MULTIDRUG-RESISTANT PATHOGENS IN FOODS

Dec. 12, 2024 | VANCOUVER, BC

SIYUN WANG, PROFESSOR
FOOD NUTRITION AND HEALTH

a place of mind

FACULTY OF LAND AND FOOD SYSTEMS

Wang Lab of Molecular Food Safety

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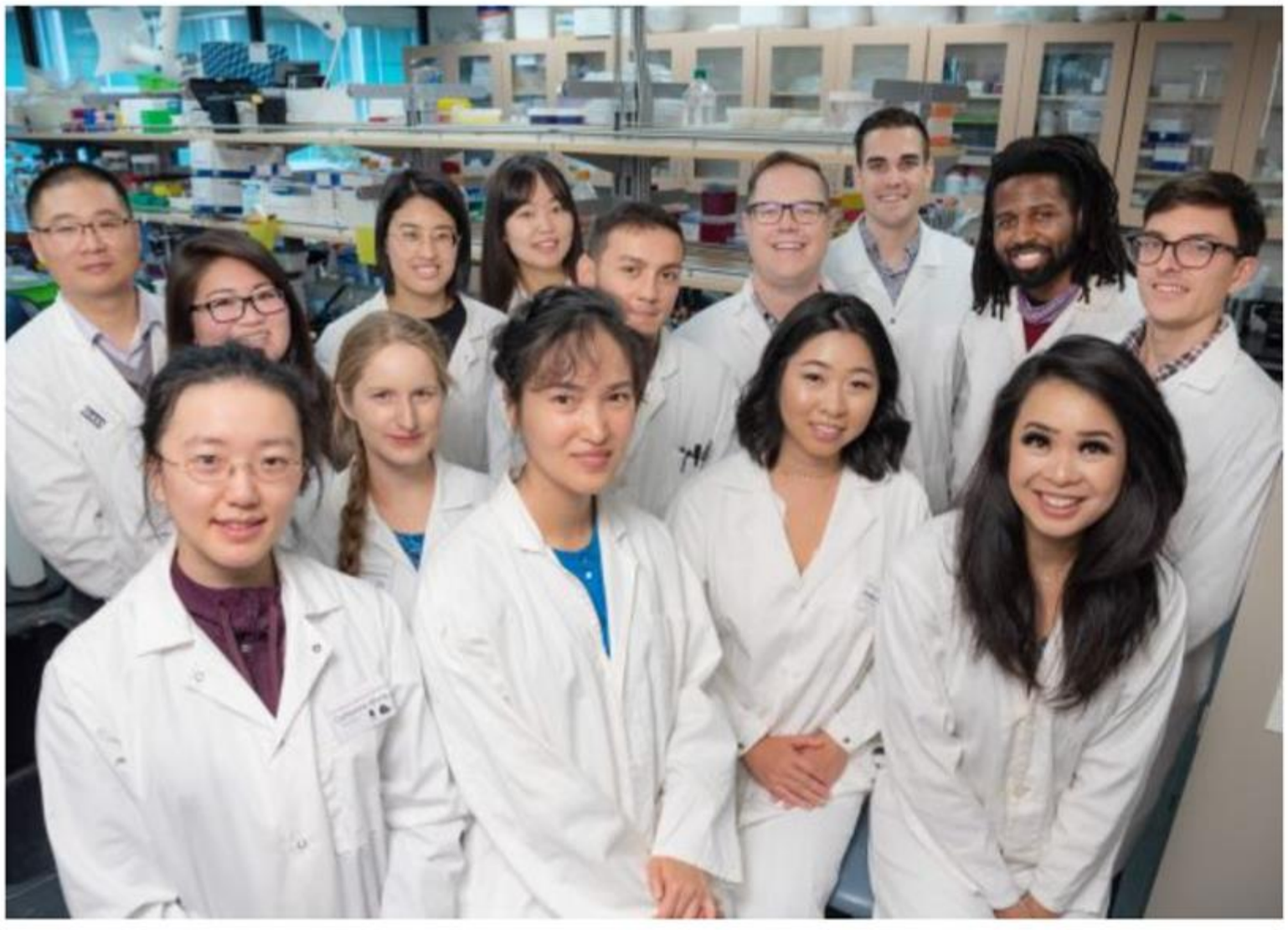
The Wang Lab of Molecular Food Safety

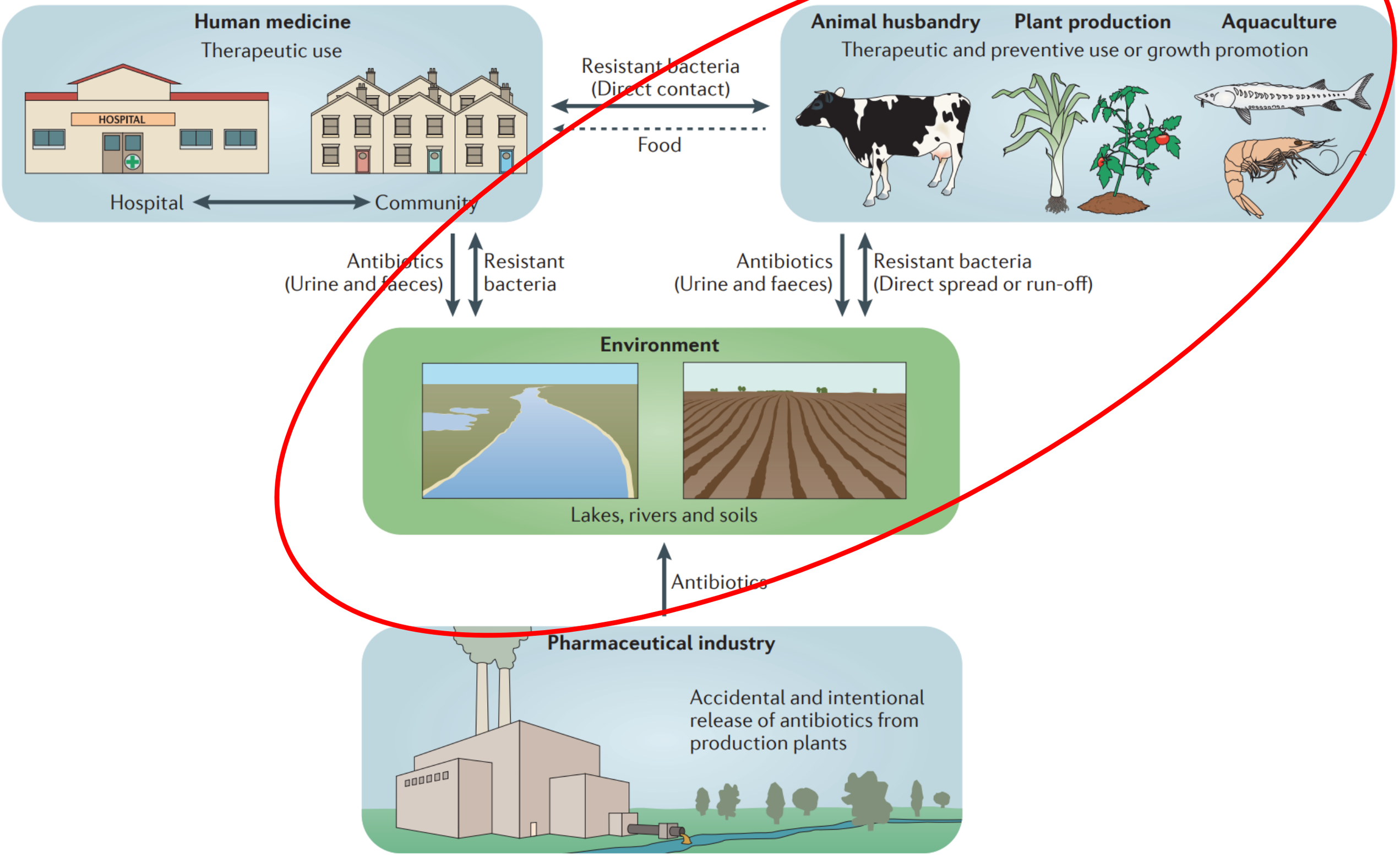


https://indigenous.ubc.ca

The Wang Lab of Molecular Food Safety

We are using molecular approaches to understand the microorganisms that post major threats to food safety, security and public health.

https://foodsafety.landfood.ubc.ca



Andersson and Hughes, 2014, Nat Rev Microbiol

Food-producing animals develop drug-resistant bacteria in their gut when antimicrobial substances are used for therapy and/or prophylaxis of bacterial infections in them or with antimicrobial substances' administration in animal feeds as growth promoters

Human beings get antibiotics and develop drug-resistant bacteria in their gut.

Fertilizer including drug-resistant bacteria can be used on food crops

Drug-resistant bacteria remain on meat of these animals and/or on food crops that manure or sewage water is used for fertilization and irrigation, and they can be eaten by human beings

Human beings directly spread drug-resistant bacteria to other people in the public or to vulnerable patients at the hospital or drug-resistant bacteria indirectly spread to other patients from surfaces within the hospital

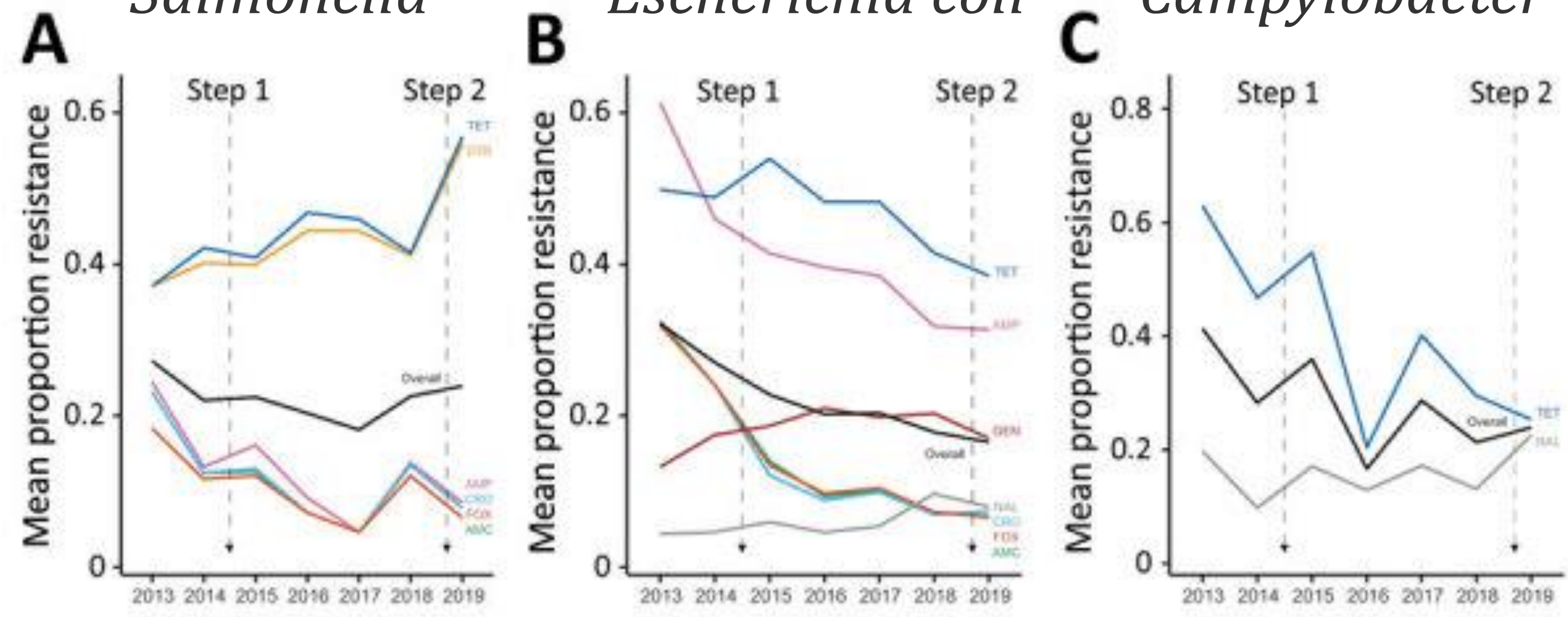
Pérez-Rodríguez and Taban, 2019, Front Microbiol

https://www.istockphoto.com/free-stock-photos

Significant changes in mean proportion of AMR in **broiler chickens** by antimicrobial class, Canada, 2013–2019

Huber et al., 2021. Emerg Infect Dis.

Salmonella *Escherichia coli* *Campylobacter*



Step 1: Elimination of the preventive use of category I antimicrobials in 2014 as part of Antimicrobial Use Reduction Strategy stewardship program.
Step 2: Elimination of the preventive use of category II antimicrobials in 2018.
Step 3: Elimination of the preventive use of category III antimicrobials by 2020 (not represented)

frontiers in Veterinary Science

Front Vet Sci. 2020; 7: 547181.
Published online 2020 Dec 21. doi: 10.3389/fvets.2020.547181

PMCID: PMC7779680
PMID: 33409294

Impacts of Short-Term Antibiotic Withdrawal and Long-Term Judicious Antibiotic Use on Resistance Gene Abundance and Cecal Microbiota Composition on Commercial Broiler Chicken Farms in Québec

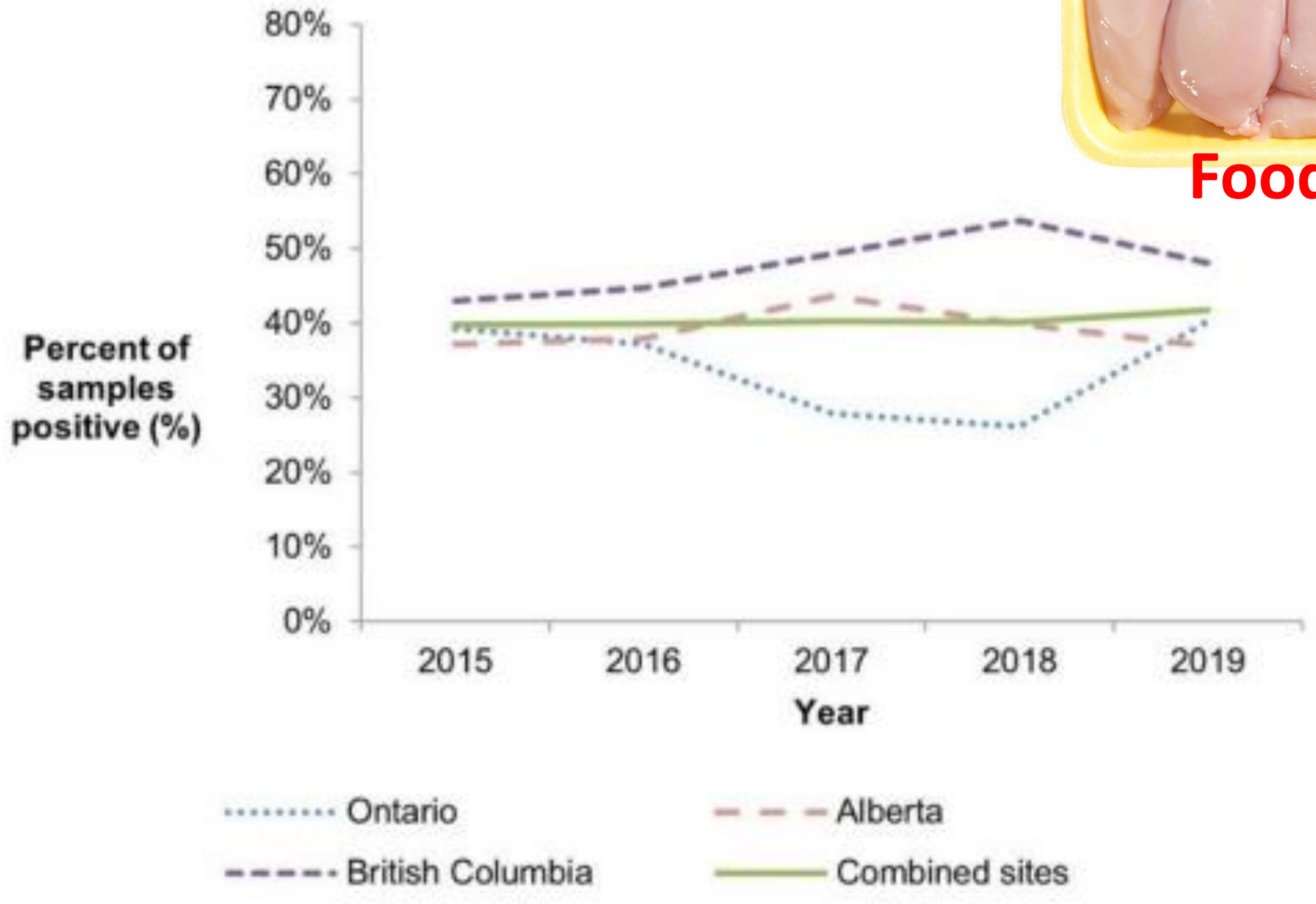
Catherine Turcotte,[1] Alexandre Thibodeau,[1] Sylvain Quessy,[1] Edward Topp,[2,3] Guy Beauchamp,[4] Philippe Fravalo,[1,5] Marie Archambault,[6] and Marie-Lou Gaucher[1,*]

The antibiotic withdrawal:

- Altered the intestinal microbiota composition: *Ruminococcaceae* and *Lachnospiraceae* (ferment and digest carbohydrates and produce small-chain fatty acids) ↓
- Production performance ↓
- *C. perfringens* populations ↑

Percent of retail chicken breast samples positive for *Campylobacter*, 2015-2019

Food Safety



Public Health Agency of Canada, 2020. FOODNET CANADA: TABLES AND FIGURES 2019

AMR in beef

- Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) monitors AMR in livestock and retail meat.
- AMR and MDR are relatively low and are not increasing because drugs of Very High Importance are very rarely used in beef cattle in Canada.

Extended-spectrum beta-lactamase producing *Escherichia coli* (ESBL-EC)

CIPARS surveillance component	Species	Number of samples tested for *E. coli*	*E. coli* recovery rate (*n*)[a]	Number of ESBL-EC (% of all ESBL-EC)	Prevalence of ESBL-EC (95% CI)[b]
On-farm	Broiler chicken (placement)	1247	80.8% (1008)	71 (18.1)	5.7% (4.5–7.1)
	Broiler chicken (pre-harvest)	2408	99.2% (2389)	112 (28.6)	4.7% (3.9–5.6)
	Turkey	920	98.7% (908)	12 (3.1)	0.4% (0.2–0.7)
	Swine	3023	98.3% (2972)	32 (8.2)	1.1% (0.8–1.5)
Abattoir	Broiler chicken	1100	99.5% (1094)	31 (7.9)	2.8% (2.0–4.0)
	Swine	1059	99.0% (1048)	5 (1.3)	0.5% (0.2–1.1)
Retail	Chicken	2739	92.6% (2535)	93 (23.6)	3.4% (2.8–4.1)
	Turkey	2730	90.2% (2462)	24 (6.1)	0.9% (0.6–1.3)
	Beef	3954	49.9% (1974)	4 (1.0)	0.1% (0.04–0.3)
	Pork	4994	25.4% (1267)	10 (2.6)	0.2% (0.1–0.4)
Total		24 174	73.0% (17 657)	394 (100)	

Preimeau et al., 2022. Epidemiol Infect.

AMR profile in Extended-spectrum cephalosporins-resistant *E. coli* isolates recovered from retail meat products from the Maritime Provinces

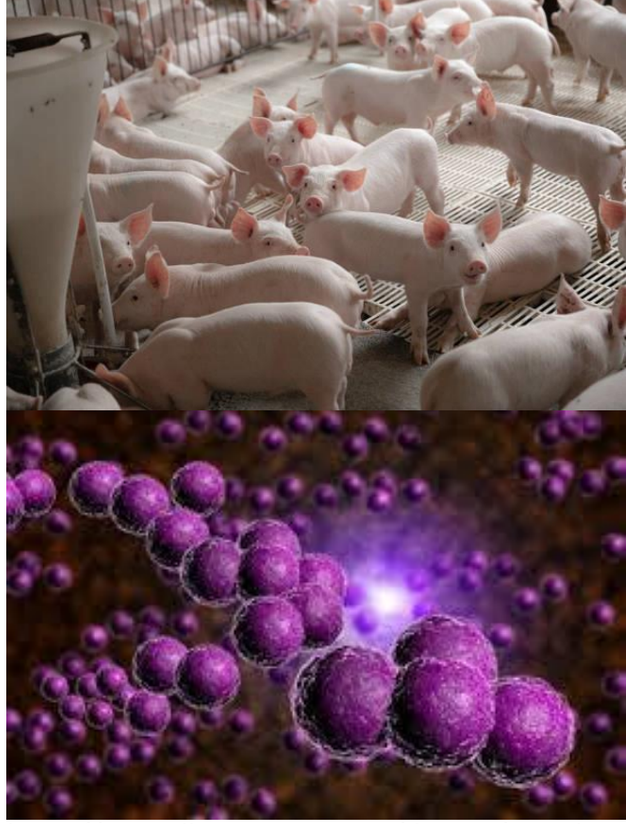
Antimicrobials	Number of resistant isolates (n)	Retail meat products				P-value	Total resistant (%)
		Beef (%)	Chicken (%)	Pork (%)	Turkey (%)		
*Ampicillin	151	5.96	62.91	5.30	25.83	<0.001	100
*AMC	148	6.08	64.19	5.41	24.32	0.032	98.01
*Chloramphenicol	15	20.00	80.00	0.00	0.00	0.007	9.93
*Ceftriaxone	151	5.96	62.91	5.30	25.83	<0.001	100
*Ceftiofur	135	5.19	65.93	2.96	25.93	0.001	89.40
*Cefoxitin	142	4.23	66.90	2.82	26.06	<0.001	94.03
Ciprofloxacin	5	0.00	60.00	0.00	40.00	0.799	3.31
Gentamicin	48	2.08	72.92	0.00	25.00	0.082	31.79
Kanamycin	24	8.33	45.83	4.17	41.67	0.171	15.89
Nalidixic acid	5	0.00	60.00	0.00	40.00	0.799	3.31
Streptomycin	70	7.14	64.29	1.43	27.14	0.249	46.35
Sulfisoxazole	86	5.81	61.63	3.49	39.07	0.550	56.95
*Tetracycline	86	5.81	55.81	2.33	36.05	0.005	56.95
TMS	19	15.79	63.16	5.26	15.79	0.201	12.58
*ESBL phenotype	151	5.96	62.91	5.30	25.83	<0.001	100
*AmpC phenotype	142	4.22	62.91	2.65	24.50	<0.001	94.04
*MDR isolates	143	4.90	65.73	2.80	26.57	<0.001	94.7

*Statistically significant recovery between meat commodities at P<0.05
AMC-Amoxicillin-clavulanate, TMS-Trimethoprim-sulfamethoxazole, MDR- Multidrug resistance

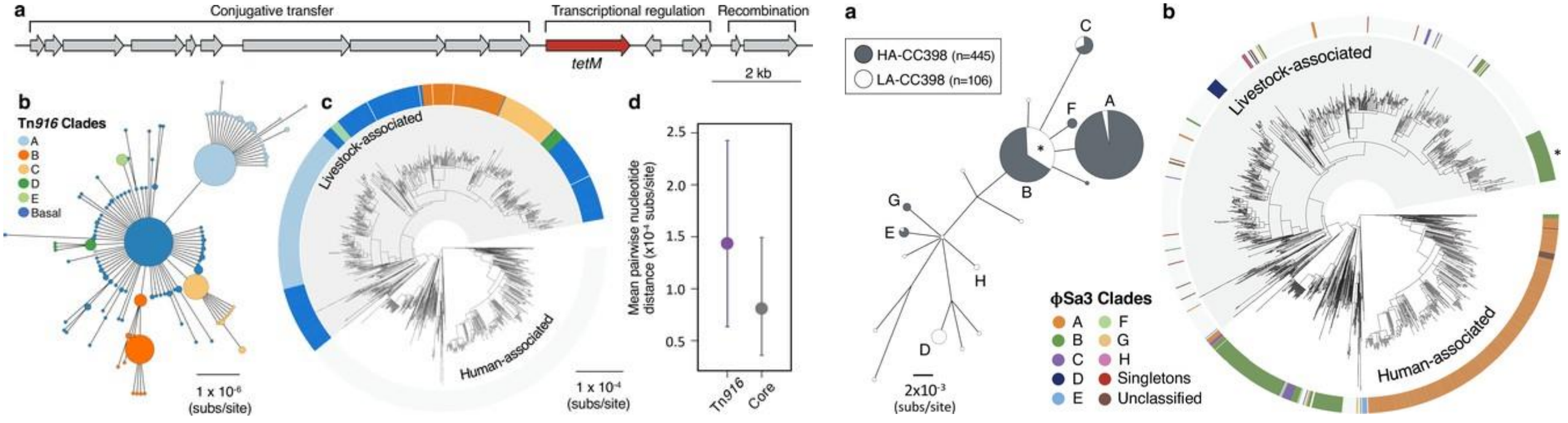
Awosile et al., 2021. Can J Microbiol.

AMR in Pork

- Methicillin-resistant *Staphylococcus aureus* (MRSA) was found in pork samples at retail outlets in all 4 surveyed Canadian provinces (BC, SK, ON, QC). Weese et al., 2010. Can Vet J.
- In Europe, a highly antibiotic-resistant strain of MRSA, CC398, has emerged in livestock in the last 50 years, probably due to widespread antibiotic use in pig farming.



https://www.dhs.wisconsin.gov/disease/mrsa.htm



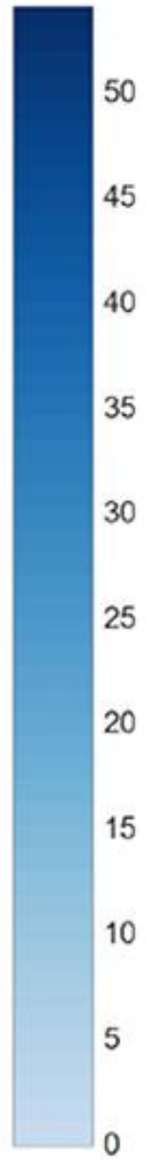
The stable inheritance of resistance-associated MGEs suggests that the impact of ongoing reductions in antibiotic use in European farms on livestock-associated MRSA will be slow to be realized.

Matuszewska et al., 2022. ELife

AMR in crops

Global Occurrence of Human Pathogens Harboring Antimicrobial Resistance in Food Crops

	Soil	Manure Fertilizer	Irrigation Water	Root Crops	Vegetable	Pulses & Grains	Culinary Herbs	Salad Crops	Ready-to-Eat	Fruit
Acinetobacter baumanii	5	1	0	0	0	0	0	3	1	0
Aspergillus fumigatus	17	0	0	0	0	0	0	0	0	0
Bacillus spp.	0	0	0	2	5	0	0	2	3	0
Enterococcus faecalis &.E. faecium	2	8	10	23	8	2	3	31	1	2
Escherichia coli	16	21	32	4	54	5	16	49	11	3
Klebsiella pneumoniae	1	3	3	7	7	1	7	19	0	6
Listeria monocytogenes	10	0	0	3	16	9	1	7	3	3
Salmonella spp.	6	7	16	3	21	1	19	40	2	1
Shigella spp.	0	0	0	0	0	0	0	2	1	0
Staphylococcus aureus	4	0	1	1	5	0	2	10	2	0
Xanthomonas spp.	1	0	0	1	0	2	0	5	0	0



Brunn et al., 2022. Front. Sustain. Food Syst.

Microbial isolates of sample groups reported in studies published in 2000 - 2020

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Public Health Notice – Outbreak of E. coli infections linked to romaine lettuce

June 22, 2018 - Final Update

This is the final update for this outbreak. This notice has been updated to advise that the outbreak appears to be over and the outbreak investigation has been closed.

More Information

- Epidemiological investigati

Why should you take note?

The United States Centers for Disease Control and Prevention (U.S. CDC) and the United States Food and Drug Administration (U.S. FDA) are investigating an outbreak of Escherichia coli O157, commonly called E. coli, linked to romaine lettuce from the Yuma growing regions in the United States (U.S.). E. coli can cause a serious, life-threatening illness.

In Canada, there were eight Canadian illnesses of E. coli O157 with a similar

FDA U.S. FOOD & DRUG ADMINISTRATION

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Outbreak Investigation of Salmonella: Cucumbers (November 2024)

Do not eat, sell, or serve recalled cucumbers or products containing recalled cucumbers. Multiple companies issue recalls.

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Outbreaks of Foodborne Illness

Investigations of Foodborne Illness Outbreaks

Product

American/slicer cucumbers grown by Agrotato, S.A. de C.V. in Sonora, Mexico and sold by importers on or after October 12, 2024 and products containing recalled cucumbers have been recalled by multiple companies.

Irrigation water safety in the Lower Mainland, BC

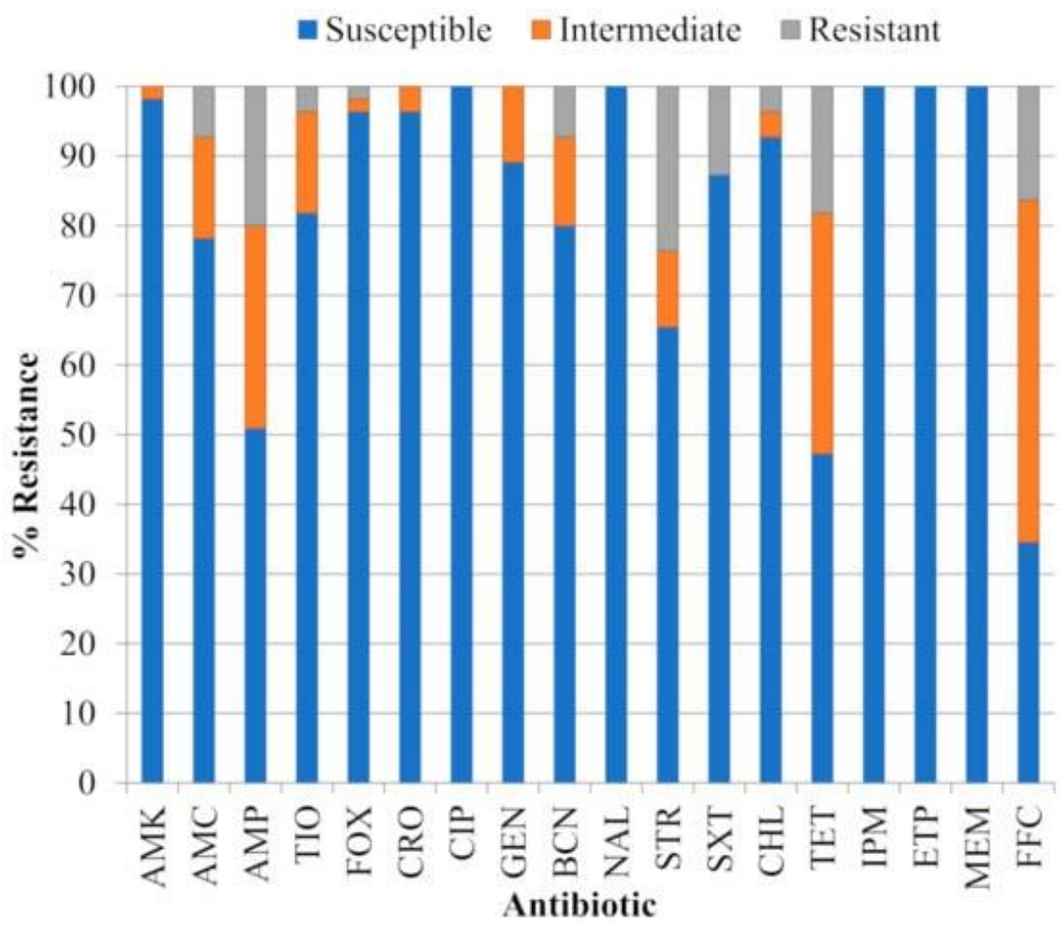
	Winter	Spring	Summer	Fall
Sumas Watershed				
VTEC	2/25 (8%)	2/39 (5.1%)	0/45 (0%)	1/20 (5%)
L. monocytogenes	2/25 (8%)	1/39 (2.6%)	2/45 (4.4%)	1/20 (5%)
Salmonella	2/25 (8%)	1/39 (2.6%)	1/45 (2.2%)	1/20 (5%)
Any	5/25 (20%)	4/39 (10.3%)	3/45 (6.7%)	2/20 (10%)
Serpentine Watershed				
VTEC	1/18 (5.6%)	3/25 (12%)	1/36 (2.8%)	1/15 (6.7%)
L. monocytogenes[α]	5/18 (27.8%)	4/25 (16%)	1/36 (2.8%)	7/15 (46.7%)
Salmonella	0/18 (0%)	0/25 (0%)	0/36 (0%)	1/15 (6.7%)
Any[α]	5/18 (27.8%)	6/25 (24%)	2/36 (5.6%)	8/15 (53.3%)
Both Watersheds				
VTEC	3/43 (7%)	5/64 (7.8%)	1/81 (1.2%)	2/35 (5.7%)
L. monocytogenes[α]	7/43 (16.3%)	5/64 (7.8%)	3/81 (3.7%)	8/35 (22.9%)
Salmonella	2/43 (4.7%)	1/64 (1.6%)	1/81 (1.2%)	2/35 (5.7%)
Any[α]	10/43 (23.3%)	10/64 (15.6%)	5/81 (6.2%)	10/35 (28.6%)

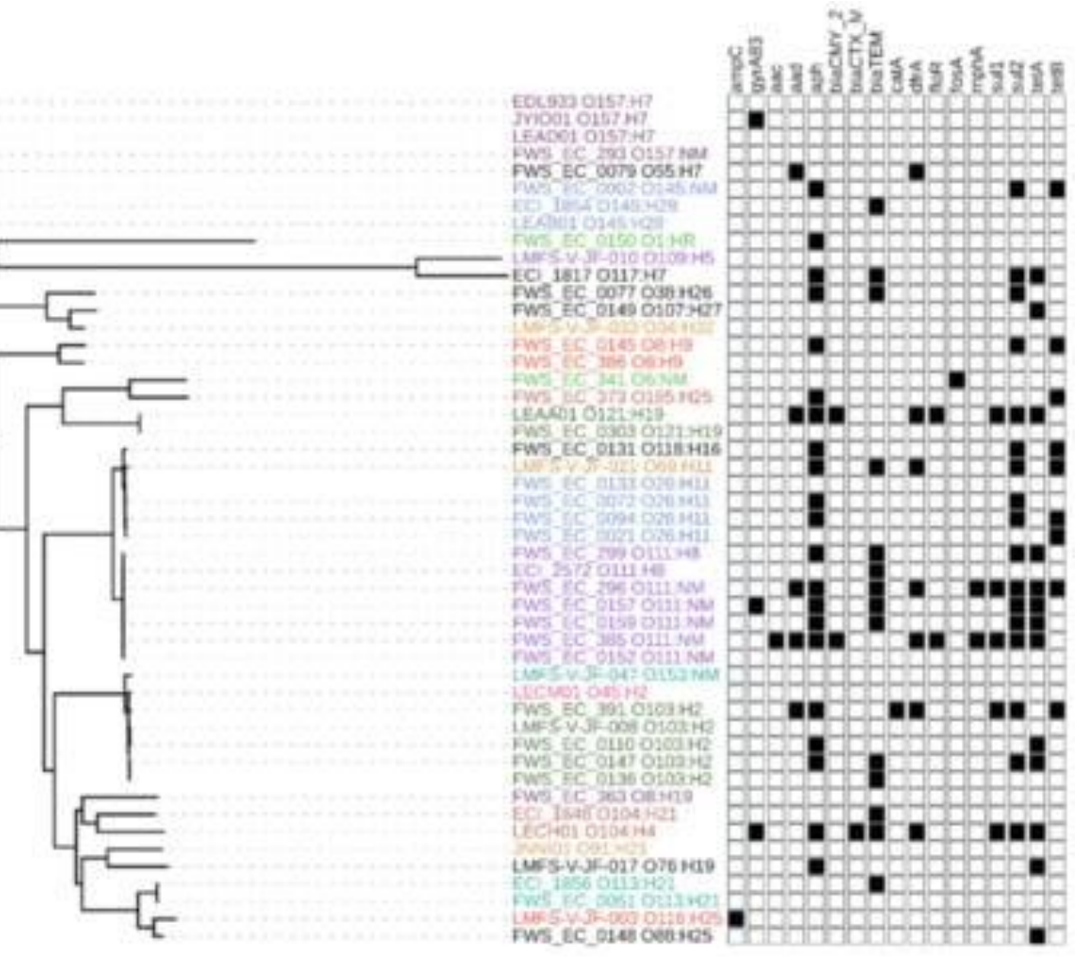
Winter = Dec-Feb; Spring = Mar-May; Summer = Jun-Aug; Fall = Sep-Nov

[α] Significant seasonal variation was observed for this pathogen(s) within respective watershed(s) (Fisher exact test; $p < 0.05$).

Falardeau et al., 2017. PLOS ONE

14.6% VTEC isolates were multidrug resistant.





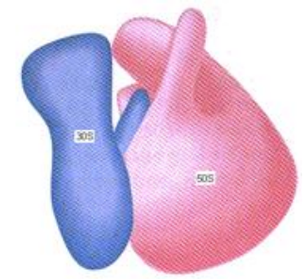
Acquired resistance determinants conferring resistance to phenicols (*floR*), trimethoprim (*dfrA*), sulfonamides (*sul1/2*), tetracyclines (*tetA/B*), and aminoglycosides (*aadA* and *aph*) were detected.

Ma et al., 2021. Antibiotics.

Alternative antimicrobial strategies

- Probiotics
- Prebiotics
- Antimicrobial peptides
- Bacteriophages
- Organic acids
- Essential oils
- Small molecules

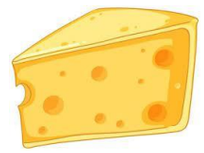
Bacteriocins



Weaver RF. Molecular Biology (1999). 602.

- Are ribosomally synthesized antimicrobial peptides produced by bacteria
- Can kill or inhibit bacterial strains closely-related or non-related to produced bacteria
- But will not harm the bacteria themselves by specific immunity proteins.

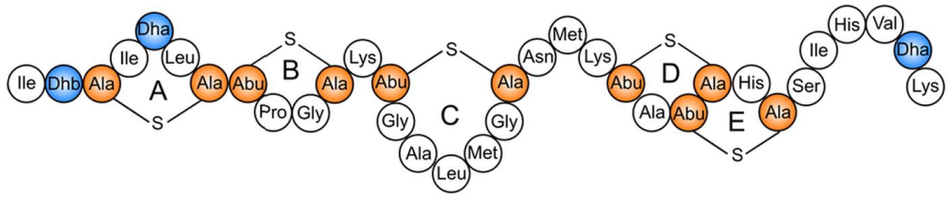
In 1928, the same year that Alexander Fleming discovered penicillin, Rogers and Whittier noted that certain lactic streptococci were inhibitory to starter cheese cultures.

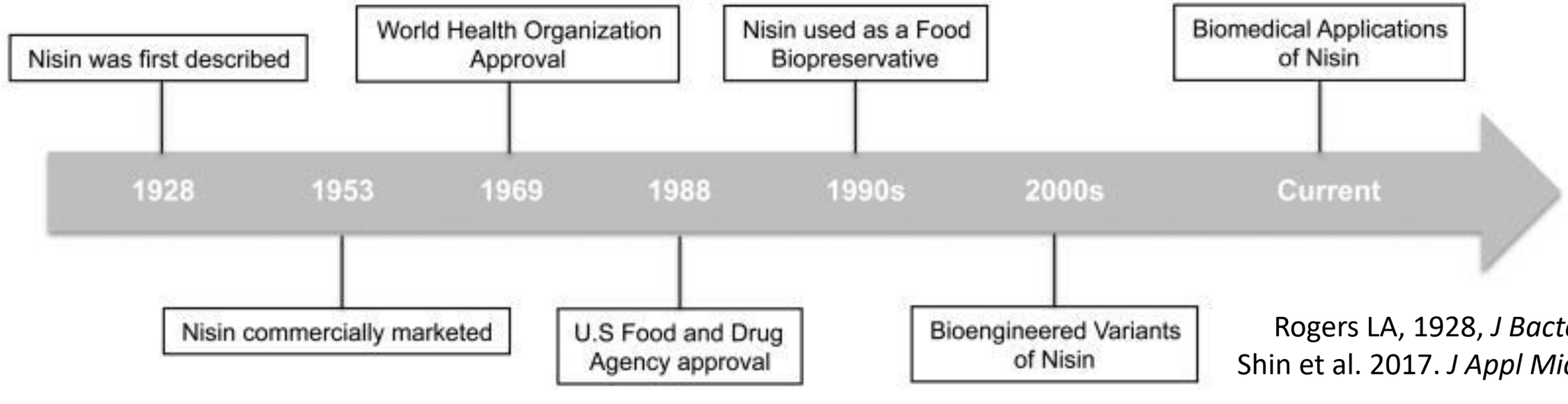


Challenge:

- development of bacterial resistance to AMPs
- high production costs
- Regulatory considerations

Nisin





Rogers LA, 1928, *J Bacteriol*
Shin et al. 2017. *J Appl Microbiol.*

The Discovery of Bacteriophages

THE LANCET,] MR. F. W. TWORT: ULTRA-MICROSCOPIC VIRUSES. [DEC. 4, 1915 1241

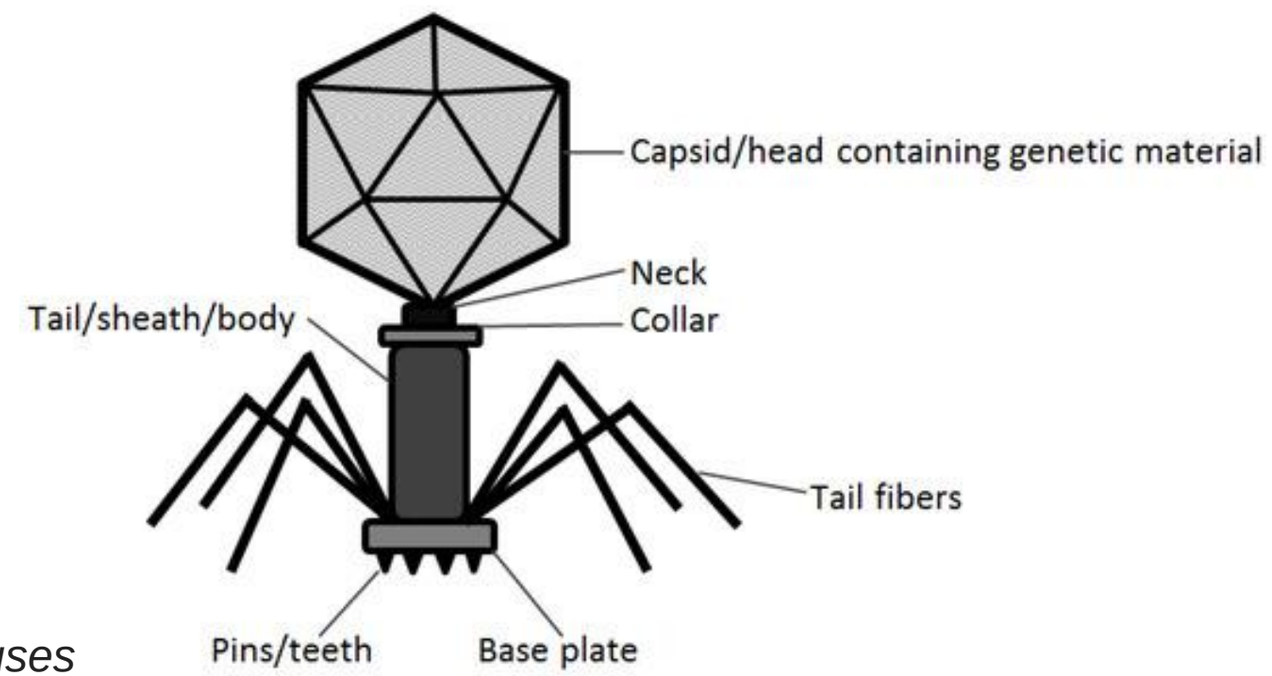
AN INVESTIGATION ON THE NATURE OF ULTRA-MICROSCOPIC VIRUSES.[1]

BY F. W. TWORT, L.R.C.P. LOND., M.R.C.S.
(From the Laboratories of the Brown Institution, London.)

"...bacterial colonies...became glassy and transparent."

Sur un microbe invisible antagoniste des bacilles dysentériques

F d'Herelle - CR Acad. Sci. Paris, 1917; 165:373-5.



Doss et al., 2017 *Viruses*

How phages infect their bacterial hosts: use the tail and associated receptor-binding proteins to interact with the host and to create a channel through which the DNA enters the cell. The baseplate initiates infection when the tail fibers bind to a host cell.

Challenge:

- Development of bacterial resistance to bacteriophages
- High host specificity
- Regulatory considerations

https://www.who.int/europe/news-room/25-06-2024-building-evidence-for-the-use-of-bacteriophages-against-antimicrobial-resistance

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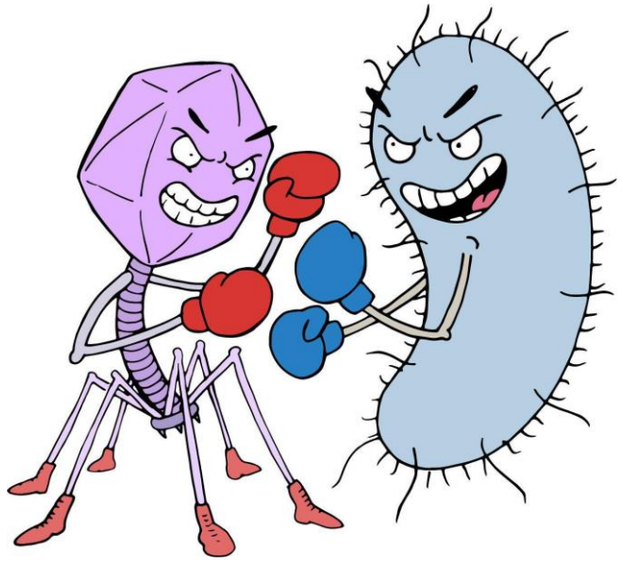
Building evidence for the use of bacteriophages against antimicrobial resistance

Jun 25, 2024, 13:33 PM

“My father felt powerless, like life was flowing out of him,” explains his daughter, Lies. At the age of 84, after Pim van Vliet underwent a surgery, he began suffering from a chronic urinary tract infection caused by a multi-drug resistant bacterium, Klebsiella pneumoniae. The persistent infection resulted in numerous hospital admissions over several months and wasn’t responding to intravenous (IV) antibiotics. Then, from his hospital bed in the Kingdom of the Netherlands, Pim watched a television programme about bacteriophages treatment at the Eliava Institute in Tbilisi, Georgia.

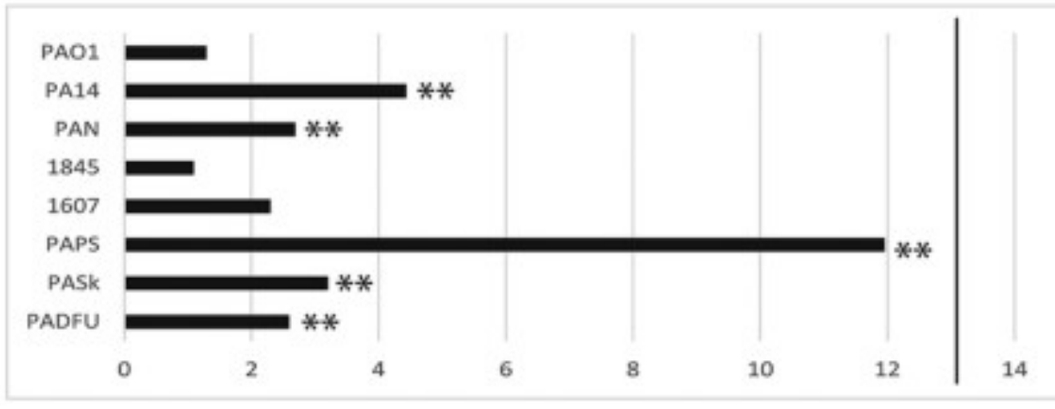


Parent KN, 2023. J Virol

Bacteria and bacteriophages face off and fight each other in an ongoing molecular arms race. Image credit: Patrick Lane, Sceyence Studios.

Antibiotic MIC

Ciprofloxacin	OMKO1 Sensitive	OMKO1 Resistant
PAO1	0.073 ± 0.023	0.057 ± 0.021
PA14	0.210 ± 0.035	0.047 ± 0.011
PAN	0.064 ± 0.000	0.024 ± 0.008
1845	0.136 ± 0.049	0.126 ± 0.039
1607	0.104 ± 0.018	0.045 ± 0.057
PAPS	0.172 ± 0.031	0.014 ± 0.010
PASk	5.333 ± 0.288	1.666 ± 0.289
PADFU	3.667 ± 0.577	1.417 ± 0.144



Selection for phage resistance causes a trade-off resulting in significantly reduced Minimum Inhibitory Concentrations (MIC) to four drugs drawn from different antibiotic classes in MDR *Pseudomonas aeruginosa*

Chan et al., 2016. Sci Rep

In Closing

https://www.who.int/

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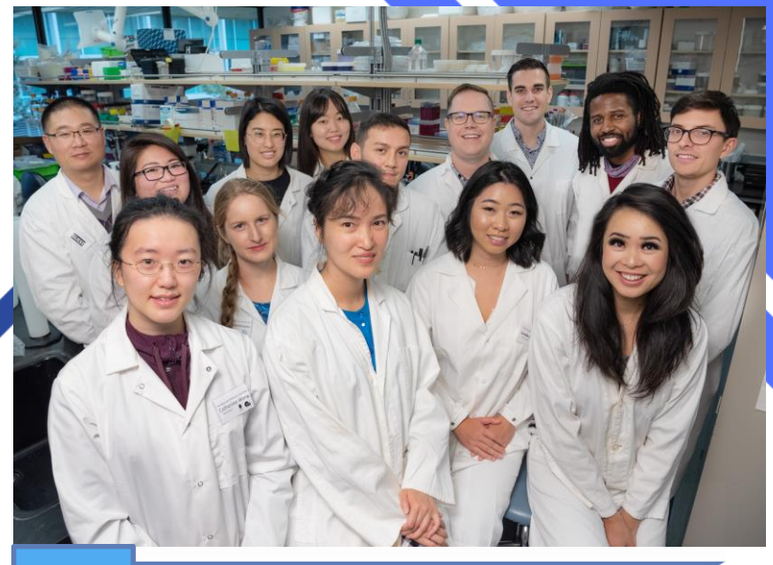

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