Why using epidemiological models to evaluate control strategies for livestock infectious diseases?

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Infectious diseases in livestock

- Animal health & welfare
- Zoonoses
  - ➔ Food safety
  - ➔ Veterinary public health

➔ Economic losses in animal productions

- ➔ Worse animal performances, production losses, culling

➔ **Effective preventive and control measures**

Infectious diseases in livestock

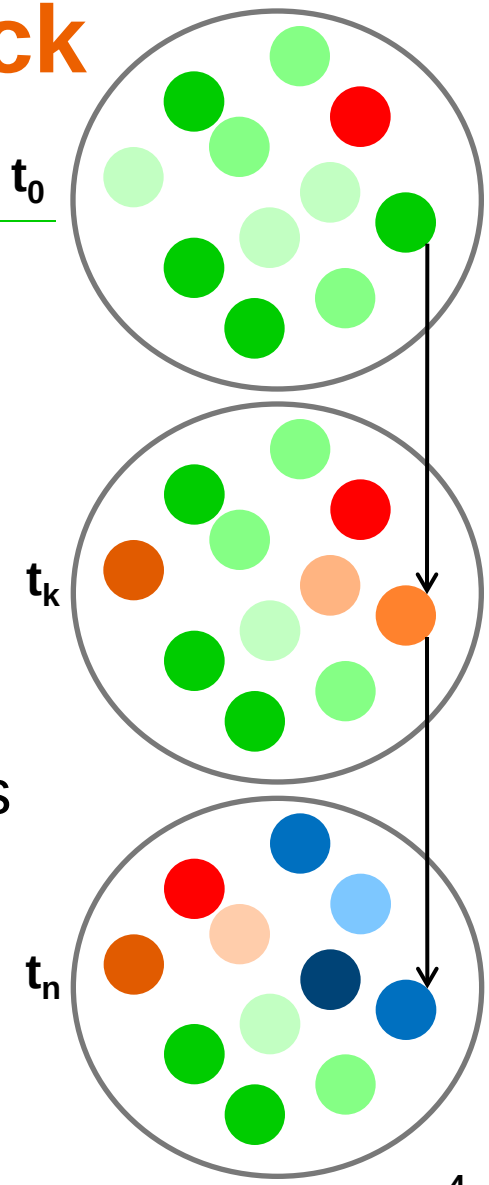
- What need to be understood?
  - Which pathogen, which source / origin?
  - Which transmission route(s)?
    - Direct, indirect (vector, environment, wind, …), vertical (*in utero*), etc.
  - Which host and environmental factors favouring?
    - Infection transmission, clinical sign appearance (disease)
  - Which efficient control measures?
    - Vaccination, test & cull, hygiene, etc.

➔ **Dynamic spread of infectious pathogens in a host population under various scenarios**

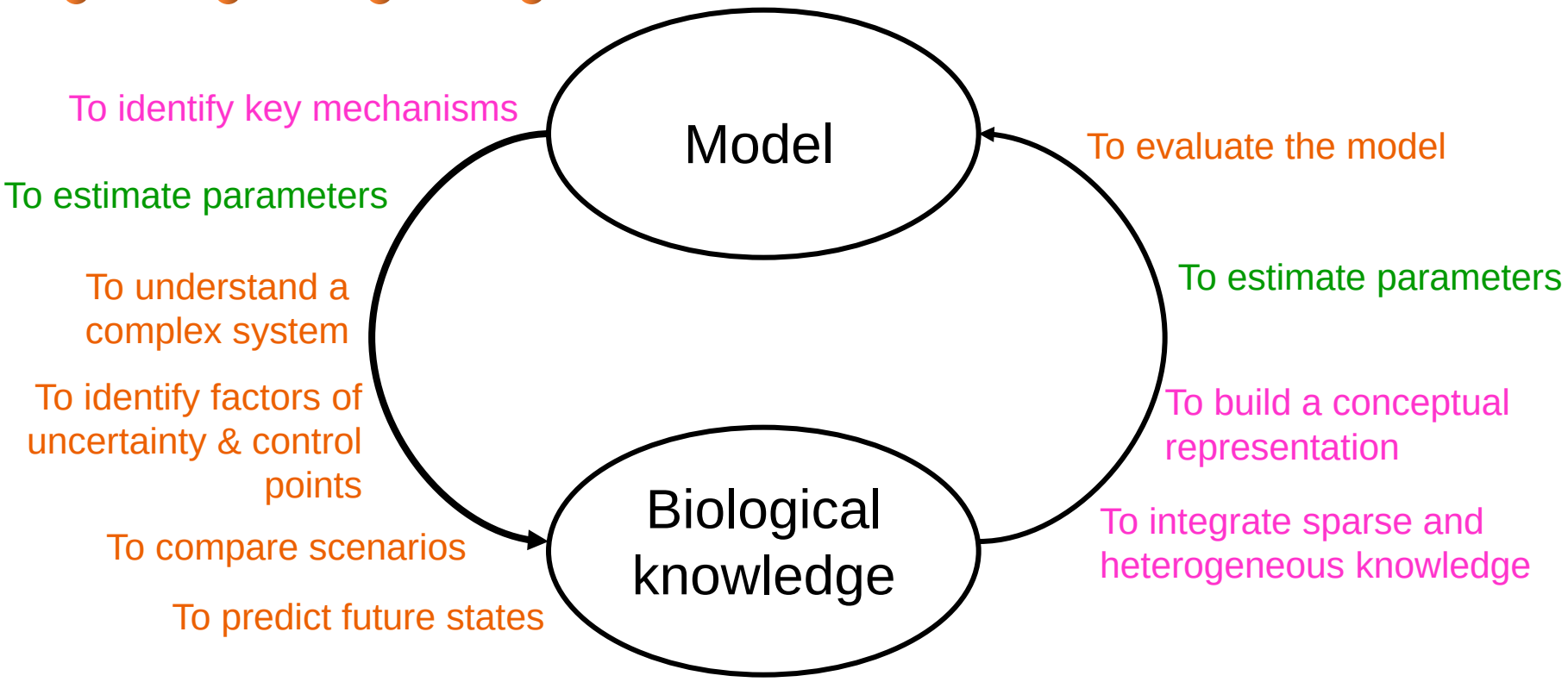
Infectious diseases in livestock

- A complex biological system
  - Interactions between hosts, pathogens, farming environment, farmers' decisions
    - Progression of the individual health status
    - Variability among susceptible / infected hosts
    - Variety of time and space scales
  - Structured and managed host populations
    - In groups of animals within a herd
    - In herds localised in a region
    - In a supply chain of primary animal production

➔ **Integrative modelling approach**



An integrative modelling approach



Which influent parameters?
Which influent assumptions?
How to control the system?

Which health states?
Which transitions?
Which assumptions?

An integrative modelling approach

- Integrated & simplified representation of a process
- To understand a biological system functioning & to predict its change over time / space
  - To predict numbers per health status in space and time
  - To estimate unobservable parameters
  - To evaluate biological assumptions
  - To test control scenarios

An integrative modelling approach

- A compromise between **realism** & **parsimony**
- Several **scales of integration** can be needed
- Accounting for **farmers' decisions** improve the predictive capability of epidemiological models and of associated **decision tools**

An integrative modelling approach

- Integration scales
  - Within-host scale

    To represent interactions between the pathogen and the host immune system and the host shedding level
  - Between-host / within-herd scale

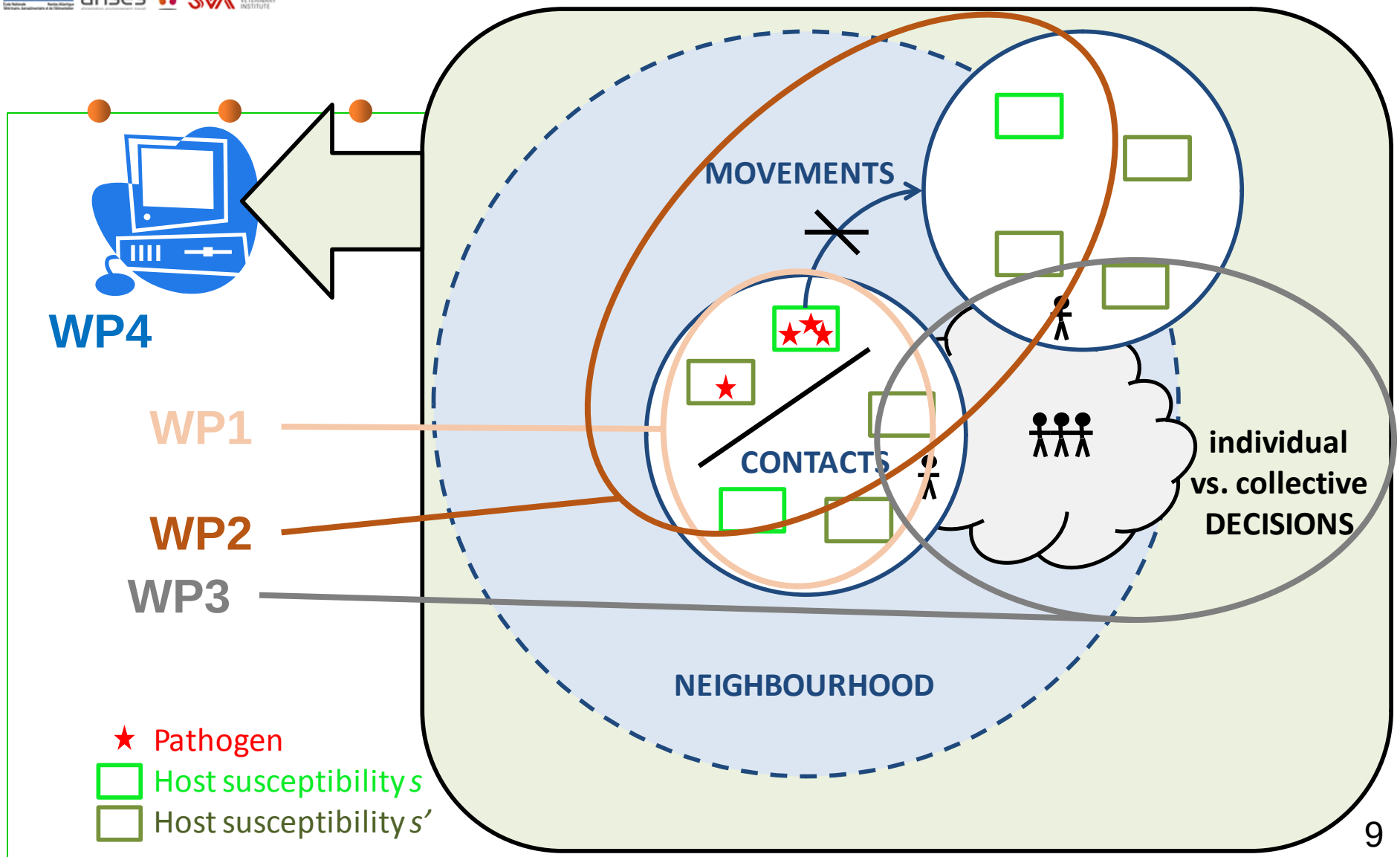
    To account for host heterogeneity in susceptibility and shedding

    To account for herd structure, management and farmer's decisions
  - Between-herd / animal (meta)population scale

    To represent animal movements, and neighbouring and indirect contacts between herds

    To account for individual & collective farmers' decisions

multi-scale **M**odelling - from the animal **I**ntra-**H**ost to the **M**etapopulation – of pathogen spread to **E**valuate control **S**trategies

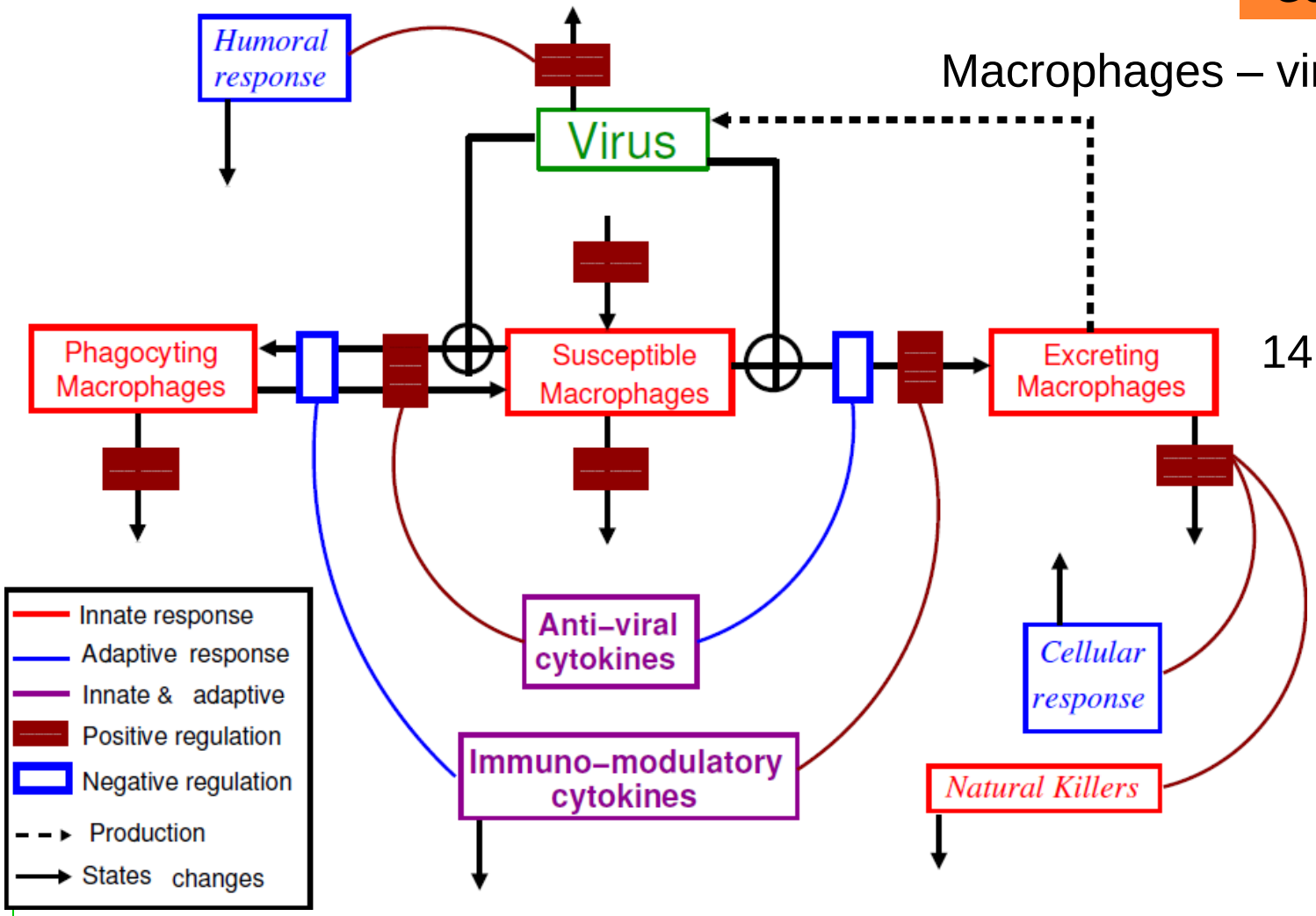


PRRSv infection dynamics within a pig

- Immune response to PRRSv infection poorly understood
  ➔ control measures not efficient enough
  ➔ major concern for the swine industry
- Aim: to identify the immune mechanisms determining host recovery considering the high variability of the immune response among pigs
- Method: a modeling approach

PRRSv infection dynamics in pig lung

Go et al., EAAP 2013



Macrophages – virus interactions, regulated by cytokines and adaptive cells
➔ ODE,
14 state variables,
28 parameters

PRRSv infection dynamics in pig lung

Go et al., EAAP 2013

Data: few experimental data, high variability and uncertainty.

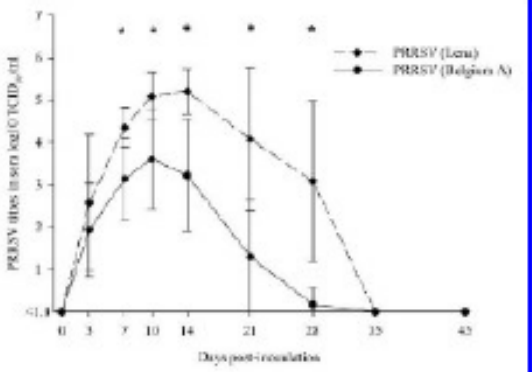
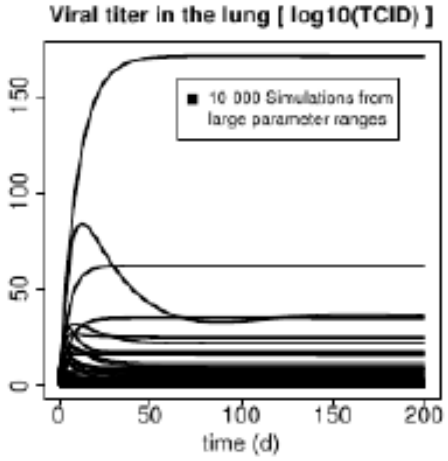


Figure 2 Virus titres in sera of pigs at different days post-inoculation with PRRSV (Lena) and PRRSV (Belgium A).

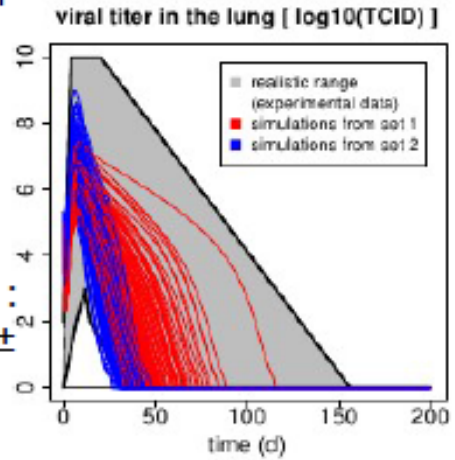
Parameter range estimation

Aim: Estimate parameter ranges resulting in simulations covering the response variability **=> ad hoc method:**



Identification of **realistic parameter sets**

Robustness : parameters ± 5%



PRRSv infection dynamics

- Model extension

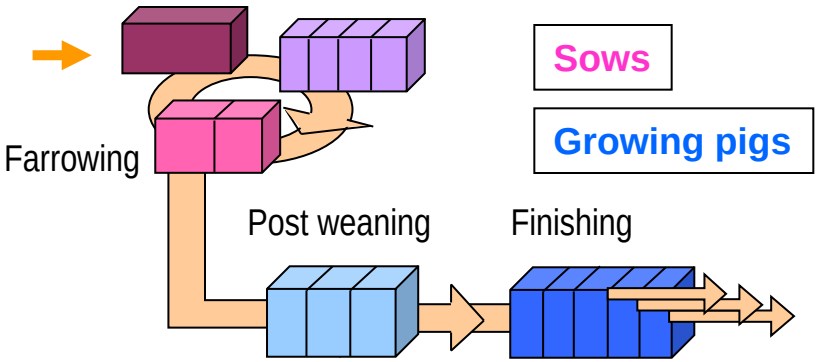
Lung model
- Contrasted viral dynamics
- Relationships between the immune mechanisms, infection duration, susceptibility & virulence

Pig model
A better representation of the adaptive response

Population model
The individual model will be integrated in an immuno-epidemiological model

Pathogen infection dynamics in a herd

- At the within-herd scale
  - Accounting for herd dynamics
    - animal populations are structured
    - Herds are heterogeneous in size, structure, composition, etc.



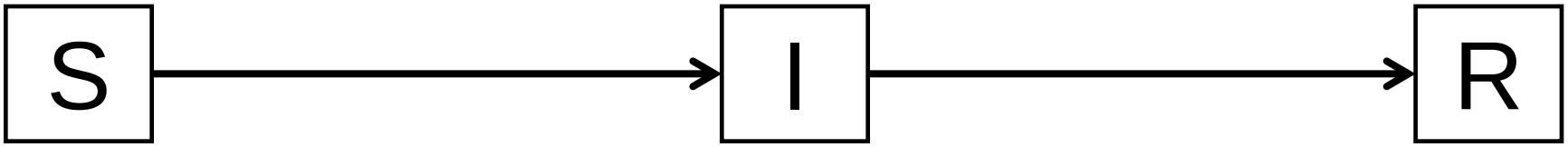
➔ Impact on infection spread, on potential target for control actions and on control efficiency

Pathogen infection dynamics in cattle

- At the within-herd scale

Courcoul et al., Vet. Res. 2011

  - Q fever in a dairy herd
    - Heterogeneity in shedding: level and routes (milk, mucus, faeces)



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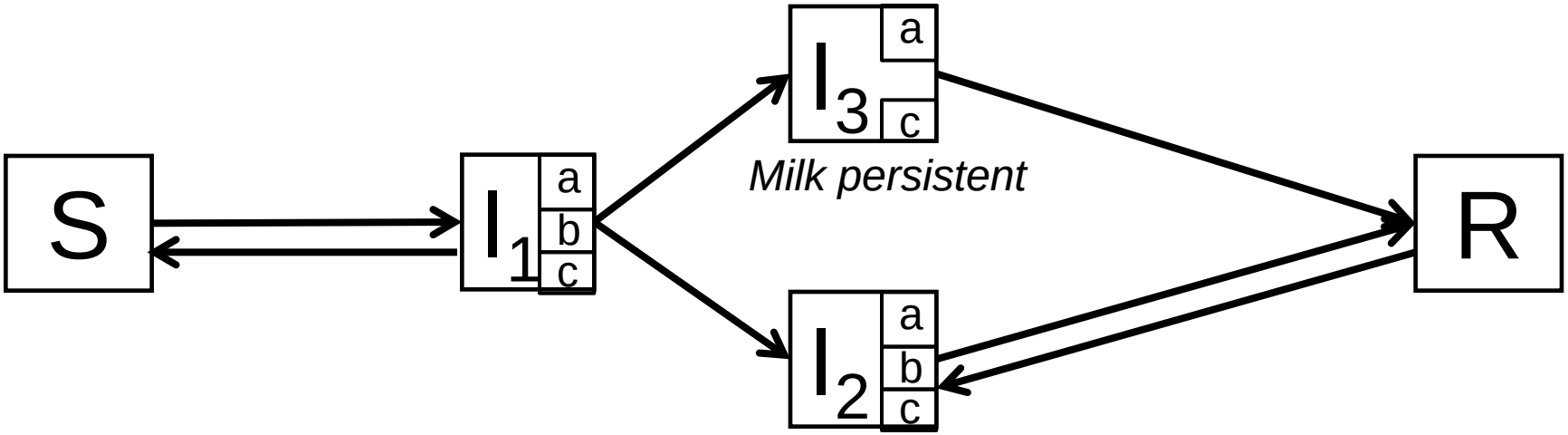
      3 categories: milk only, mucus/faeces or both, milk + mucus/faeces or the 3 routes



Pathogen infection dynamics in cattle

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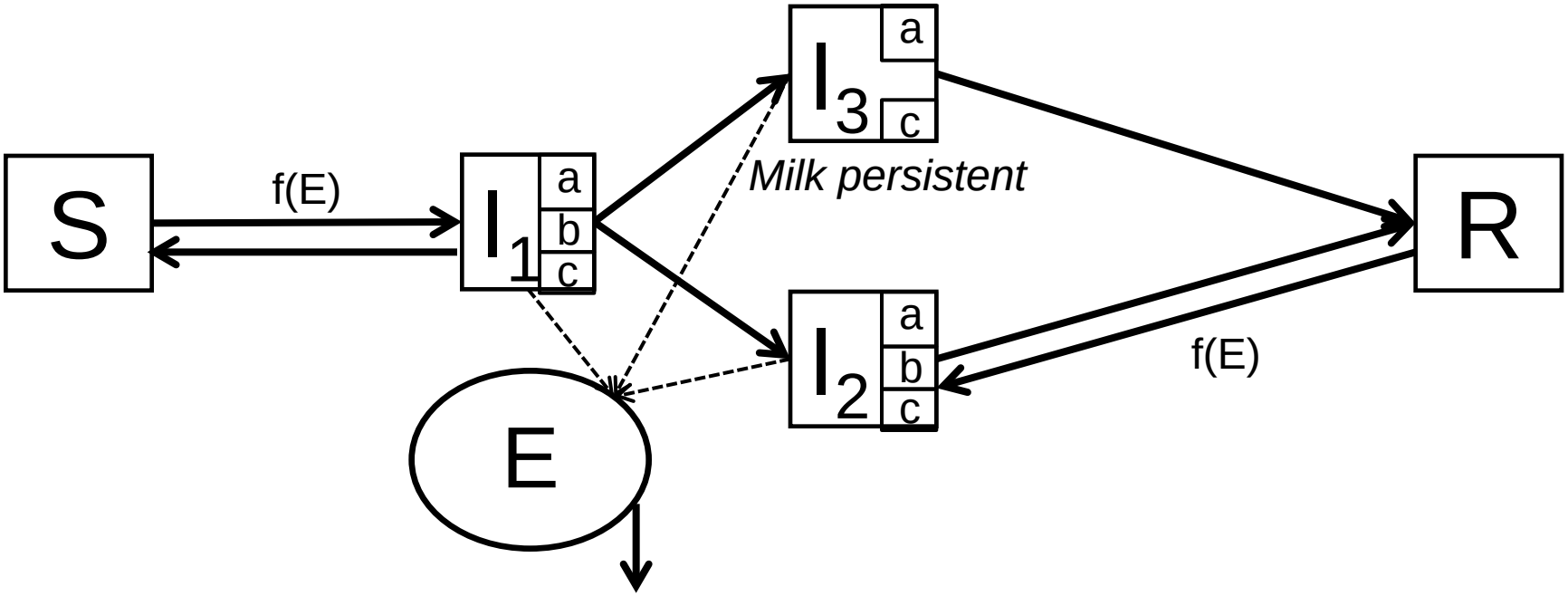
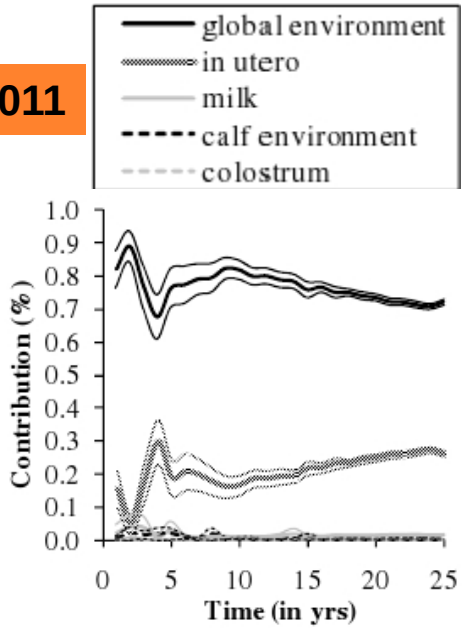
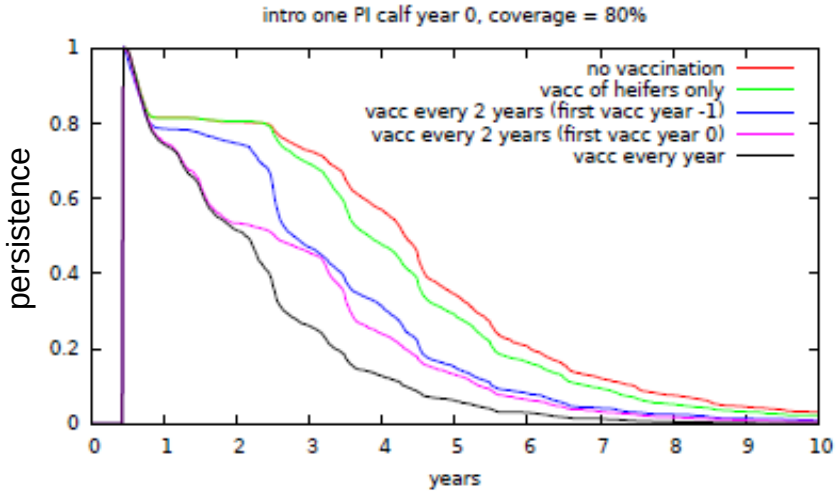


Pathogen infection dynamics in cattle

Marcé et al., Vet. Res. 2011



- At the within-herd scale
  - Paratuberculosis in dairy herd
    - To understand the infection spread in a herd: relative contribution of transmission routes
  - BVD in beef herd **Damman et al., EAAP 2013**
    - To evaluate vaccination strategies



Pathogen infection dynamics in cattle

- At the between-herd scale
  - Network of cattle movements between herds

    Dutta et al., EAAP 2013

    - Temporal and spatial variations in contacts
    - Large range of herd types: size, production type
    - Regional particularities: density, herd types, movement types

  - ➔ Coupling within-herd models through a contact network
    - ➔ Animal movements
    - ➔ Neighborhing relationships

Summary

- Complementary skills to be mobilised
  - Epidemiology, immunology, infectiology, modelling, mathematics, computer sciences, health economics
- To answer new research questions
  - To model multi-scale biological processes
  - To understand and formalised farmers' behaviours

Viet et al., EAAP 2013

- To guide management decision at different scales
  - After evaluating models' predictive capability

Krebs et al., EAAP 2013

Thank you for listening!

This work is supported by:

- French Research Agency, program *Investments for the future*, project ANR-10-BINF-07 (MIHMES)
- Doctoral school ABIES
- Region Pays de la Loire
- INRA, Oniris, ANSES, INRIA, Univ. Rennes 1, SVA

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