EFSA Food Safety Conference
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Drivers for Emerging Issues in Animal and Plant Health

Broad-brush analysis of livestock disease drivers, ecology and pathogen evolution

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Hostility vs Intimacy

Parasites compromise host fitness and bring damage to the host body.

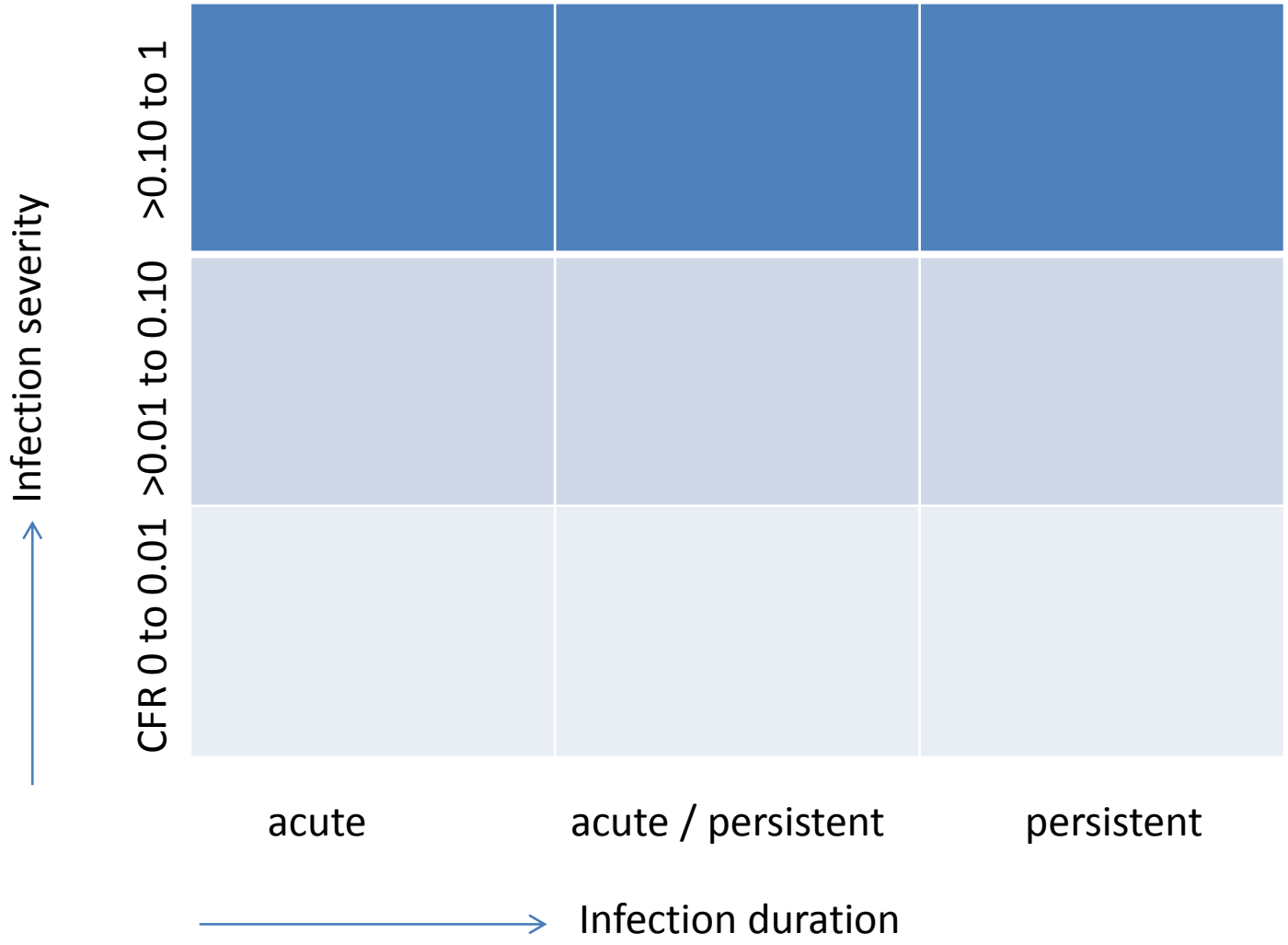
Still, the parasite – host encounter is not just about hostility.

Over time and in a stable host environment, a parasite – host relationship tends to become more intimate and the parasite more **host specific**.

Intimacy is about peaceful **co-existence**.

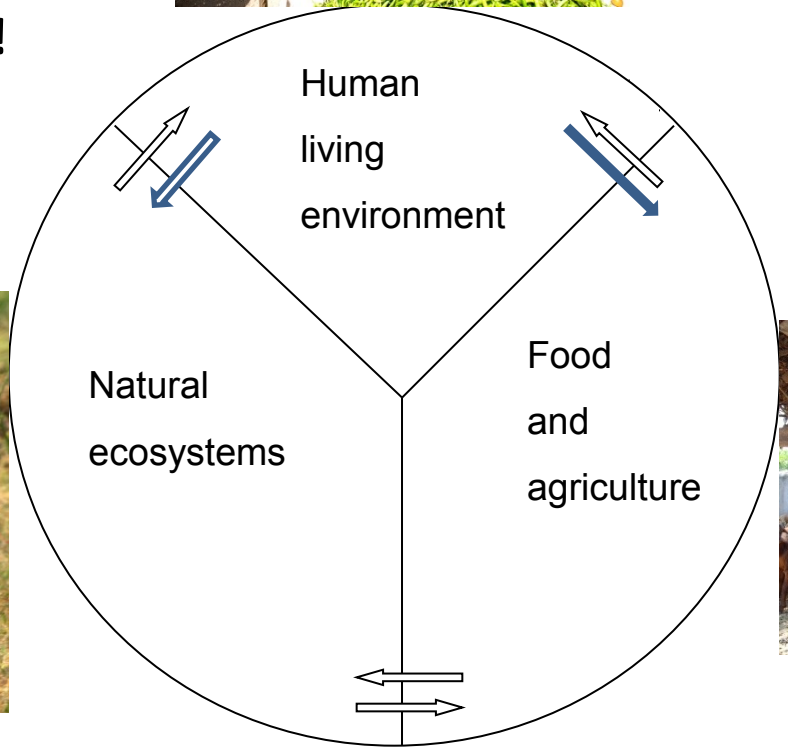
A shift from parasite to commensal!

Infection plane encompassing intimacy and hostility,
creating space for all possible outcomes of the pathogen-host encounter



There are three related "animal" host domains with pathogen fluxes going into 6 directions!

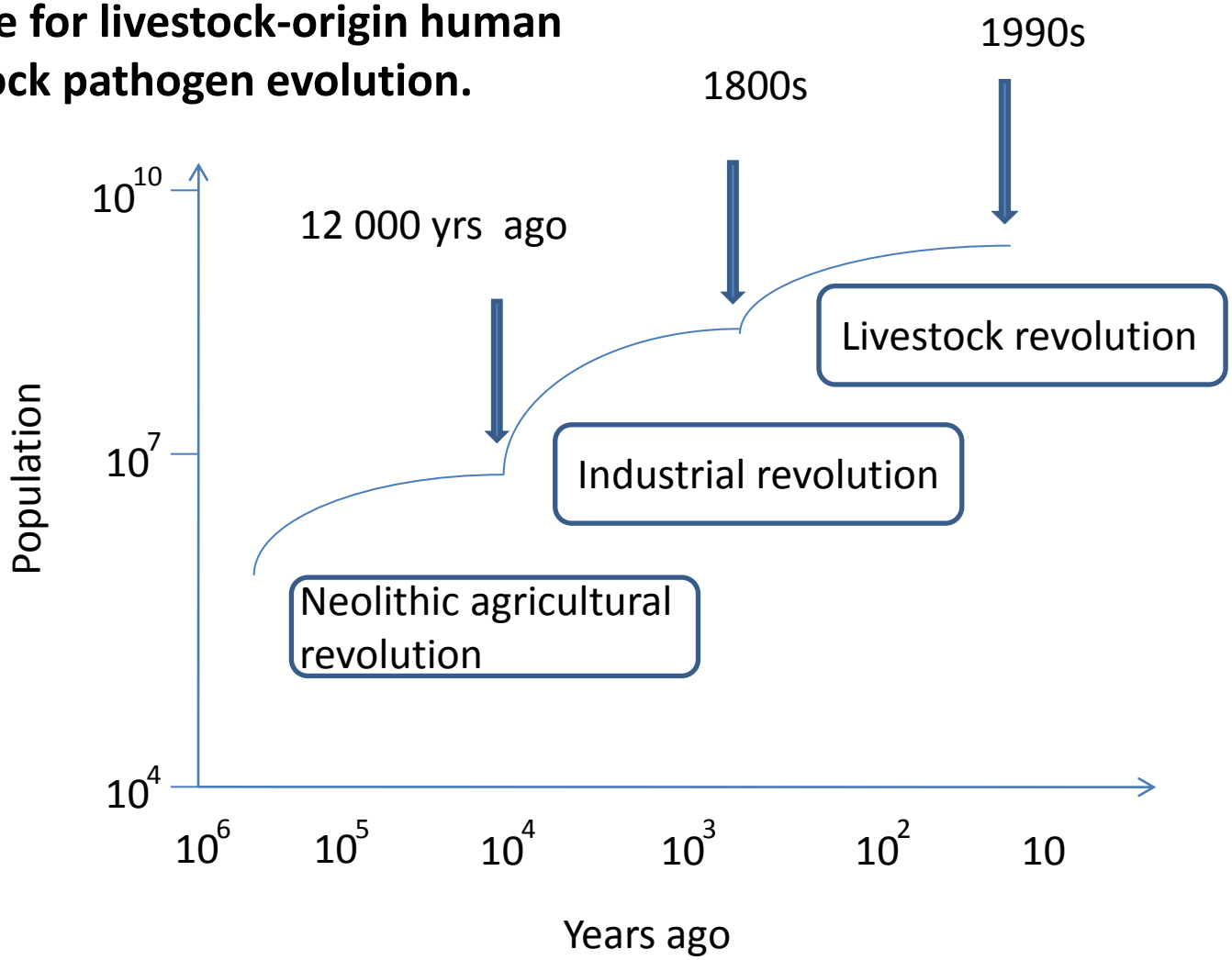
Two of these host domains are quite new in evolutionary time.



All three domains are in fact highly dynamic.

Livestock diseases, zoonoses and food safety hazards form a goldmine for disease ecologists.

Time frame for livestock-origin human and livestock pathogen evolution.



Human population, from 1 million years ago to around 10 years ago, shown as a doubly logarithmic plot.

After: Anderson, Roy M. and May, Robert M. (1991) *Infectious diseases of humans - dynamics and control*; The ecology and genetics of host-parasite associations. Oxford University Press, Oxford.

Background information / data sources

- The **1990s** form the peak of the so-called **livestock revolution**, characterised by rapid growth of world animal protein production, featuring **mass rearing of monoculture type animals, enhanced feed conversion and rapid growth** ->
FAOSTAT and literature sources.

- Livestock infection and **disease data** were drawn from the **1995 FAO/OIE/WHO Animal Health Year Book**, the last edition in a series that ran since 1955, just prior to the introduction by OIE of a more real time and internet based animal health information system.

- Selected are 34 v**iruses and 25 bacteria** all causing a typical infection and disease in world livestock, with one or more of the common **livestock species acting as primary host** and with infection and transmission dynamics **congruent with the Koch postulates**.

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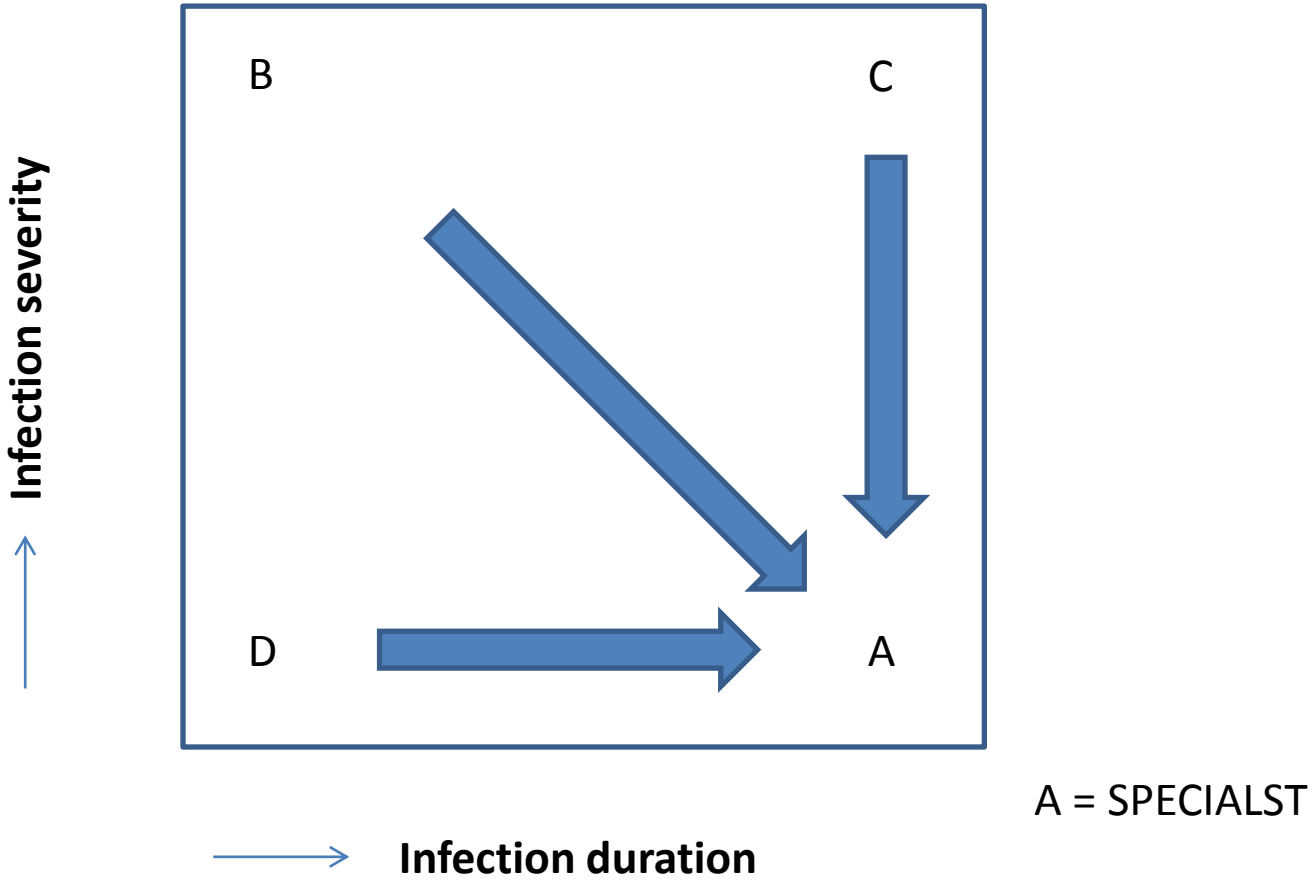
Twofold hypothesis:

(i) Given enough time and in a stable host environment a parasite – host relationship will become more intimate and the parasite more host specific, moving towards peaceful coexistence with its long term host.

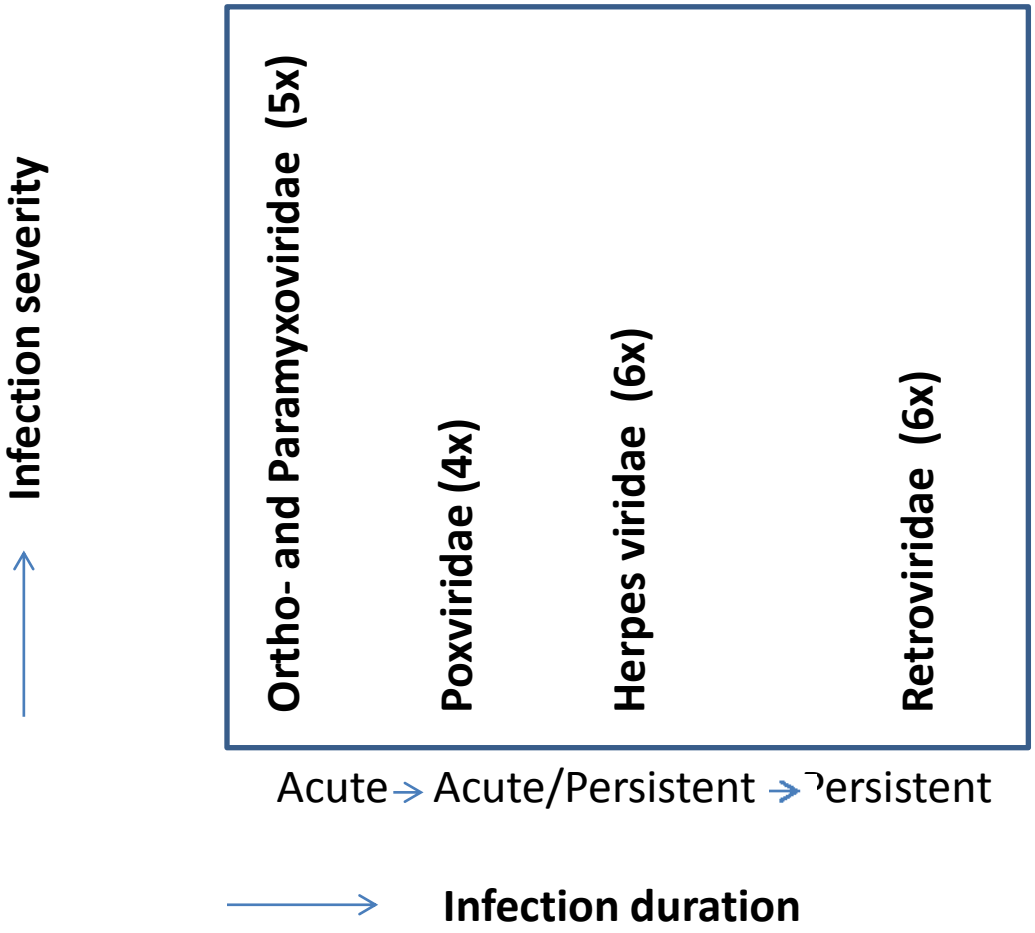


A = SPECIALST

(ii) For microbial pathogens turning less parasitic and more of a commensal this would entail an infection becoming both more persistent and benign.

Avian inf. bronchitis **Avian laryngo-trach.** **Duck enteritis** **HPAI** **Newcastle disease** **PPR** **Rinderpest**	**Classical swine fever** **Gumboro** **PRRS** **Enterov.-encephalom.** **SECD**	**Jaagsiekte**
Blue tongue Transm. gastro-enter.	Aujeszky disease Av. inf. encephalomyel. Bovine viral diarrh./MD Fowl pox Lumpy skin disease Marek disease Orf or cont. ecthyma Sheep & goat pox	Avian leukosis Caprine arthr./enceph. Maedi-Visna
Equine influenza Foot and mouth disease Swine vesicular disease	Eq. coital exanthema Eq. viral arteritis IBR/IPV	Enzootic bov. leukosis Equine inf. anaemia

Virus families broadly align according to infection duration



Second finding……

An increase in infection duration

Acute -> Acute / Persistent -> Persistent

entails a shift from

Epithelial Infections	->	Infections of epithelia and internal organs	->	Infection of internal organs

Persistent infections are more deeply ingrained within the body.

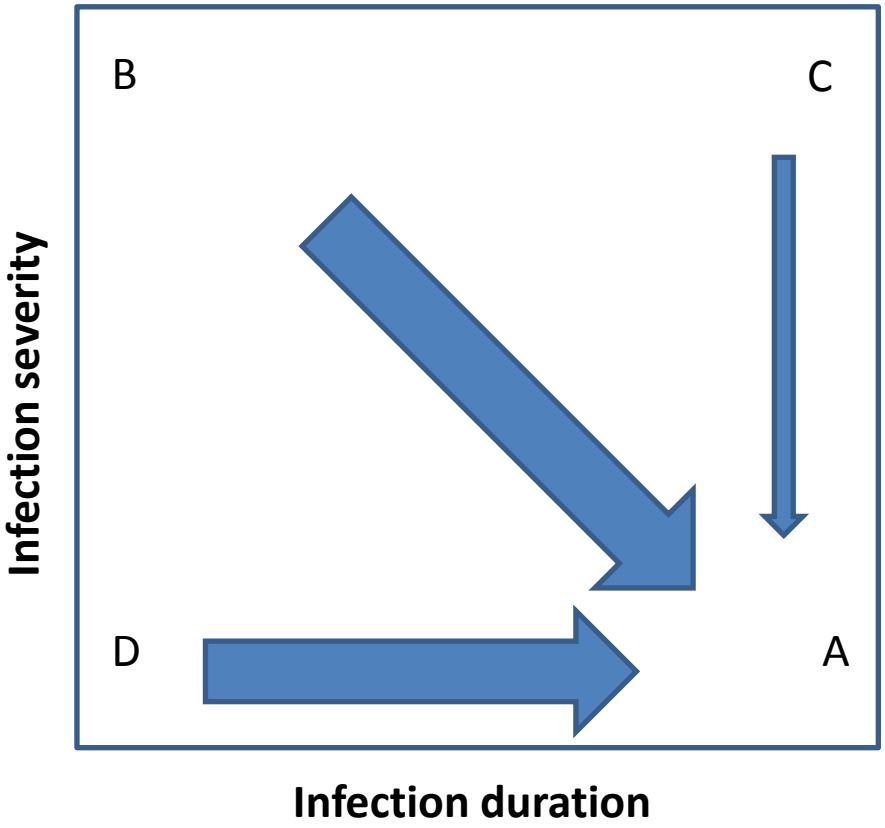
Devising a **Virus Specialist** score, with low(1), medium(2) or high(3) accorded to

- **Host specificity**, the inverted host range width
- **Durability and benignity of infection** as given by the infection plane
- **Infection** shifting from the outer- to the **inner-body environment**
- Reliant on **vertical transmission**, as opposite to horizontal
- Sensitive / **vulnerable** to the conditions prevailing outside the body
- **Endemic** form of disease, as opposed to epidemic
- **Stable** host environment; life cycle, open system and sexual contact

Av. IB 1 3 1 2 1 1 **Av. LT 1 1 1 2 1 1** **Duck ent. 1 3 1 2 1 1** **HPAI 1 1 1 2 1 1** **Newc. dis. 2 1 1 2 1 1** **PPR 1 2 1 2 1 2** **RP 1 1 1 2 2 3**	**CSF 2 x 2 1 2 1** **Gumboro 2 3 1 1 2 1** **PRRS 2 x 2 2 2 1** **Porc.ent. 1 x 1 1 2 1** **SECD 1 x 1 2 2 1**	**Jaagsiekte 2 3 2 3 3 2**
Blue tongue 2 1 2 2 1 2 TGE 1 x 1 2 1 1	Aujeszky 2 x 2 2 1 1 Av. inf. enc. 2 1 2 2 2 1 BVD/MD 2 3 2 1 2 3 Fowl pox 1 2 1 1 3 1 LSD 1 2 1 1 3 3 Marek dis. 1 3 1 2 2 1 Orf 1 1 1 1 1 2 Sh&G pox 1 2 1 1 1 2	Av. leuk. 3 3 2 3 3 1 CAE 3 3 3 3 3 2 Maedi-V. 2 2 2 3 3 2
Eq. infl. 1 2 1 2 1 3 FMD 1 1 1 2 1 2 SVD 1 x 1 1 1 1	Eq. coital ex. 1 3 1 2 3 3 Eq. viral art. 1 3 1 3 3 3 IBR/IPV 1 2 1 2 2 3	Enz bov leuk. 3 3 2 3 3 3 Swamp fever 3 2 2 3 3 3

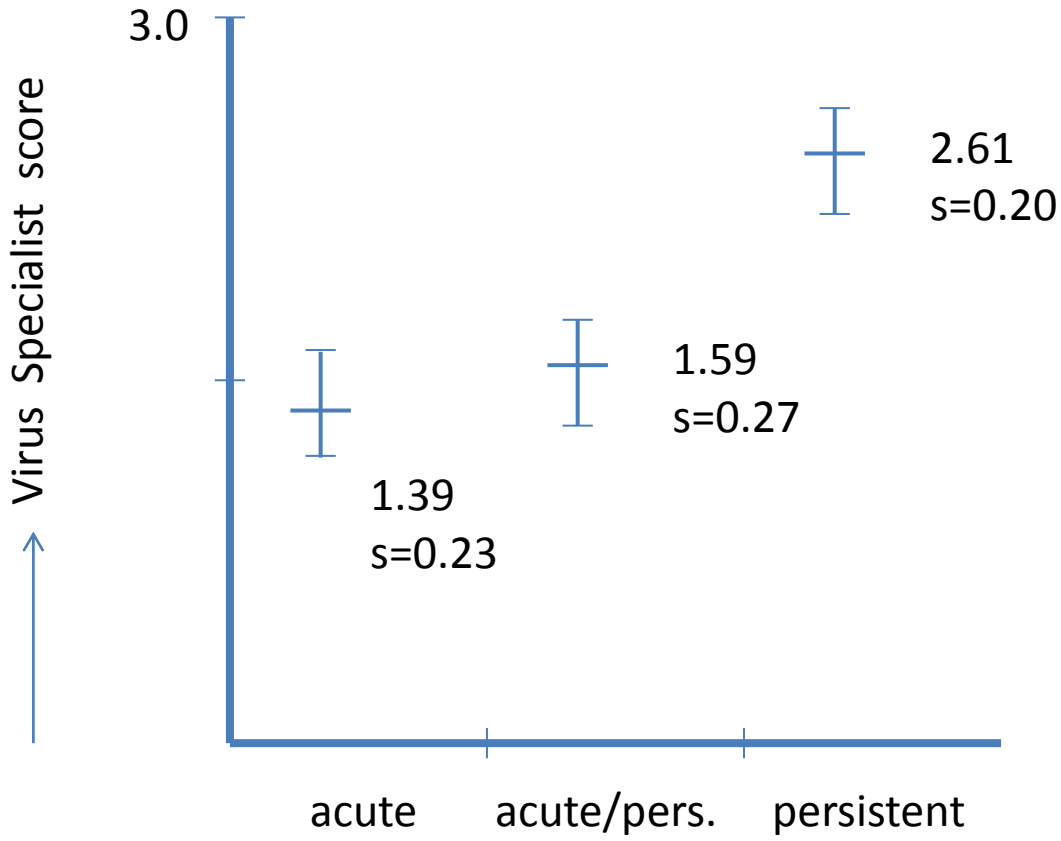
Infection durability defines the virus as specialist, more strongly so than infection benignity.

1.40	1.53	2.50
1.44	1.62	2.56
1.33	2.11	3.0



	Acute	Acute / Persistent	Persistent
Host specificity	1.17	1.38	2.67
Organ system tropism	1.60	2.27	2.67
Vertical transmission	1.08	1.31	2.17
Virus vulnerability	1.92	1.56	3.0
Disease enzooticity	1.08	2.06	3.0
Stable host env.	1.58	1.75	2.17

Infection durability and virus specialist score



- Host specificity
- Organ system tropism
- Vertical transmission
- Virus vulnerability
- Disease enzooticity
- Stable host environment

Main Findings

- A specialist virus causes a persistent, not necessarily benign, inner body infection

- This infection type is reflected in the transmission ecology and the type of host environment

- A specialist virus is more likely to become transmitted directly from parent to offspring, featuring hardly any virus shedding, if at all. The virus infects hosts species that live sufficiently long for the sustenance of durable infections. The host is likely to engage in reproductive behaviour.

- The Specialist – Generalist continuum runs diametrically through the infection plane, with lots of hybrid infections

Findings cont'd

- The right bottom corner of the infection matrix is populated by virus infections in equine + bovine host, with infections transmitted sexually, vertically or also by bloodsucking arthropods

- A diametrically opposite position in the infection plane is taken by highly pathogenic generalist viruses in poultry and pigs, causing severe, often systemic, infections affecting respiratory and/or enteric tract, with profuse virus shedding securing swift horizontal transmission in monoculture type mass rearing units

- Small ruminant infections are intermediate to the specialist virus infections in equines / bovines and the generalist virus infections in poultry and pigs

Av. IB 1 3 1 2 1 1 **Av. LT 1 1 1 2 1 1** **Duck ent. 1 3 1 2 1 1** **HPAI 1 1 1 2 1 1** **Newc. dis. 2 1 1 2 1 1** **PPR 1 2 1 2 1 2** **RP 1 1 1 2 2 3**	**CSF 2 x 2 1 2 1** **Gumboro 2 3 1 1 2 1** **PRRS 2 x 2 2 2 1** **Porc.ent. 1 x 1 1 2 1** **SECD 1 x 1 2 2 1**	**Jaagsiekte 2 3 2 3 3 2**
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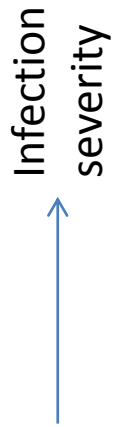
Pathogenic livestock bacteria



(Anthrax)
(Blackleg)
(HS)

CBPP
CCPP
Glanders

Bov. TB

Fowl cholera
Fowl typhoid

Enz. ab. ewes
Salm. ab. eq.
Strangles

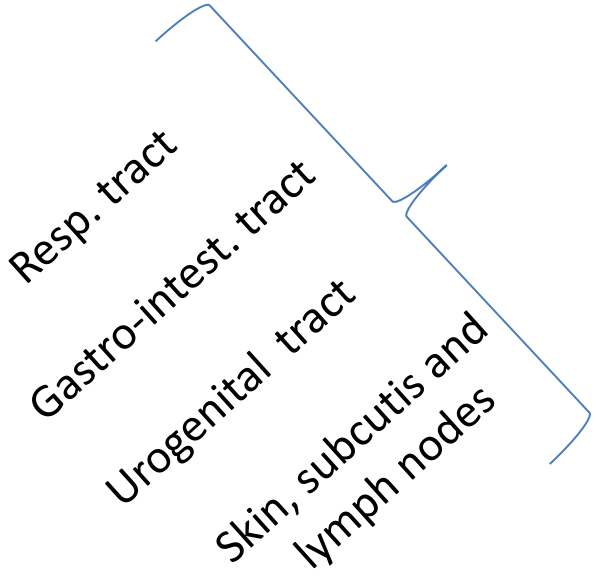
Johne's dis.
Bov. bruc.
Capr. & ov. bruc.
Porc. bruc.

Inf. coryza

Bov. gen. camp.
Cont. eq. metritis

Caseous lymphad.
Dermatophilosis
Ovine epididymitis
Cont. agal.

Swine erysipelas



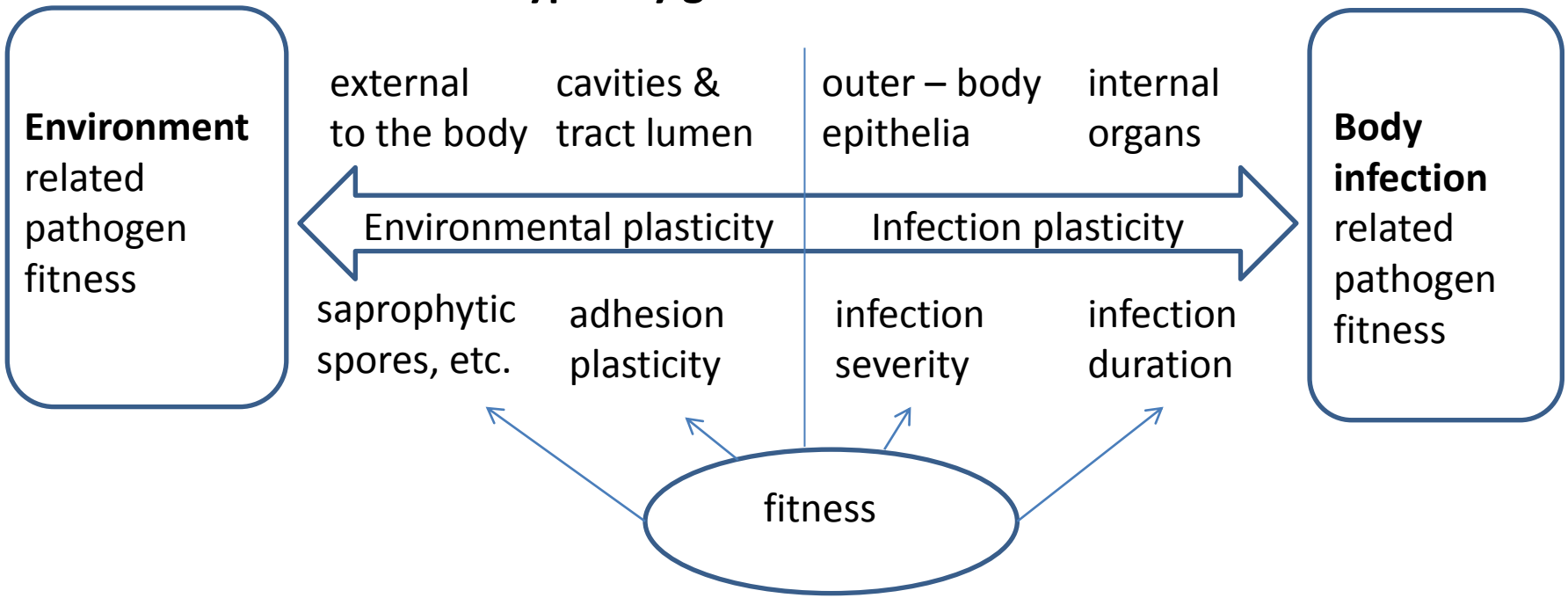
(no equivalent to rodent reservoirs: Lyme, plague, Q fever)

Infection plane based on infections caused by pathogenic livestock bacteria….

- Does not suggest a Specialist – Generalist continuum
- Livestock do not appear as a reservoir of persistent, benign, inner-body bacteria
- Severe fatal infections feature disease ecologies not always congruent with Koch's postulates
- Bacterial livestock infections mainly affect the epithelia, are less intrusive than the obligate intracellular viruses

How much of a micro-parasite is a bacterial livestock pathogen really?

Bacteria typically grow at the mucosal surface



bacteria	+++	++++	++	+
viruses	+	+	++++	++++

Bacteria take a different position than viruses in the pathogen ecology continuum.

Not all bacteria colonise the mucosal surface!

Specialist bacteria are found in two opposite directions in the pathogen ecology continuum**:**

Predominantly extracellular -> facult. intracellular -> obligate intracellular

Comparable to a specialist virus, a specialist, intracellular bacterium may cause a persistent inner-body infection.

or, alternatively

Integrate in host friendly biota in body cavities and tracts or, also display fitness related to the environment external to the host body

Hence, two diametrically opposite pathogen evolutionary pathways!

Likewise, opportunistic bacteria may

→ colonise epithelia and cause generalised or ascending tract infections; these concern the classical, contagious bacterial diseases that disappeared from the modern livestock systems, including CBPP, bovine tuberculosis and brucellosis, infectious coryza, fowl typhoid, etc.

or, alternatively

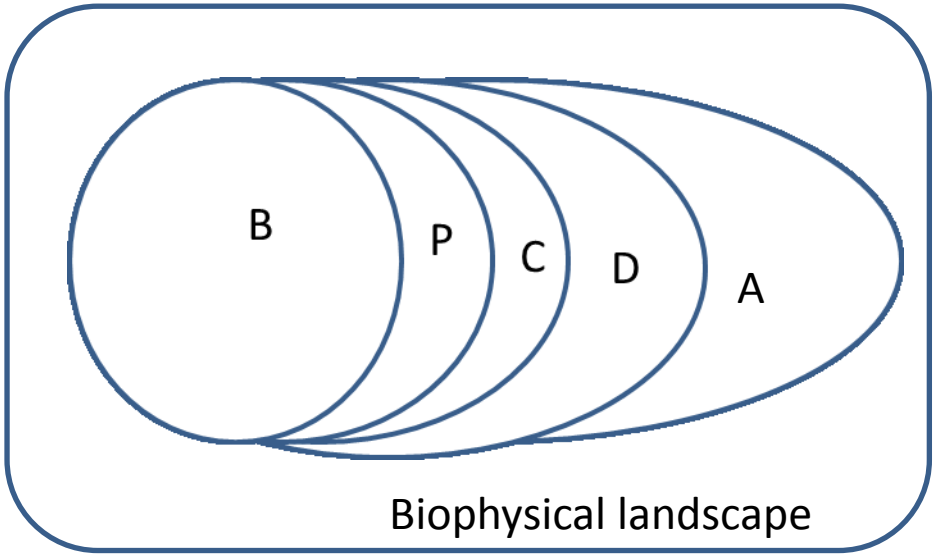
← produce novel bacterial extracellular substances and AMR related challenges arising in the **enteric tract environment of fast growing poultry, pigs and beef cattle**, and relevant in a VPH context

importantly, the latter do not show up in a livestock infection matrix or disease reporting system

Discussion points

Host compartment	Pattern formation
B Body	Infection course
P Population	Disease behaviour
C Community	Host range
D Domain	Domain width
A Area	Geographic range

Host environment compartments



With human action dramatically altering the host environment and the host resource availability to the existing pathogens, the ecological sorting and pathogen evolution process involves continual inter-compartmental level interaction, balancing and fine-tuning

We need to interrelate and match

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host environment dynamics

pathogen life history **disease transmission ecology**

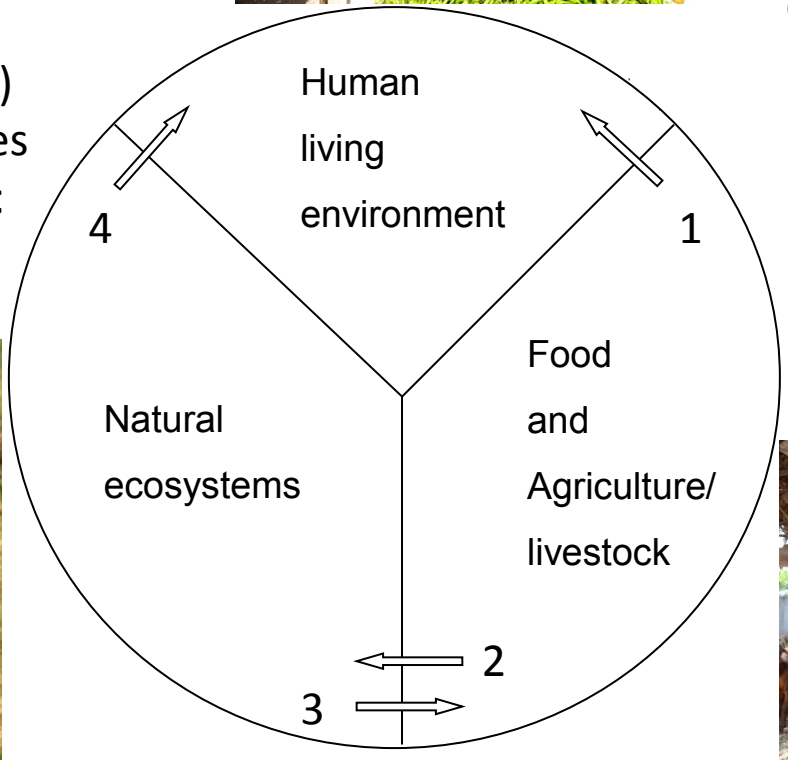
Differential interface dynamics

1. Species jumps and spill-over involving **generalist** viruses (HPAI, MERS, Nipendra)

or

Generalist bacteria and toxines and AMR challenges showing up in the enteric tract environment of food animals

4. Wildlife form a main reservoir and source of **specialist** viruses (filo-, lentiviruses) and also **generalist** viruses (Nipendra) and **specialist** bacteria (plague)



2. G**eneralist** bacteria -> classical livestock diseases

3. Spill-over by **specialist** bacteria (Qfever)
or **generalist** viruses (Nipendra, SARS, MERS)