Animal reservoirs in disease control and eradication

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Numerous infectious diseases are shared by animals and humans

Table 1. *Infections shared*

(Estimated from McNeill 1

animal	
dog	
cattle	
sheep, goat	
pig	42
horse	35
poultry	26
rats, mice	39
wild species	114
total	298

[a] Numbers overlap as some infections are shared among many species.


J. Comp. Path. 2016, Vol. 155, S41–S53
Available online at www.sciencedirect.com
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www.elsevier.com/locate/jcpa

Companion Animals as a Source of Viruses for Human Beings and Food Production Animals

L. A. Reperant*, I. H. Brown†, O. L. Haenen‡, M. D. de Jong§, A. D. M. E. Osterhaus*, A. Papa¶, E. Rimstad‖, J.-F. Valarcher# and T. Kuiken*

Weiss, 2001

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… and this is not new!

Table 3. *Examples of human infectious diseases of animal origin*

disease	microbe	animal source	date of crossover
malaria	parasite	chimpanzee	*ca*. 8000 BCE
measles	virus	sheep or goat	*ca*. 6000 BCE
smallpox	virus	ruminant?	> 2000 BCE
tuberculosis	mycobacterium	ruminant?	> 1000 BCE
typhus	rickettsia	rodent	430 BCE
			1492 CE
plague	bacterium	rodent	541 CE
			1347 CE
			1665 CE
Dengue	virus	monkey	*ca*. 1000 CE
yellow fever	virus	monkey	1641 CE
Spanish 'flu	virus	bird, pig	1918 CE
AIDS/HIV-1	virus	chimpanzee	*ca*. 1931 CE
AIDS/HIV-2	virus	monkey	20th century

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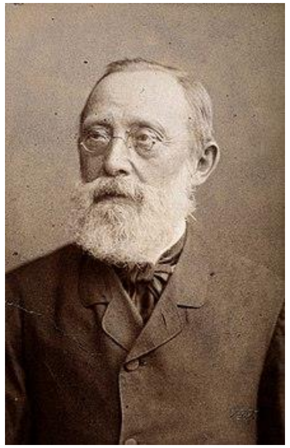
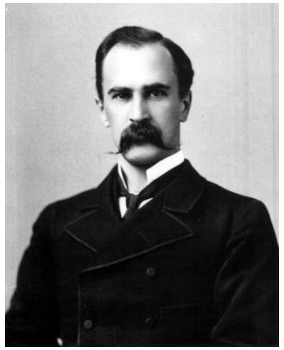
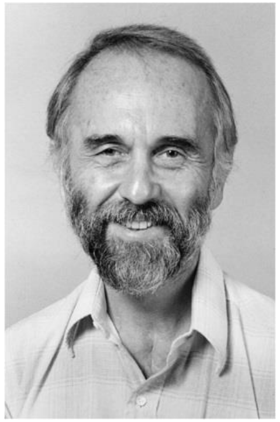
Weiss, 2001

The interface between animal and human diseases







1821-1902: Rudolf Virchow recognizes the link between human and animal health

1849-1919: William Osler, father of (comparative) veterinary pathology

1947: the Veterinary Public Health division is established at CDC

1927-2006: Calvin Schwabe coins the term "one medicine" and calls for a unified approach against zoonoses that uses both human and veterinary medicine

2004: the Wildlife Conservation Society published the 12 Manhattan principles

12 Manhattan Principles – key words
(http://www.wcs-ahead.org/manhattan_principles.html)

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How the concept "one health" was born?

"The One Health concept is a worldwide strategy for expanding interdisciplinary collaborations and communications in all aspects of health care for humans, animals and the environment."

Emphasis on zoonosis and vector-borne diseases

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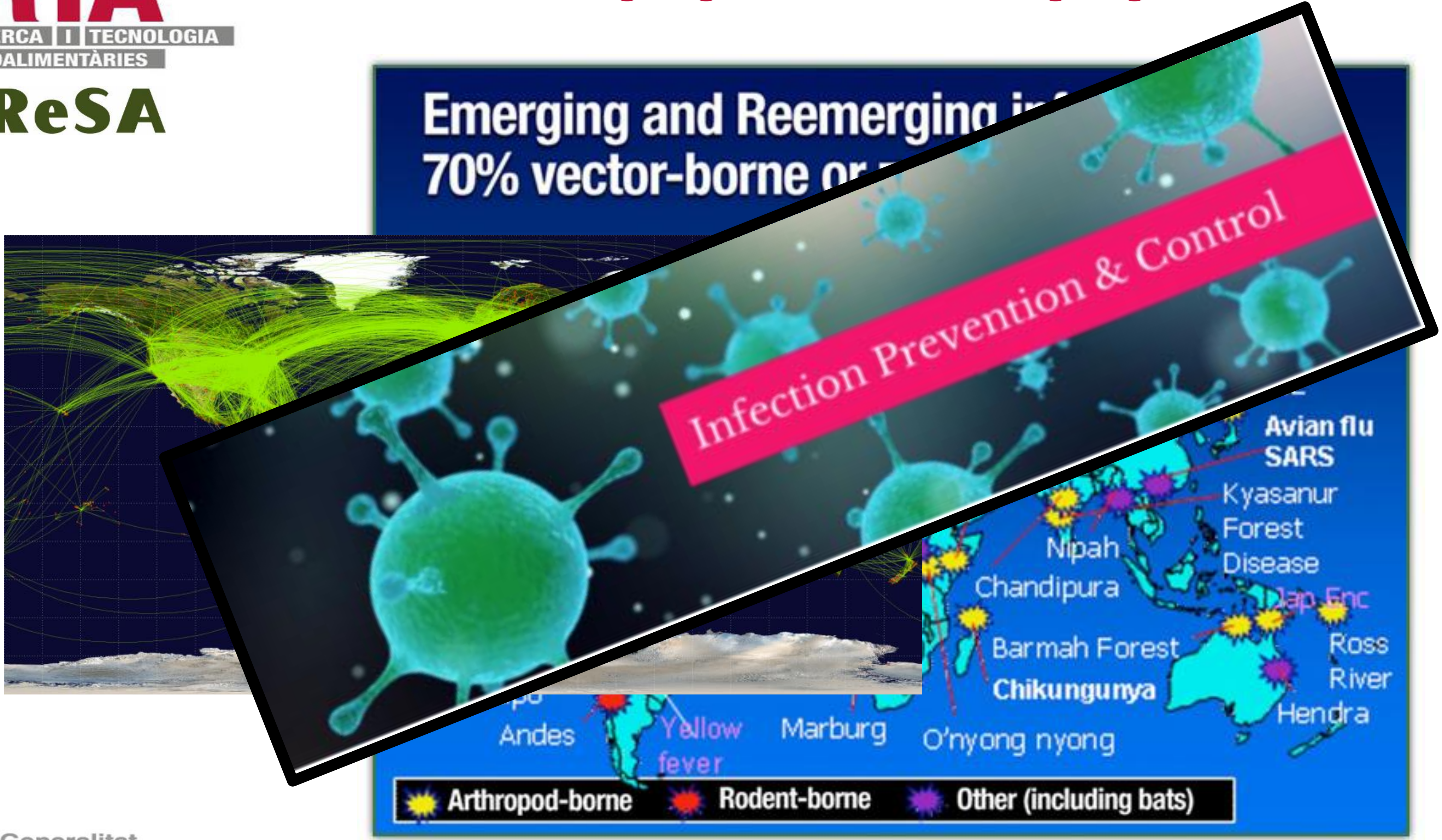
Emerging and re-emerging diseases



http://www.onehealthinitiative.com/map.php

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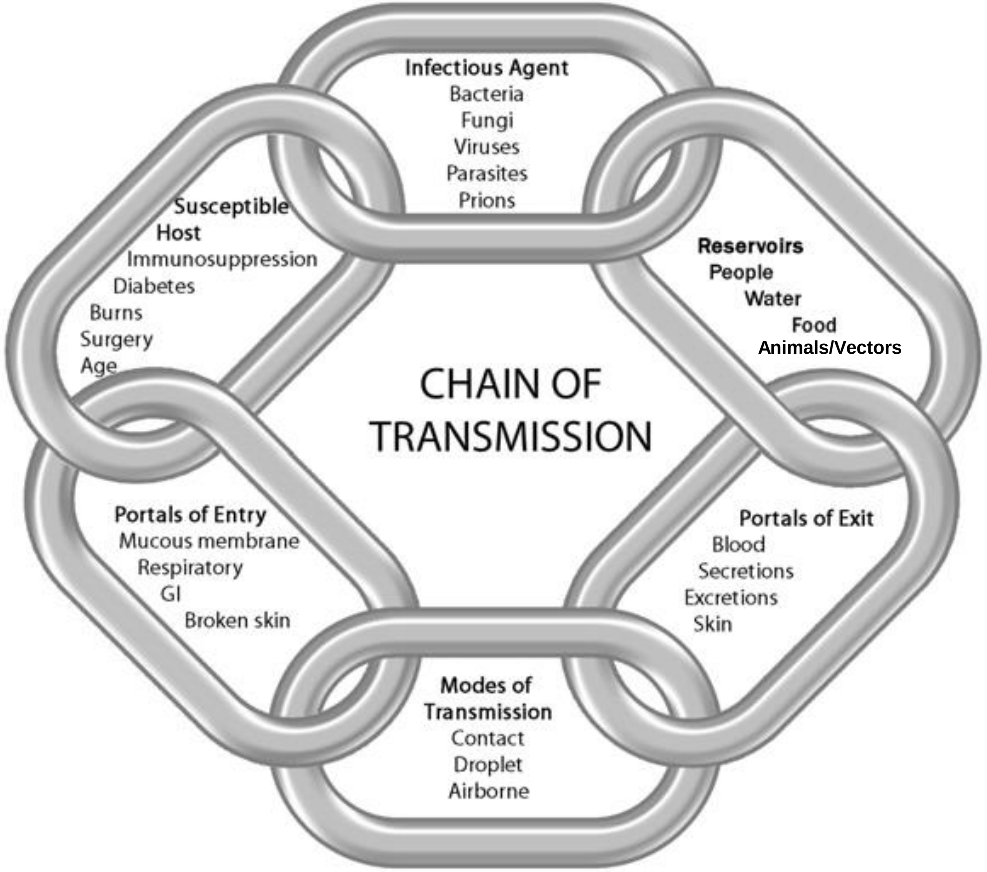
Control, prevention and eradication of zoonotic and vector-borne diseases

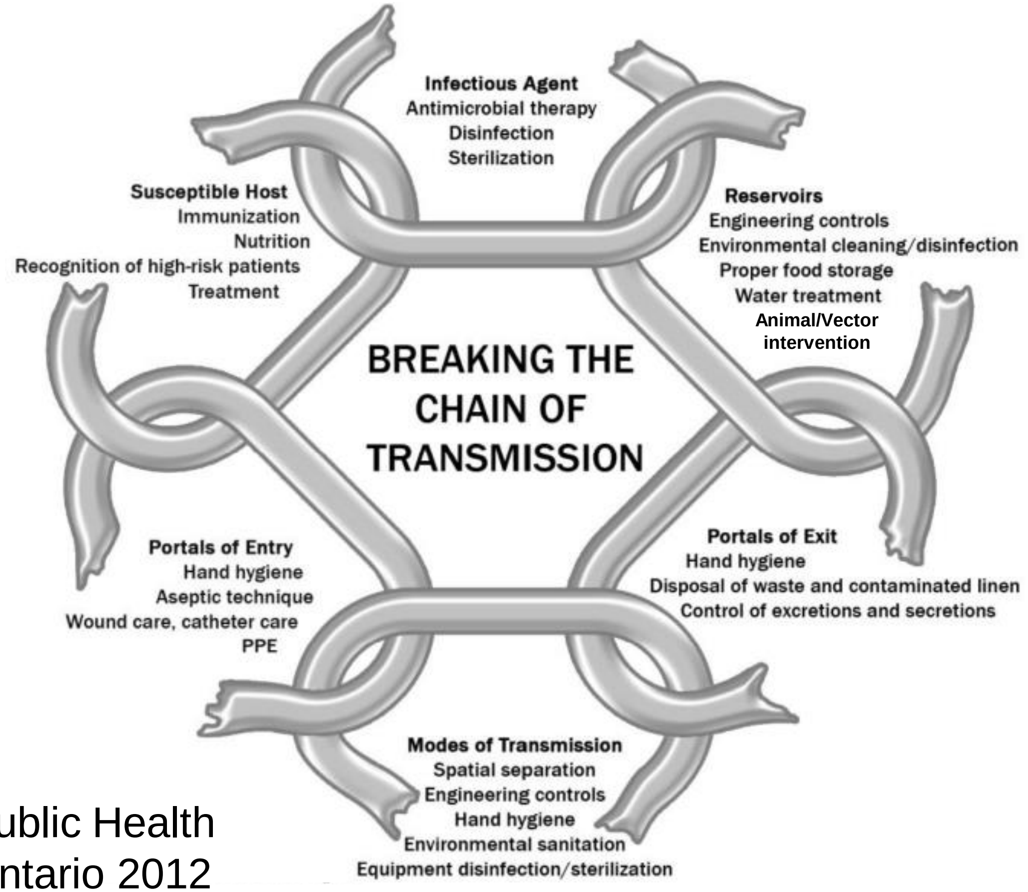


Public Health Ontario 2012

Focus on breaking the chain of transmission at its epidemiological weakest step

The most susceptible one for intervention

Control at the weakest epidemiological step… options…



Public Health Ontario 2012

RESERVOIR

- Control or eliminate the agent at the source of transmission
- Protect portals of entry (manner in which a pathogen enters a susceptible host)
- Increase host's defenses
- Others…

Definition of reservoir

"A reservoir is any person, animal, arthropod, plant, soil, or substance (or combination of these) **in which an infectious agent normally lives and multiplies, on which it depends primarily for survival, and where it reproduces itself in such manner that it can be transmitted to a susceptible host**."

https://emedia.rmit.edu.au/infection_control/content/1_Reservoir/01_rese_de.htm

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Definition of reservoir - complexity (Haydon *et al*., 2002)

- One or more epidemiologically **connected populations or environments in which the pathogen can be permanently maintained** and from which infection is transmitted to the defined target population.

- Populations in a reservoir may be **the same or different species as the target and may include vector species**

Definition of reservoir (Haydon *et al*., 2002) - glossary

- **Target population (TP)**: population of interest (humans in this case)
- **Non-target populations (NTP):** potentially susceptible host populations epidemiologically connected with the TP **("RESERVOIR")**
- **Critical community size (CCS):** minimum size of a closed population within which a pathogen can persist indefinitely
- **Maintenance populations (MP):** populations larger than the CCS
- **Non-maintenance populations (NMP):** populations smaller than the CCS
- **Maintenance community:** in complex systems, NMPs able to keep pathogen transmission (behaves as a MP)
- **Source population:** population that transmits infection directly to the TP

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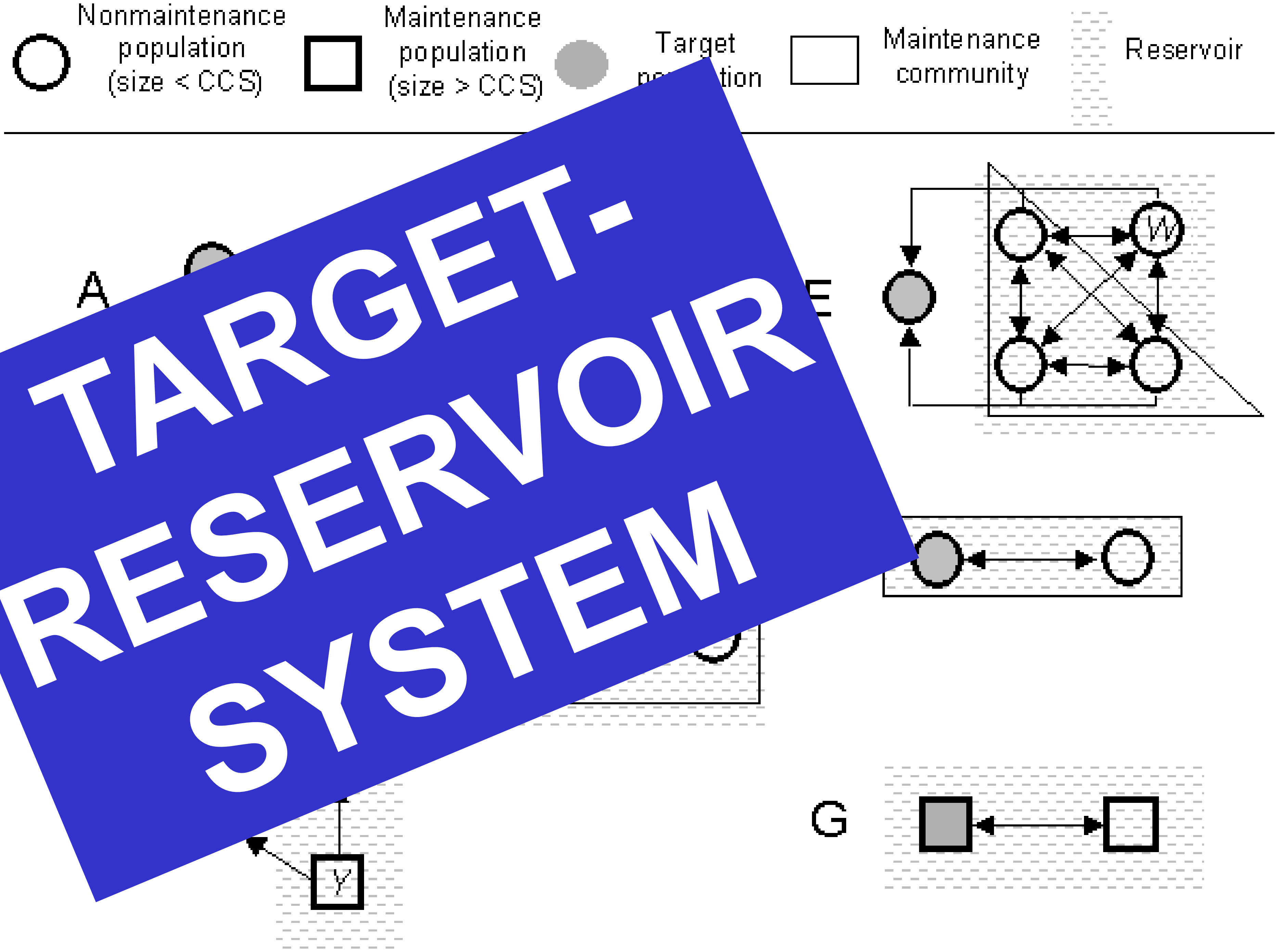
Definition of reservoir (Haydon e *al*., 2002)



TARGET-RESERVOIR SYSTEM

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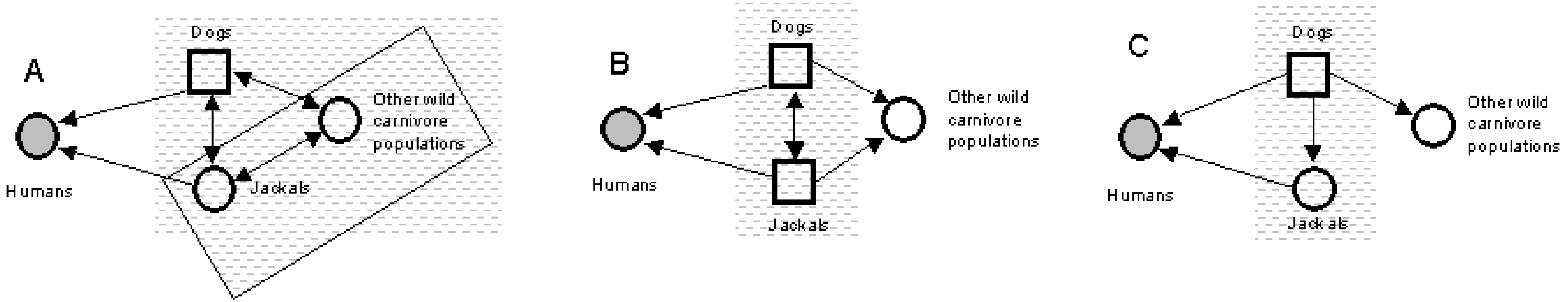
Definition of reservoir (Haydon *et al*., 2002)

Example: potential complexity of rabies reservoir in Zimbabwe and eventual intervention



If jackals with (A) or without (B) other wild carnivore populations constitute a maintenance community independent of dogs, then vaccination of dogs alone will not result in rabies elimination in the target

If jackals do not constitute a maintenance community independent of dogs (C), then dog vaccination should clear rabies from the reservoir

Identification of the reservoir is not an easy task sometimes…

A reservoir needs to maintain the pathogen and have a feasible transmission route

High-genetic similarity of the pathogen found in the reservoir system
High degree of functional similarity (infectivity and viability)
Spatial and temporal connectivity
Maintaining pathogen viability

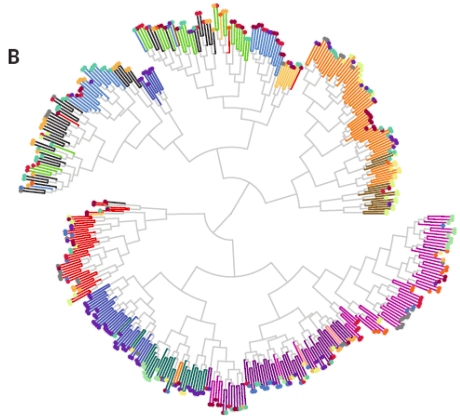
Hallmaier-Wacker et al., 2017

Examples of NTP as maintenance populations (Hallmaier-Wacker *et al*., 2017)

Pathogen	Target	Non-target	Main transmission route	Maintenance in NT: High-genetic similarity	Maintenance in NT: Functional similarity
Influenza A virus (H1N1)	Human	Swine	Aerosol	X	X
MERS-Coronavirus	Human	Camel	Direct contact	X	X
Brucella melitensis (localized brucellosis)	Human	Sheep	Food-borne	X	X
Immunodeficiency virus	Human	NHP	Direct contact	(X)	NP
Treponema pallidum pertenue (yaws)	Human	NHP	Direct contact/vector	X	(X)
Mycobacterium bovis (bovine tuberculosis)	Human	Cattle	Food-borne/aerosol	X	X
Rabies virus	Human	Fox	Bite	X	X
Echinococcus multilocularis (alveolar echinococcosis)	Human	Fox	Oral/fecal	X	X
Hantavirus	Human	Rodent	Aerosol	X	X
Ebola virus	Human	Bats	Contact/aerosol	X	NP
Zika virus	Human	NHP	Vector	(X)	NP
Borrelia burgdorferi (borreliosis)	Human	Wildlife	Vector	X	X
Yellow fever virus	Human	NHP	Vector	X	X

Identification of the reservoir is not an easy task sometimes…

It may require years of field and e
limiting an early and timely interve

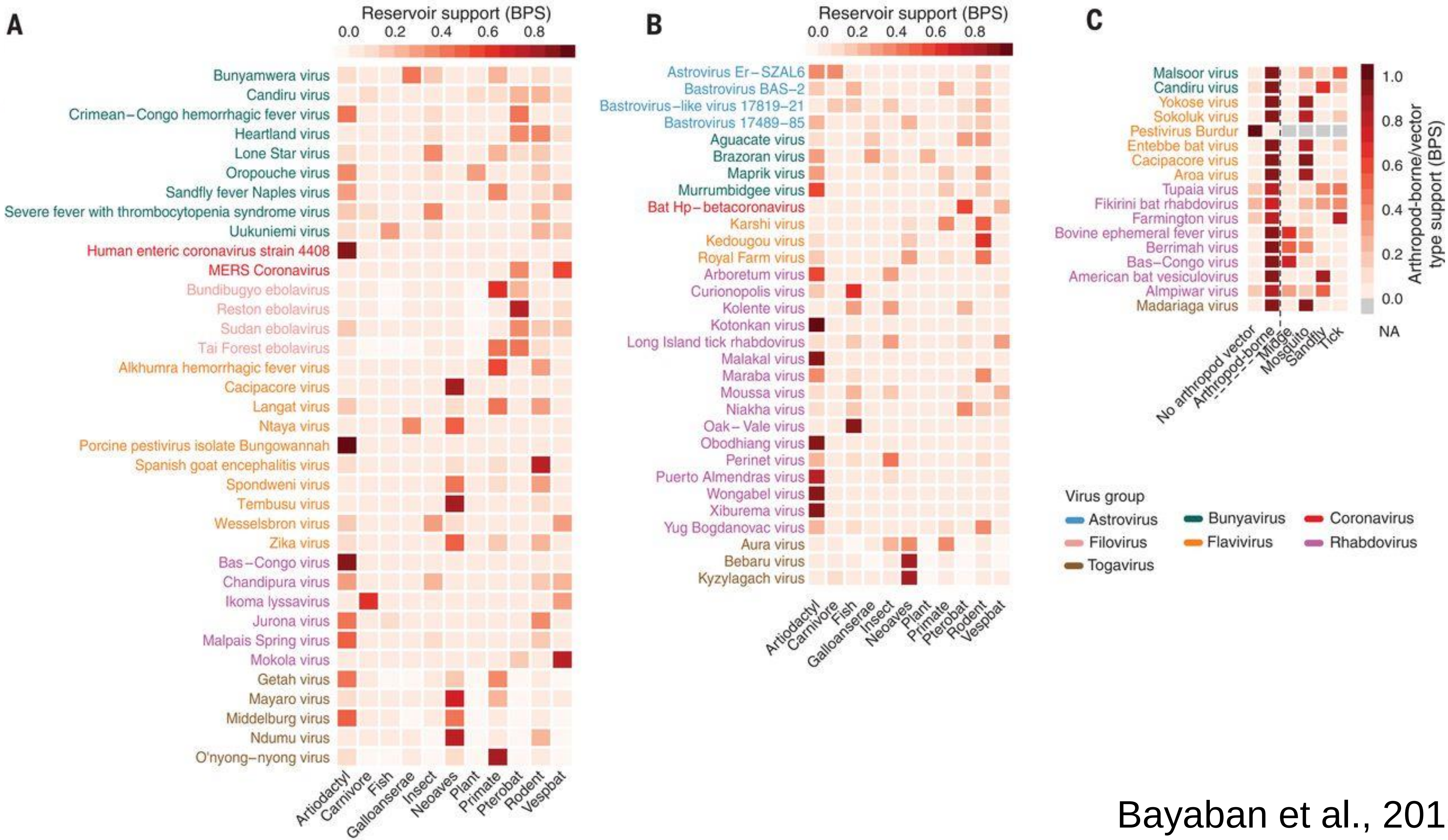


EPIDEMIOLOGY

Predicting reservoir hosts and arthropod vectors from evolutionary signatures in RNA virus genomes

Simon A. Babayan[1,2], Richard J. Orton[3], Daniel G. Streicker[1,3]*

Science AAAS



Bayaban et al., 2018

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Identification of the reservoir is not an easy task sometimes…

EPIDEMIOLOGY

Predicting reservoir hosts and arthropod vectors from evolutionary signatures in RNA virus genomes

Simon A. Babayan[1,2], Richard J. Orton[3], Daniel G. Streicker[1,3*]

Advantages:

- decrease the time between virus discovery and targeted research
- surveillance and management, mostly focused on disease control (and eventual eradication) at the origin

Disadvantages:

- limitations in accuracy (prediction of vector type of 91% and host type of 72%)

Woolhouse et al., 2018

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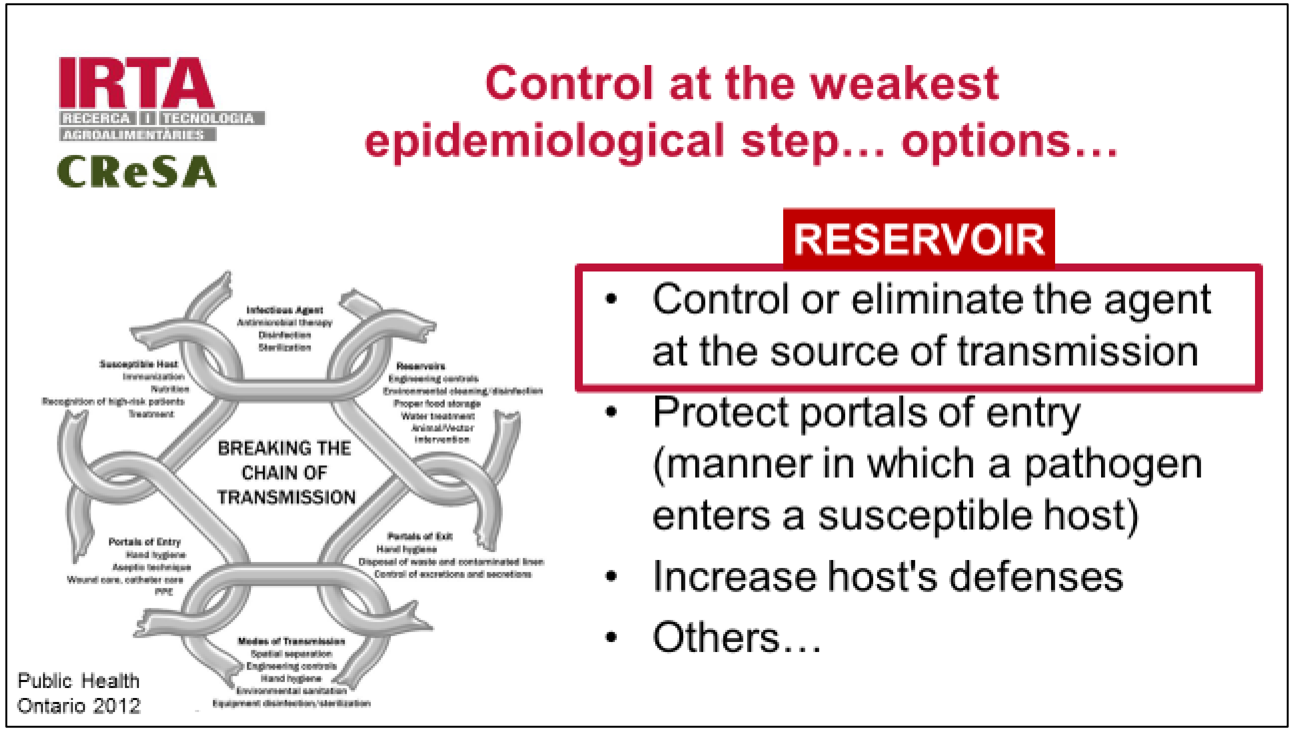
Intervention strategies



Once the reservoir system has been identified, control or elimination at the source will depend on a number of factors:

- Policy (region, country) – culling policies, quarantine, vaccination
- Diagnostic capabilities
- Treatment/prevention measures available
- Likelihood of intervention (wildlife)

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Examples of pathogen control at the source: avian influenza

AVIAN DISEASES 51:332–337, 2007

Efficacy of Two H5N9-Inactivated Vaccines Against Challenge with a Recent H5N1 Highly Pathogenic Avian Influenza Isolate from a Chicken in Thailand

Michel Bublot,[A] François-Xavier Le Gros,[A] Daniela Nieddu,[B] Nikki Pritchard,[C]

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

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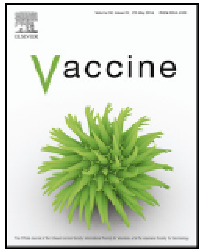

Vaccine protection of chickens against antigenically diverse H5 highly pathogenic avian influenza isolates with a live HVT vector vaccine expressing the influenza hemagglutinin gene derived from a clade 2.2 avian influenza virus

Darrell R. Kapczynski[a,*], Motoyuki Esaki[b], Kristi M. Dorsey[b], Haijun Jiang[a],

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Examples of pathogen control at the source: Nipah virus infection

1998-99: Infected zones of 2 km radius and buffer zones of 10 km radius were imposed around infected premises. All pigs within the buffer zone were culled over a 2-month period (a total of 901,228 pigs from 896 farms) (source: FAO)

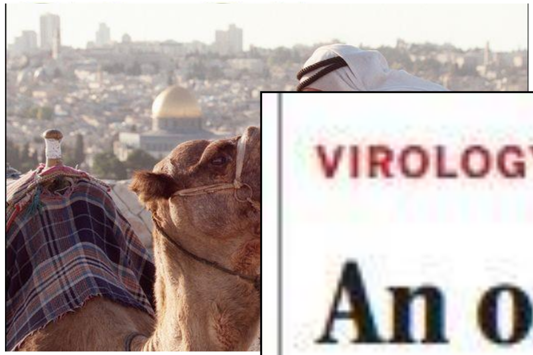
Examples of pathogen control at the source: rabies

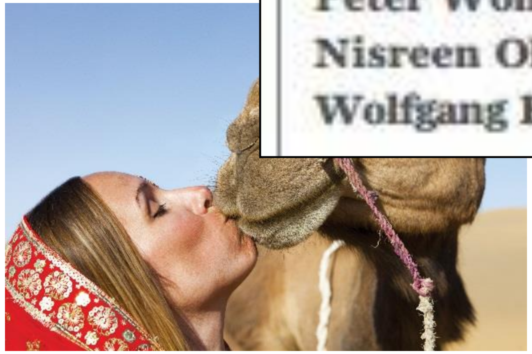
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

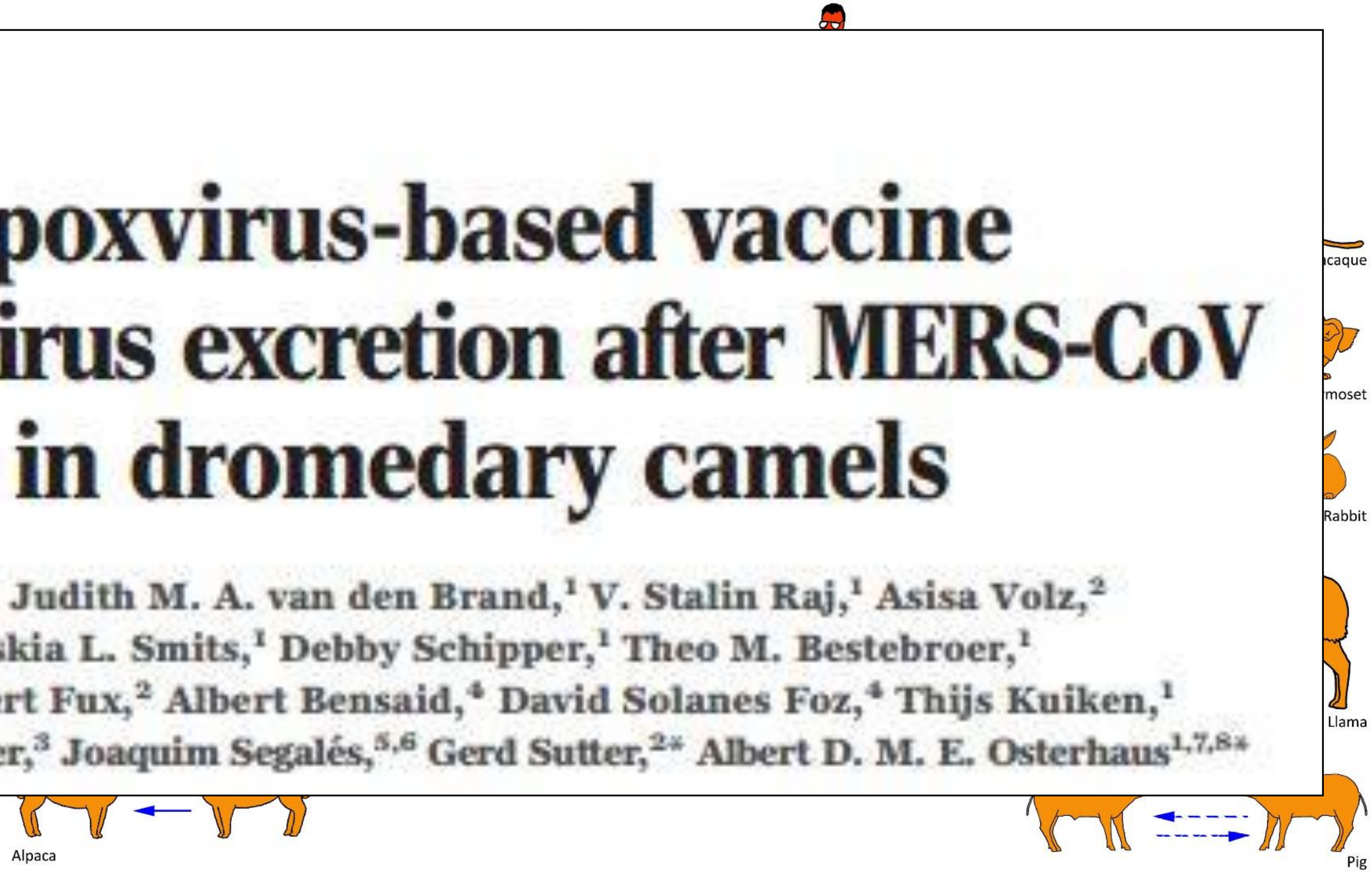
The elimination of fox rabies from Europe: determinants of success and lessons for the future

Conrad M. Freuling[1,†], Katie Hampson[2,†], Thomas Selhorst[3,†], Ronald Schröder[3], Francois X. Meslin[4], Thomas C. Mettenleiter[1] and Thomas Müller[1]

Examples of pathogen control at the source: MERS-CoV







VIROLOGY

An orthopoxvirus-based vaccine reduces virus excretion after MERS-CoV infection in dromedary camels

Bart L. Haagmans,[1*] Judith M. A. van den Brand,[1] V. Stalin Raj,[1] Asisa Volz,[2] Peter Wohlsein,[3] Saskia L. Smits,[1] Debby Schipper,[1] Theo M. Bestebroer,[1] Nisreen Okba,[1] Robert Fux,[2] Albert Bensaid,[4] David Solanes Foz,[4] Thijs Kuiken,[1] Wolfgang Baumgärtner,[3] Joaquim Segalés,[5,6] Gerd Sutter,[2*] Albert D. M. E. Osterhaus[1,7,8*]

Vergara-Alert et al., 2017

Take home messages

- Most emerging and re-emerging diseases are of zoonotic or vector-borne origin
- A reservoir is a complex network of populations in which the pathogen is maintained and from which infection is transmitted to the target population
- Animal and vector reservoirs might be potentially predicted based on signatures of RNA viral genomes
- Most of the control measures at reservoir level, when feasible, imply culling or immunization; eventually, action can be taken on wildlife

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Universiteit Utrecht

VETBIONET
Veterinary Biocontained research facility Network

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Thank you very much for your attention!!!

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