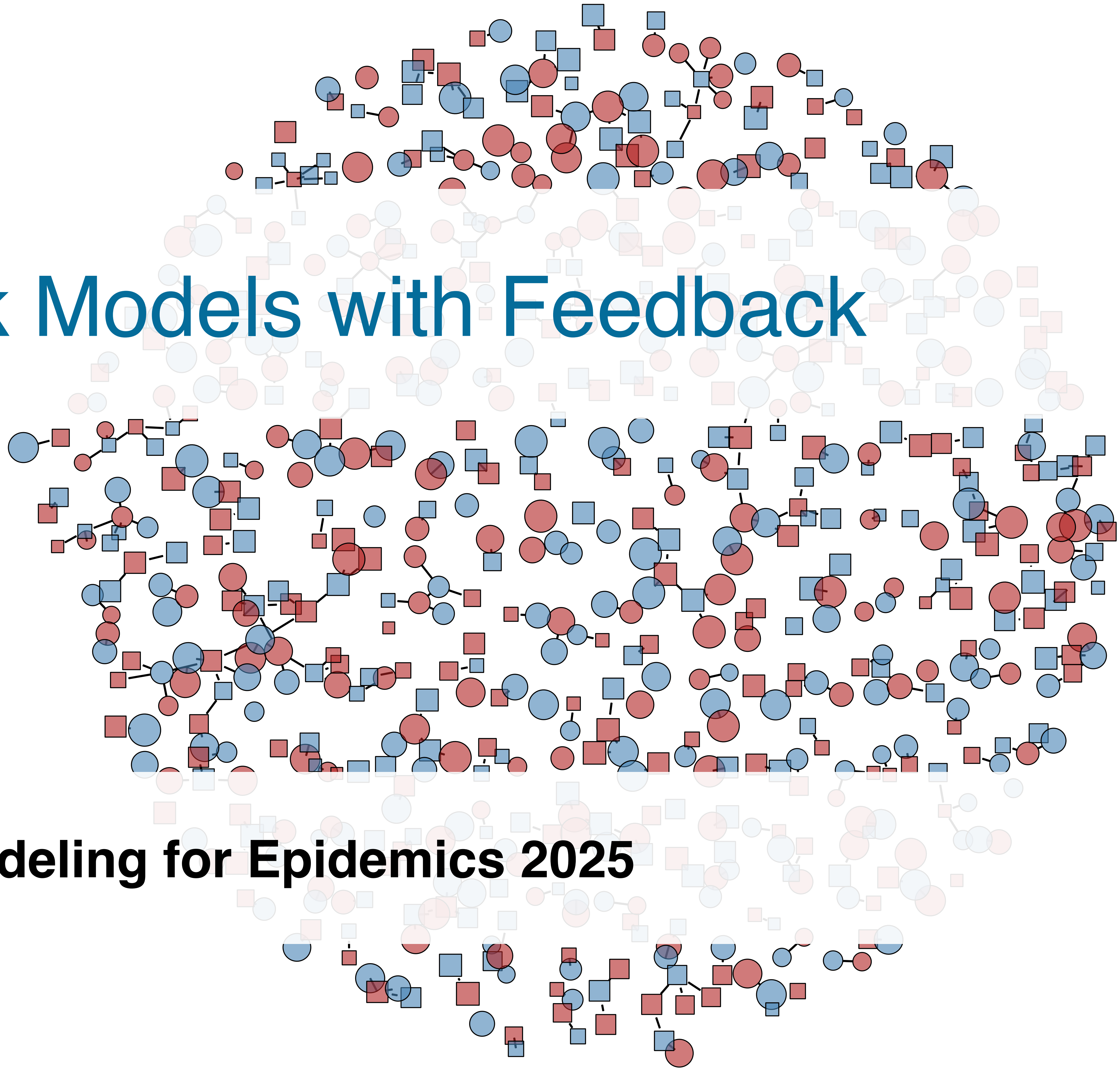
Network Models with Feedback

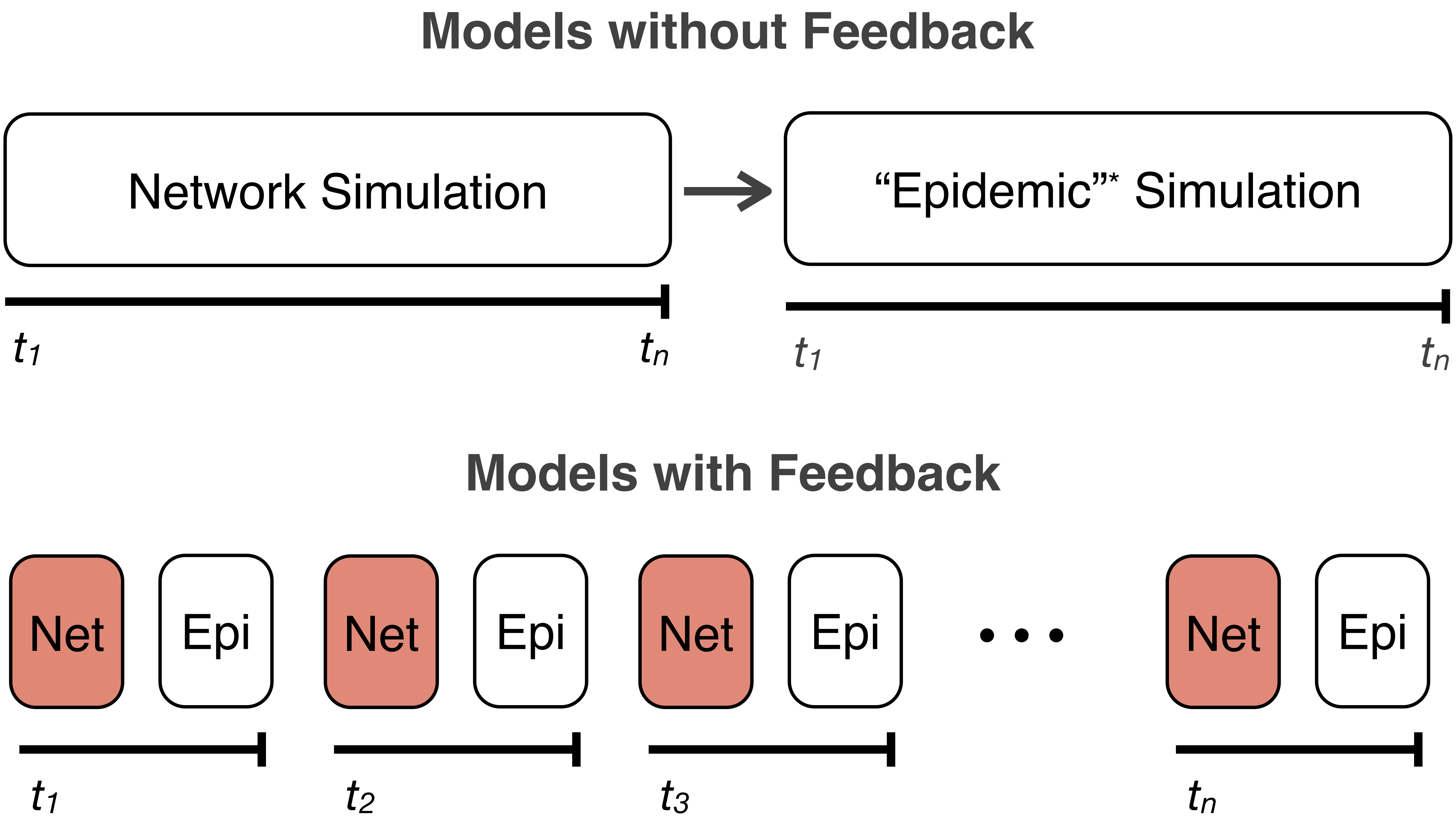


Network Modeling for Epidemics 2025

Causes of Model Feedback

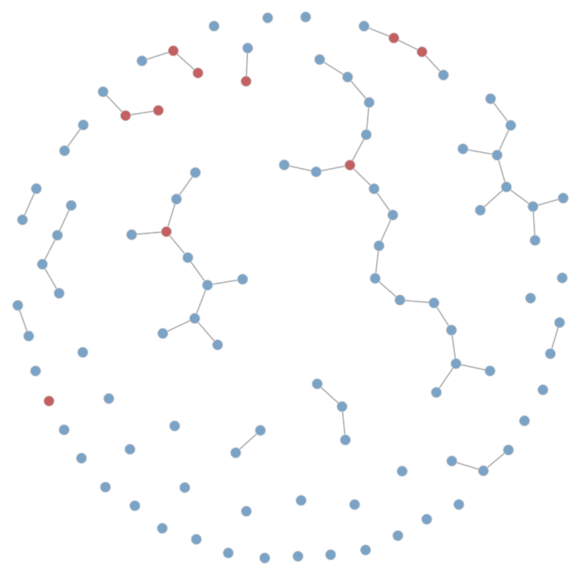
- Changes to the node set
  - Demographic churn (birth, death, migration)
    - Deaths and out-migration result in inactive nodes, which also dissolve edges
    - Births and in-migration result in newly active nodes, open for new edges
  - Sometimes, entry and exit from the epidemic-relevant network means something other than birth and death
    - e.g., initiation and cessation of sexual activity
    - We use the terms arrival and departure accordingly
- Changes to nodal attributes
  - Simulating from an ERGM involves evaluating current nodal attributes reference in formula
    - e.g., preferential mixing on age and disease status with `absdiff` and `nodematch` terms
  - These attributes may change over time, in different ways
- Broader temporal shifts in behavior or biology
  - Monotonic increases in sexual partnership rates
  - Social distancing!

Model Feedback



"Epidemic" = biological, behavioral, demographic, etc., changes*

“Built-in Epidemiology”



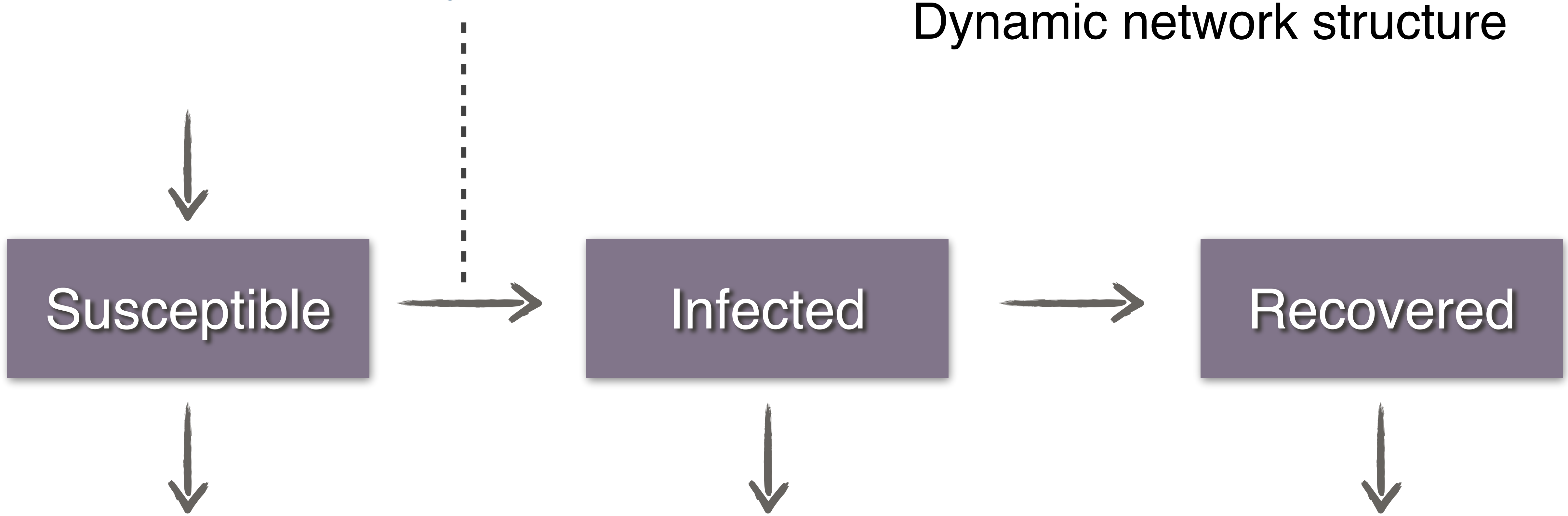
Fixed

Basic structure of states and flows

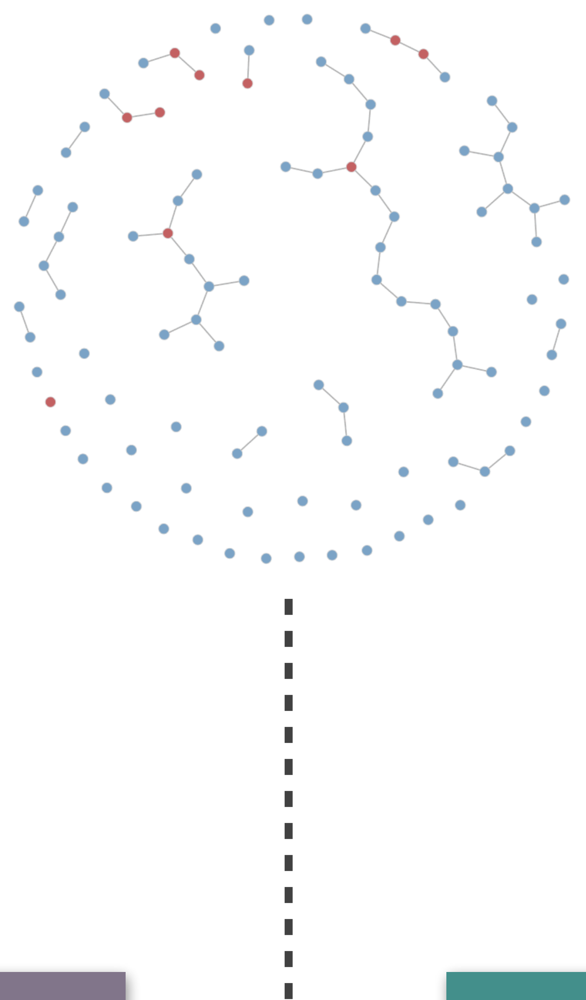
Modifiable

Epidemic parameters

Dynamic network structure



EpiModel Extensions



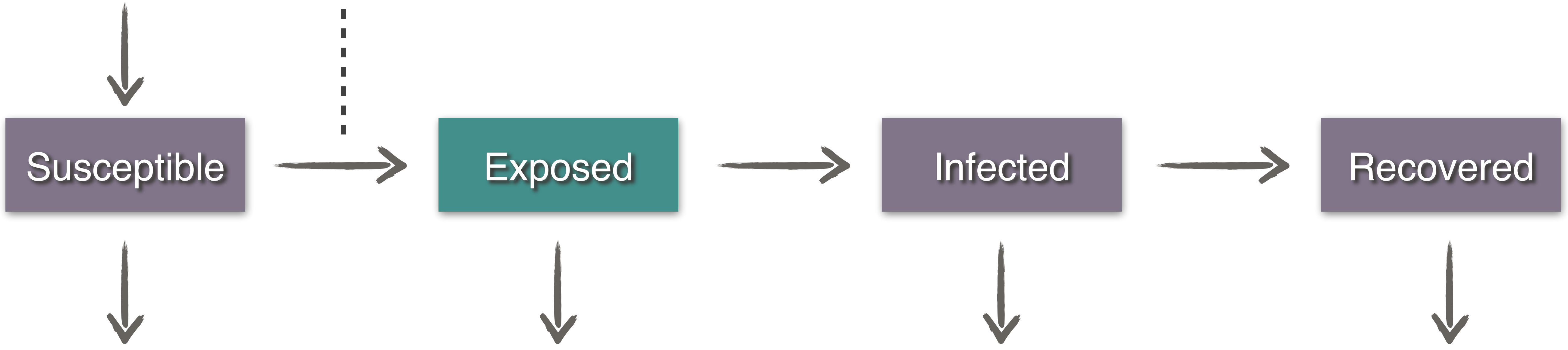
Modifiable

Basic structure of states and flows

Modifiable

Epidemic parameters

Dynamic network structure



Changing Network Size and Composition

As social networks change in size (say, for instance, as a village of n = 5,000 nodes grows to n = 10,000 nodes), which of the following do you think is generally preserved?

Number of edges? e

Mean degree? $2e/n$

Density? $e/\binom{n}{2}$

Changing Network Size and Composition

- Applying the coefficients as-is from a TERGM fit to a network of changing size will lead to preservation of density across time
- For one-mode networks, preserving mean degree instead requires a simple transformation of the edges coefficient in the formation model:

$$\theta_{new} = \theta_{old} + log(N_{old}) - log(N_{new})$$

- Mathematically equivalent to partitioning the original edges term into an offset equal to *log(N)* and a residual, and then updating the offset as N changes

Relational Dissolution through Death

- We fit our dynamic network using static data, with a process for dissolving relationships governed by a coefficient derived from relational duration
- All of this was done in a context that contained no information about death — another process that terminates relationships
- If we simply layer death on to our model (even with the size correction on the previous slide) we will see two measures drop down below the expected values we want:
  - *Relationship durations*
  - *Number of relationships*
- Some aspect of this might be desired…
  - *If we could interview deceased people, we might find their past relationships to be shorter than those of the same birth cohort in our sample who are still alive*
- … but others are likely not

Relational Dissolution through Death

An approximate correct for this is:

1. Calculate dissolution coefficients as before (without considering death)
2. Estimate formation coefficients conditional on these dissolution coefficients
3. Calculate new dissolution coefficients that reflect the log-odds of a relationship sustaining conditional on both actors living, which equals:

$$\text{logit}\left[1-\frac{P(E_t)-P(N_t)}{P(\neg N_t)}\right]$$

where

- $P(E_t)$ = the overall probability of a tie dissolving at time t from any cause = $1/D$
- $P(N_t)$ = the probability of either incident node dying at time t

Review of Offsets and Corrections

When approximating the fit of a formation STERGM conditional on dissolution STERGM...	…subtract dissolution coefficients from corresponding formation ones (edapprox=TRUE)
When network size N changes and you want to preserve mean degree…	…add the *ln* of the old N and subtract the *ln* of the new N to the edges coefficient in the formation model (or equivalently, use an edges offset and update it with *ln* of new N)
To adjust for node departures in simulating from a STERGM model estimated from a cross-sectional network and durations	$\operatorname{logit}\left[1-\frac{P(E_t)-P(N_t)}{P(\neg N_t)}\right]$