Livestock Disease Resilience:

from Individual to Herd Level

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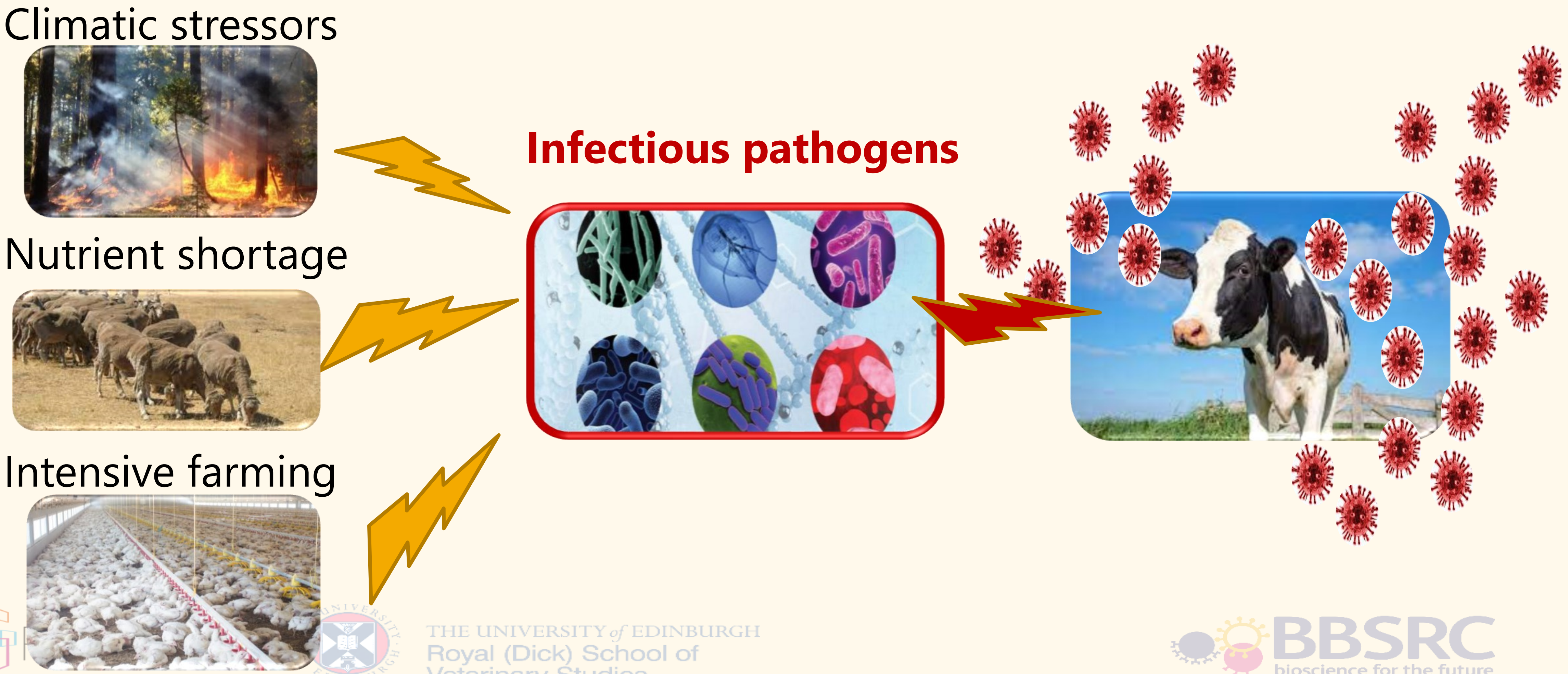
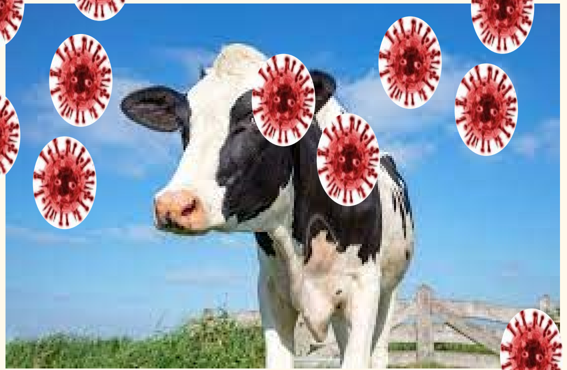
Disease Resilience is paramount for sustainable livestock production



Infectious disease requires HERD resilience rather than individual resilience



Resilient animal
… or asymptomatic superspreader?

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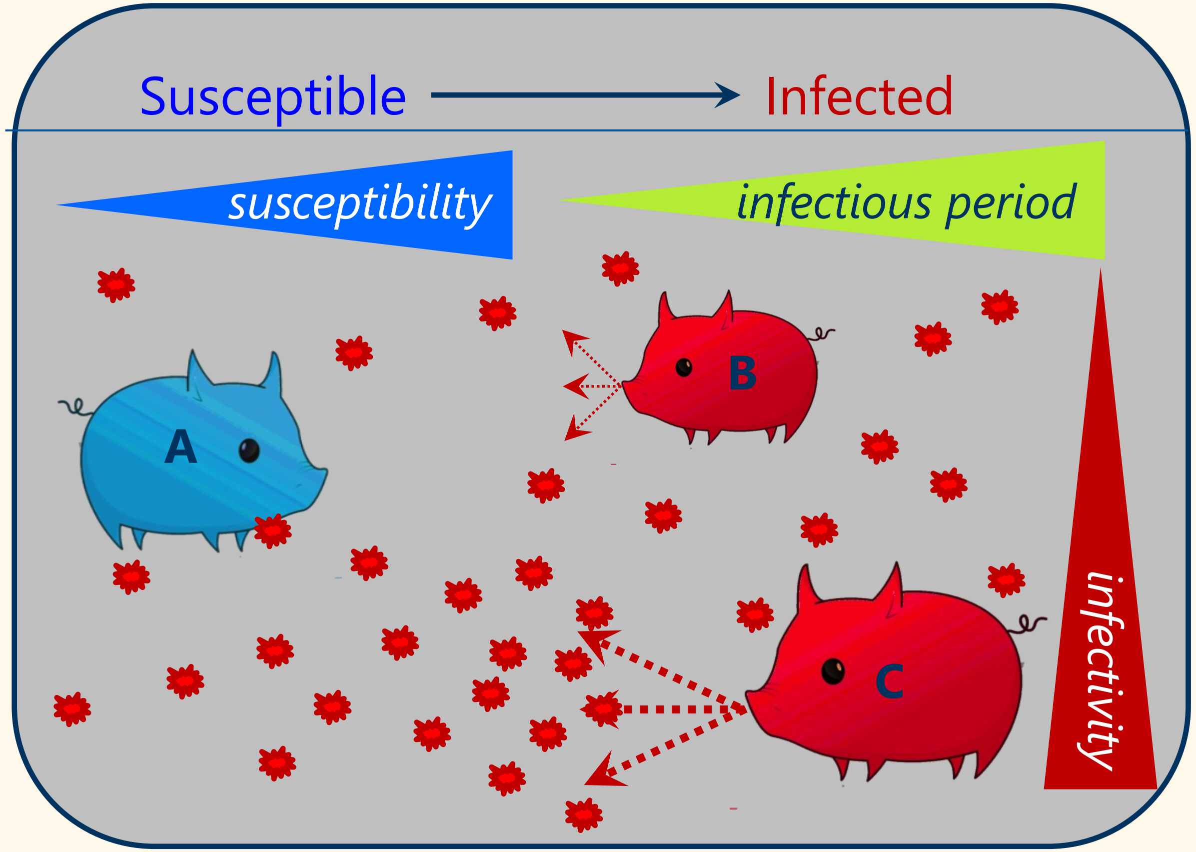
Herd disease resilience implies low pathogen transmission



4 individual host traits contribute to herd resilience:

- **Resilience** – ability to maintain high performance under infection challenge
- **Susceptibility** – propensity to become infected
- **Infectivity** – ability to transmit infection
- **Infectious period** – duration of pathogen shedding

Adapted from Doeschl-Wilson et al., Animal 2021

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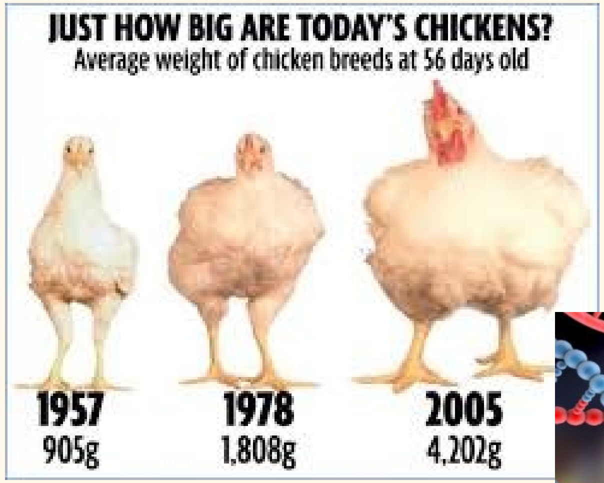
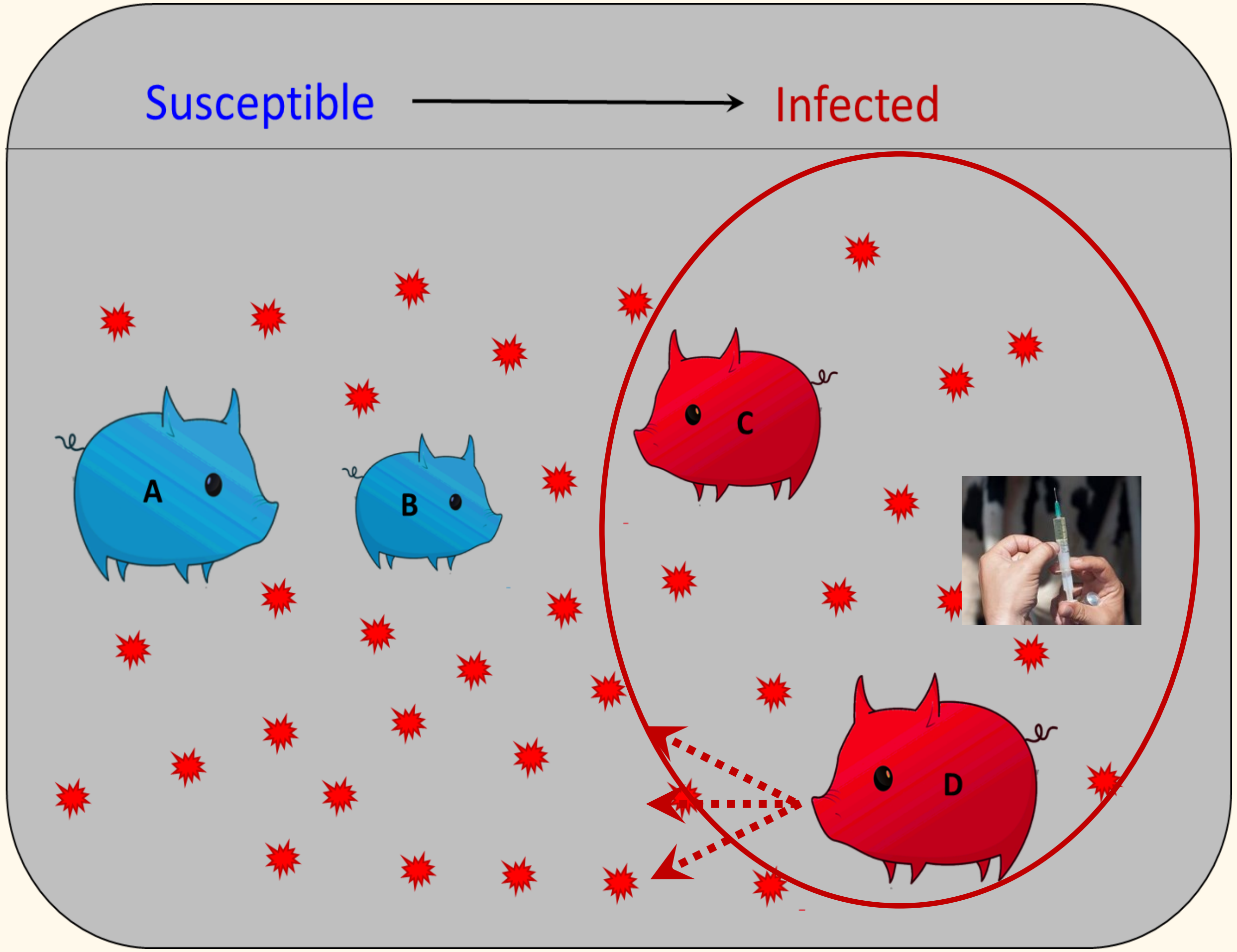
How do current disease control methods affect herd disease resilience?

Vaccination

Selective breeding



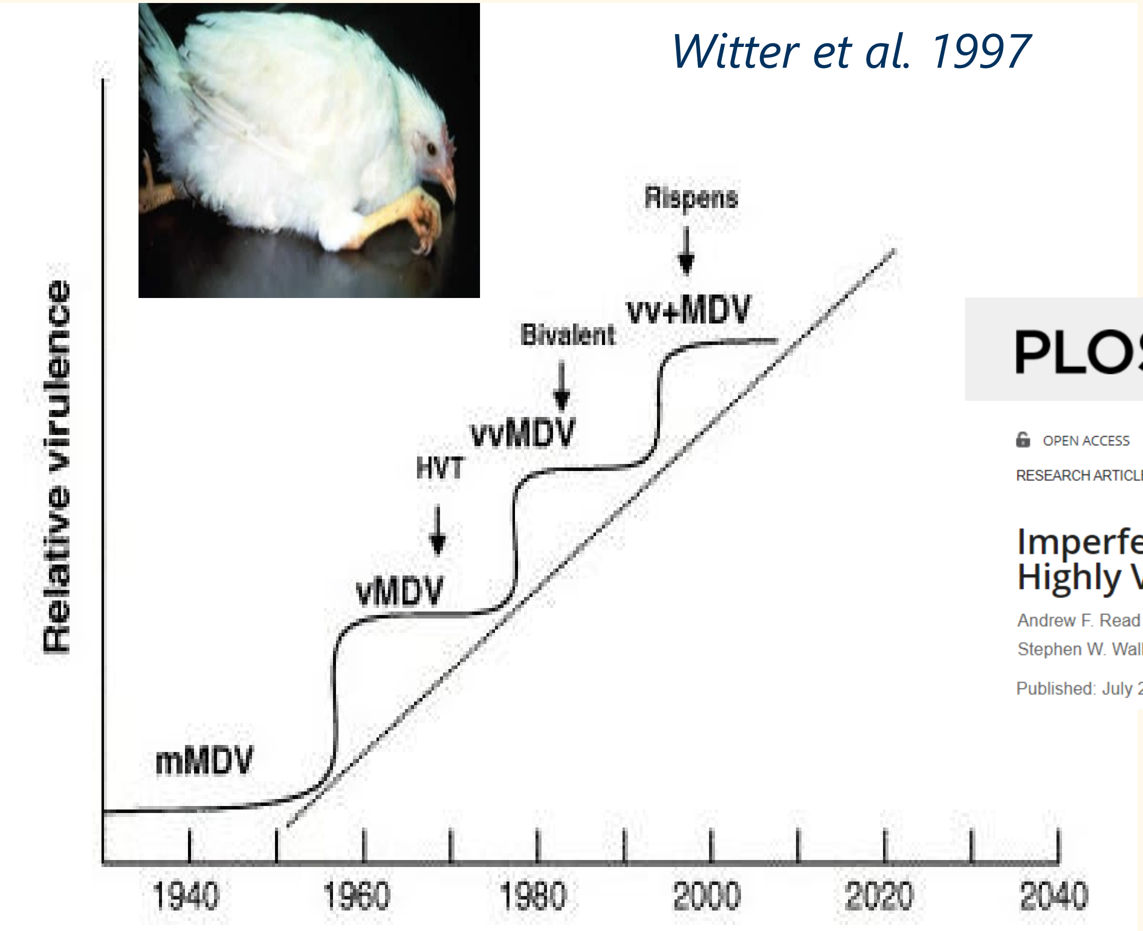
Vaccination effects on herd resilience



Vaccine efficacy:
The ability of a vaccine to **protect against adverse effects of the infection to the vaccinated individual** (Pastoret, 1997)

- Vaccines primarily target improvement of individual resilience
- Vaccines do not necessarily protect from becoming infected & transmitting the infection
- Vaccine effects on transmission usually poorly understood

Example: Marek's disease vaccination in poultry



MD vaccines are 'leaky', i.e. they inhibit formation of tumour & death, but don't protect from infection & transmission of the virus

PLOS BIOLOGY

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

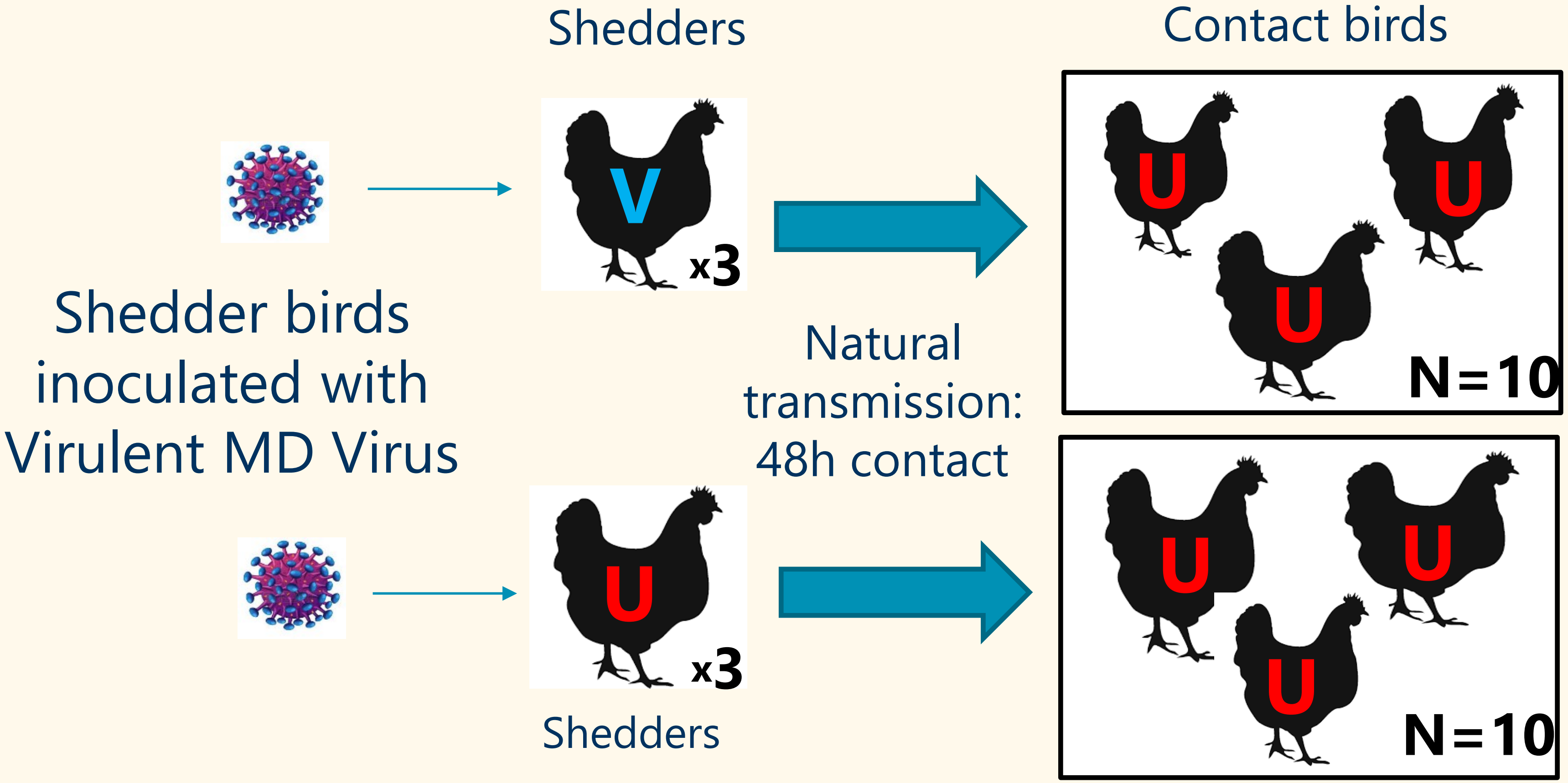
Imperfect Vaccination Can Enhance the Transmission of Highly Virulent Pathogens

Andrew F. Read, Susan J. Baigent, Claire Powers, Lydia B. Kgosana, Luke Blackwell, Lorraine P. Smith, David A. Kennedy, Stephen W. Walkden-Brown, Venugopal K. Nair

Published: July 27, 2015 • https://doi.org/10.1371/journal.pbio.1002198

How does vaccination affect virus transmission & herd resilience?

New insights from Marek’s disease transmission experiments



X 16 experimental replicates

Measures:

- Virus load in blood & feather follicles at different time points
- Presence of tumour 8 weeks post contact
- Mortality

V= Vaccinated Birds (HVT)
U= Unvaccinated Birds (sham vaccine)

Dunn, Cheng et al., USDA ADOL

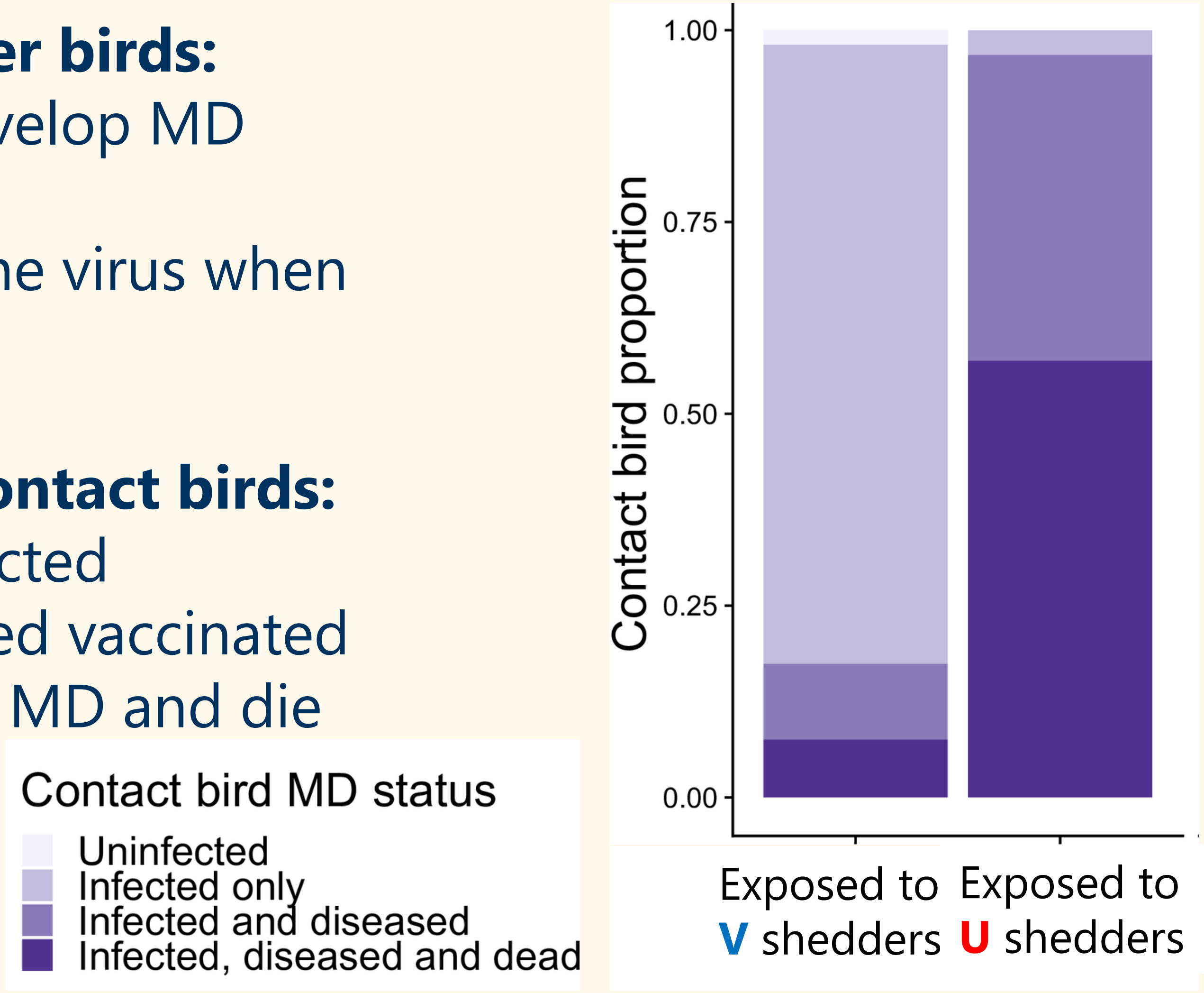
Surprising positive indirect effects of vaccination

Vaccine effects on vaccinated shedder birds:

- Vaccinated shedder birds did not develop MD when infected with MDV
- Vaccinated shedder birds still shed the virus when infected

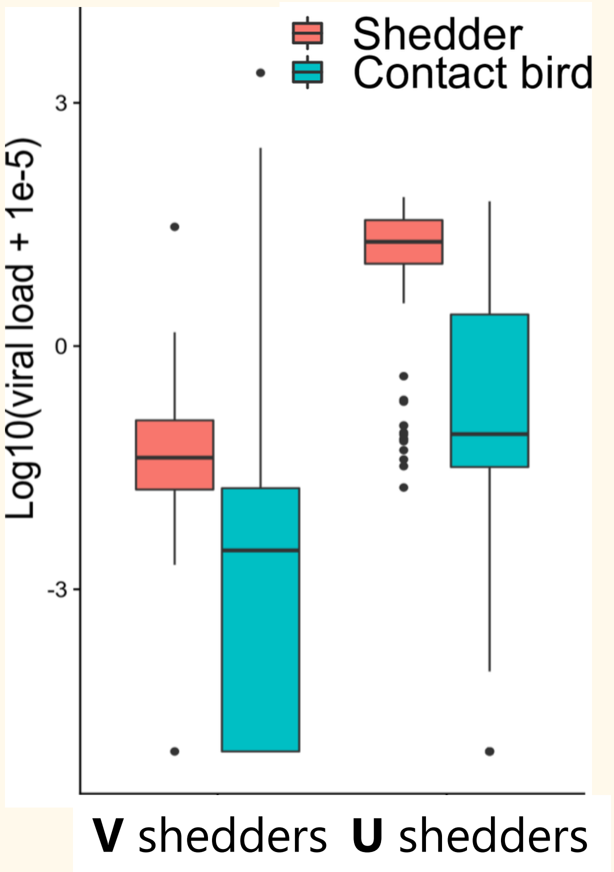
Vaccine effects on non-vaccinated contact birds:

- Almost all contact birds became infected
- BUT: contact birds exposed to infected vaccinated shedders were less likely to develop MD and die

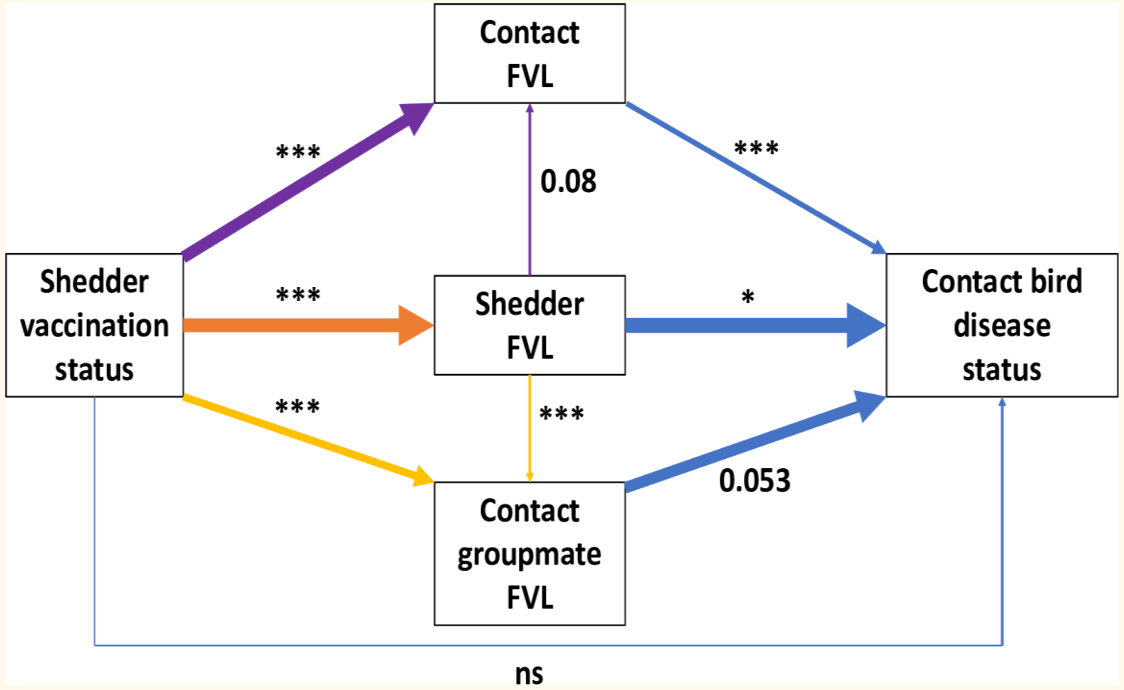


Bailey et al., PloS Biol. 2019

Virus transmission from vaccinated birds causes dose-dependent reduction in pathogen virulence



Mediation analysis:

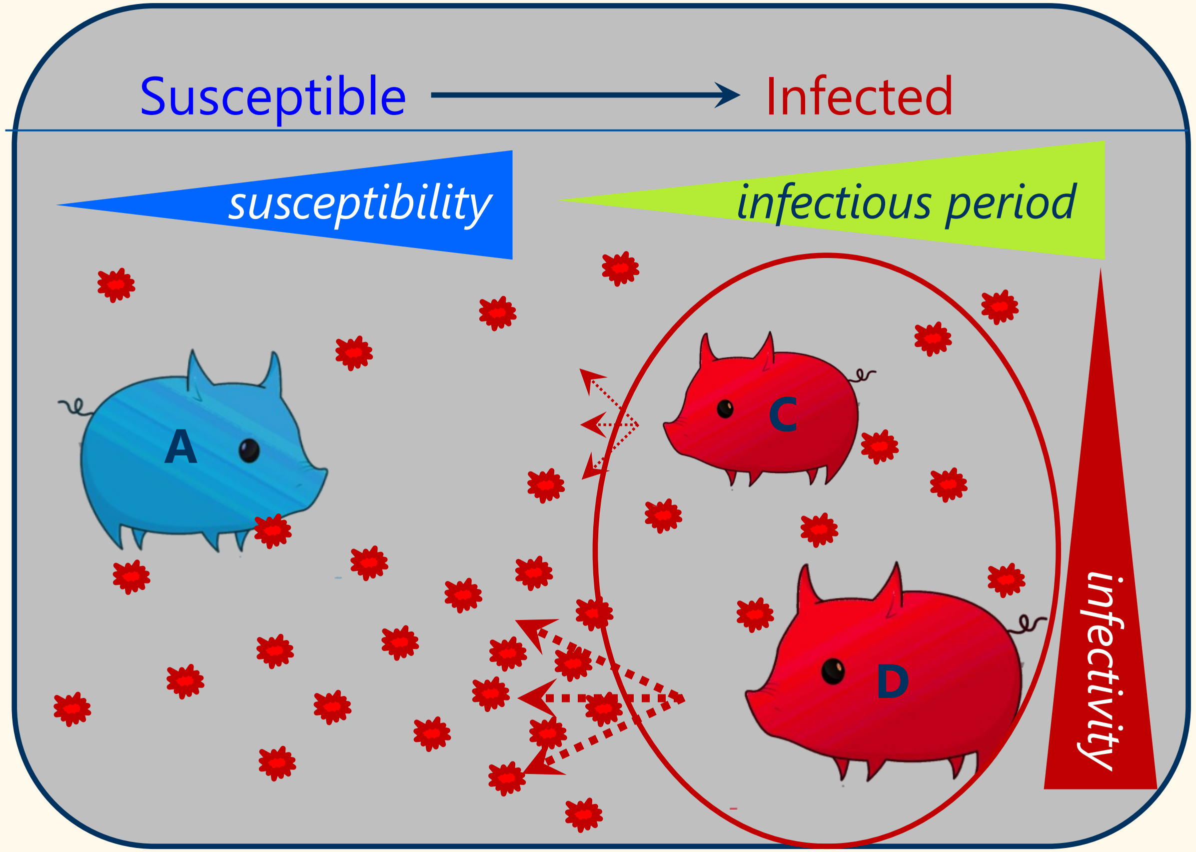


Bailey et al., PloS Biol. 2019

Indirect effects of vaccination on pathogen transmission & evolution should be assessed more

- Vaccines or other control methods may reduce pathogen transmission & increase herd resilience more than expected
- What are the implications on pathogen evolution?

Breeding for disease resistance / resilience



Current focus on improving individuals' "disease resistance":

- Usually means resistance to adverse side effects of infection, once infected, i.e. resilience

Genetic effects on epidemiological herd resilience traits rarely known

- But methods & applications for estimating these are emerging

- Anacleto et al., *Genetics* 2015, *201*(3), 871-884.
- Biemans et al., *Genetics Selection Evolution*, 2017, *49*(1), 1-13.
- Pooley et al., *PloS Comp Biol*, 2020, *16*(12), e1008447

ISA virus infections in Atlantic salmon

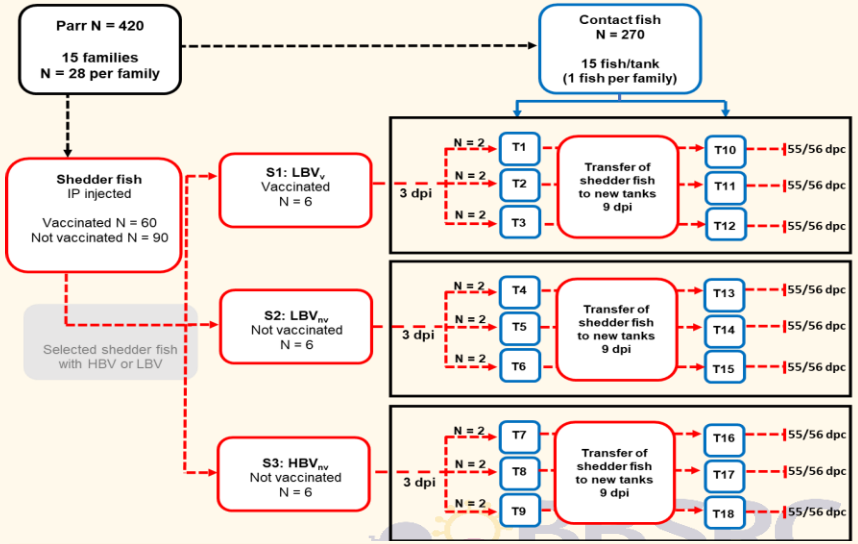
Benchmark Genetics Norway

Nofima

- **I**nfectious **S**almon **A**nemia Virus
- Listed as notifiable disease → control virus spread
- Mostly controlled by vaccines with limited effectiveness
- Genetic selection for ISA resistance (EBV for survival given exposure) ongoing

Does vaccination or selection for ISA resistance reduce ISAV transmission?

→ Transmission experiment to assess effect of genetic selection & vaccination on ISAV transmission



Chase-Topping et al., Aquaculture 2021

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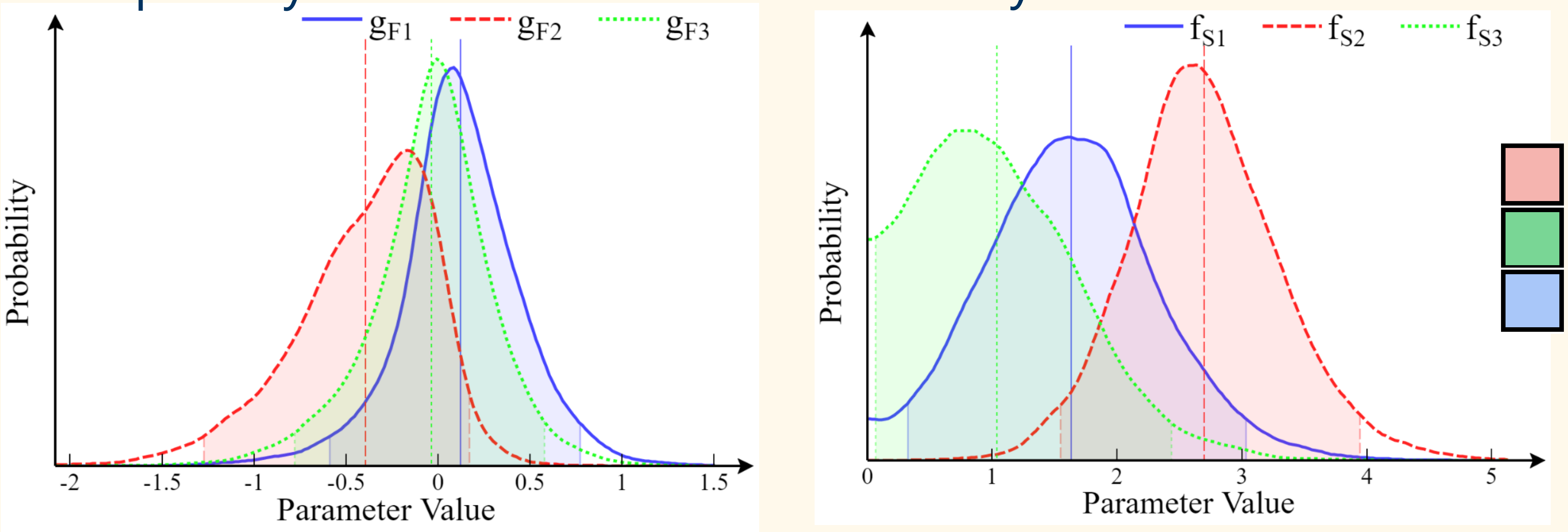
Genetic selection for ISA resistance reduces infectivity, but not susceptibility

Susceptibility

Infectivity



Low resistance EBV

High resistance EBV

Low resistance EBV + Vaccinated

- 'Resistance' EBV has larger effects on infectivity than susceptibility
- Genetic effects on infectivity larger than vaccine effects

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Chase-Topping et al., Aquaculture 2021

Conclusions

- Disease resilience is vital for sustainable livestock production
- Herd resilience rather than individual resilience
  - Reducing pathogen transmission is important for herd resilience
- A better understanding of vaccination and host genetic effects on pathogen transmission is urgently needed:
  - Routine integration of transmission experiments or field studies in vaccine and genetic studies
  - Incorporate epidemiological models into evaluations

➢ More effective vaccination and breeding programs

➢ Healthier & more resilient livestock populations

Accompanying papers

Knap and Doeschl-Wilson *Genet Sel Evol* (2020) 52:60
https://doi.org/10.1186/s12711-020-00580-4

Genetics Selection Evolution

REVIEW **Open Access**

Why breed disease-resilient livestock, and how?

Pieter W. Knap[1*] and Andrea Doeschl-Wilson[2]

Abstract

Background: Fighting and controlling epidemic and endemic diseases represents a considerable cost to livestock production. Much research is dedicated to breeding disease resilient livestock, but this is not yet a common objective in practical breeding programs. In this paper, we investigate how future breeding programs may benefit from recent research on disease resilience.

ARTICLE IN PRESS

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Animal
The international journal of animal biosciences

Review: Livestock disease resilience: From individual to herd level

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ABSTRACT

Infectious diseases are a major threat to the sustainable production of high-producing animals. Control efforts, such as vaccination or breeding approaches often target improvements to individual resilience to infections, i.e., they strengthen an animal's ability to cope with infection, rather than preventing infection *per se*. There is increasing evidence for the contribution of non-clinical carriers (animals that become infected and are infectious but do not develop clinical signs) to the overall health and production of live-

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Marek's disease studies

- John Dunn, Hans Cheng, Jody Mays (ADOL - USDA)
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ISA study

- Margo Chase-Topping (Roslin), Chris Pooley (BioSS)
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Smarter
SMAll RuminanTs breeding for Efficiency and Resilience

HORIZON 2020

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