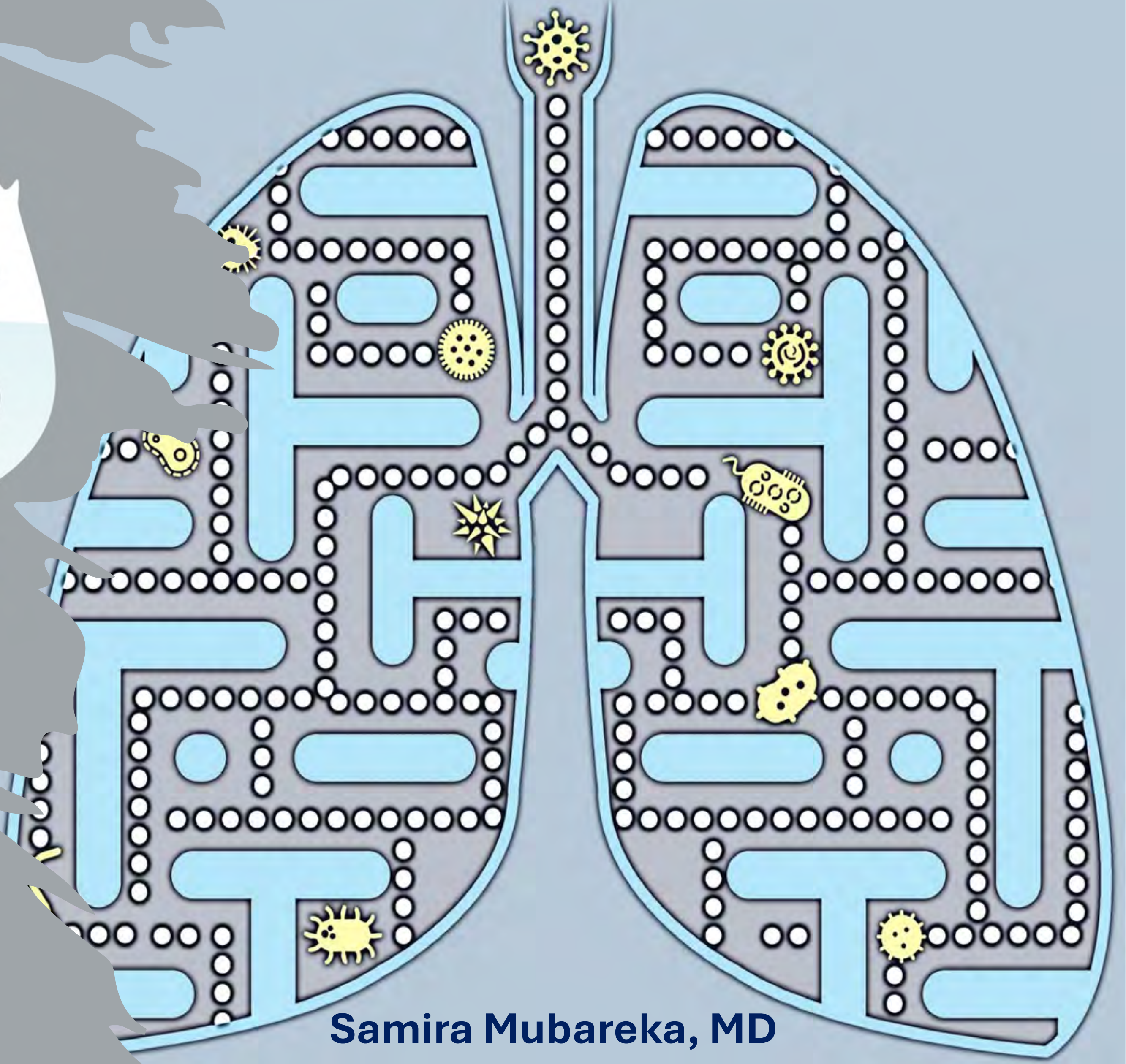
One Health and pandemic preparedness



Samira Mubareka, MD
Sunnybrook Research Institute
University of Toronto
CIHR-PHAC Applied Public Health Chair

Outline

1. The big picture

2. Lessons from the past pandemic

3. Preparing for the future

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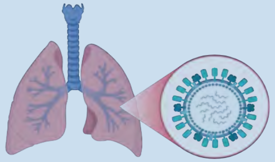
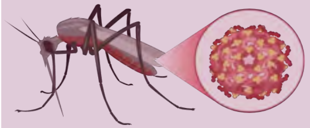
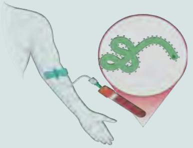
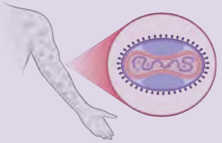
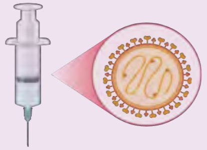
Emerging and resurging viruses

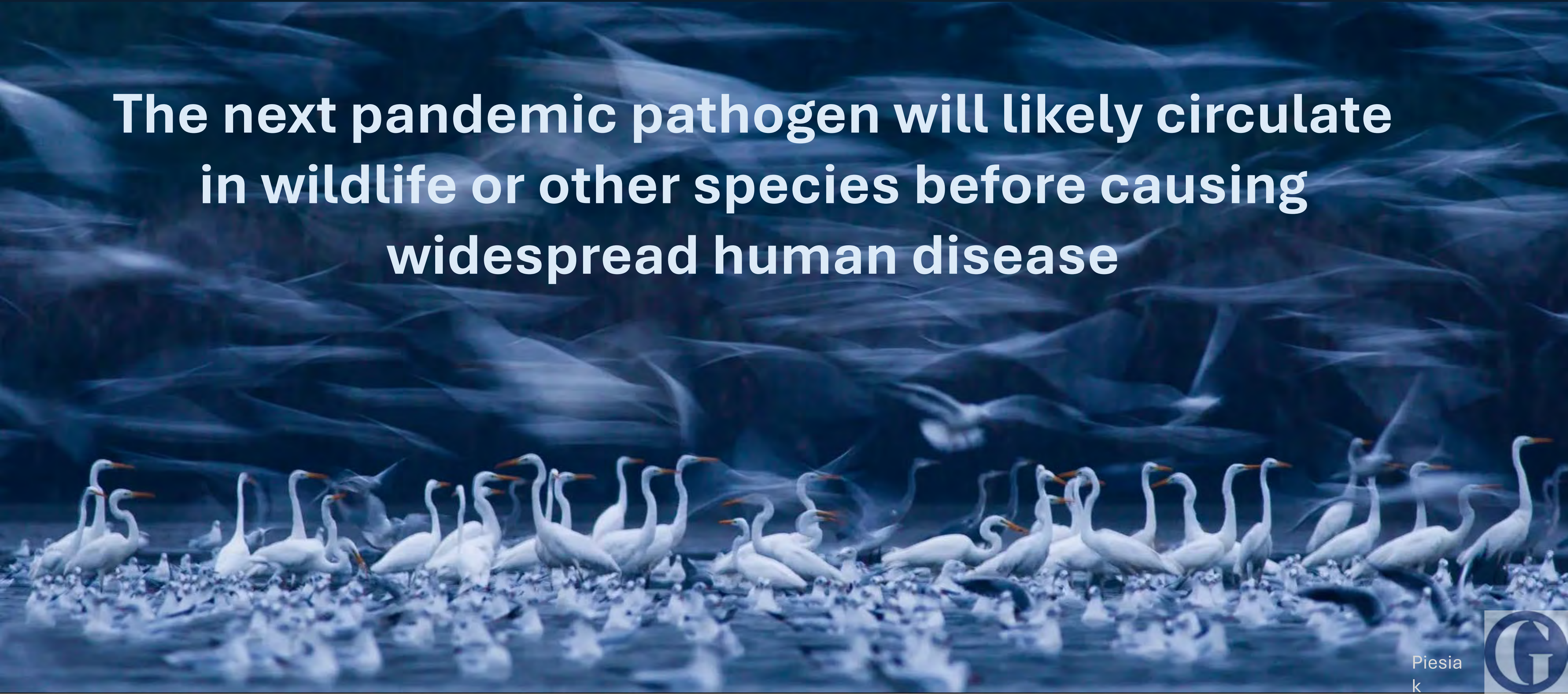
				
ZOONOSES	RESPIRATORY VIRUSES		2009 pH1N1 HPAI SARS-CoV SARS-CoV-2 Hantavirus	2009 pH1N1 HPAI SARS-CoV SARS-CoV-2 MERS Hantavirus
ZOONOSES	ARBOVIRUSES		WNV Jamestown Canyon Cache Valley Snowshoe hare Eastern equine encephalitis	Dengue Zika Chikungunya Oropouche Yellow fever Usutu
ZOONOSES	HEMORRHAGIC FEVER VIRUSES			Ebola Marburg Lassa Crimean-Congo Nipah Rift Valley fever
ZOONOSES	POX VIRUSES		Mpox	Mpox
	VACCINE PREVENTABLE DISEASES		Measles	Measles Polio

- **Over 50 viruses have 'emerged' since 2000**
  - Endemic vs novel
  - Etiologic agents of health emergencies
    - Known
    - Potential
      - Risk registries
- **63.7% of the 212 viruses discovered/reported since 1900 have been zoonotic/arthropod-borne**

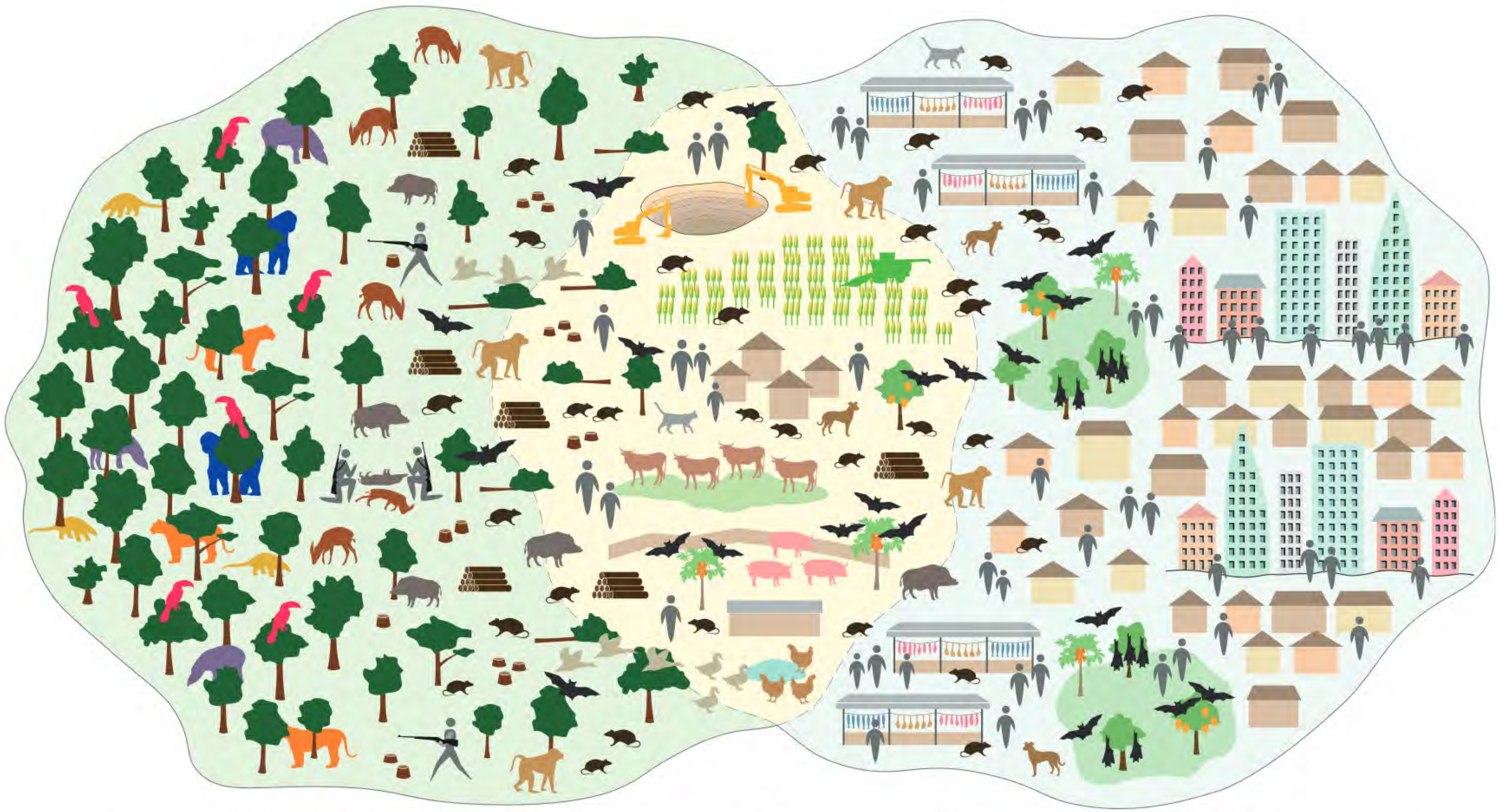
BMC Infect Dis. 2025 Dec 20;26(1):136.
doi: 10.1186/s12879-025-12362-8

Animal and ecosystem health matters

The next pandemic pathogen will likely circulate in wildlife or other species before causing widespread human disease



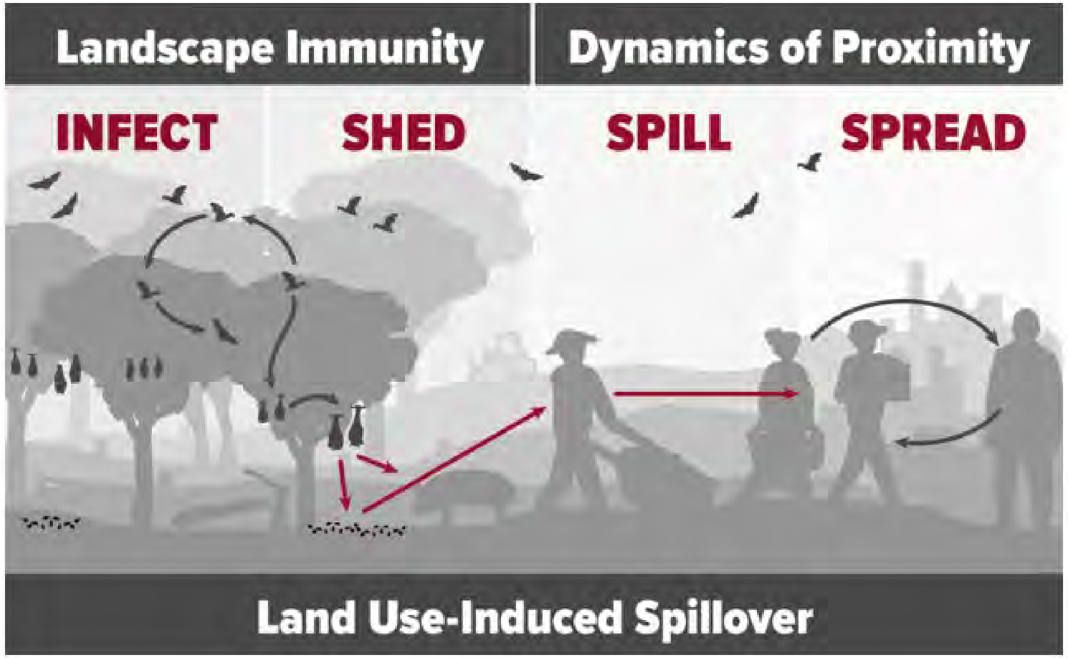
Socio-ecological drivers of inter-species pathogen transmission: land use-induced spillover (LUIS)

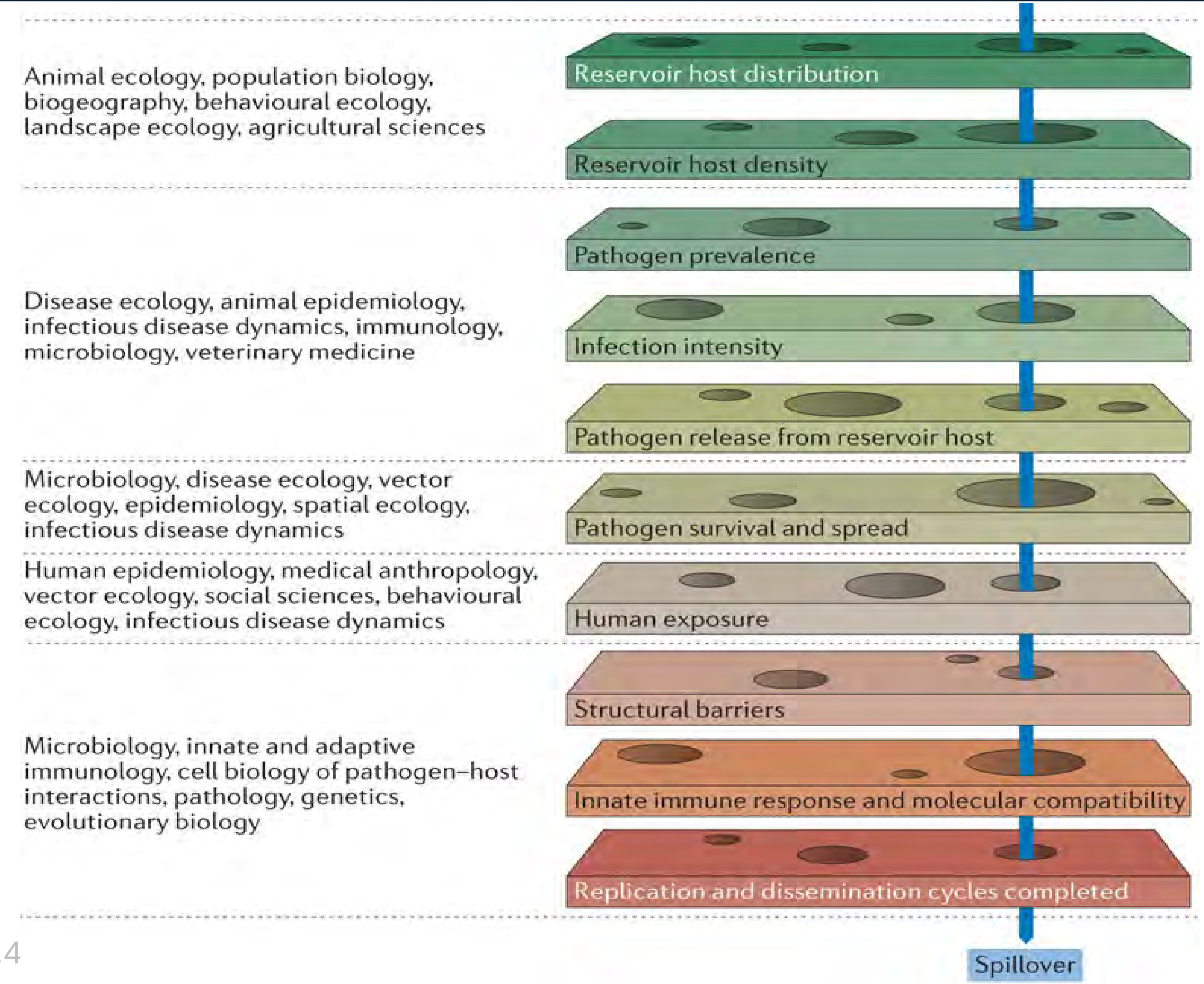


PRISTINE FOREST	ECOTONE	URBAN / PERI-URBAN
- Penetration by illegal loggers and hunters leads to habitat degradation, the reduction of large fauna and the proliferation of rodent, bat, bird and primate species which can act as disease reservoirs	- Human activities, especially livestock farming and feedstock cultivation, cause deforestation and bring wild animals in contact with humans and domestic animals - Sylvatic pathogens are no longer controlled by environmental stochasticity	- As wild habitats are degraded, wild animals enter urban areas in search of food - Crowding and food deprivation may increase wildlife susceptibility to pathogen infection and shedding

EClinicalMedicine. 2022 May;47:101386

Maintaining health through immunity, from human and other animal cells to ecosystems





Nat Rev Microbiol. 2017 Aug;15(8):502-510. doi: 10.1038/nrmicro.2017.4
Conservation Letters.2022;15:e12869

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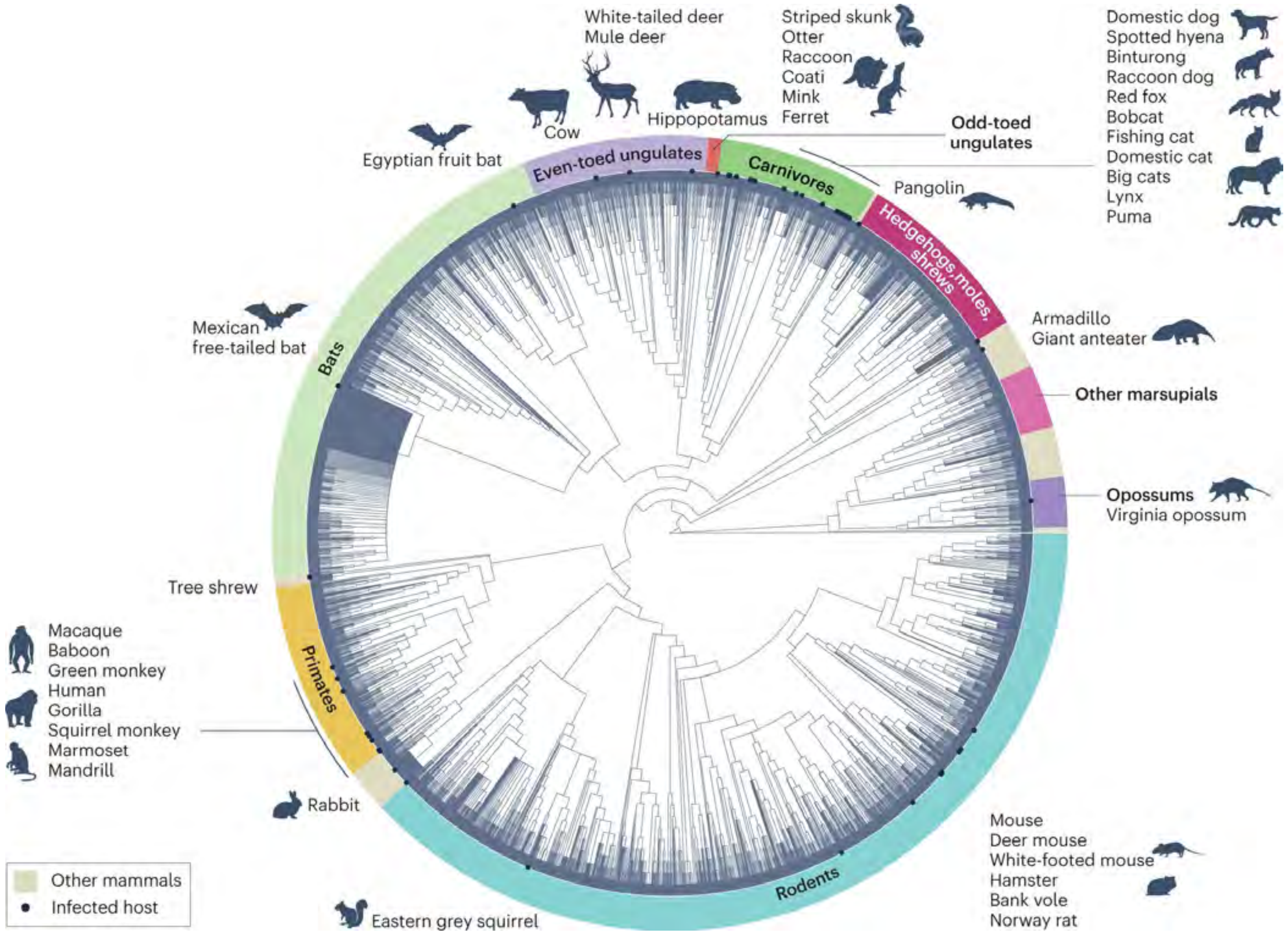
Human-other animal spillover



Comment | Published: 25 May 2023

Coordinated surveillance is essential to monitor and mitigate the evolutionary impacts of SARS-CoV-2 spillover and circulation in animal hosts

Suresh V. Kuchipudi, Cedric Tan, Lucy van Dorp, Maureen Lichtveld, Bradley Pickering, Jeff Bowman, Samira Mubareka & Francois Balloux

Nature Ecology & Evolution **7**, 956–959 (2023) | Cite this article

Kuchipudi *et al*, Nat Ecol Evol. 2023 May 25. doi: 10.1038/s41559-023-02082-0

White-tailed deer ACE2 resembles human ACE2

	24	27	28	30	31	34	35	37	38	41	42	45	62	83	330	353	354		355	357	393	/20	/5
NP 001373189.1 ACE2 Human:	Q	T	F	D	K	H	E	E	D	Y	Q	L	M	Y	N	K	G	–	D	R	R		
XP 032945086.1 ACE2 Bat:	E	K	F	E	E	Q	I	K	V	N	E	E	R	F	K	N	G	K	D	R	R	5	0
NP 001123985.1 ACE2 Mouse:	N	T	F	N	N	Q	E	E	D	Y	Q	L	S	F	N	H	G	–	D	R	R	13	[illegible]
NP 001012006.1 ACE2 Rat:	K	S	F	N	K	Q	E	E	D	Y	Q	L	N	F	N	H	G	–	D	R	R	13	[illegible]
NP 001164540.1 ACE2 Rabbit:	E	R	F	E	E	R	S	Q	A	N	E	E	R	F	K	N	G	K	D	R	R	5	[illegible]
NP 001297119.1 ACE2 Ferret:	L	T	F	E	K	Y	E	E	E	Y	Q	L	T	Y	N	K	R	–	D	R	R	14	3
NP 001034545.1 ACE2 Cat:	L	T	F	E	K	H	E	E	E	Y	Q	L	T	Y	N	K	G	–	D	R	R	16	3
NP 001158732.1 ACE2 Dog:	L	T	F	E	K	Y	E	E	E	Y	Q	L	T	Y	N	K	G	–	D	R	R	15	[illegible]
NP 001116542.1 ACE2 Pig:	L	T	F	E	K	L	E	E	D	Y	Q	L	T	Y	N	K	G	–	D	R	R	16	4
XP 006212709.1 ACE2 Alpaca:	L	T	F	K	E	H	E	E	D	Y	Q	L	I	Y	N	K	G	–	D	R	R	16	[illegible]
NP 001019673.2 ACE2 Cattle:	Q	T	F	E	K	H	E	E	D	Y	Q	L	T	Y	N	K	G	–	D	R	R	[illegible]	4
XP 020768965.1 ACE2 WhitetailedDeer:	Q	T	F	E	K	H	E	E	D	Y	Q	L	T	Y	N	K	G	–	D	R	R	[illegible]	4
XP 019781177.2 ACE2 BottlenoseDolphin:	R	T	F	Q	K	R	E	E	D	Y	Q	L	T	Y	N	K	G	–	D	R	R	16	4
XP 022444817.1 ACE2 BelugaWhale:	E	R	F	E	E	R	R	R	V	N	E	E	K	F	K	N	G	K	D	R	R	5	0
XP 012949915.3 ACE2 Duck:	Q	M	F	A	E	V	R	E	D	Y	E	L	N	F	N	K	N	–	D	R	R	11	3
XP 416822.3 ACE2 Chicken:	E	T	F	A	E	V	R	E	D	Y	E	L	R	F	N	K	N	–	D	R	R	11	[illegible]
XP 019467554.1 ACE2 Turkey:	E	T	F	A	E	V	R	E	D	Y	E	L	R	F	N	K	N	–	D	R	R	11	[illegible]

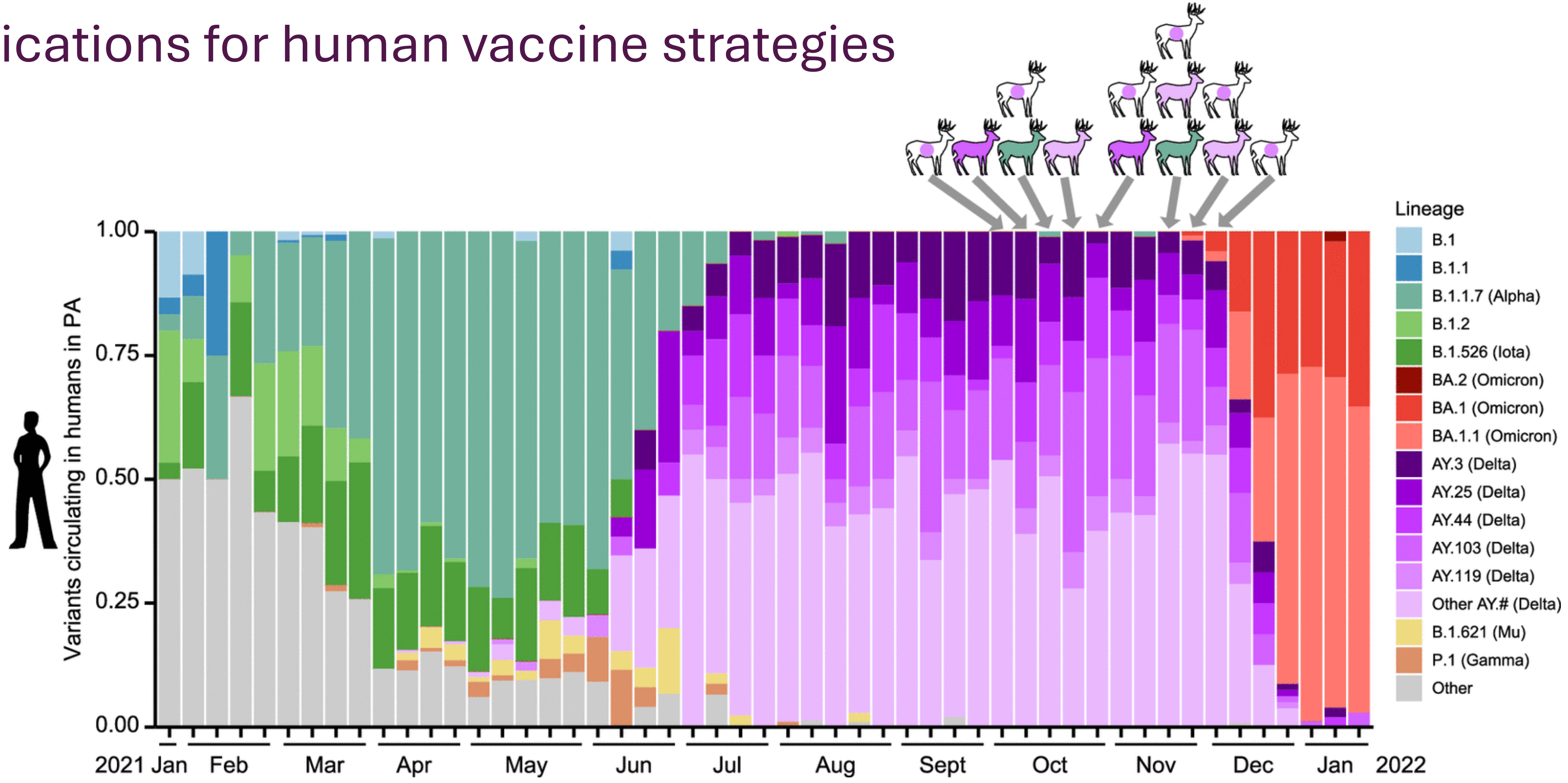
18/20 key amino acids across the domain

4/5 critical residues match

Proc Natl Acad Sci U S A, 2021. 118 (12) e2025373118 https://doi.org/10.1073/pnas.2025373118

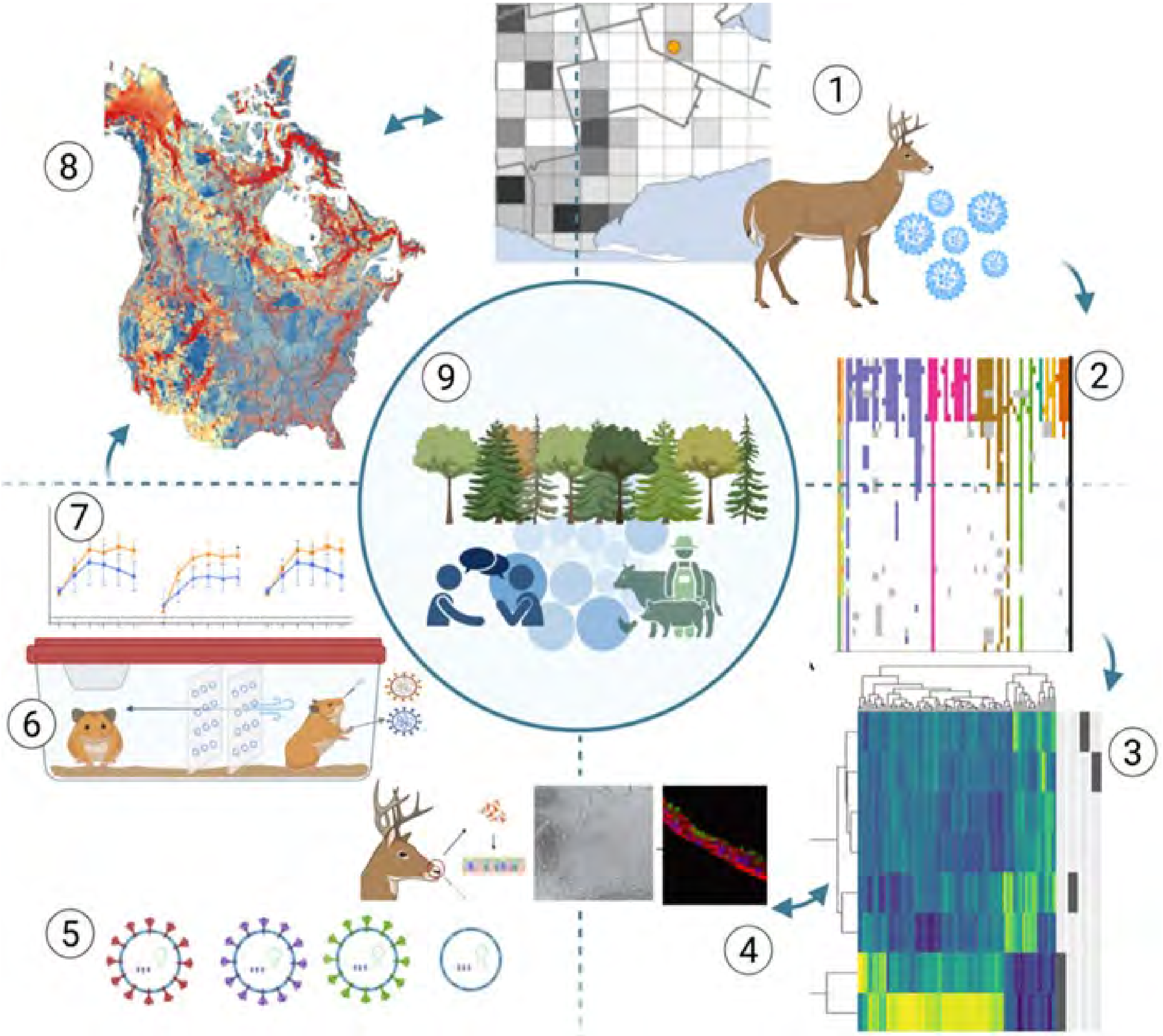
Persistence of VOCs in deer

Implications for human vaccine strategies



mBio. 2022 Oct 26;13(5):e0210122. doi: 10.1128/mbio.02101-22

Wild EPI, a multidisciplinary approach

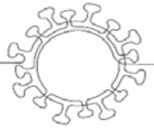


Wild EPI, a multidisciplinary collaboration

MNRF
MPPF
CWHC
Trent
Guelph
Carleton

Sunnybrook
Dalhousie

Detection
Sequencing, GISAID
Virus isolation
Risk assessment/phenotyping



MNRF
MPPF
NCFAD

Confirmation, CAHSS, GISAID
Sequencing
Virus isolation
Risk assessment

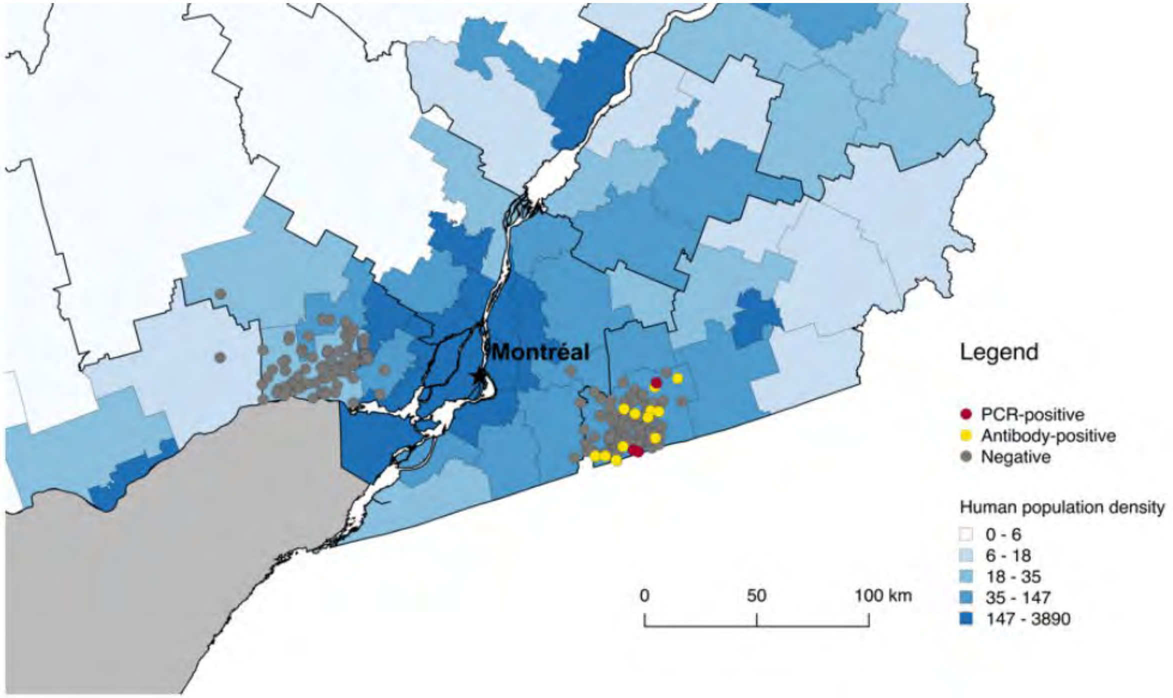
ECCC

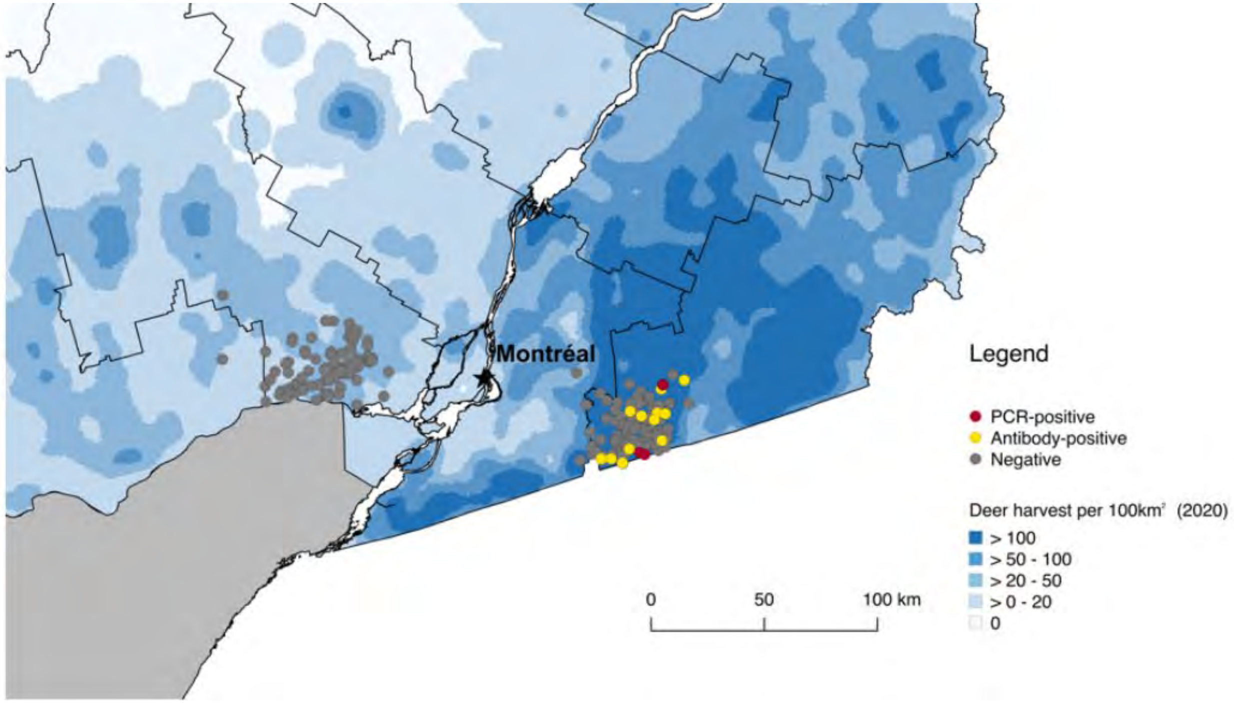
WOAH

iScience, volume 27, Issue 7110317July 19, 2024

MNRF: Ministry of Natural Resources and Forests (ON)
MFFP: Ministère des Forêts, de la Faune et des Parcs (QC)
CWHC: Canadian Wildlife Health Cooperative
NCFAD: National Centre for Foreign Animal Disease
ECCC: Environment and Climate Change Canada
WOAH: World Organization for Animal Health
GISAID: Global Initiative on Sharing Avian Influenza Data
CAHSS: Canadian Animal Health Surveillance System https://cahss.ca/cahss-tools/sars-cov-2-dashboard

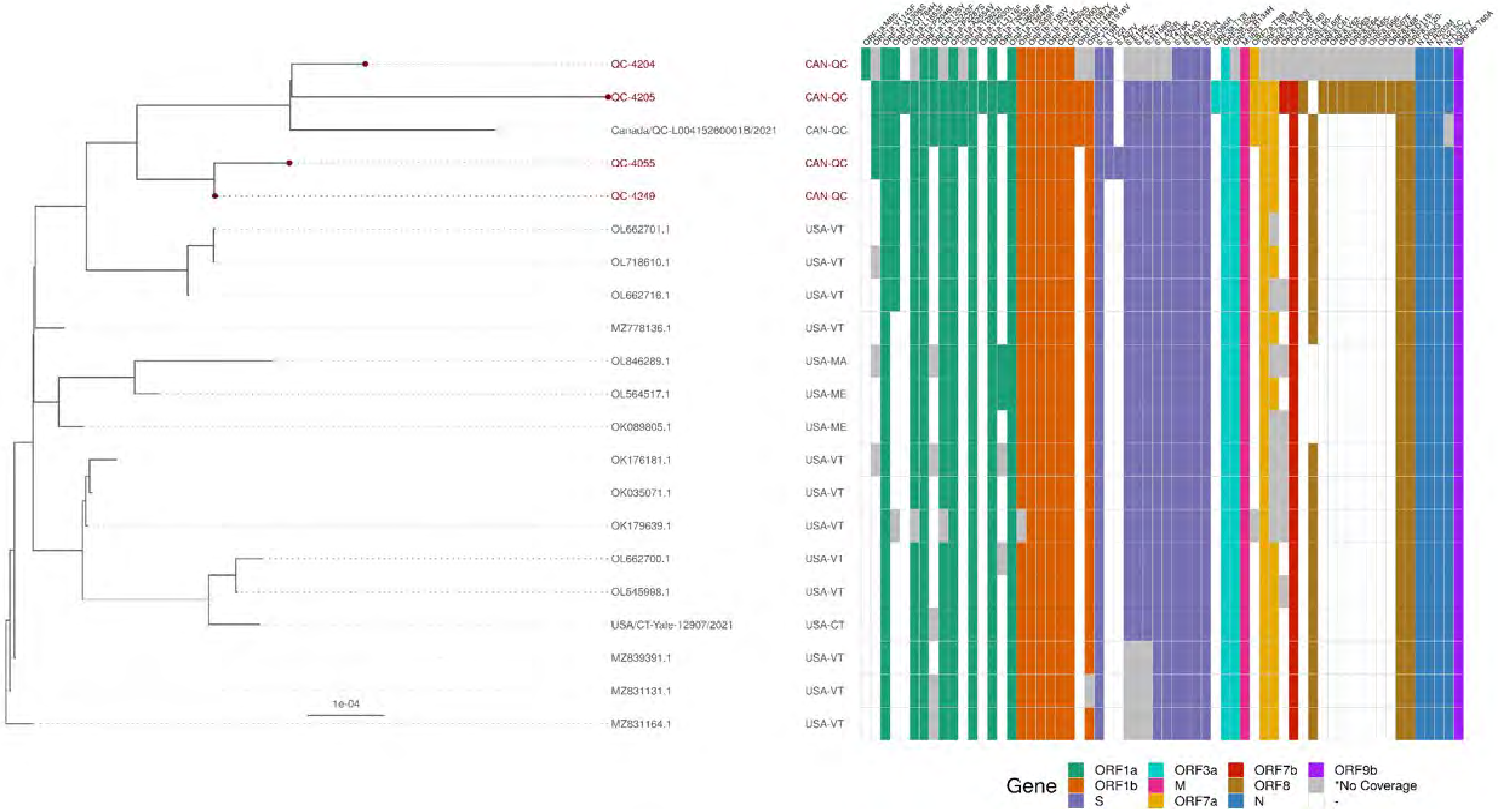
Detection of SARS-CoV-2 in deer, QC





iScience 2023 Oct 24;26(11):108319. doi: 10.1016/j.isci.2023.108319

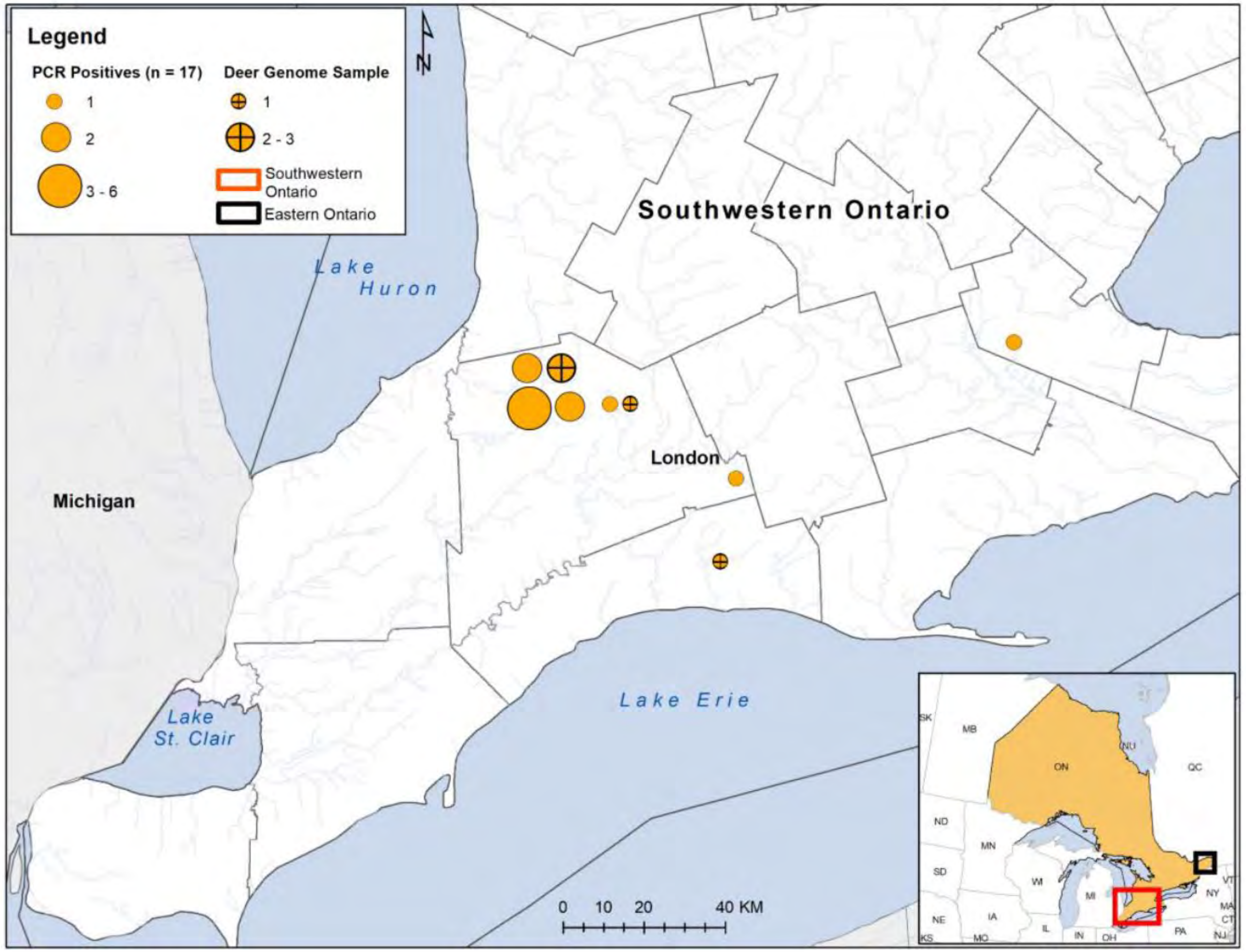
Detection of SARS-CoV-2 in deer, QC



- Delta VOC detected in QC deer from Estrie region
- Most closely related to SARS-CoV-2 from humans in Vermont

iScience 2023 Oct 24;26(11):108319. doi: 10.1016/j.isci.2023.108319

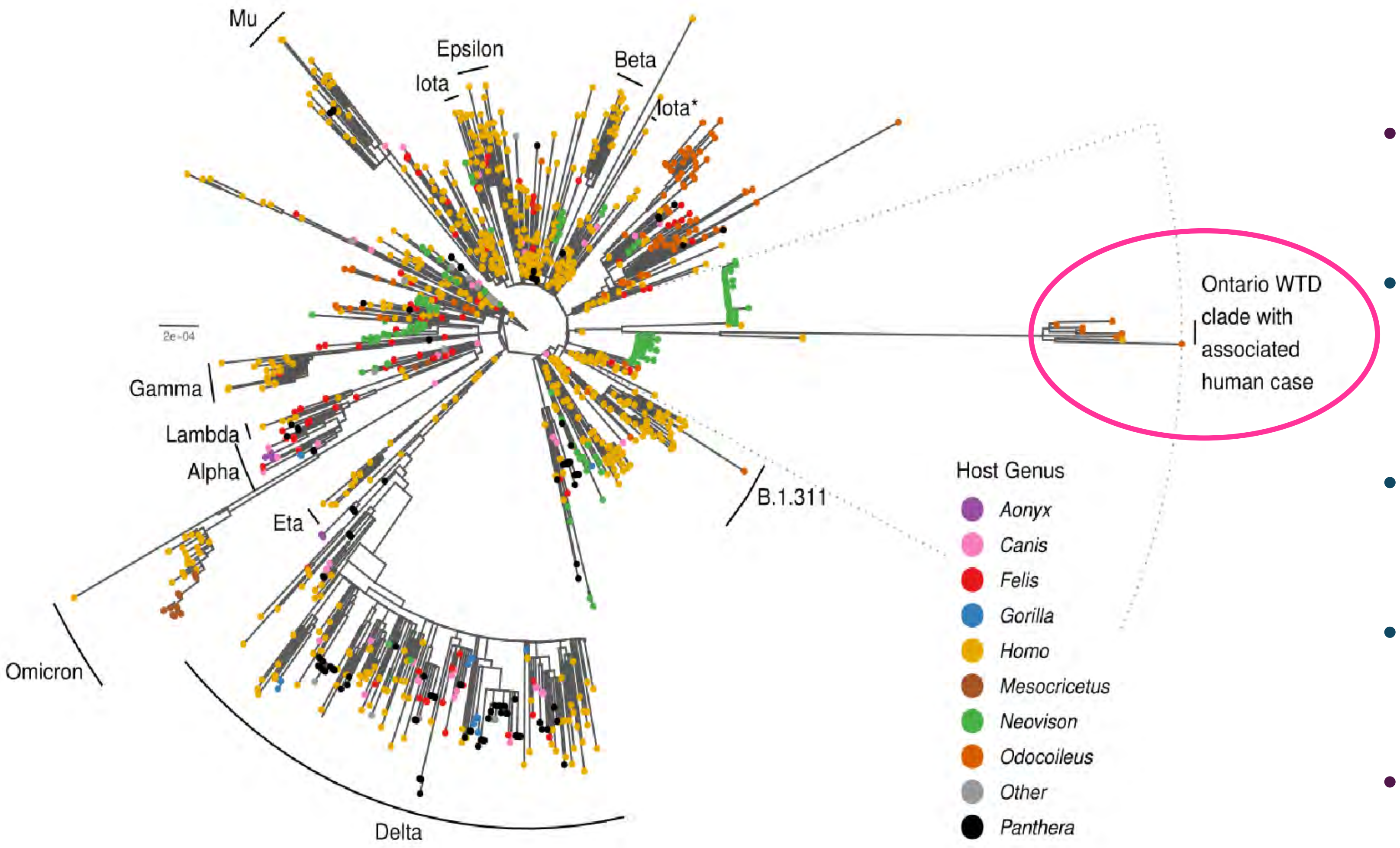
SARS-CoV-2 detected in deer, ON



- 300 hunter-harvested deer sampled Nov-Dec 2021 from Southwestern (83%) and Eastern (17%) ON
- 94% adults, 45% F
- 213 nasal swabs 294 RPLNs
- 5 nasal swabs and 16 RPLNs were confirmed positive; all RNAseP negative
- **Overall, SARS-CoV-2 RNA detected in 21 samples representing 17 animals**

Nat Microbiol. 2022 Dec;7(12):2011-2024. doi:10.1038/s41564-022-01268-9

Highly divergent deer-derived SARS-CoV-2 clusters with one human-derived virus

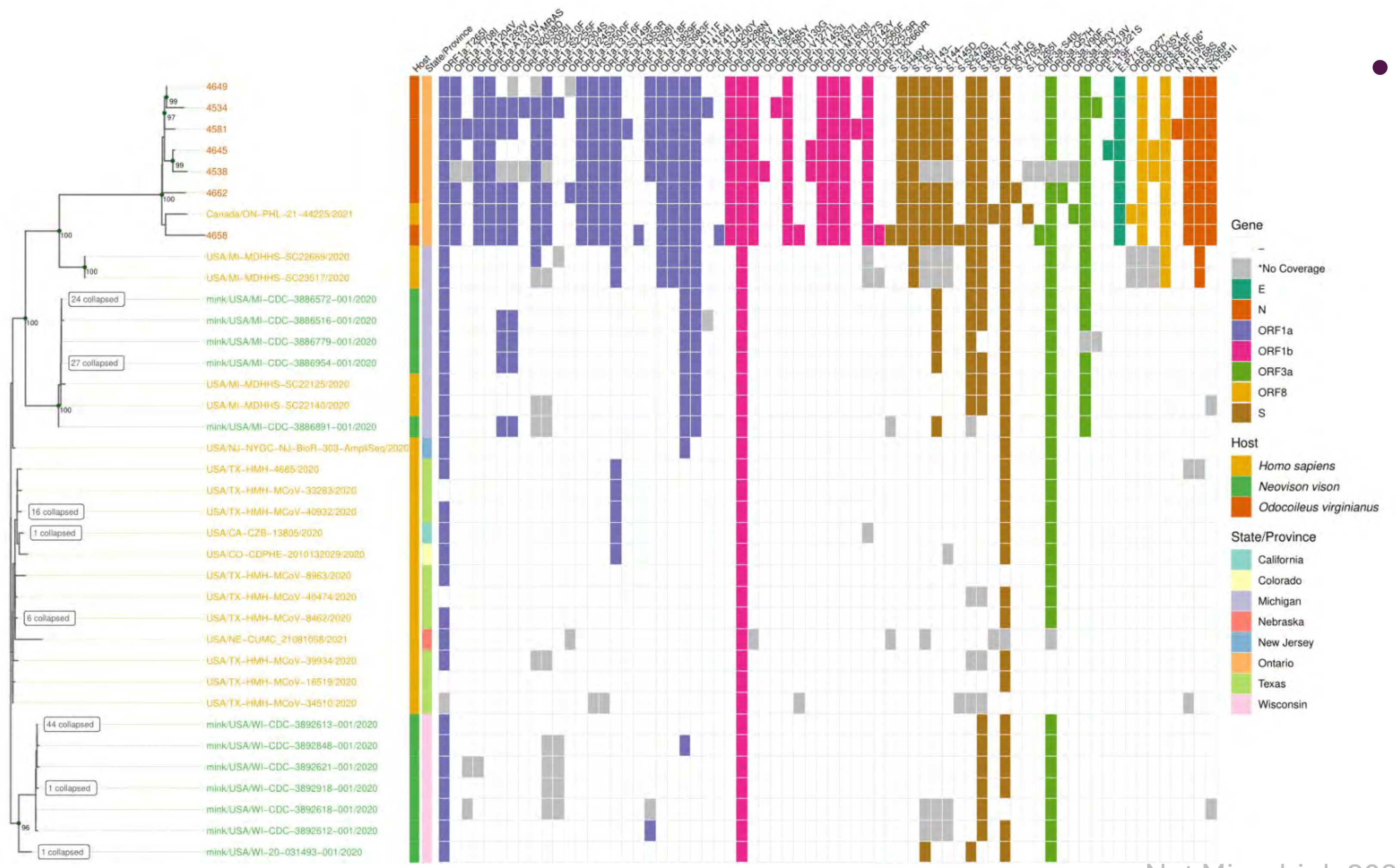


- 5 high quality deer-derived SARS-CoV-2 genomes + 1 human (GISAID)
- **highly divergent clade within the B.1 PANGO lineage**
- 76 conserved nucleotide mutations relative to ancestral and 49 relative to their closest common ancestor
- Closest relatives are a human and mink viruses from Michigan
- Genomic and epi support for monophyletic grouping
- **No evidence of forward transmission among humans**

Nat Microbiol. 2022 Dec;7(12):2011-2024. doi:10.1038/s41564-022-01268-9

Lineage assignment B1.641 & SNP analysis

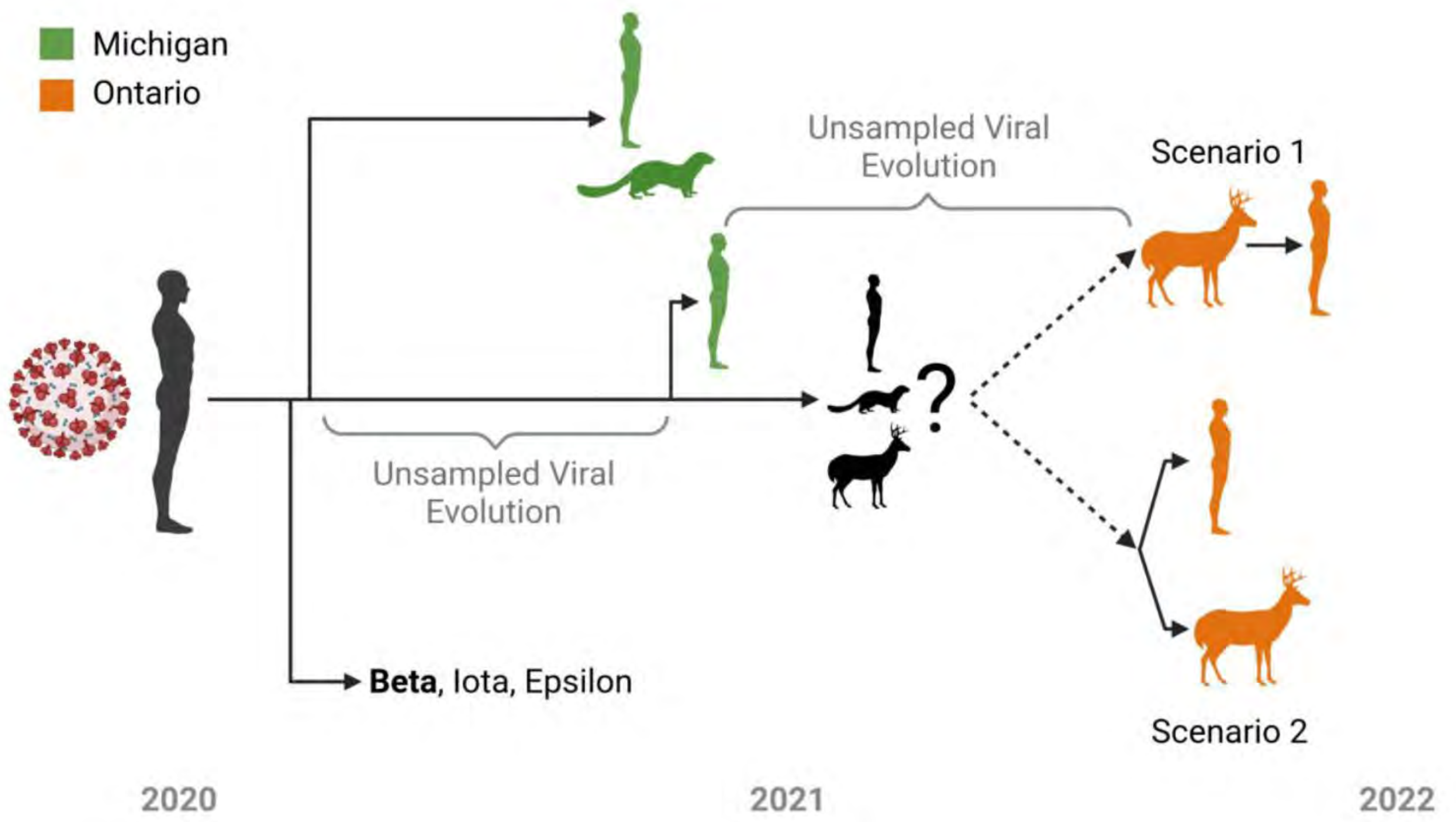
Non-structural proteins   structural proteins



- **Mutations previously found in deer:**
  - S:613H and ORF8:Q27* (human sample only)
  - S:T22I; also in Delta-like virus from deer from Québec
  - 5 conserved mutations not been previously observed in WTD and are rare (n=32, including 31 mink from Michigan, USA)

Nat Microbiol. 2022 Dec;7(12):2011-2024. doi:10.1038/s41564-022-01268-

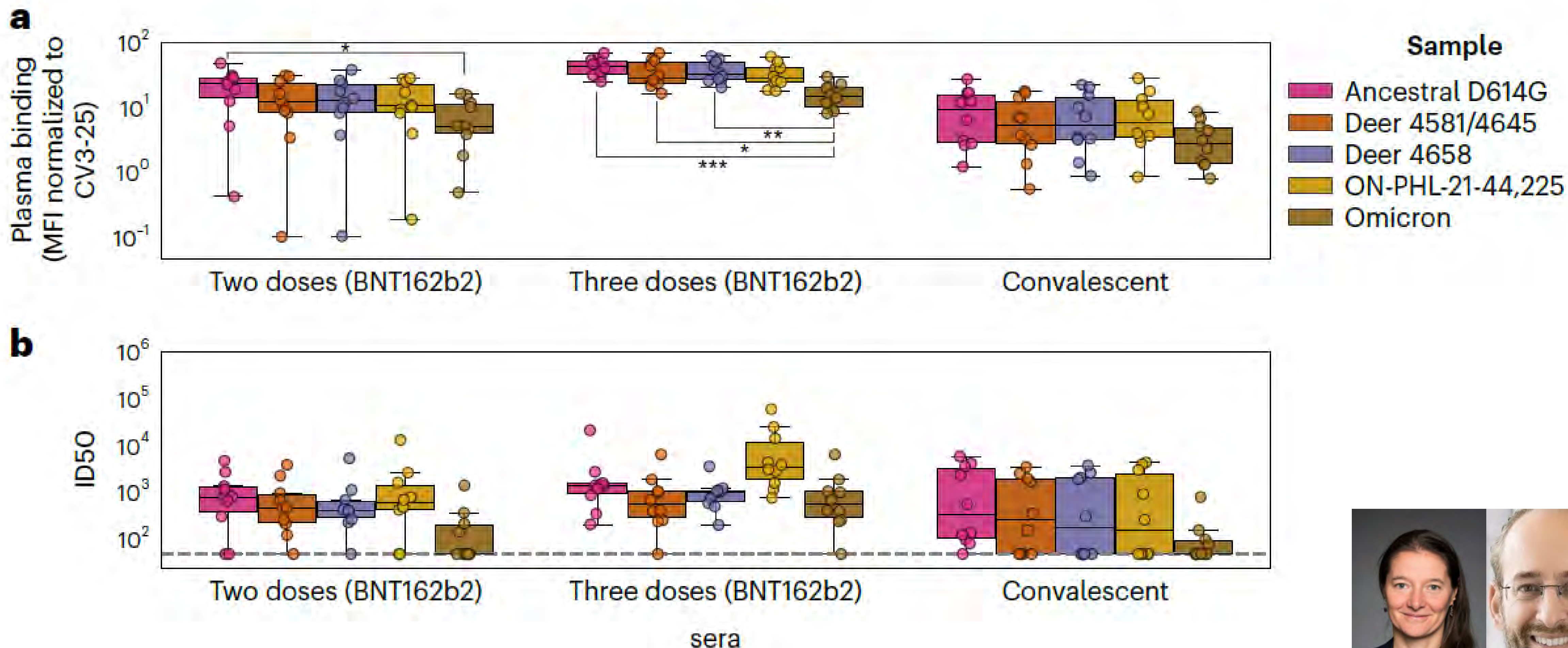
Potential transmission scenarios; substantial undersampling



- dN/dS lower for ON WTD clade- neutral selection; less immune-selective pressure, slow accumulation across the genome over a protracted period?
- No. mutations proportional to gene length: ORF1ab (54.1 expected vs 51 actual) and spike (9.7 expected vs 9 actual)

Nat Microbiol. 2022 Dec;7(12):2011-2024. doi:10.1038/s41564-022-01268-9

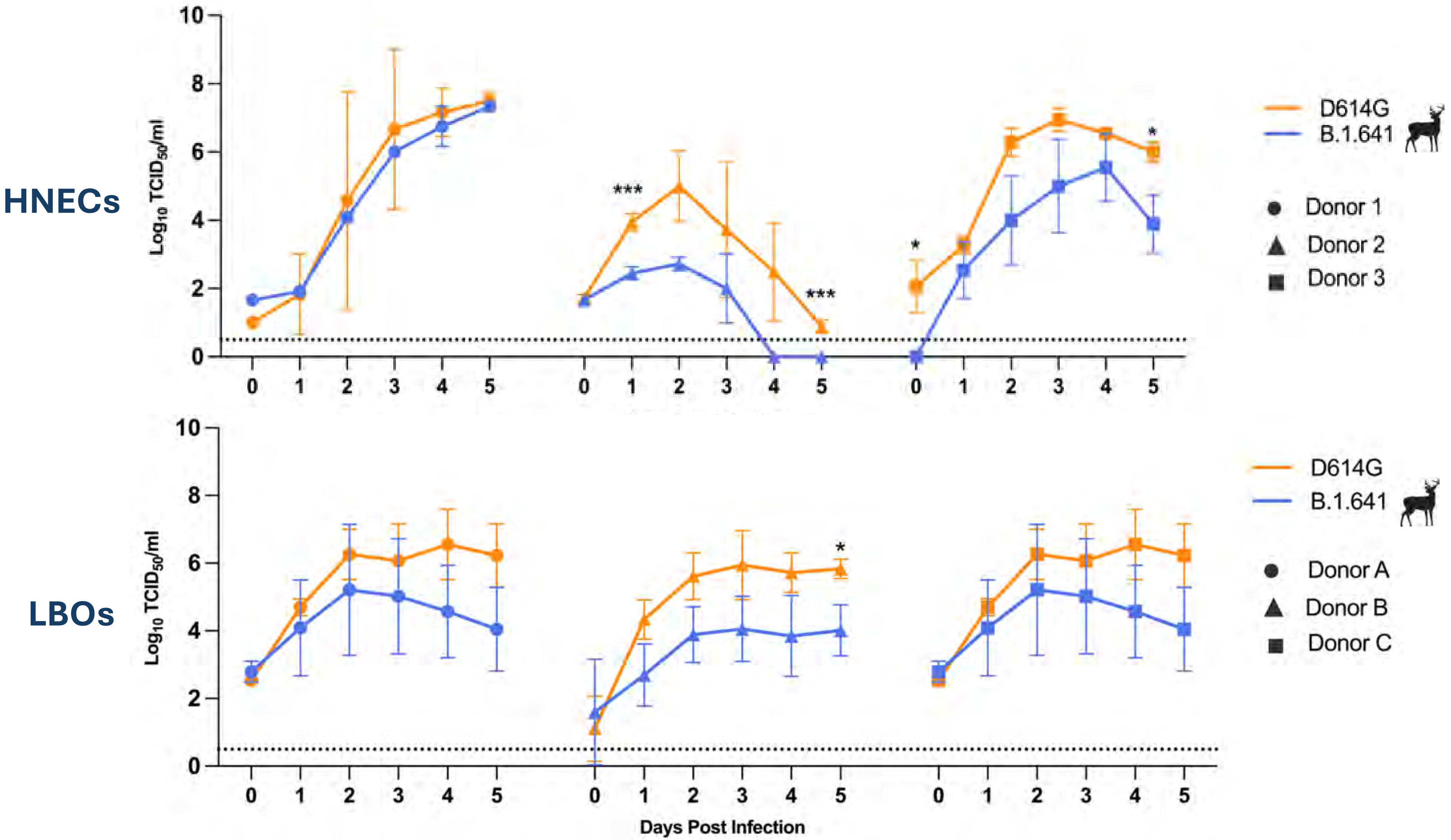
No evidence of reduced antibody neutralization



Nat Microbiol. 2022 Dec;7(12):2011-2024. doi:10.1038/s41564-022-01268-9

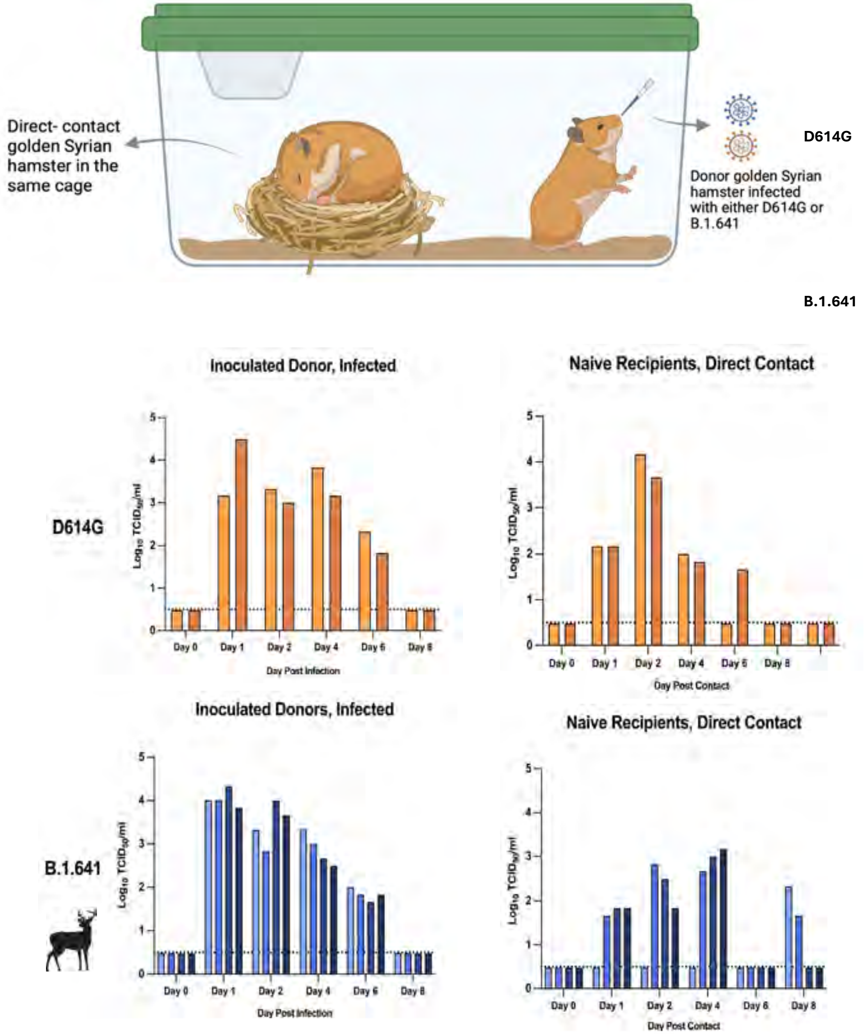
M. Coté (U Ottawa)
A. Finzi (CRCHUM)

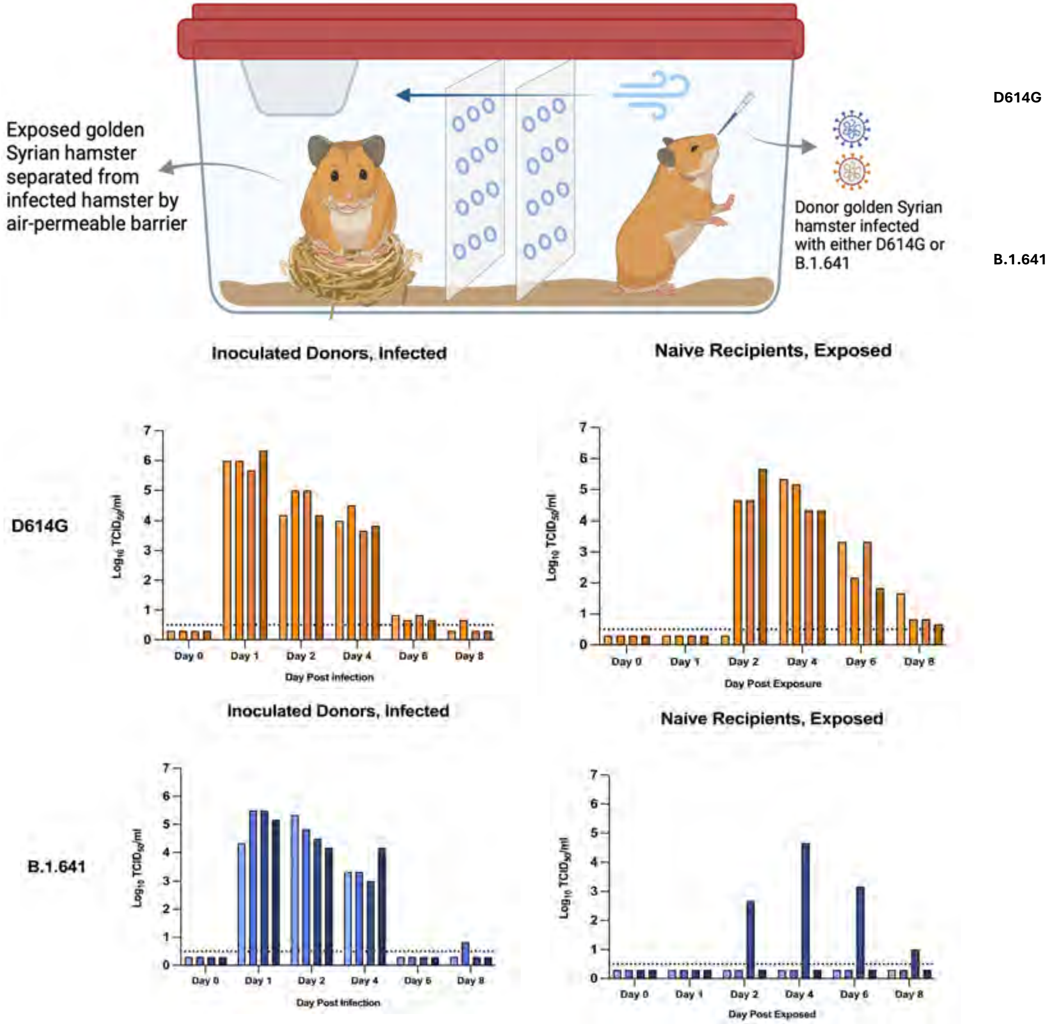
No evidence of increased viral replication in human *in vitro* systems



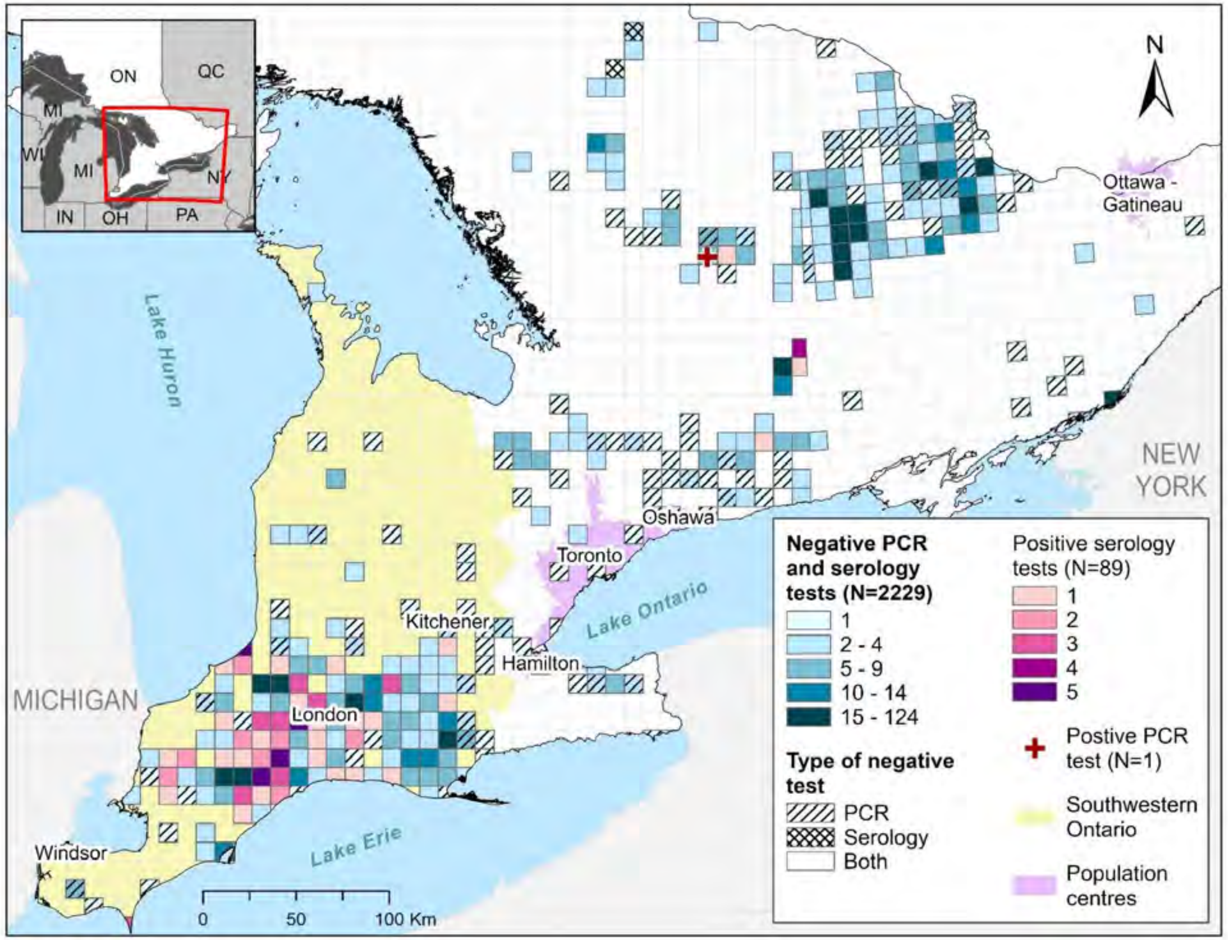
Y. Lee, J. Corredor
T. Moraes (Hosp Sick Children)
H. Zhang (Unity Health)

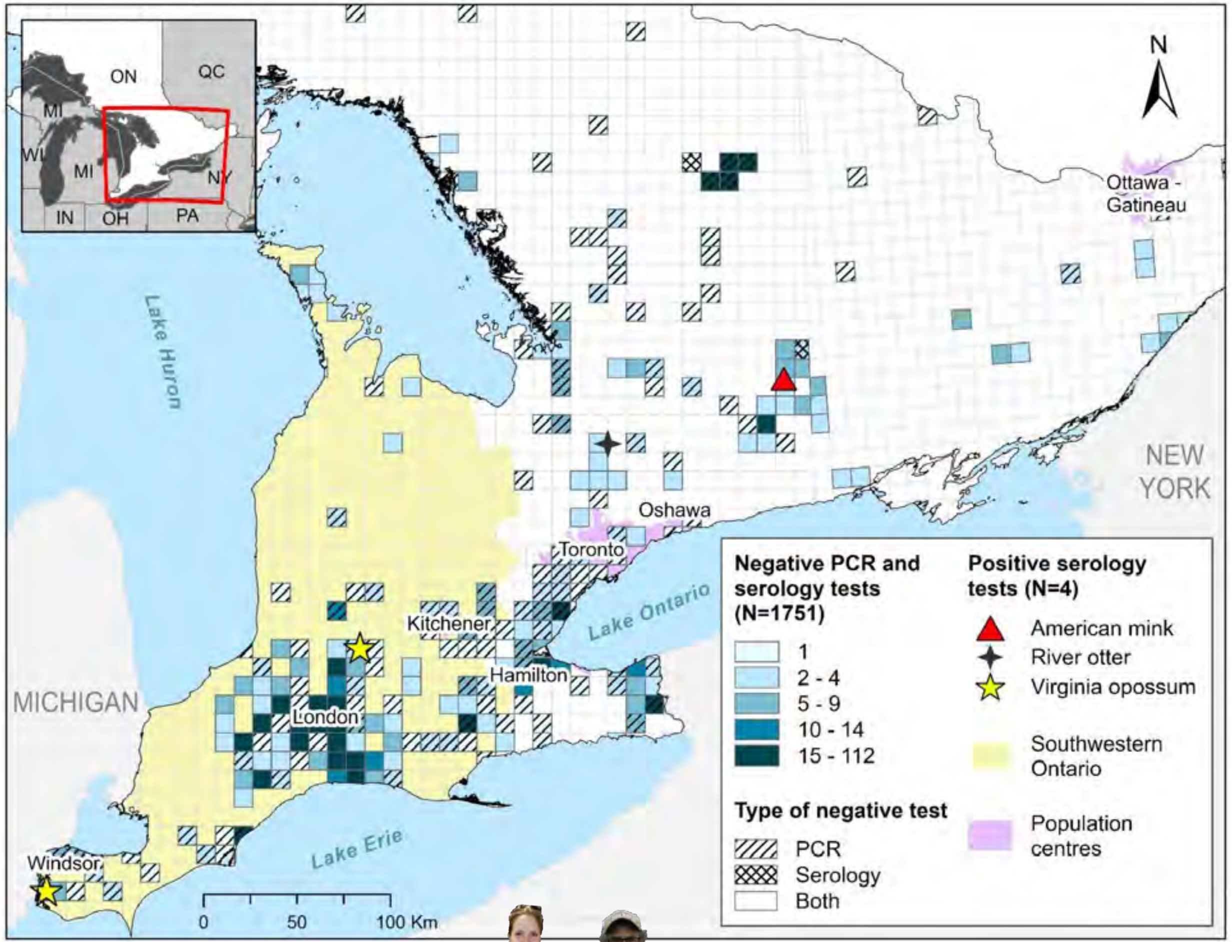
No evidence of increased transmission of deer-derived SARS-CoV-2





SARS-CoV-2 surveillance in mammals ON, 2020-24

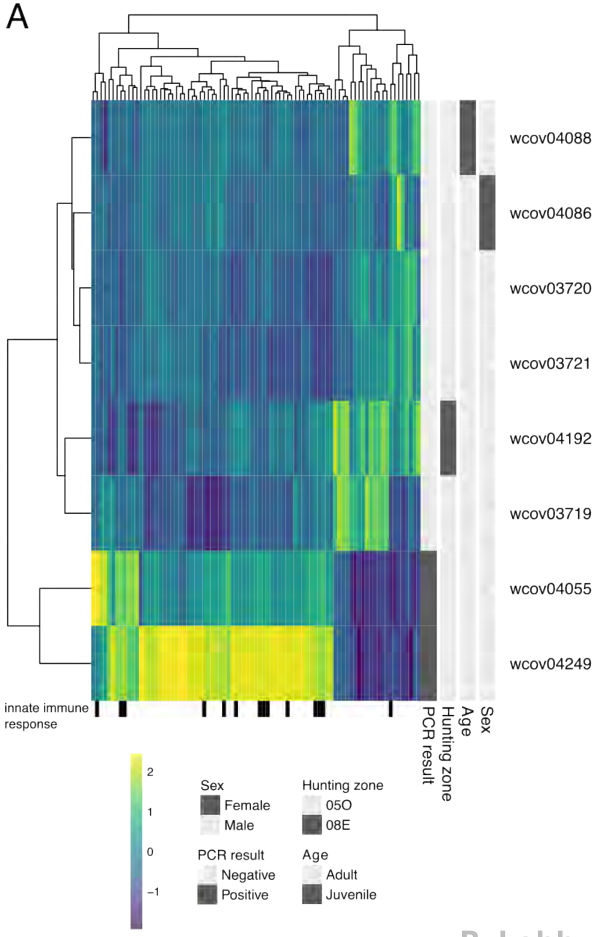


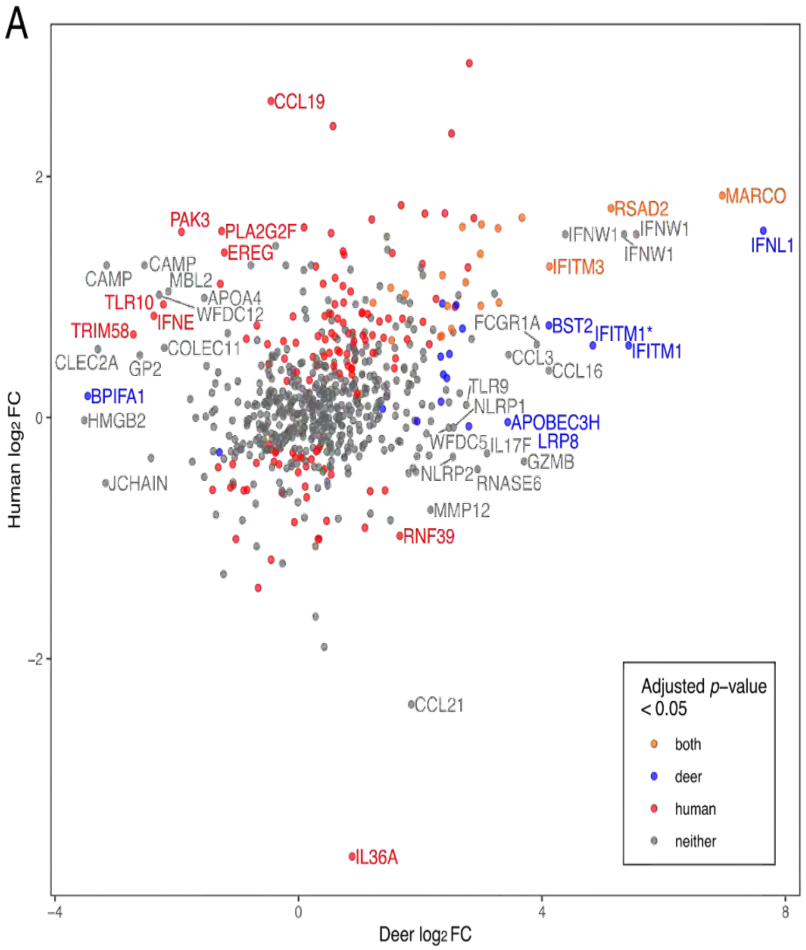


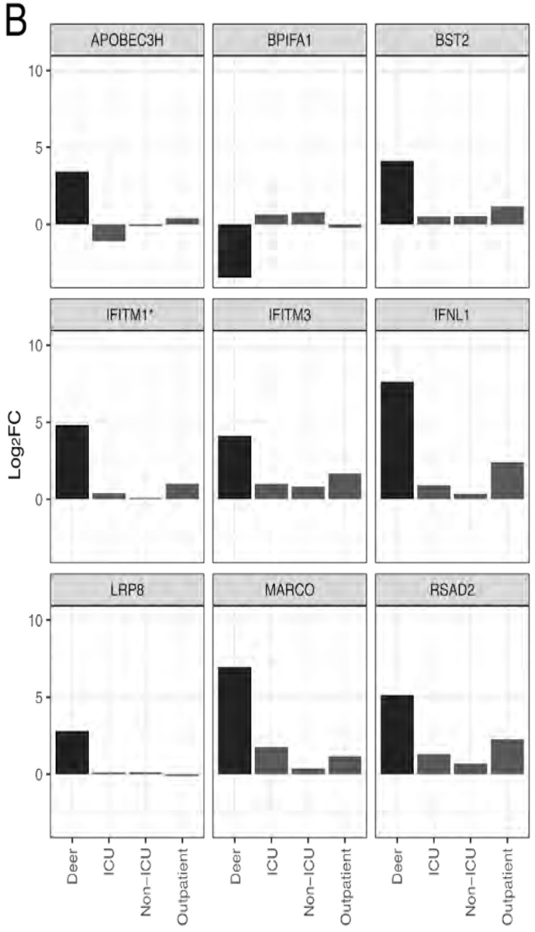
L. Crawshaw and J. Bowman, MNR

FACETS 10 April 2026 doi.org/10.1139/facets-2025-0213

What can we learn from deer host response?





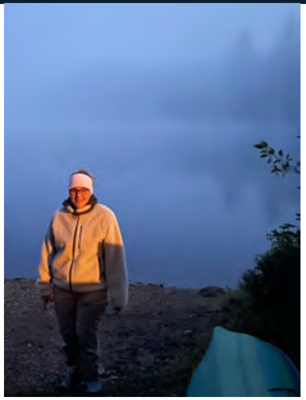


B. Lobb, A. Doxey (U Waterloo)
A. Banete, J. Kotwa (SRI)
A. Banerjee (VIDO)

Kotwa 2023, *iScience* 26 (11): 108319

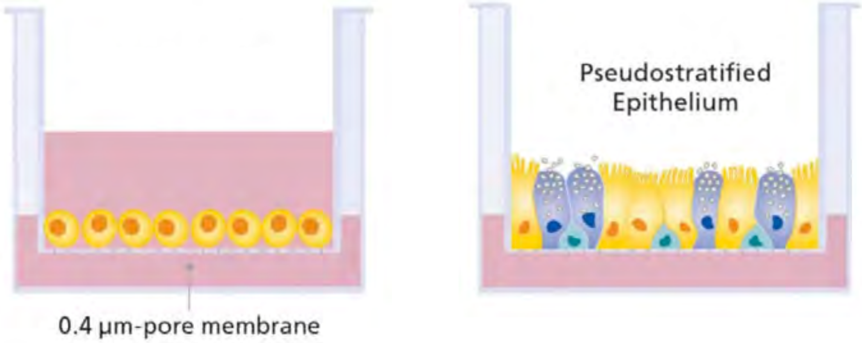
Leveraging existing wildlife health programs

Deer nasal epithelial cell (DNE) culture at ALI



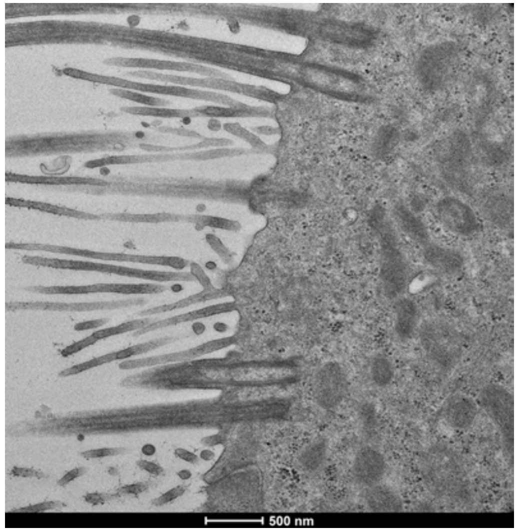
S. Aicher

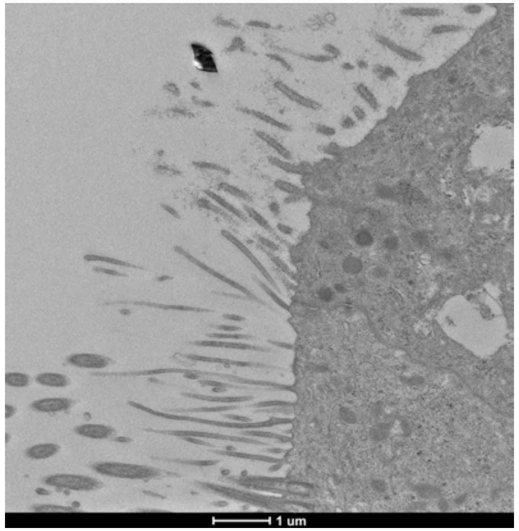
L. Crawshaw and J. Bowman, MNR



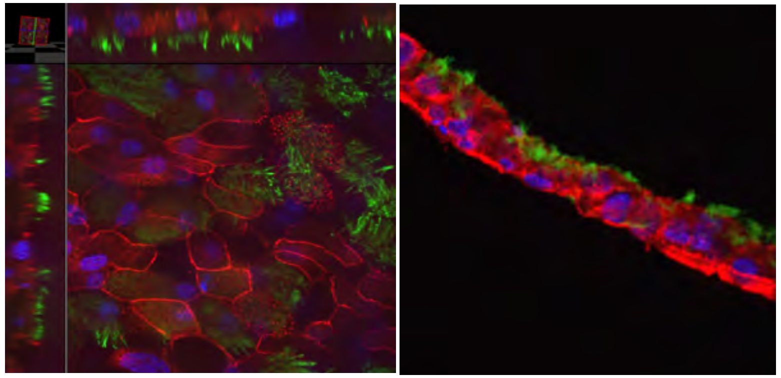
Seeding and expansion **Differentiation**

Deer **Human**



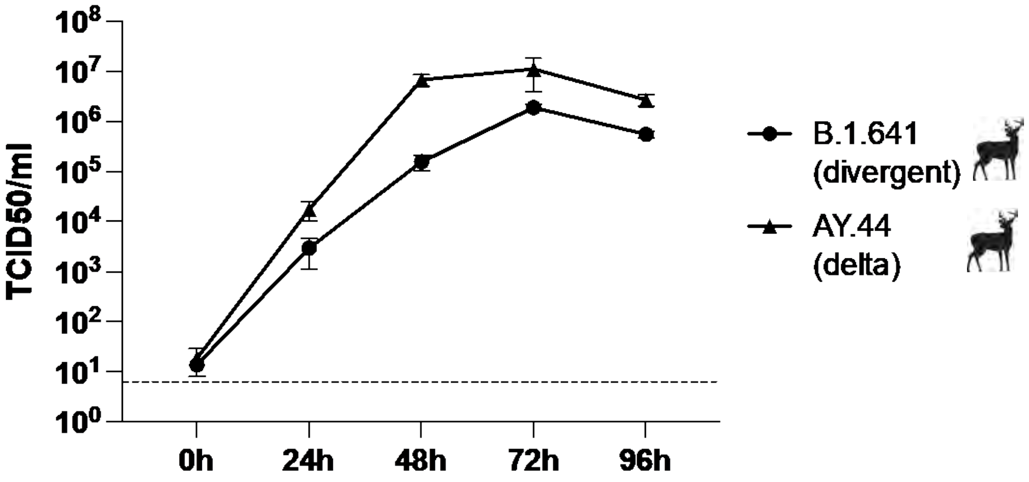


Primary deer nasal epithelia cells (DNEs)



IF Zo-1 β-tubulin Dapi

DNE infection & induction of IFN response

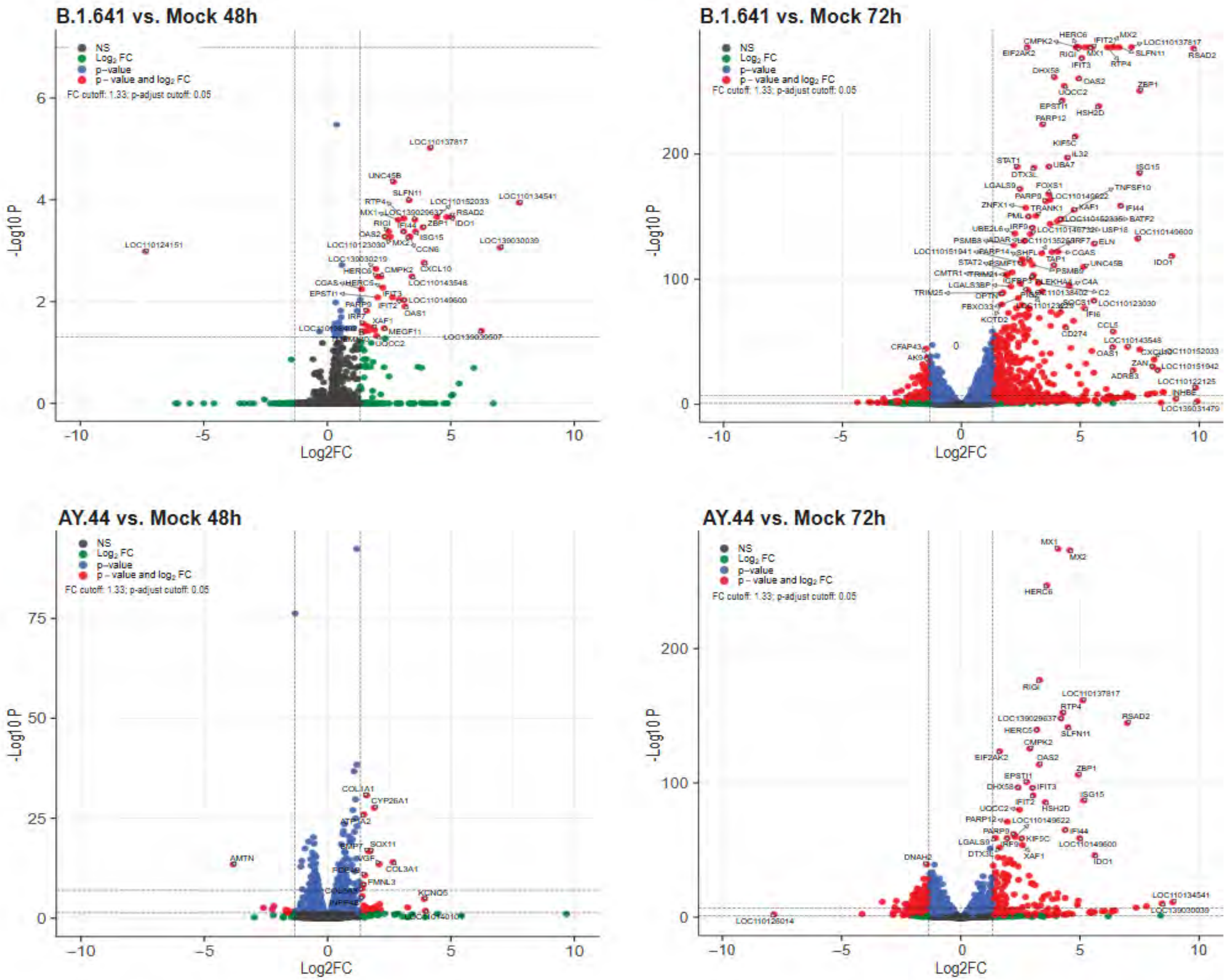


B.1.641 (divergent)

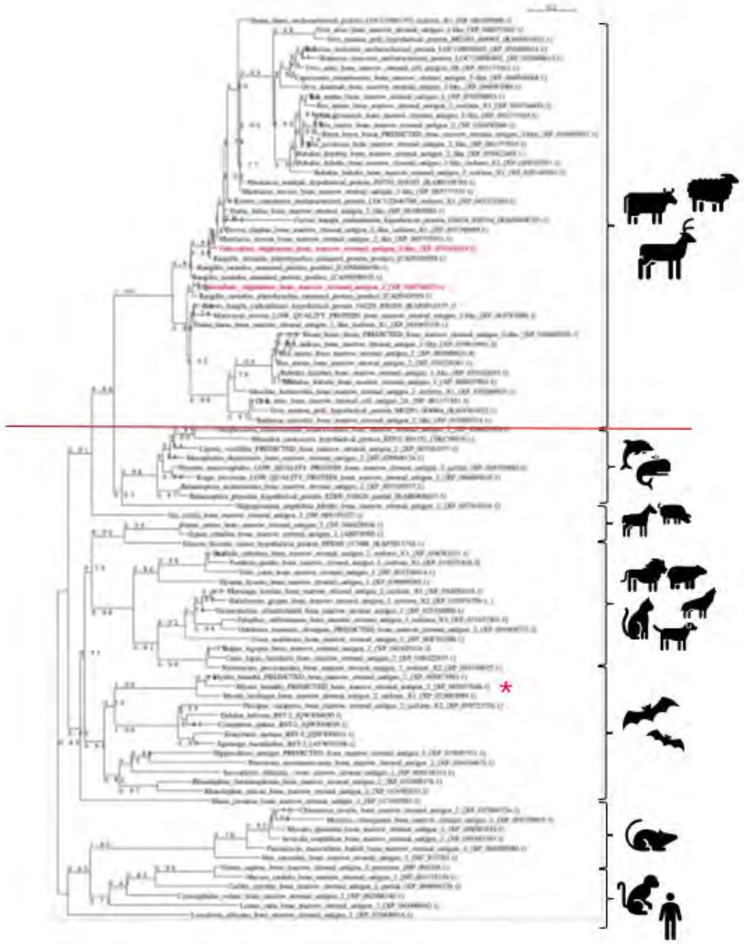
AY.44 (delta)

Arinjay Banerjee (VIDO)

DNE infection & induction of IFN response

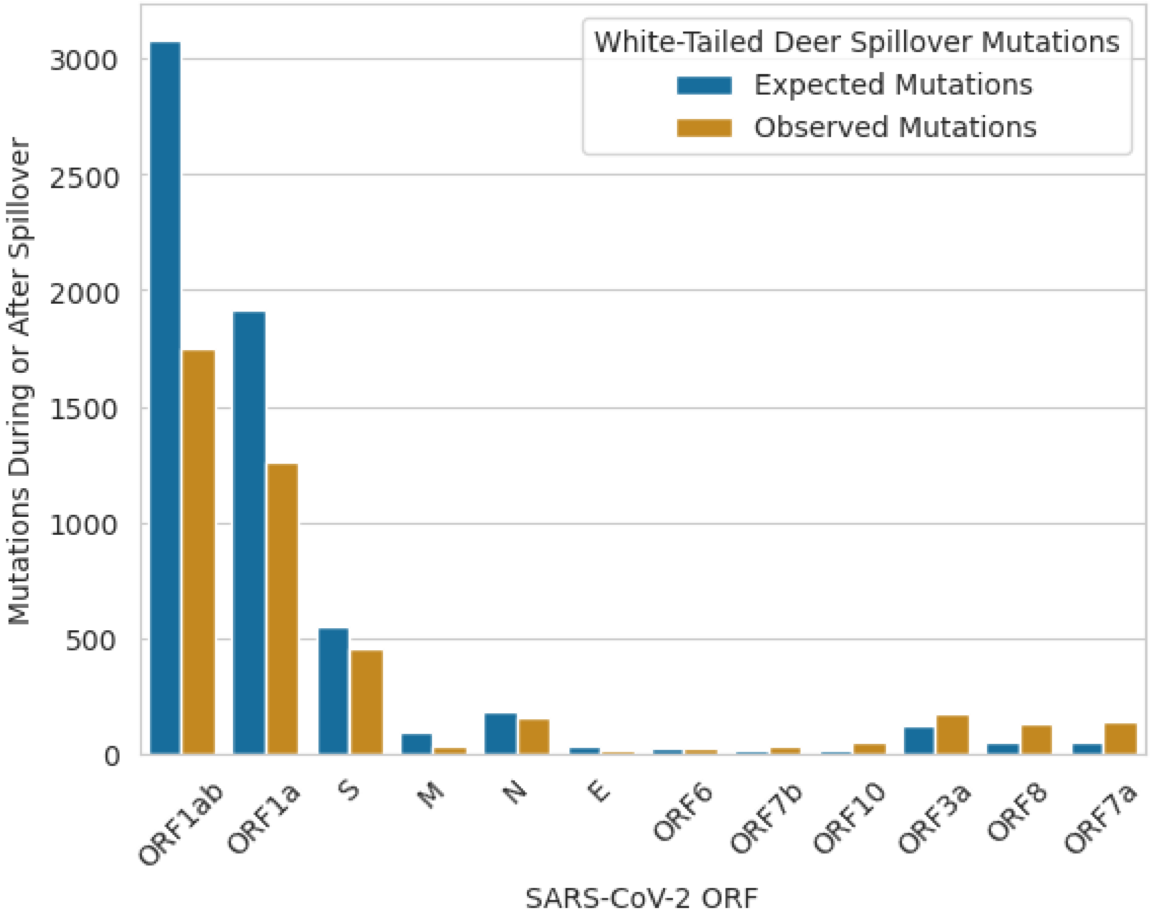


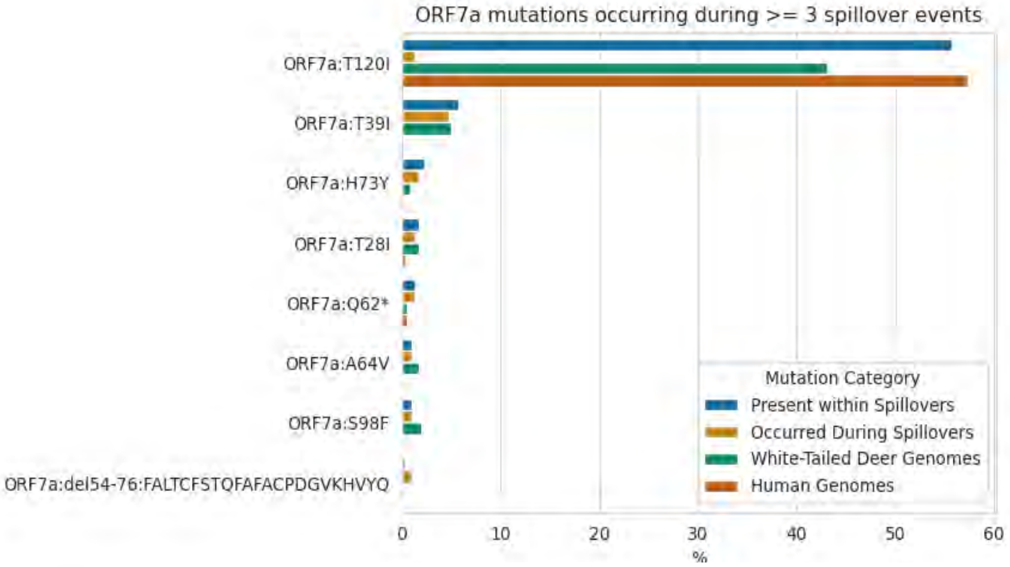
Gene duplications
BST2

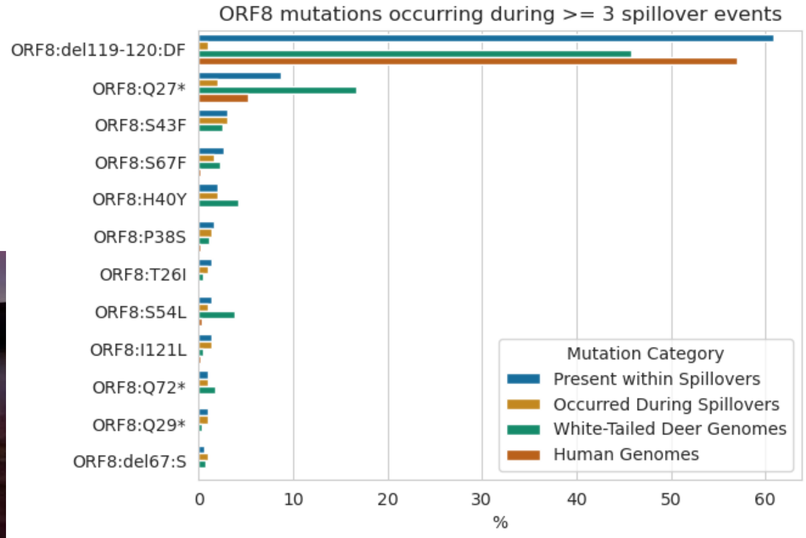


Andrew Doxy
(U Waterloo)

ORF7a and ORF8 mutations over-represented in WTD-related viral genomes







Fin Maguire (Dalhousie U)

Quick take

- SARS-CoV-2 circulated among white-tailed deer, diverging from an ancestral lineage; no evidence to support potential as VOC
- White tailed deer may be immunotolerant
- Questions remain around host response and viral evolution; importance of understanding potential for secondary wildlife reservoirs
- Transdisciplinary research is essential for rapid research response and preparedness
- A well-trained, competent workforce, key relationships, and infrastructure must all be maintained to effectively respond to health threats

Outline

1. The big picture

2. Lessons from the past pandemic

3. Preparing for the future

Action track 2: Reducing the risks from emerging and re-emerging zoonotic epidemics and pandemics

2.1.1 Research and risk assessments on the drivers, processes and pathways for zoonotic diseases; characterize intact resilient eco- and health systems and their effect on disease prevention

2.1.3 Identify drivers and indicators to monitor their impacts on zoonotic diseases including those that can lead to increased interfaces or disruptions of natural host-pathogen dynamics

2.1.4 Develop a One Health indicator framework to monitor the health of humans, wildlife, domestic animals, vectors and the environment, including in intact, resilient eco- and health systems

2.2.2 Incorporate land-use planning in health and biodiversity risks assessment, and vice versa

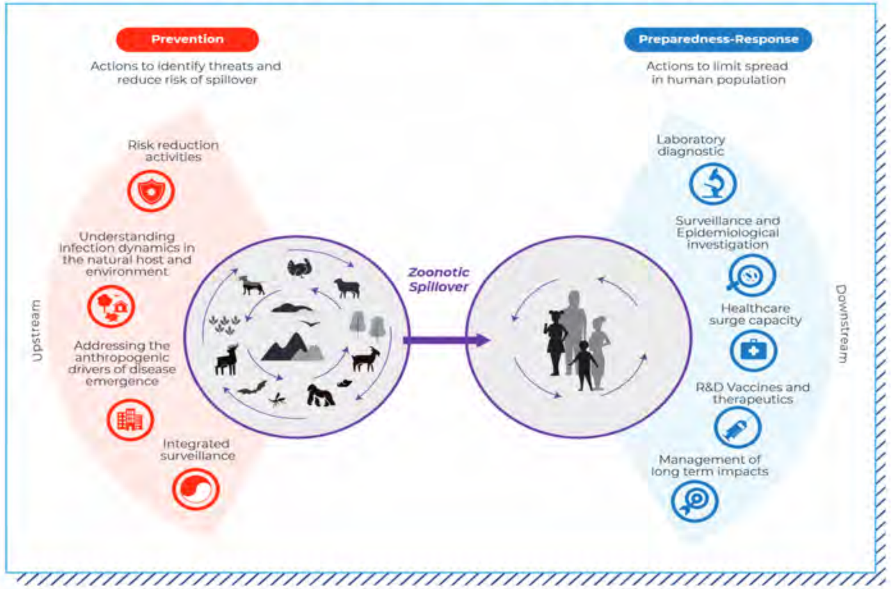
2.2.3 Establish standards for the management of ecosystem processes to support resilience, including mainstreaming habitat degradation prevention and biodiversity protection

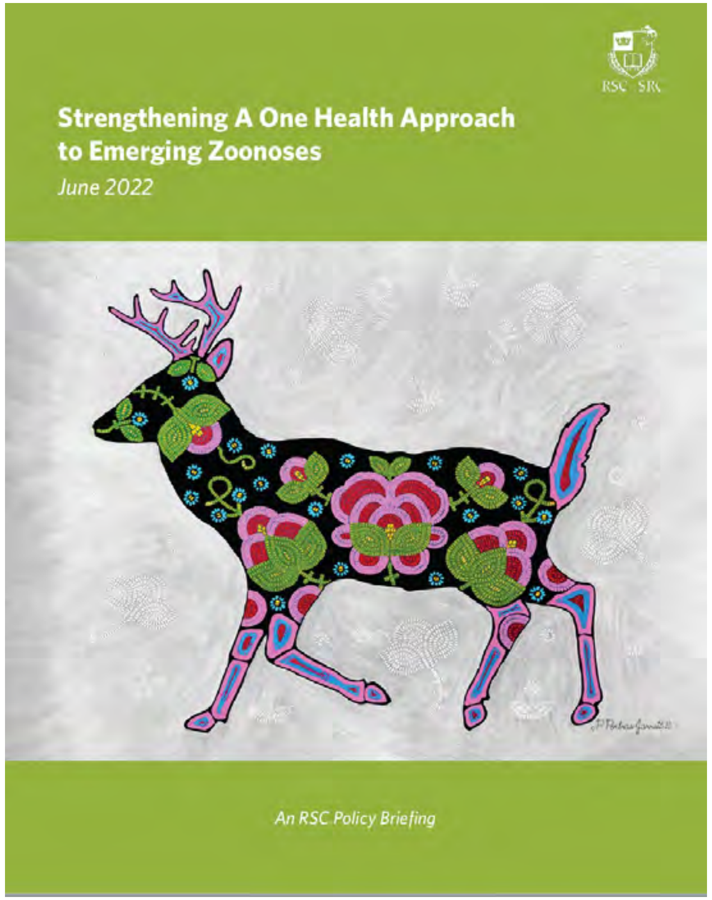
2.2.4 Engage with local communities, including Indigenous Peoples, to identify sustainable solutions, nature-based where applicable, to increase community preparedness and resilience

Action 2.1. Understand the drivers of emergence, spillover and spread of zoonotic pathogens

Action 2.2. Identify and prioritize interventions to prevent zoonotic emergence, spillover and spread

FIGURE 1. PREVENTION OF ZOONOTIC SPILLOVER TO HUMANS

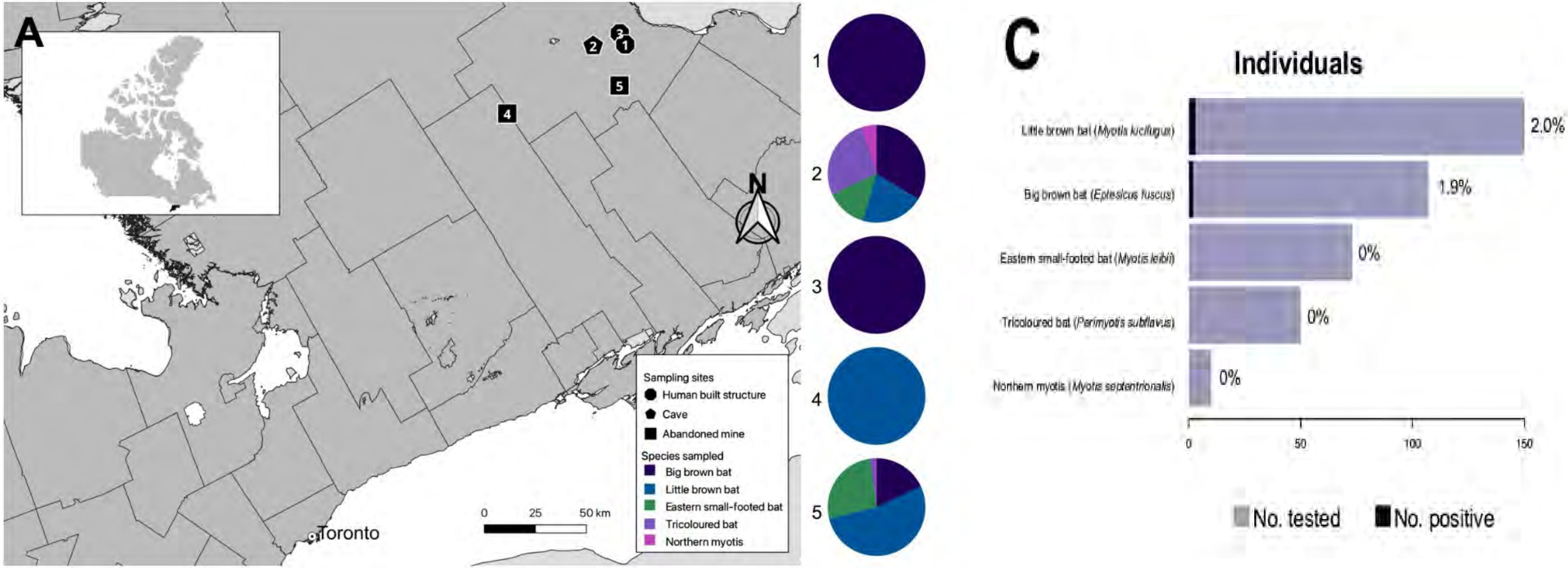




who.int/groups/one-health-high-level-expert-panel
unep.org/bitstream/handle/20.500.11822/40843/one_health.pdf?sequence=1&isAllowed=y
FACETS 12 January 2023 doi.org/10.1139/facets-2021-0190

Paul Colley

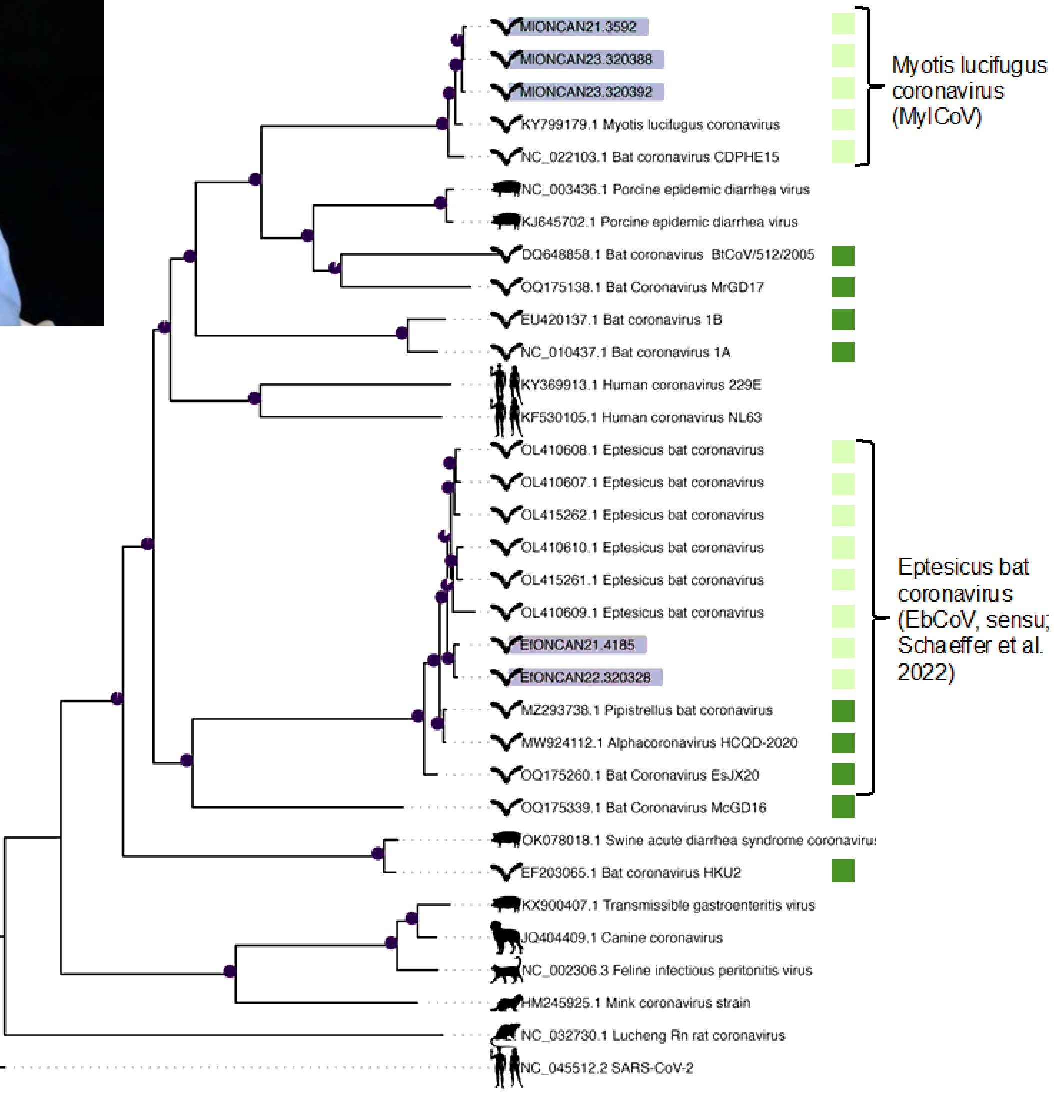
Endemic bat alphaCoVs in eastern ON



J. Kotwa (Sunnybrook)
C. Davy (Carlton)

npj Viruses volume 3, Article number: 38 (2025)

Eptesicus fuscus and *Myotis lucifugus*-derived alphaCoVs



98% identify between *M. lucifugus*-derived alphaCoVs identified in Ontario

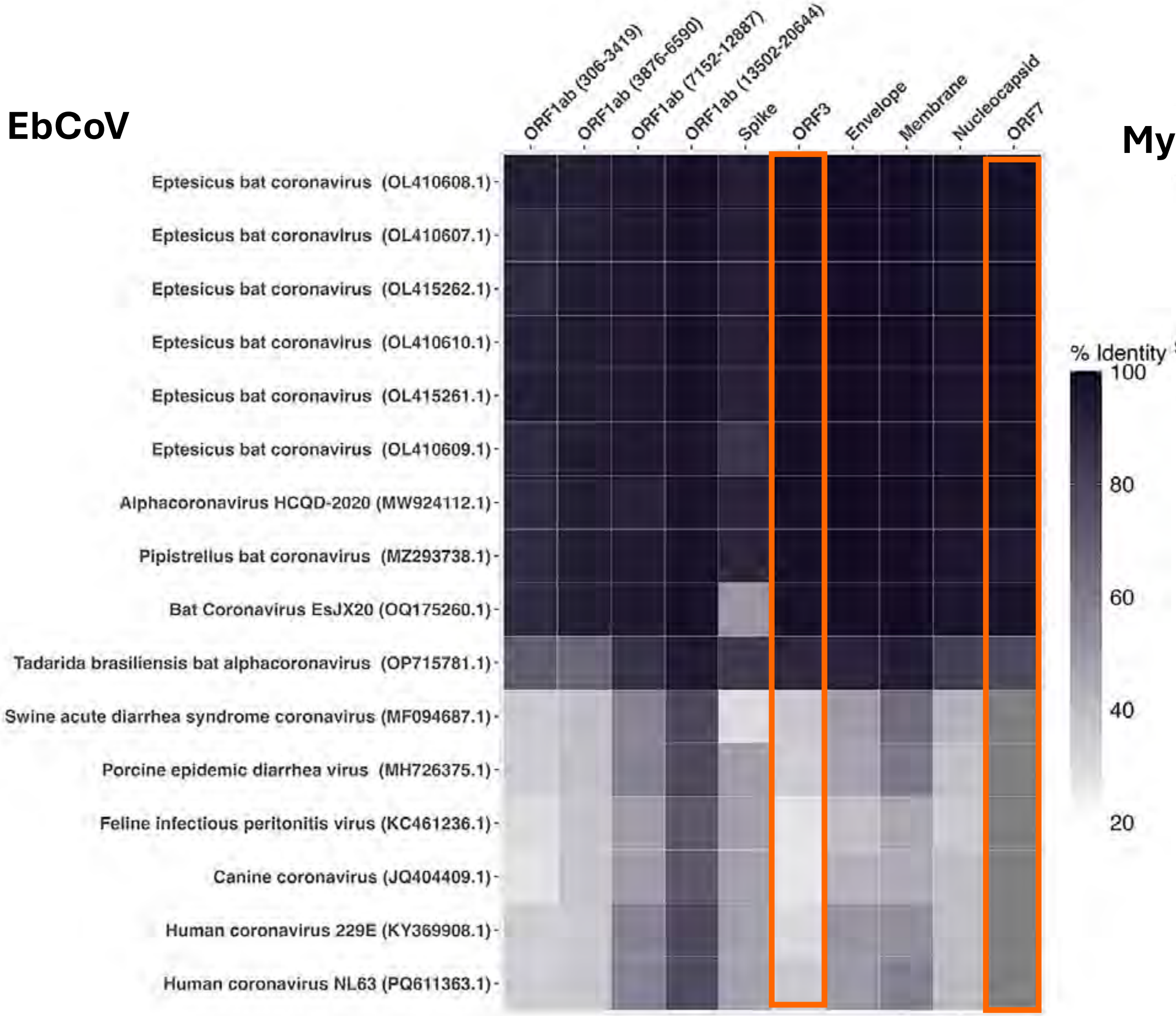
S 94% identical to MylCoV from Manitoba & 74% identical to MylCoV from Colorado

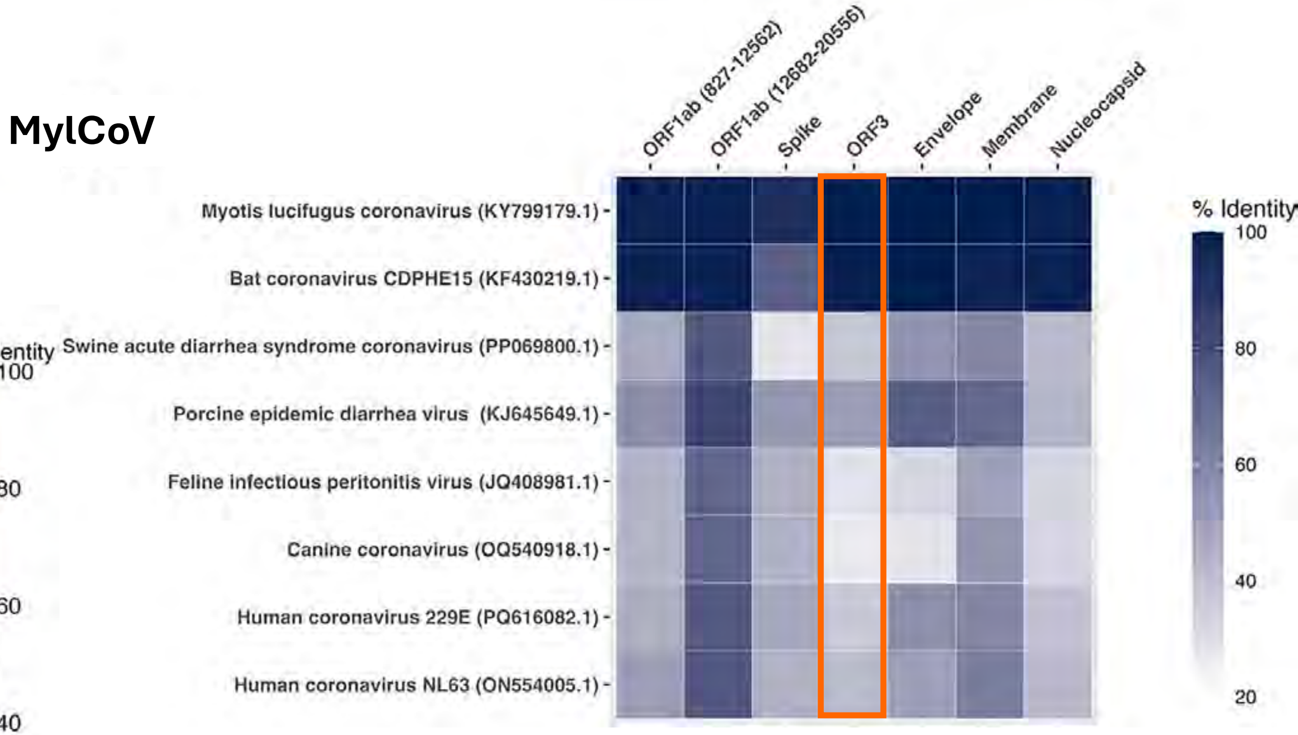
98% identify between *E. fuscus*-derived alphaCoVs identified in Ontario

J. Kotwa
F. Maguire (Dalhousie U)

npj Viruses volume 3, Article number: 38 (2025)

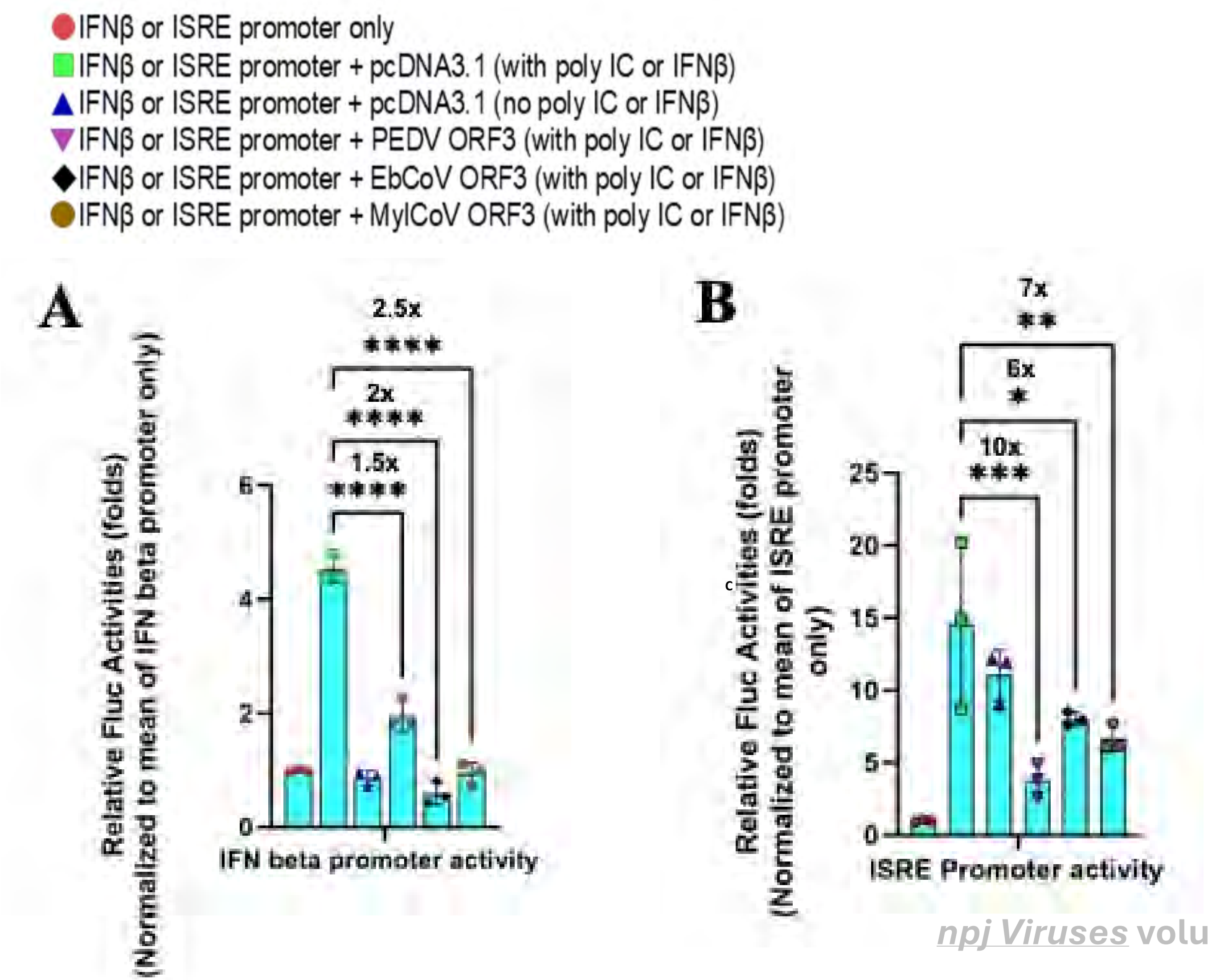
Pairwise amino acid comparisons of EbCoV and MylCoV

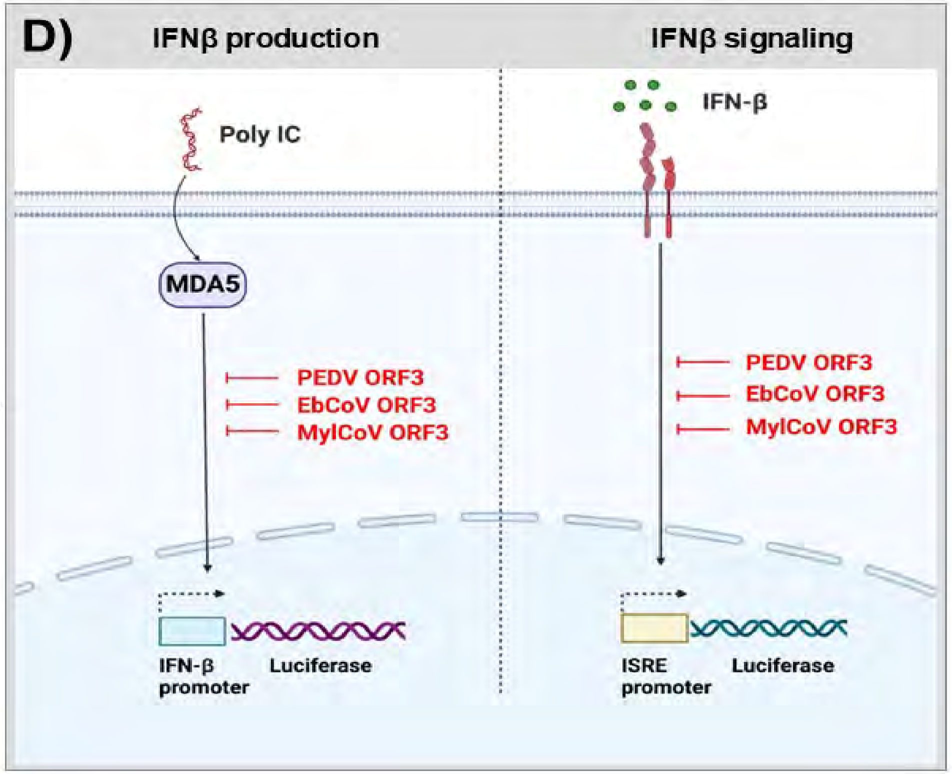




npj Viruses volume 3, Article number: 38 (2025)

EbCoV and MylCoV ORF3 inhibits type 1 IFN responses





Arkadeb Bhuinya (VIDO)
Arinjay Banerjee (VIDO)

npj Viruses volume 3, Article number: 38 (2025)

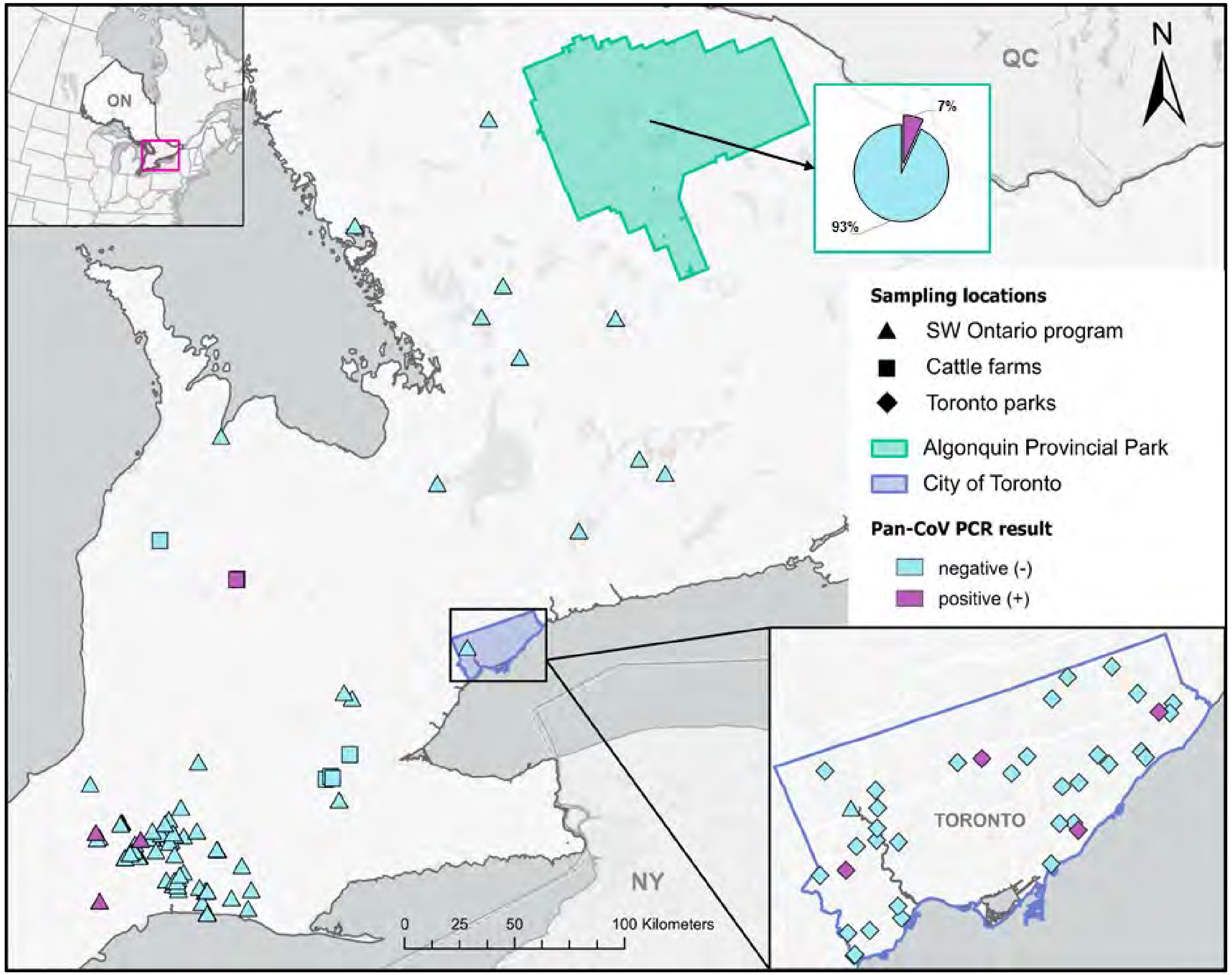
Quick take

- Bat CoVs are endemic in Ontario and host species-specific
- Possess accessory proteins with potential for IFN antagonism

Chien Lee


Ontario
Wildlife
Research
Area
This area closed to fishing, hunting,
camping and public travel.

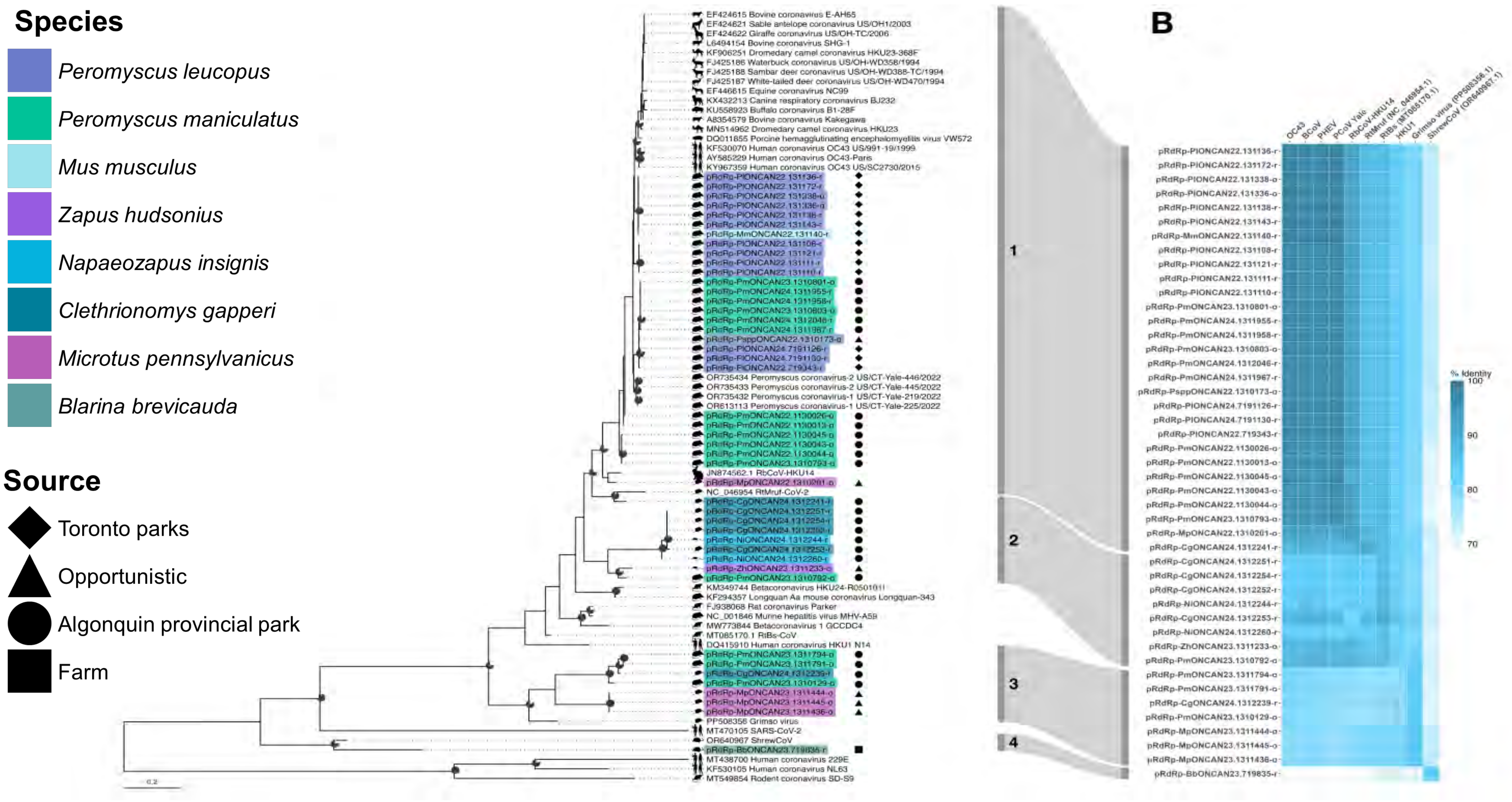
Endemic betaCoVs detected in *Peromyscus* & other small mammals in Ontario



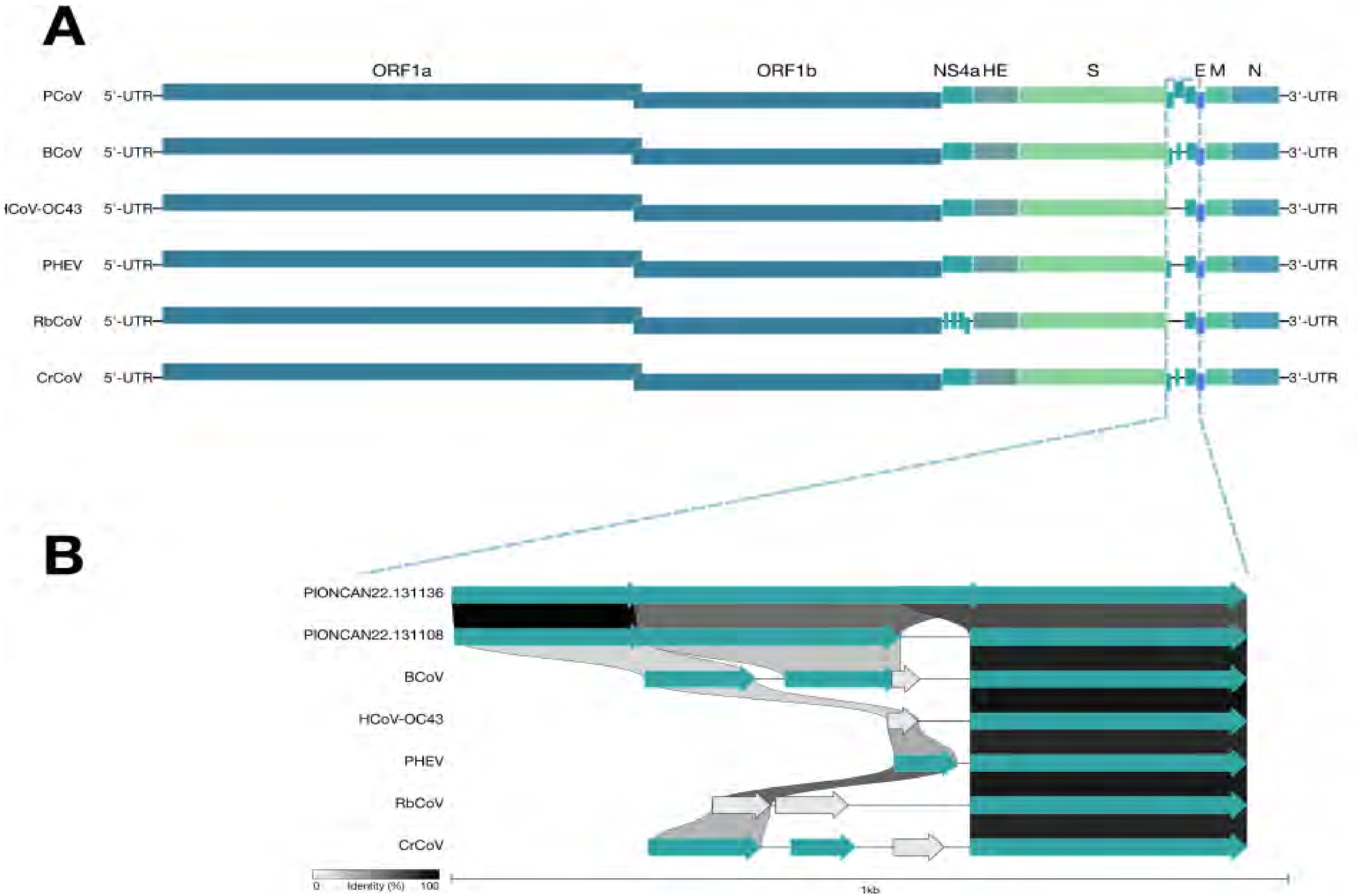
- N=980
- 3.4% *P. leucopus* +
- 4.9% *P. maniculatus* +
- 45 partial RdRp sequences
- 14 WGS, 69-100% completeness

J. Kotwa
C. Jardine (U Guelph)
S. Jeeves (U Guelph)
J. Bowman (MNR)

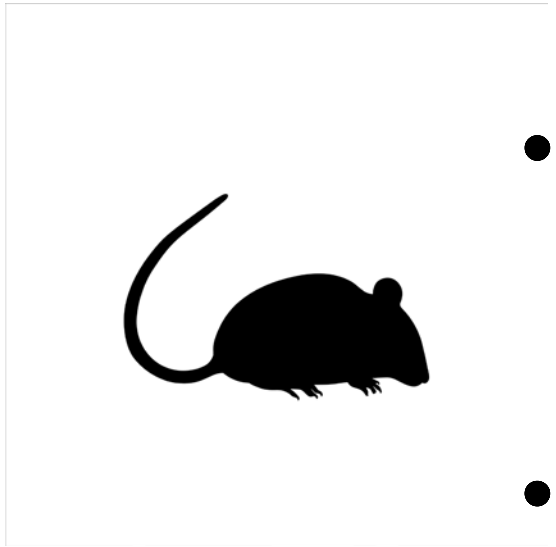
Four clusters of small mammal-derived betaCoVs in Ontario (partial RdRp)



PCoV genome organization



Quick take

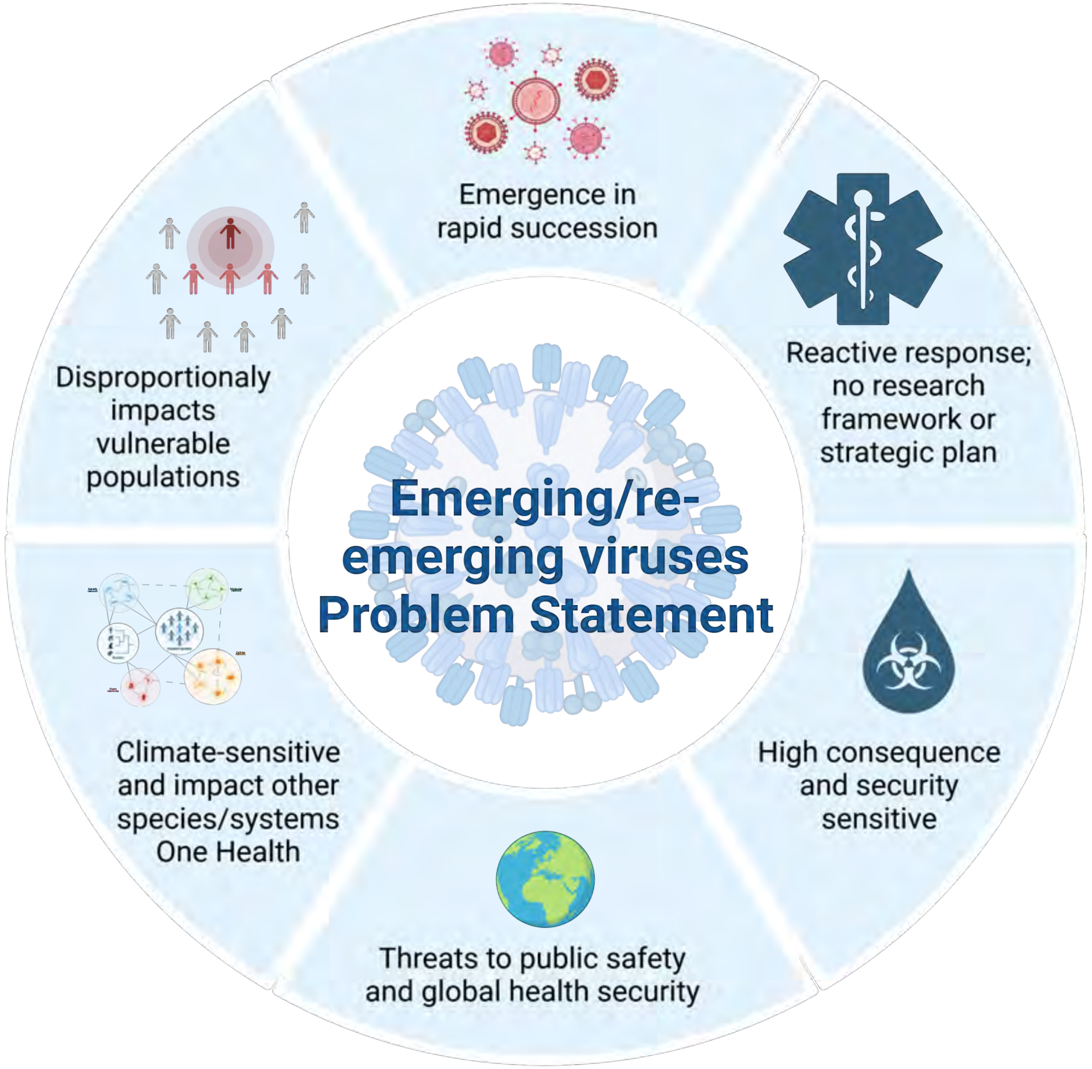


- *Peromyscus* and other small mammal CoVs are endemic in Ontario
- Possess distinct accessory proteins

The key message of this report is that ***Canada needs to take further action now if it is to be adequately prepared for future health emergencies.*** *Now is the time to build on the unprecedented collaboration and actions taken during the COVID-19 pandemic and to act on the important lessons learned from this crisis and previous outbreaks of infectious diseases.*

This requires better monitoring, understanding, and communication *of the most important infectious diseases and other public health risks that face the country.*

Why Canada needs a strategic plan for emerging and resurging viruses



1. Domestic and international outbreak and pandemic preparedness and response
2. Risk registration
3. Critical infrastructure
4. Responding to intersecting polycrises
5. Scientific excellence and global leadership
6. Subject matter expertise, knowledge transfer and mobilization
7. Productive and competitive research collaborations
8. Participatory research

Why Canada needs a strategic plan for emerging and resurging viruses

- Protection of health security & public safety

- Scientific collaboration, discovery and advancement of innovative solutions

- Workforce recruitment and retention

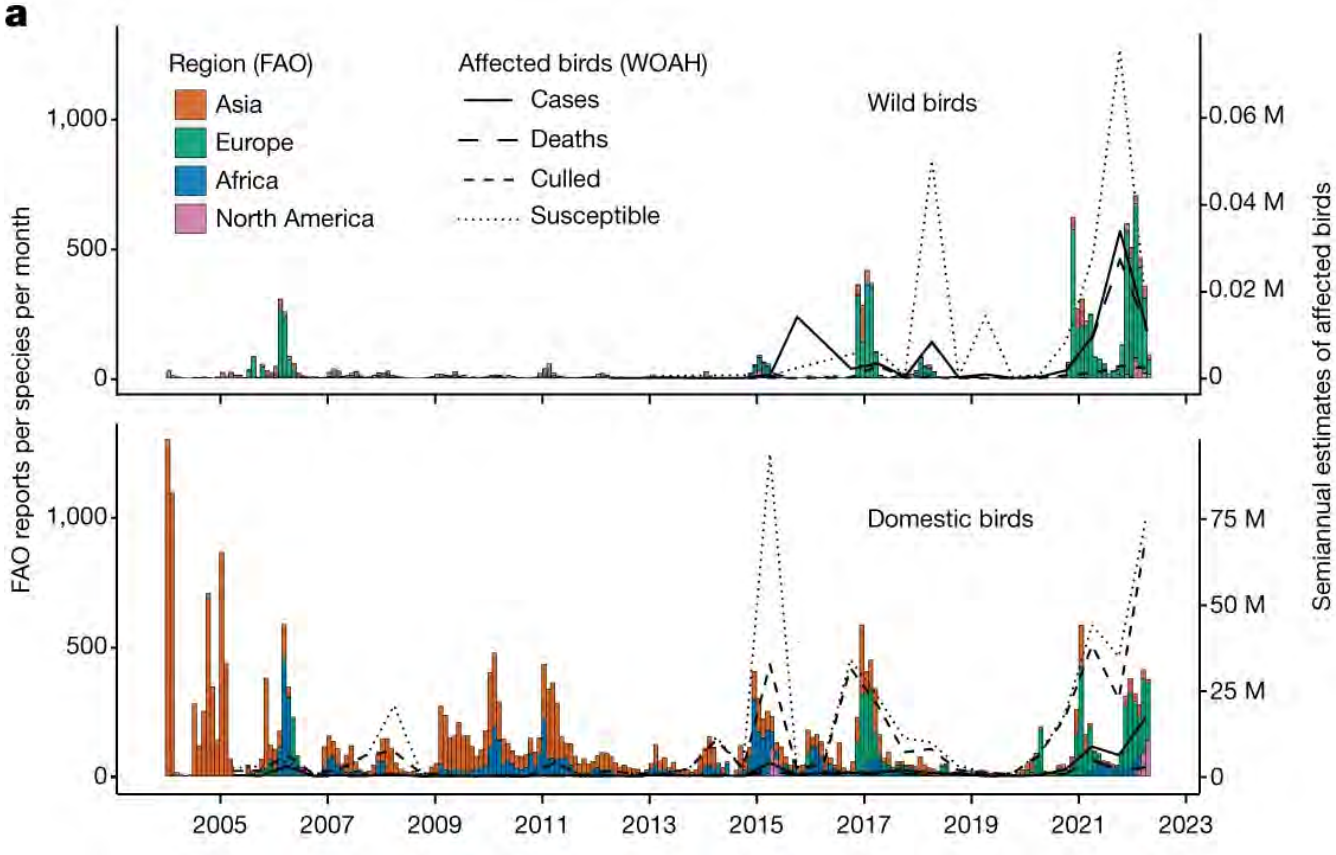
- Improve Canada's global standing and capacity to contribute to international response
    - Soft diplomacy
    - International leadership

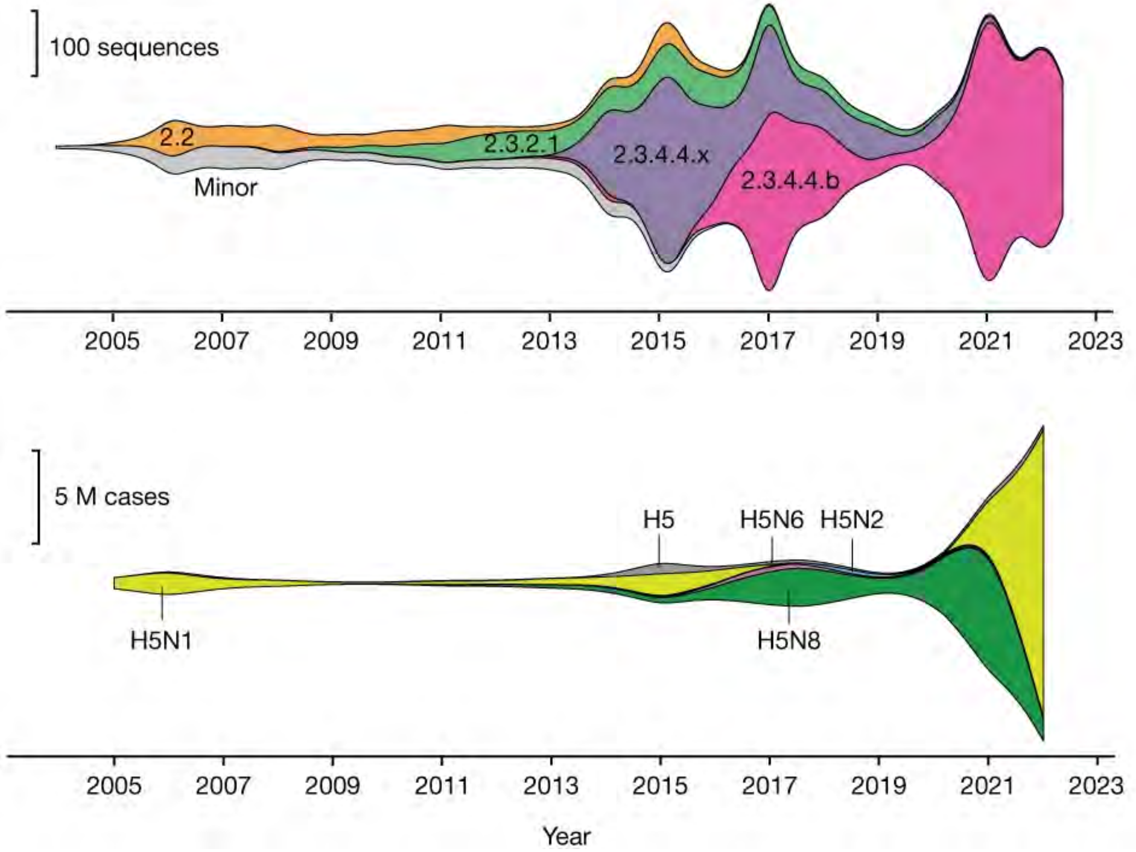
- Implement recommendations from key reports (Naylor, Walport)
    - Risk registration
    - Provide science advice
    - Advance PHAC's Science strategy; *Integrating Science in Public Health Emergencies*

- Ability to meet expectations outlined in inter-governmental tools and instruments
    - Pandemic Accord
    - Quadripartite One Health Plan of Action, action track 2
    - PREZODE

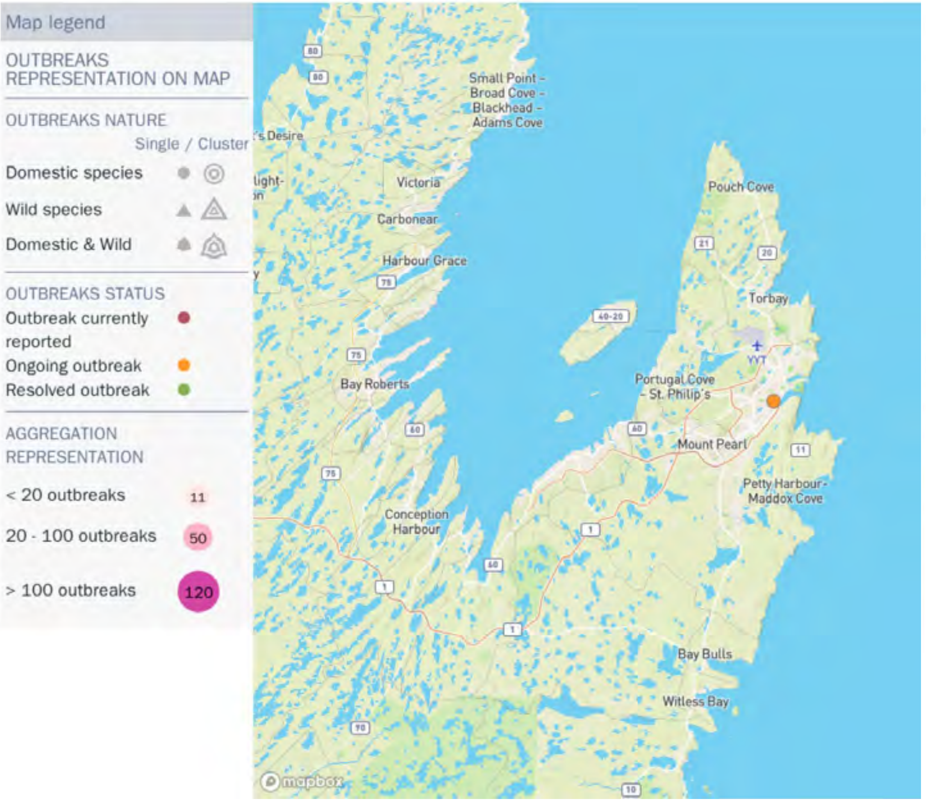
- Leverage major infrastructure investments, including CL3 facilities

HPAI epidemiology, genomics, ecology





Emergence in the Americas



WORLD ORGANISATION FOR ANIMAL HEALTH

Immediate notification

22/12/2021

The event is ongoing. Weekly follow-up reports will be submitted.

Sender	Country/territory	Report ID
Delegate of Canada	Canada	IN_153046
Report reference	Event status	Self-declaration
CAN-2021-HPAI-001	On-going	No

Mortalities of harbour seals in the St. Lawrence Estuary in Quebec associated with infections by a highly pathogenic H5N1 avian influenza virus

BY CAROLYN BLUSHKE · 2022-07-12

Like 28 Tweet SHARE

Over the last few weeks, the *Réseau québécois d'urgence pour les mammifères marins* has reported an unusually high number of dead or sick harbour seals in the St. Lawrence Estuary. In fact, the number of harbour seals found dead so far

Government of Canada Gouvernement du Canada

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Domestic dog tests positive for avian influenza in Canada

From: Canadian Food Inspection Agency

Statement

April 4, 2023 – Ottawa, Ontario

Today, the Canadian Food Inspection Agency and the Public Health Agency of Canada issued the following joint statement:

The Canadian Food Inspection Agency's (CFIA) National Centre for Foreign Animal Disease, confirmed on April 1, 2023, that a domestic dog in Oshawa, Ontario has tested positive for highly pathogenic avian influenza (HPAI).

First case of highly pathogenic H5N1 avian influenza virus infection in a black bear

BY CAROLYN BLUSHKE · 2022-08-30

Like 780 Tweet SHARE

An adult female black bear exhibiting unusual behaviour was reported by visitors in June at Forillon National Park in the Gaspésie region, Quebec. This bear was exhibiting strange behaviour early in the day on June 14. It wandered between vehicles, went down to the

Influenza A (H5N1) virus detected in Wild Foxes (Vulpes vulpes) in Ontario

BY CAROLYN BLUSHKE · 2022-05-04

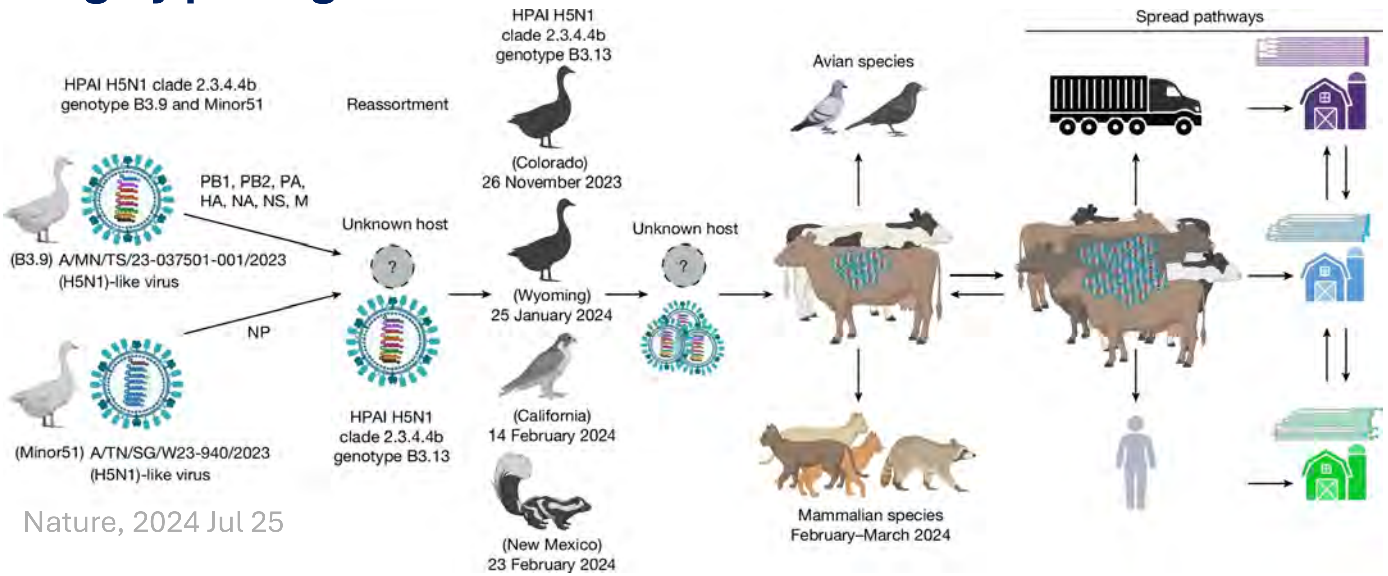
Like 1K Tweet

Working with our partners at the Canadian Food Inspection Agency (CFIA) and the Animal Health Laboratory, the CWHC ON/NU diagnosed influenza A (H5N1) in 2 wild fox kits in Ontario, on May 2, 2022. These cases represent the first detections of highly pathogenic

cwhc-rcsf.ca

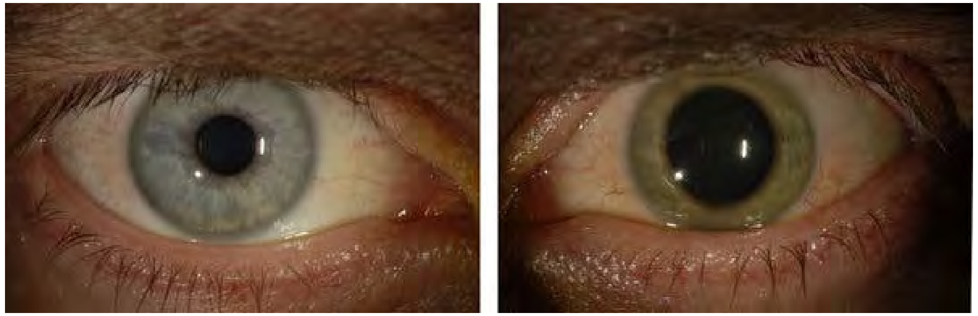
Expect the unexpected

Highly pathogenic avian influenza virus



Nature, 2024 Jul 25

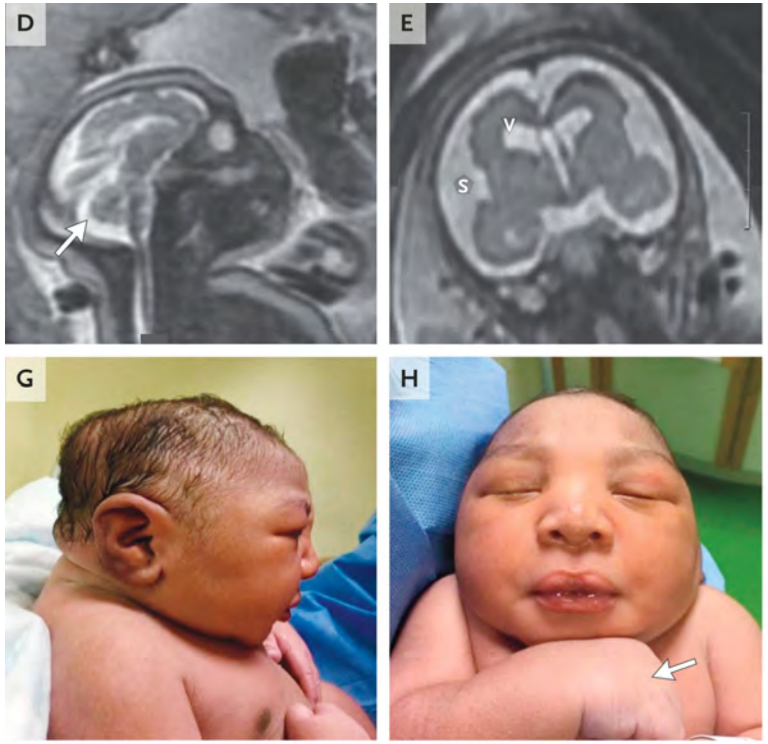
Ebola virus



nytimes.com/2015/05/08/health/weeks-after-his-recovery-ebola-lurked-in-a-doctors-eye.html

N Engl J Med 2015;372:2423-2427 DOI: 10.1056/NEJMoa1500306

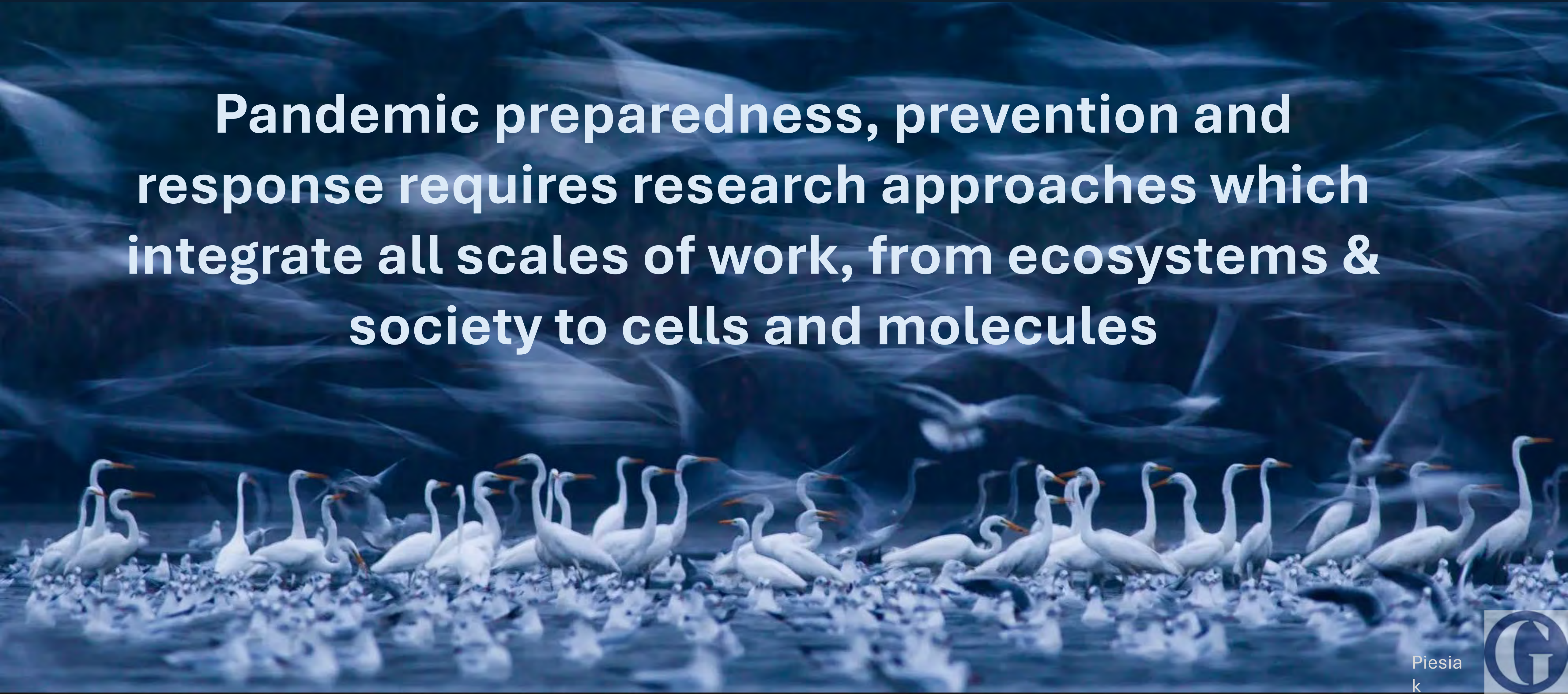
Zika virus



N Engl J Med 2019;381:1444-1457

DOI: 10.1056/NEJMra1808246

Transdisciplinary research matters



Pandemic preparedness, prevention and response requires research approaches which integrate all scales of work, from ecosystems & society to cells and molecules

Piesiak

Many, many thanks

Wild EPI
A. Banerjee (VIDO)
F. Maguire (Dalhousie U)
C. Jardine (U Guelph)
J. Bowman (Trent U, MNR)
B. Pickering (CFIA)
A. Doxey (U Waterloo)

Sunnybrook Research Institute
L. Yip
W. Yim
E. Chien
A. Hou
J. Blais-Savoie
L. Klassen

Carlton U
C. Davy

U Saskatchewan
V. Misra (the OG CDN bat virologist)

Pirbright
G. Gallo
D. Bailey

Province of Ontario
L. Crawshaw & crews (MNR)
H. McClinchey (Office of CMOH)
J. Guthrie (PHOL; Western)

Government of Canada
O. Lung (CFIA)

Algonquin Wildlife Research Station
D. Evans

Harkness Laboratory of Fisheries Research
M. Ridgway

Hobbitstee
C. Theijin

Pinery Provincial Park
A. MacKenzie

Public Health Agency of Canada
Agence de la santé publique du Canada

CIHR IRSC
Canadian Institutes of Health Research
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EPIC
Emerging & Pandemic Infections Consortium

Canadian Safety and Security Program
Programme canadien pour la sûreté et la sécurité

NSERC
CRSNG


MERCI!
QUESTIONS?