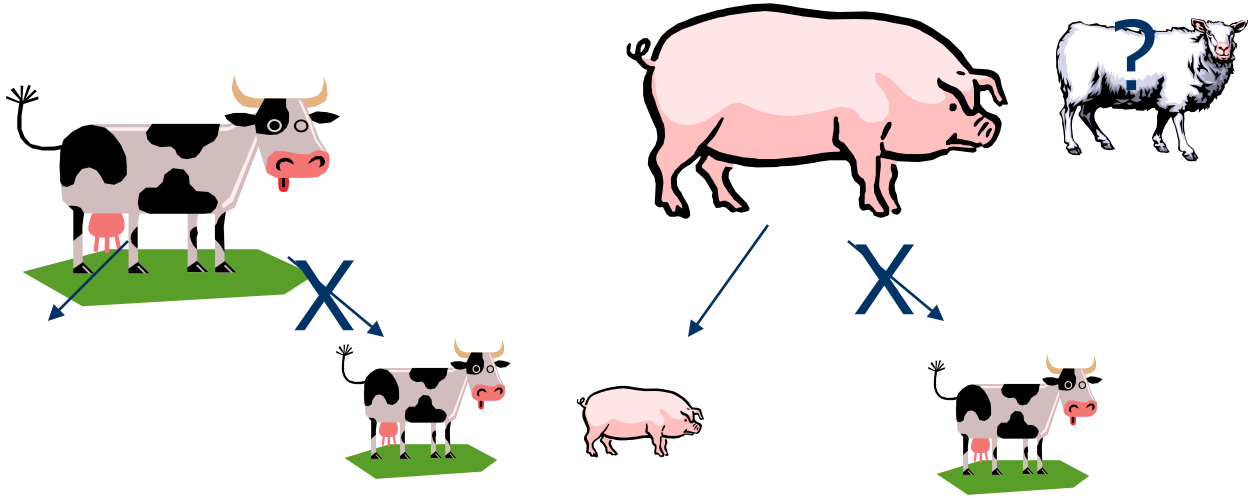
- Trace destruction
- Destroy all units that have been the recipient of a direct (or indirect) contact from a detected unit within a given number of days prior to detection



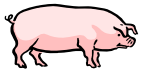
Destruction

- Production type, pairing issues

Detection



Rings
Tracing



Destruction capacity and priority

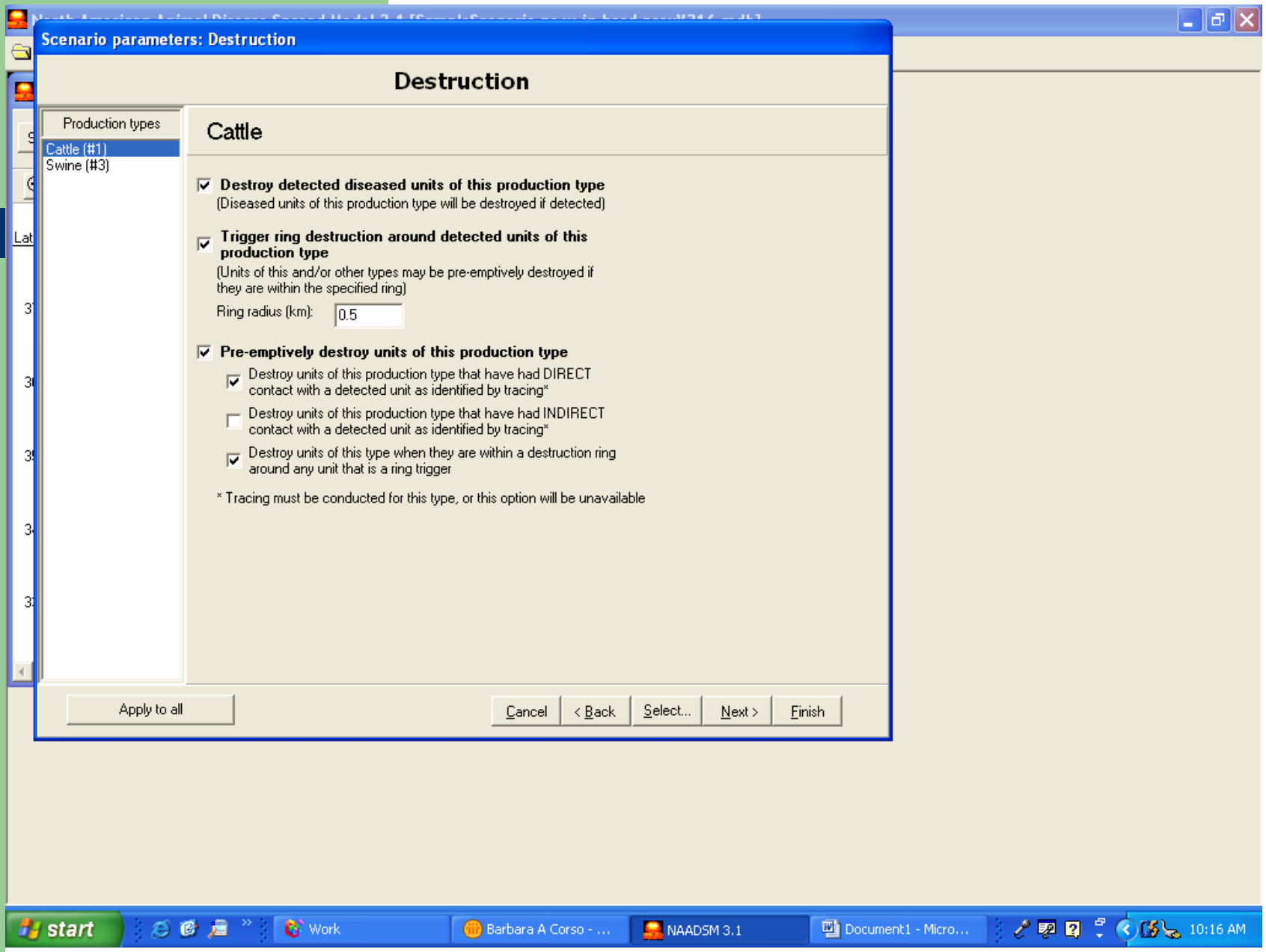
- The authorities' daily capacity to destroy units is given as a chart (to simulate the resources available to destroy)
- Number of units slated for destruction may exceed the capacity; therefore, units are prioritized by a combination of
  - Production type, reason for destruction, number of days waiting

Destruction capacity and priority

- Priorities example,
  - Pig units might have unconditionally higher priority than cattle units
  - Cattle units discovered by trace investigations (either direct or indirect contact) might have higher priority than cattle units near a detected unit (ring destruction)
  - Cattle units identified for destruction 5 days ago will have higher priority than cattle units identified for destruction for the same reason only 1 day ago

Destruction parameters

- Global parameters:
  - Destruction? – yes/no
  - Delay to begin a destruction program (days)
  - Destruction capacity (units/day) vs. days since the first detection 
  - Priority order
- Per-production type parameters:
  - Destroy diseased units?
  - Trigger a ring?
  - Radius of destruction ring (km)
  - Destroy if direct contact? Indirect?
  - Is this production type killed if in a ring?


Scenario parameters: Destruction
Destruction
Production types
Cattle (#1)
Swine (#3)
Cattle
Destroy detected diseased units of this production type
(Diseased units of this production type will be destroyed if detected)
Trigger ring destruction around detected units of this production type
(Units of this and/or other types may be pre-emptively destroyed if they are within the specified ring)
Ring radius (km):
0.5
Pre-emptively destroy units of this production type
Destroy units of this production type that have had DIRECT contact with a detected unit as identified by tracing*
Destroy units of this production type that have had INDIRECT contact with a detected unit as identified by tracing*
Destroy units of this type when they are within a destruction ring around any unit that is a ring trigger
* Tracing must be conducted for this type, or this option will be unavailable
Apply to all
Cancel
< Back
Select...
Next >
Finish
start
Work
Barbara A Corso - ...
NAADSM 3.1
Document1 - Micro...
10:16 AM

Vaccination

- Vaccination program begins after a “trigger” number of detected units
- Ring vaccination
  - Vaccinate all units within a given distance of a detected unit
- If a unit is not susceptible, it will not progress to vaccine immune
- If the unit is vaccine immune, re-vaccination will extend time in that status

Vaccination

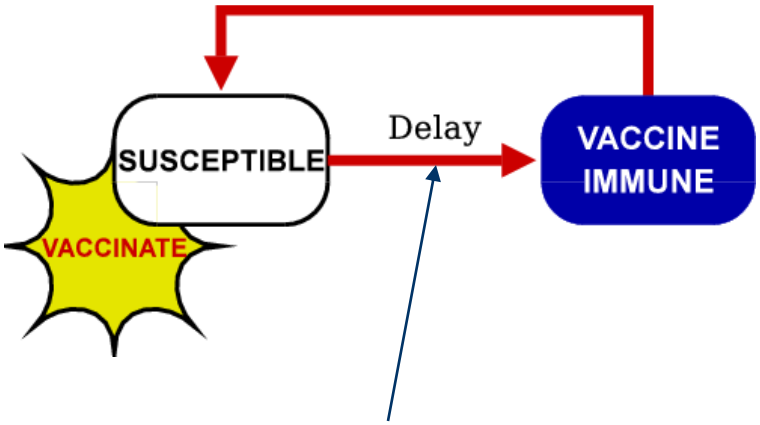
- Not set to automatically revaccinate
- Will revaccinate if unit ends up in another circle
- Infection can occur after vaccination but before unit becomes vaccine immune
- After vaccine immune period expires, unit becomes susceptible
- Parameters much like destruction

Vaccination - parameters

- Global
  - Vaccinate yes / no
  - How many units must be detected before start?
  - Capacity 
  - Priority
- Production type specific
  - Vaccinate this production type?
  - Immune period 
  - Delay in immunity
  - Minimum time between vaccinations
  - Trigger a vaccination ring if disease is detected in this production type?
  - Radius of ring

Vaccine

- Progression of a vaccination

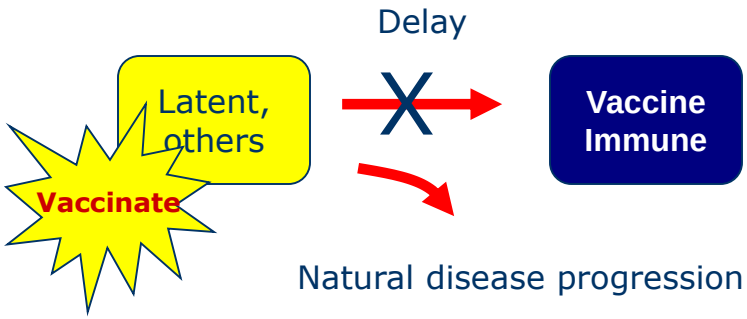


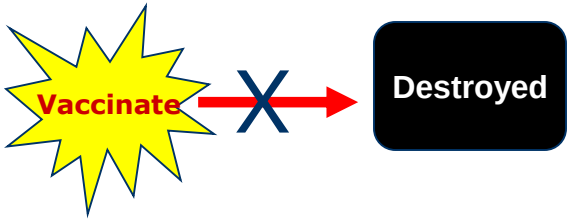
If infection occurs during this delay (transition to latent), there is no longer a transition to vaccine immune.

Duration of immunity given as a probability function.
Chosen stochastically each time that a unit is vaccinated.

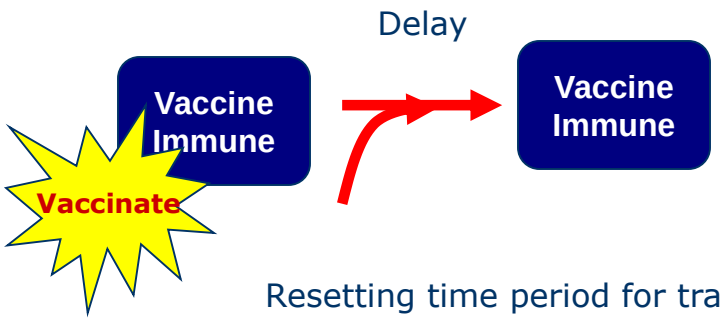
Duration of immunity is specific to production type.

Vaccination





If a unit is scheduled for destruction, it will not be vaccinated



Resetting time period for transition state

Vaccination capacity and priority

- The authorities' daily capacity to vaccinate units is given as a chart (to simulate the resources available to vaccinate)
- Number of units slated for vaccination may exceed the capacity; therefore, units are prioritized by production-type and number of days waiting

Zones

- User defined zones created around detected or traced units
- Can create multiple zones
- Number and size of zones is same for all production types – production type specific choice is yes or no zones
- Zones are never removed – once placed, stay until end of simulation

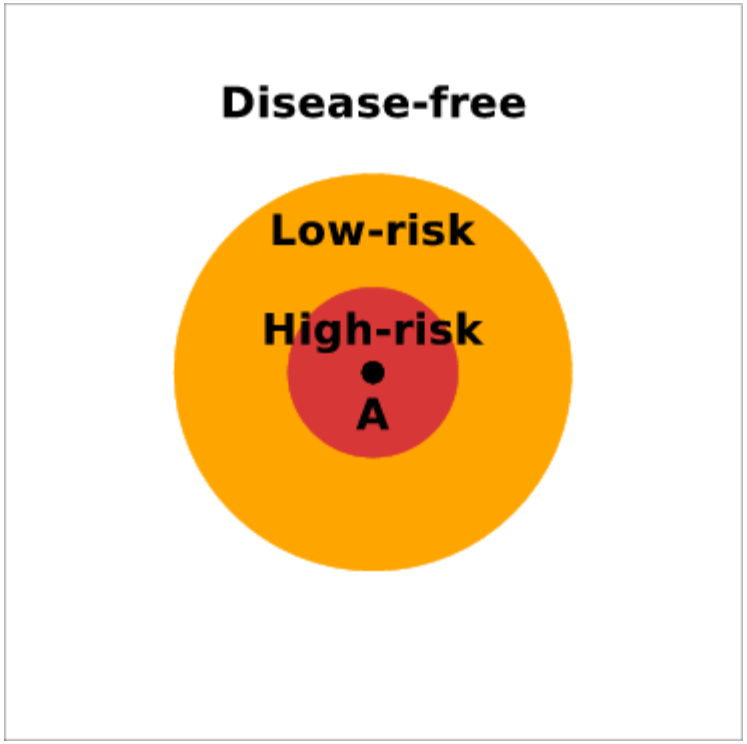
Zones

- Modify direct and / or indirect movement and / or detection
- Higher level of surveillance is a smaller circle (closer to detected or traced unit)
- Detection adjusted within zone using a multiplier
  - allows for the simulation of greater vigilance in higher-level zones
- Contact rules built-in to zone definition

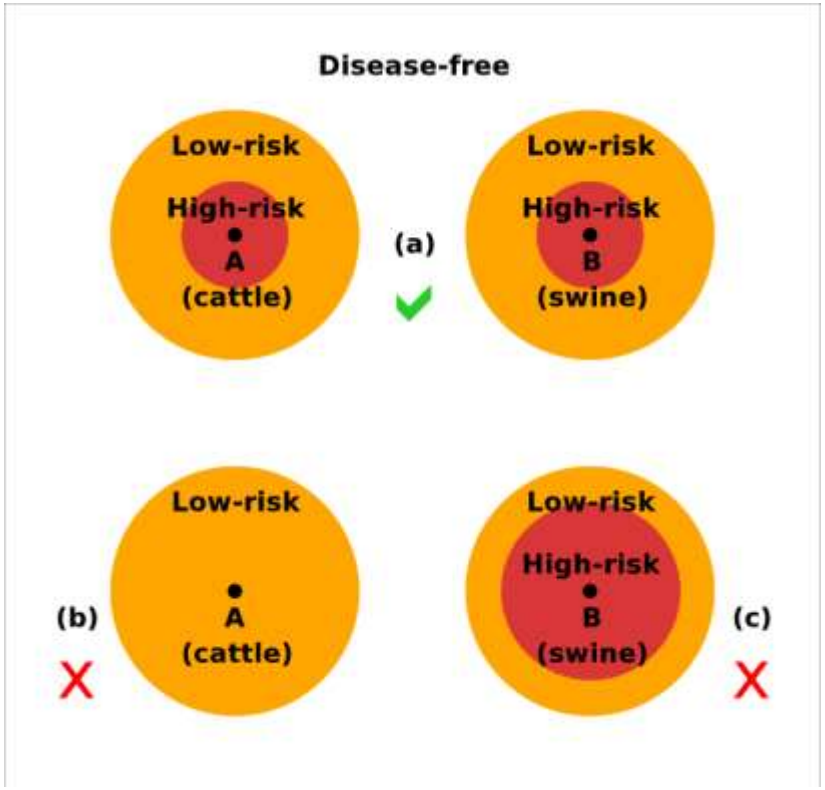
Zones

- Global Parameters
  - Presence of zones
  - Name of zone
  - Radius (km)
- Production type specific
  - Whether zone is created by detection, direct or indirect contact (check box for each)
  - Specify how movement rate for direct and indirect contact and / or detection rate are altered in each zone

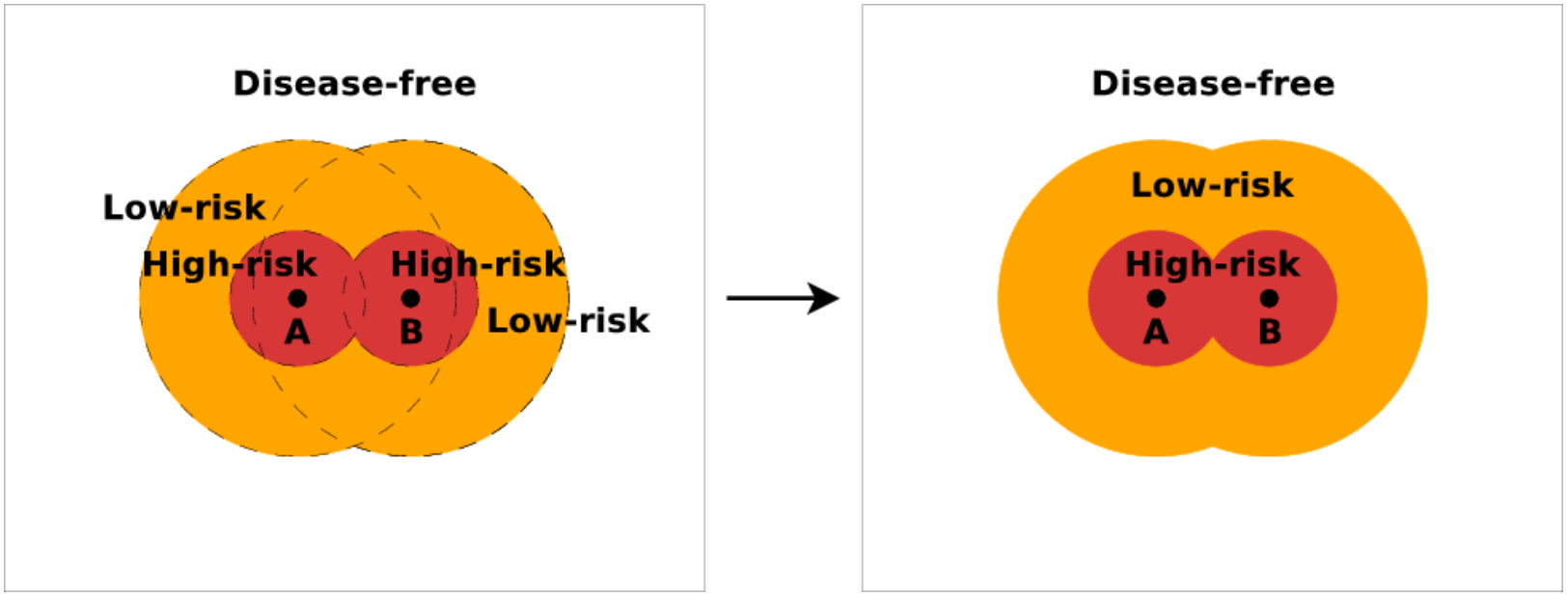
Zone creation



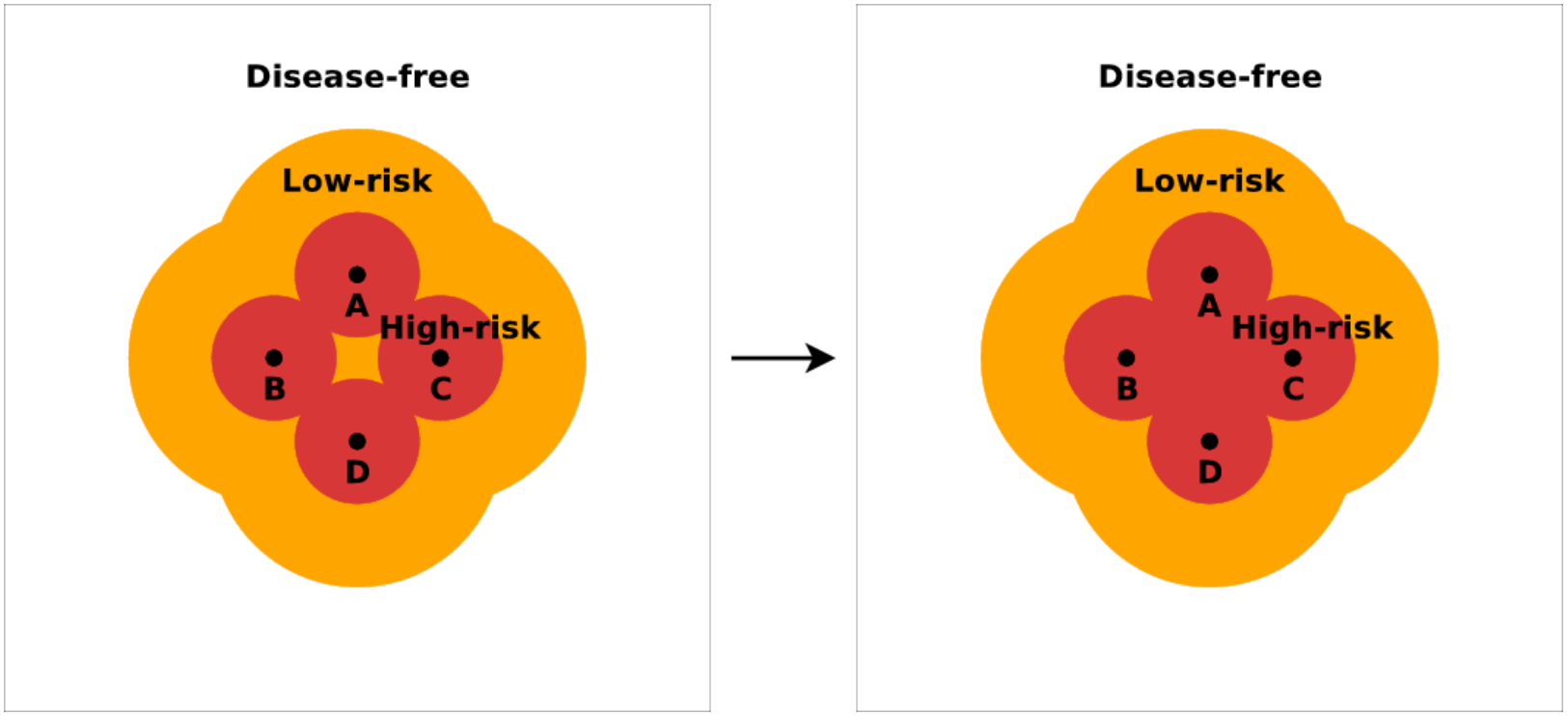
Zone creation



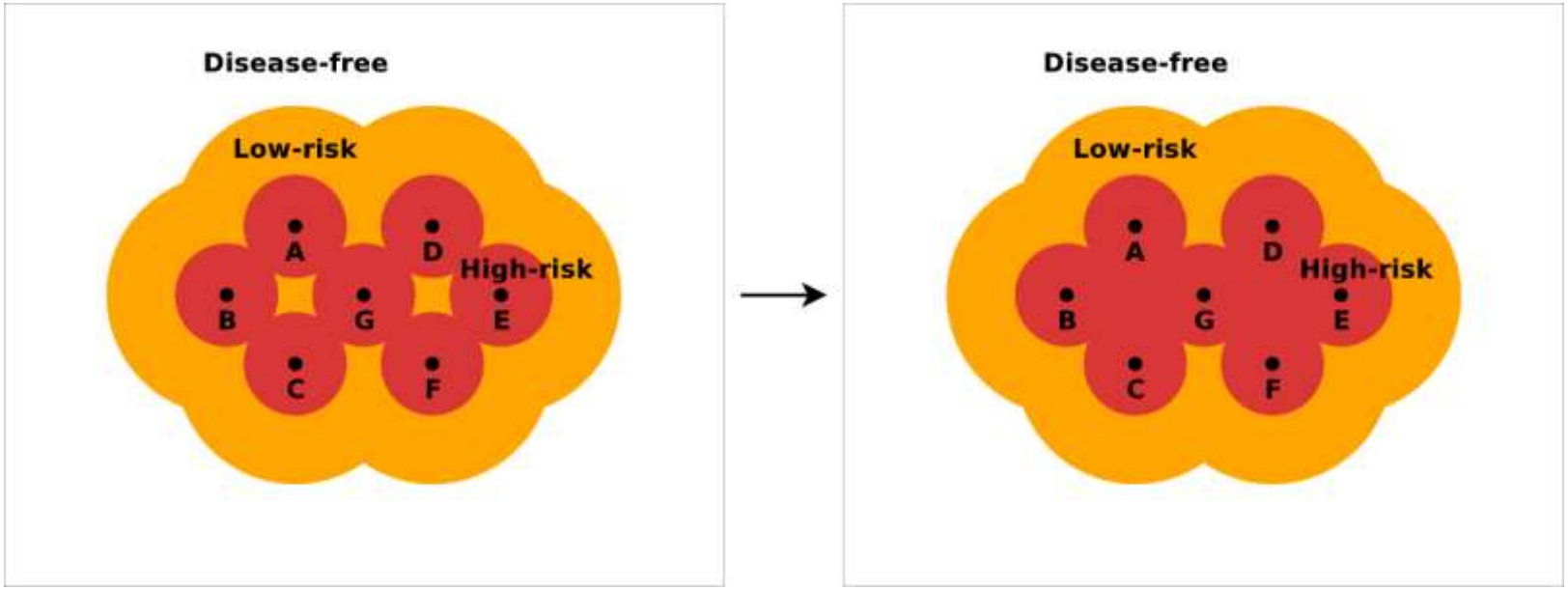
Zone creation



Zone creation



Zone creation

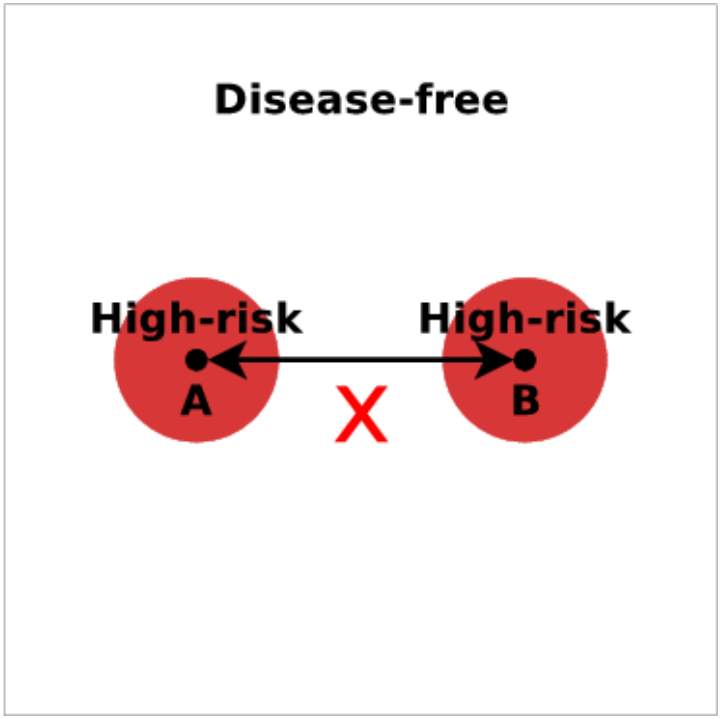


Zone - movement

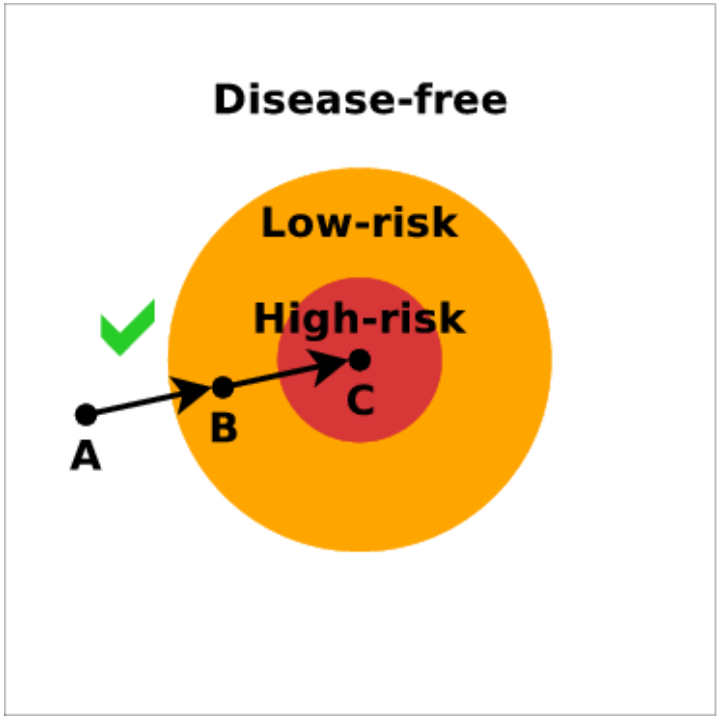
- Movement when zones are used
  - List potential recipients of a direct or indirect movement that meet all requirements
  - If two are exactly the same distance away, can eliminate ones that are blocked by zone rules
  - Otherwise, select best recipient based on distance
  - If potential recipient is forbidden by zone rules, movement does not occur and is dropped
  - Doesn’t look for another recipient

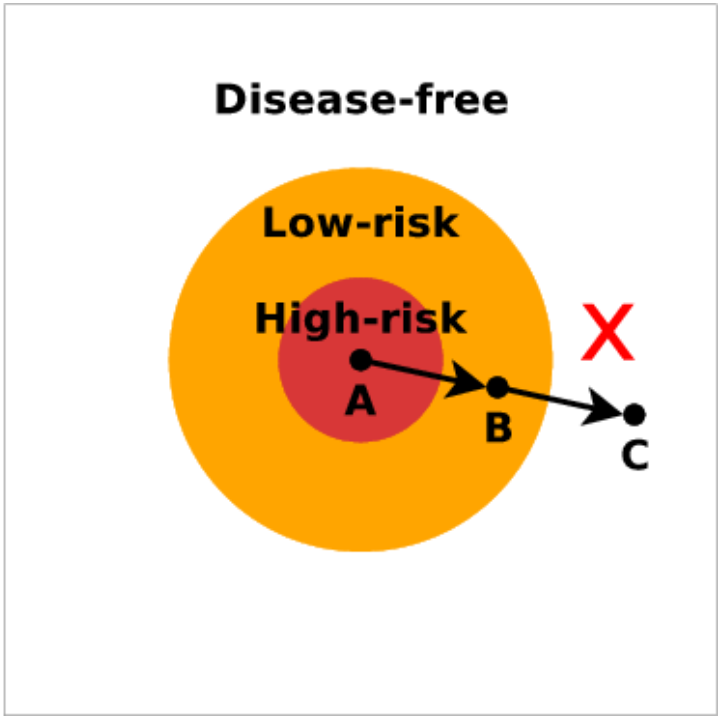
- Movement is forbidden if source unit and receiving unit are in physically separated foci of the same zone, or if the source unit is in a zone of a higher surveillance level than the receiving unit

Zone movement

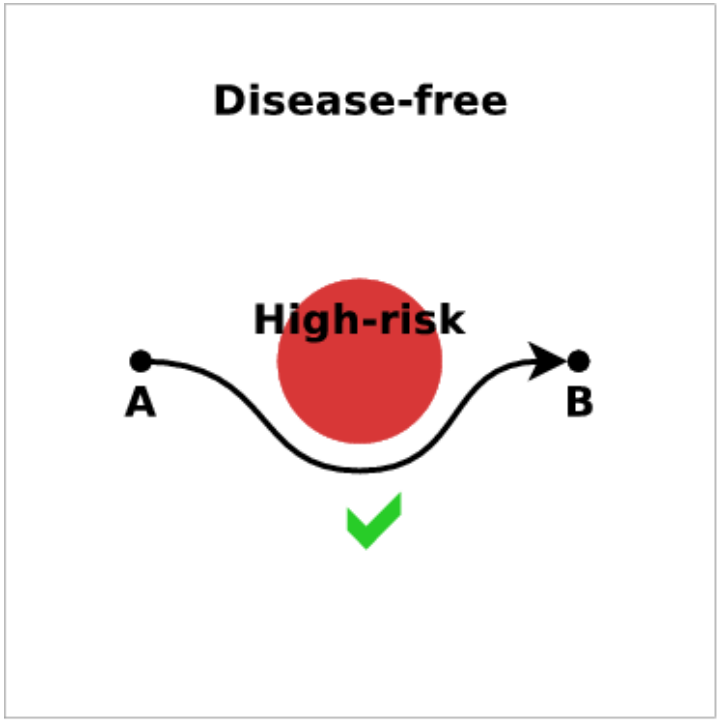


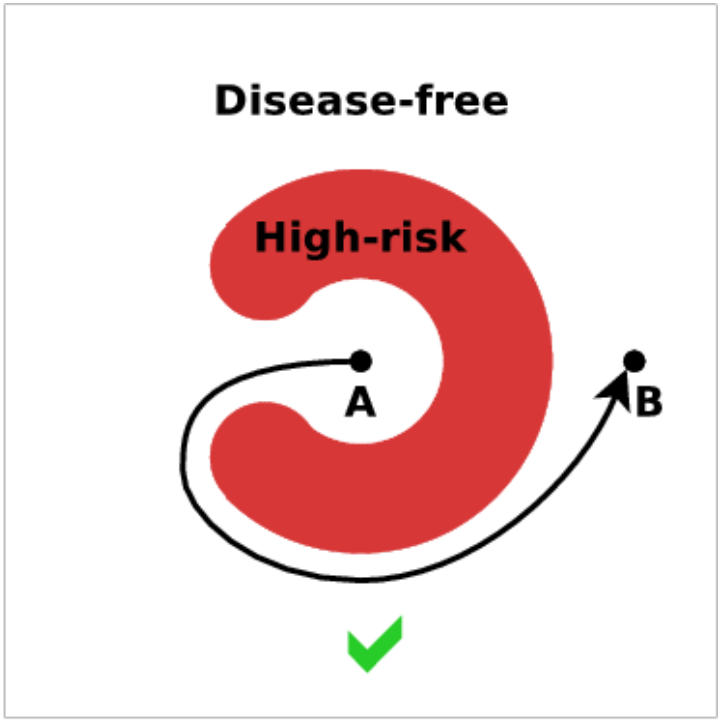
Zone movement





Zone movement





Movement example when using Zones in your simulation

- Suppose the beef herd is inside a zone focus
  - Unit 1, dairy, susceptible, quarantined, same zone focus, 30 km away
  - Unit 2, dairy, susceptible, not quarantined, same zone focus, 31 km
  - Unit 3, dairy, susceptible, not quarantined, outside zone focus, 25 km
- A 30 km movement – who is selected?

- Suppose the distance to unit 2 and 3 are exchanged:
  - Unit 1, dairy, susceptible, quarantined, same zone focus, 30 km away
  - Unit 2, dairy, susceptible, not quarantined, same zone focus, 25 km
  - Unit 3, dairy, susceptible, not quarantined, outside zone focus, 31 km
- A 30 km movement – who is selected?

- A final example:
  - Unit 1. Dairy, Susceptible, quarantined, inside the same zone focus, 30 km away
  - Unit 2. Dairy, Susceptible, not quarantined, inside the same zone focus, 30 km away
  - Unit 3. Dairy, Susceptible, not quarantined, outside the zone focus, 30 km away
- 30 km movement – who is chosen?

How does NAADSM allow us to try to control disease?

- Detection
- Tracing
- Quarantine
- Movement controls
- Destruction
- Vaccination
- Zones

Order of actions

- The simulation contains a number of processes
- Different orderings of these processes could lead to different outcomes
  - e.g., exposure and transition to Vaccine Immune on the same day -- which takes precedence?

Order of actions

- First: Exposure and infection, vaccination, or destruction
  - If unit is exposed and destroyed, or exposed and vaccinated both on same day, which occurs first is random
- Next: Natural progression through states due to infection or vaccination

Order of actions

- So movements (exposure) occur before progression to next disease state
- Movements (exposure) may occur before destruction or after it (if after, movement couldn’t occur)

Order of actions

- If there is more than one reason for destroying or vaccinating a given unit, a single reason is chosen randomly for reporting purposes
- If a unit is infected by two or more modes of spread on a single day, one mode is chosen randomly for reporting purposes