Anthropogenic impacts on the antimicrobial resistance in the environments

Jian-Qiang Su

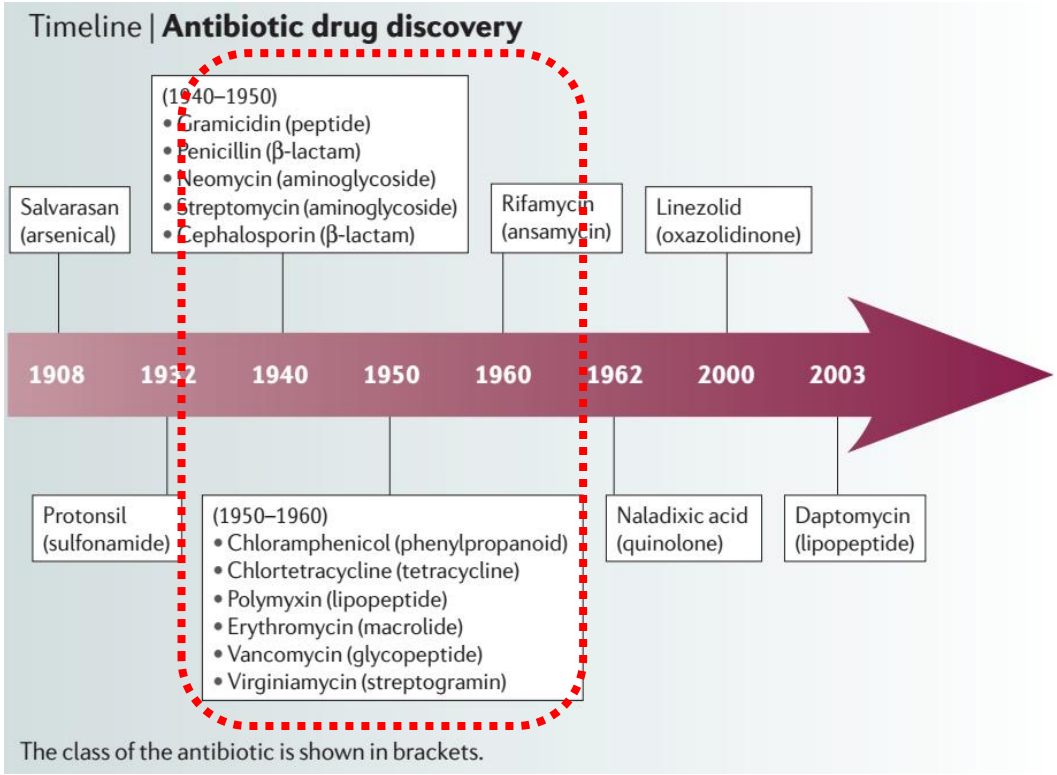
20.06.2023

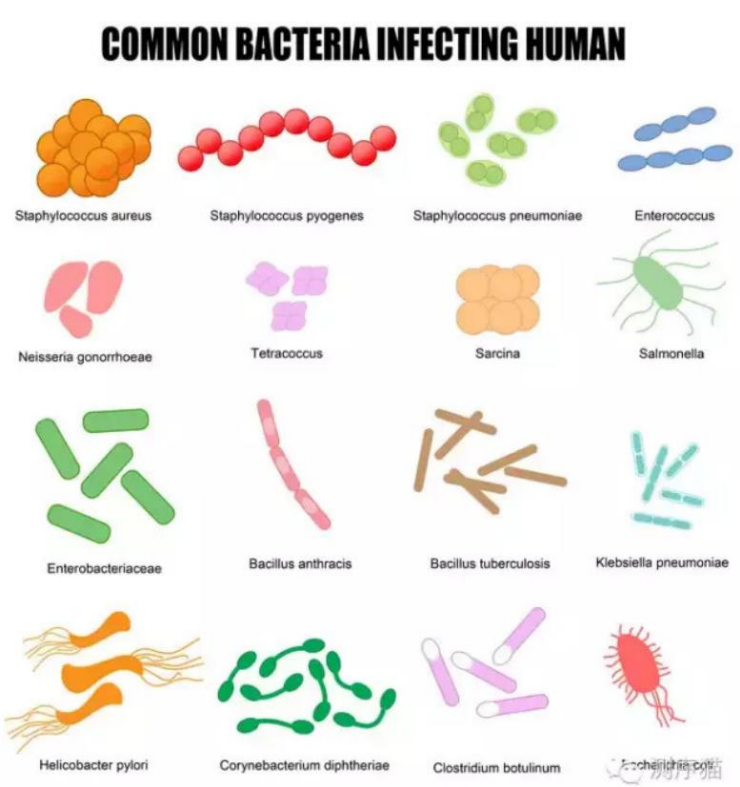
Institute of Urban Environment

Chinese Academy of Sciences

jqsu@iue.ac.cn

Antibiotics



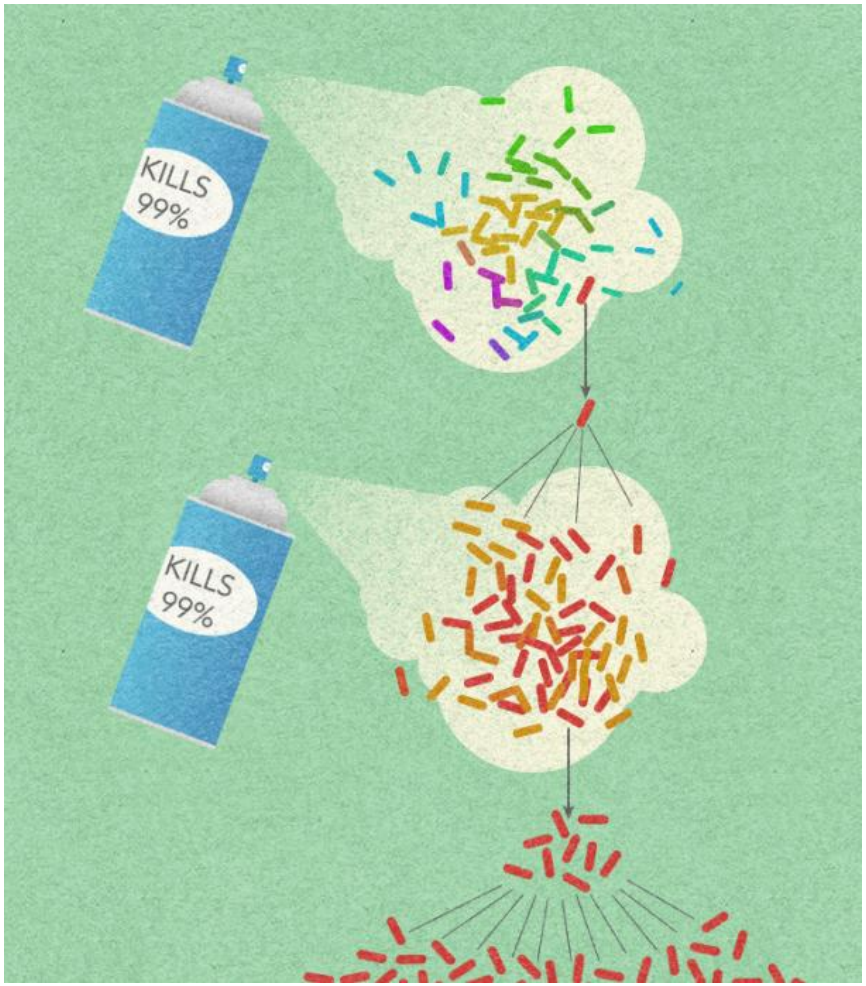


- **Therapeutic agent --- treat bacterial infections**
- **Various types: 1940-1960, golden age**
  - **Sulfonamides, tetracyclines, beta-lactamas, vancomycin, rifamycin**
- **Countless lives have been saved since antibiotic is discovered**

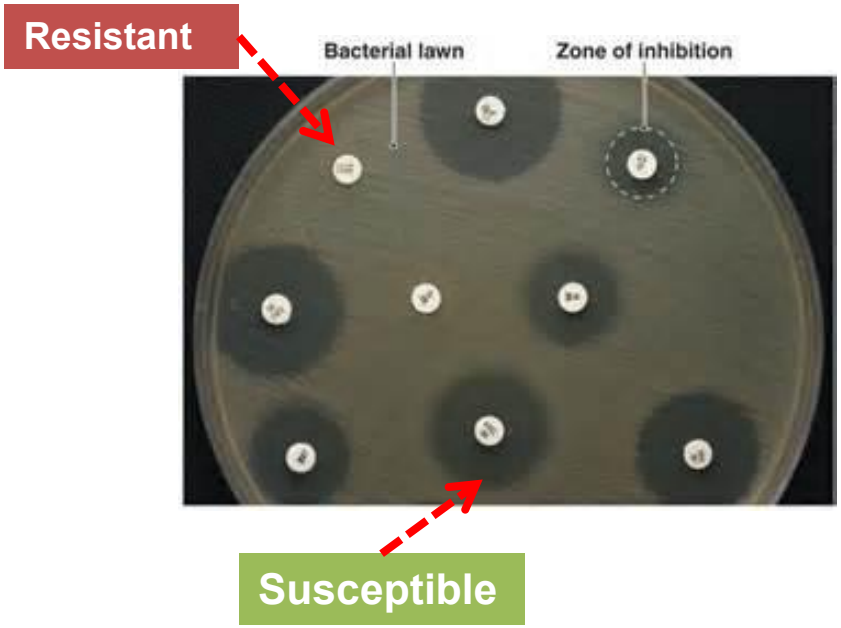
Pathogens

Wright, G. D. (2007). Nature Reviews Microbiology **5**(3): 175-186.

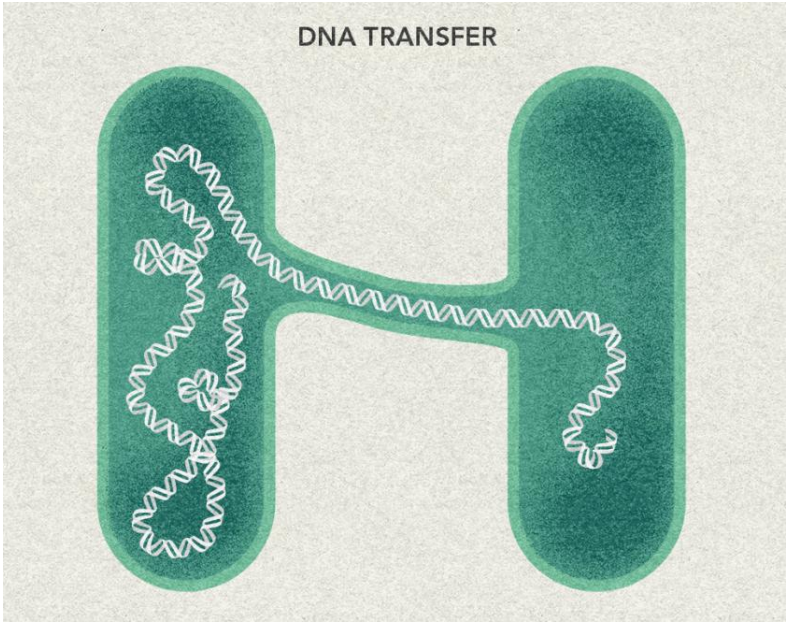
Antibiotic Resistance



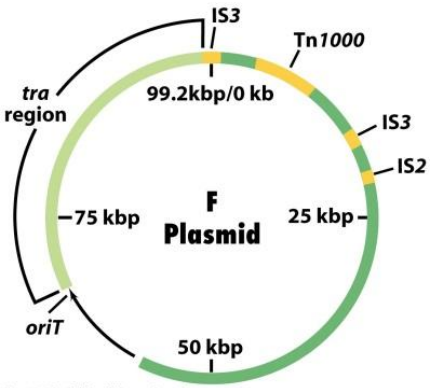
- Bacteria can not be killed
- Survive, proliferate, dominate
- Antibiotic treatment failure
- Antibiotic Resistance Genes (ARGs) genetic determinant of antibiotic resistance



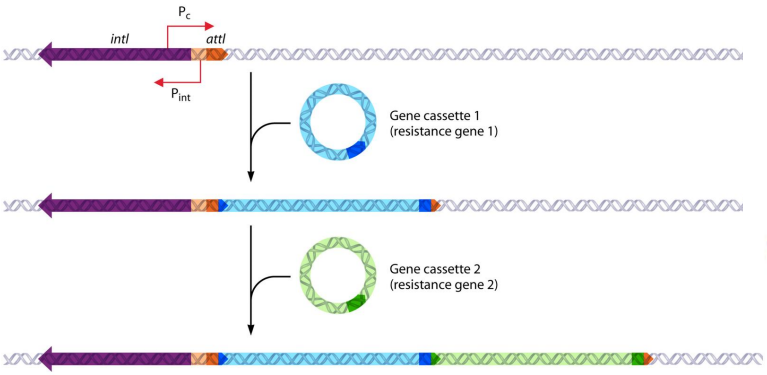
Horizontal gene transfer (HGT)



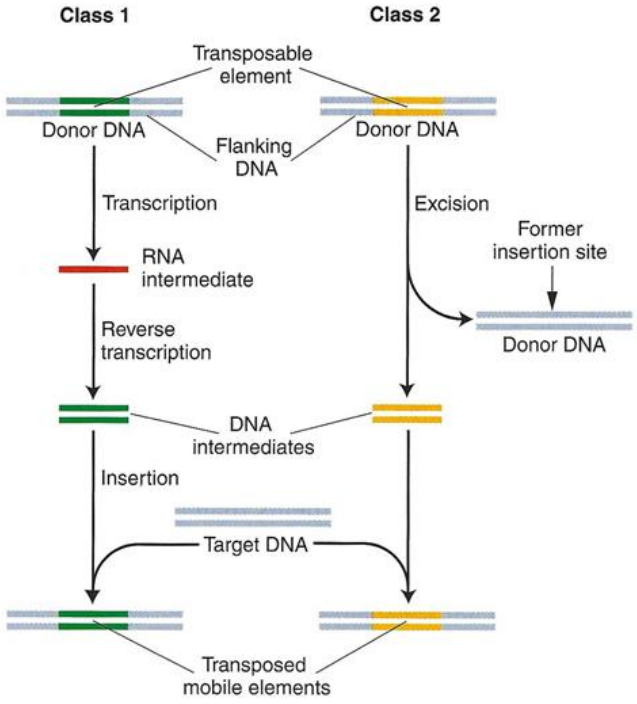
Mobile genetic elements （MGEs）



plasmid



integron



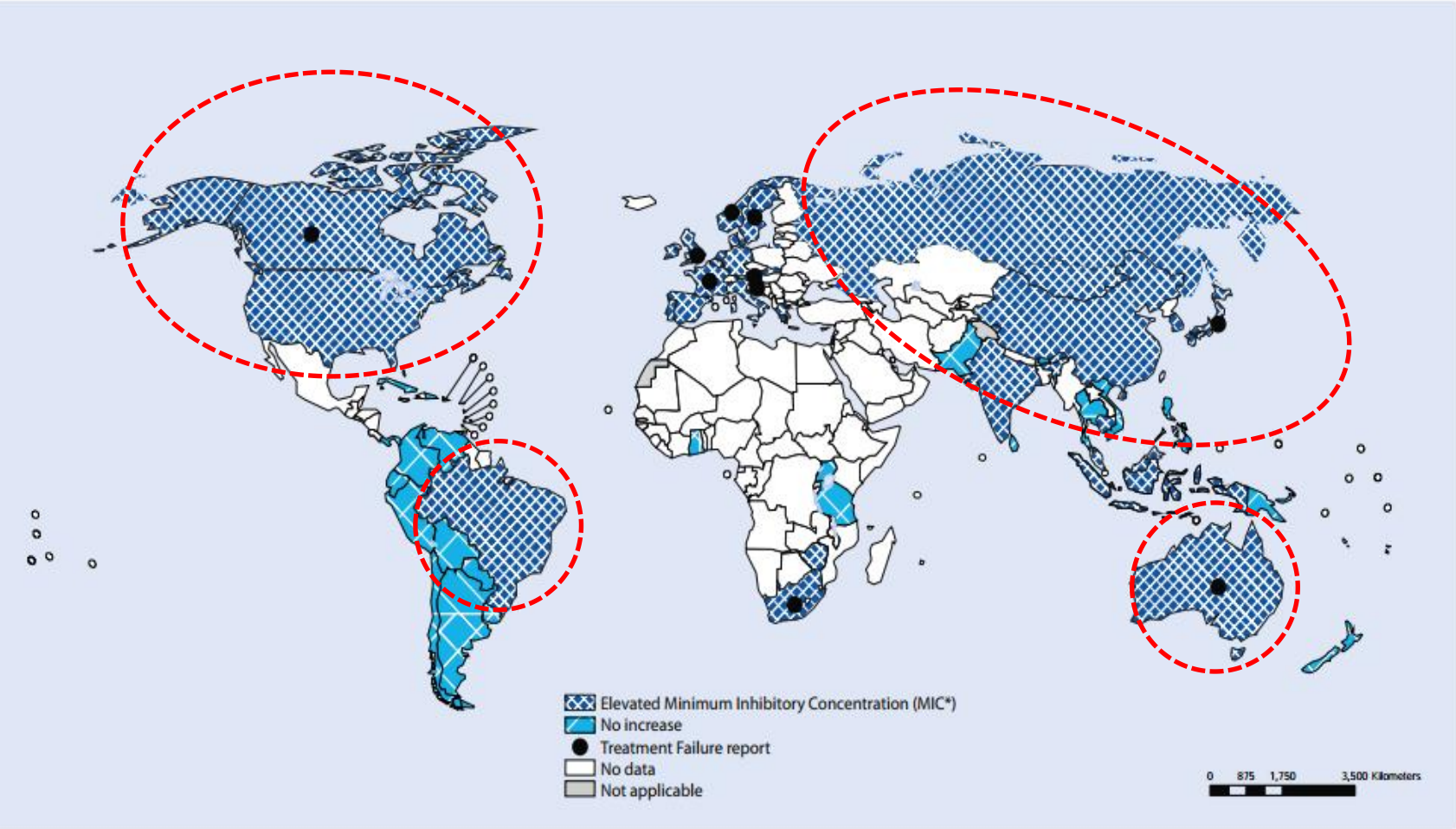
transposon

Spread of ARGs

Davies et al., 2010

Paul, et al., 2013

AMR - global challenge

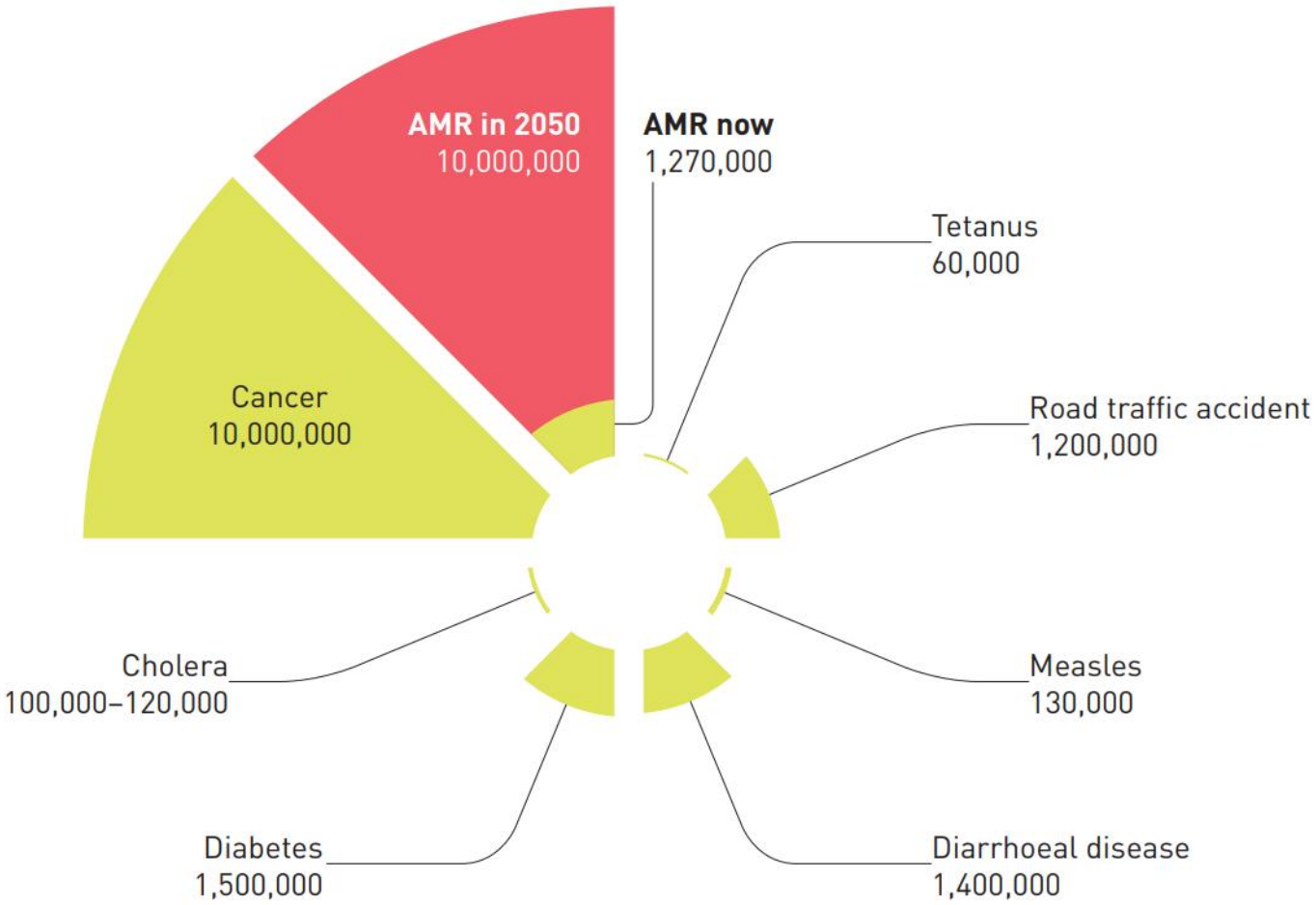


* Note: cefixime > 0.25µg/L or ceftriaxone > 0.125µg/L. The definition of decreased susceptibility to third-generation cephalosporins differs across AMR testing methods. Countries are shaded where there has been any report of decreased susceptibility within their jurisdiction.

WHO, 2014, Global decreased susceptibility to 3rd generation cephalosporins

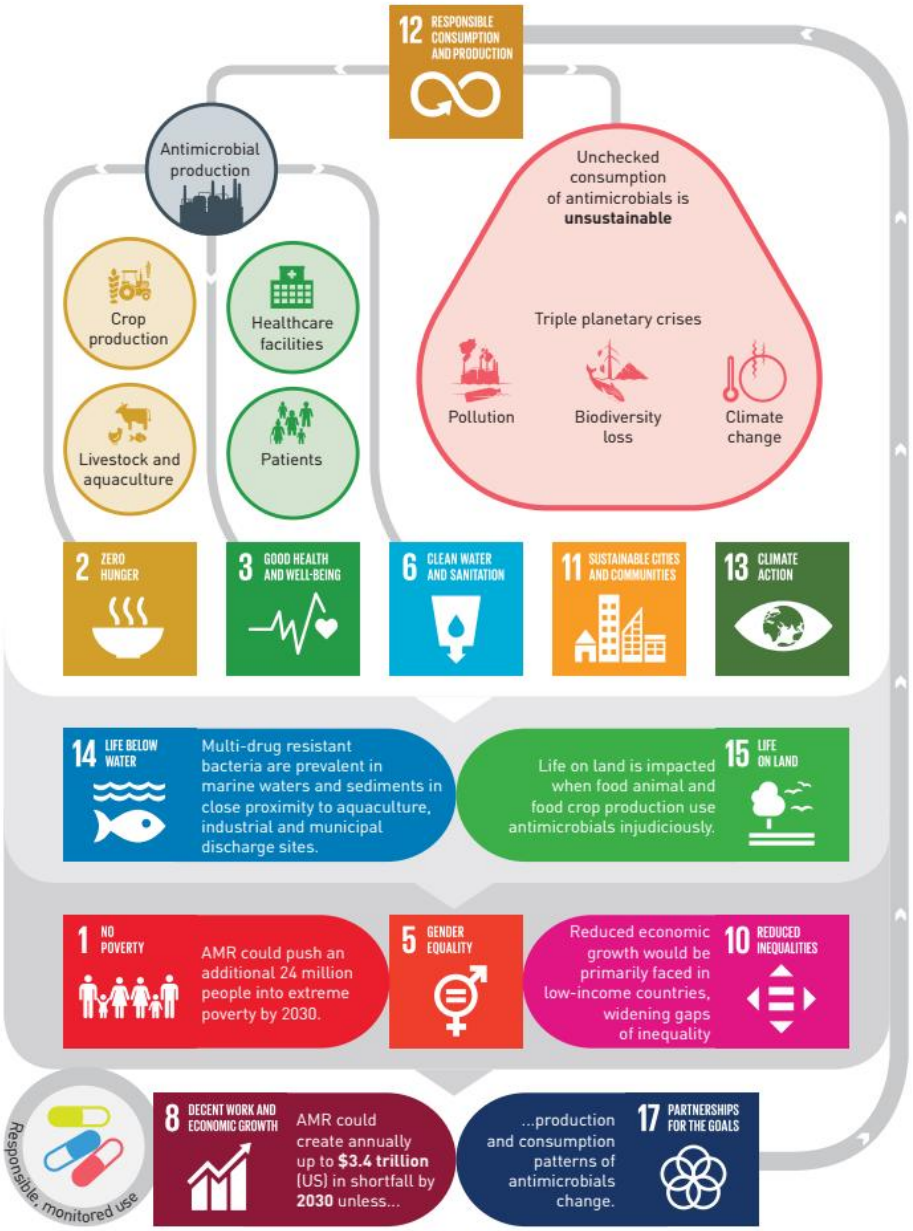
Post-antibiotic era

It is estimated that by 2050, human death caused by antibiotic resistance will be equal or more than that by cancer.

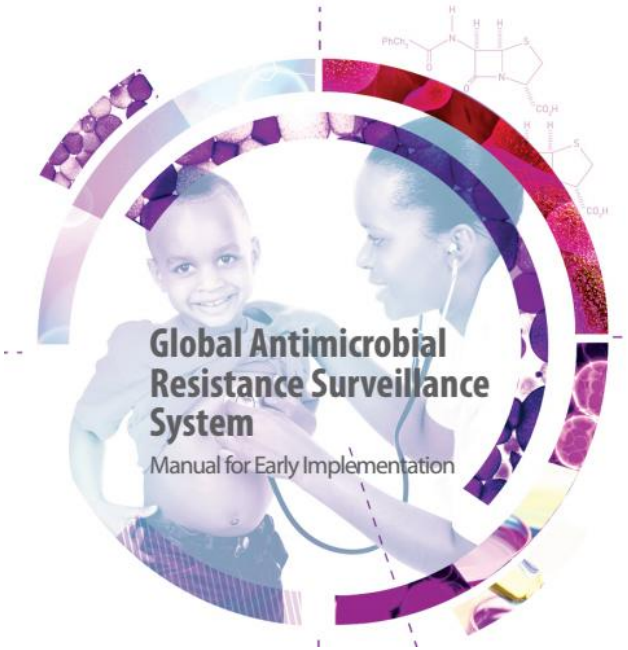


UNEP 2023, O'Neill, J. (2014).

Sustainable production and consumption of antimicrobials can impact many SDGs



UNEP 2023



Global surveillance system, 2015

WHO 2015

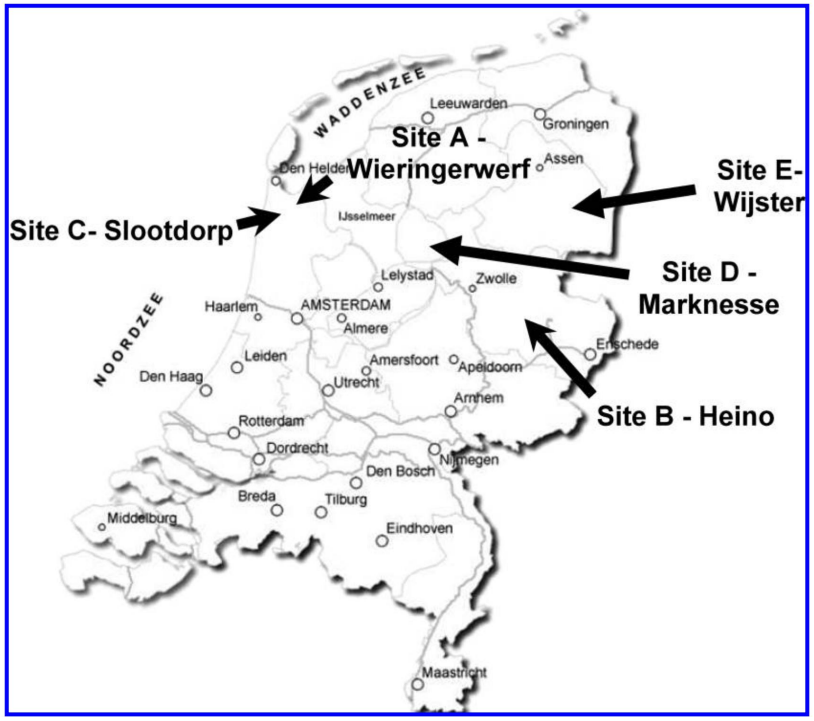
Increased antibiotic resistance gene (ARGs) abundance

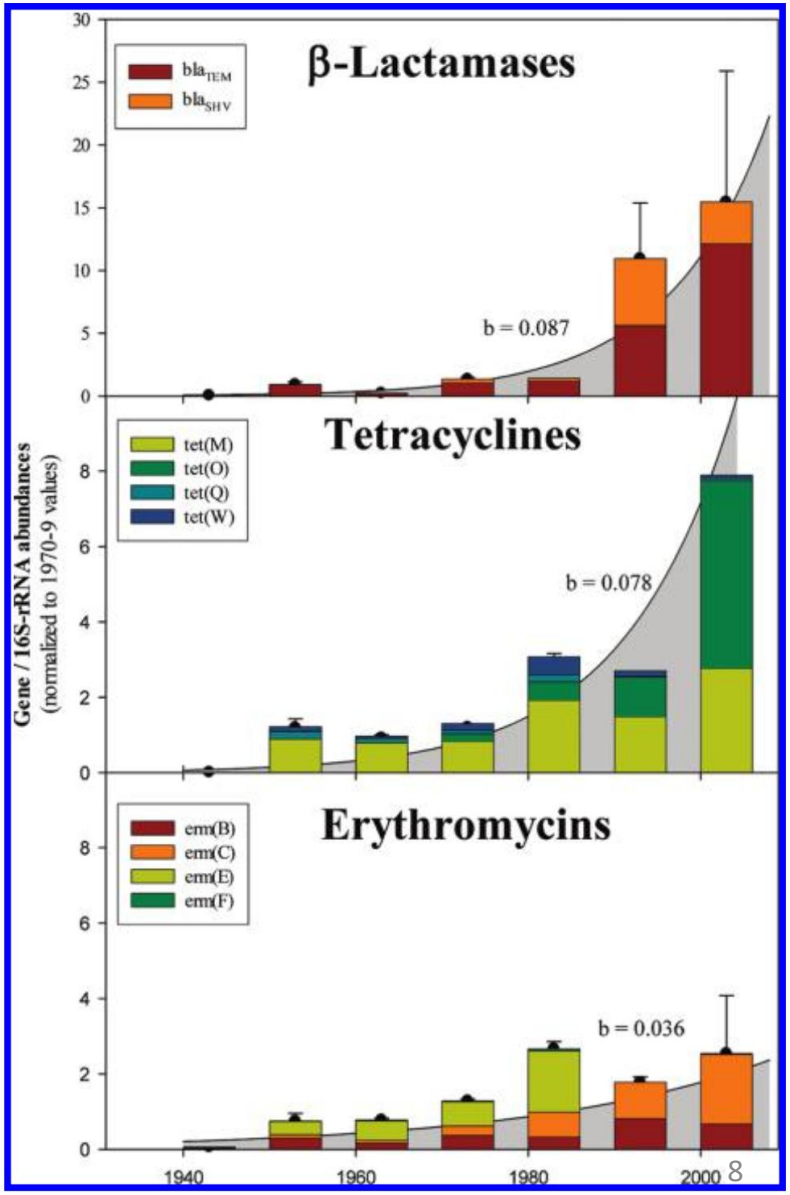
Evidence of Increasing Antibiotic Resistance Gene Abundances in Archived Soils since 1940

CHARLES W. KNAPP,[†,§] JAN DOLFING,[†] PHILLIP A. I. EHLERT,[‡] AND DAVID W. GRAHAM*[,†]

School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, United Kingdom NE17RU, and Alterra, Wageningen University and Research Center, Soil Science Centre 6700 AA Wageningen, The Netherlands

Received April 24, 2009. Revised manuscript received October 6, 2009. Accepted December 8, 2009.





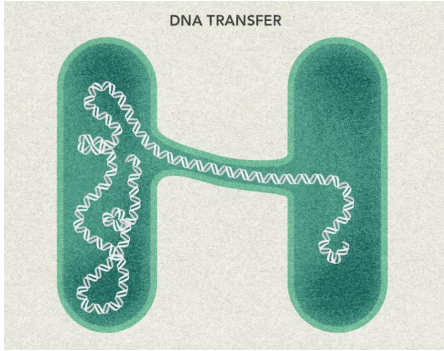
ARGs in the environments

- **Transmission of microbes and ARGs**

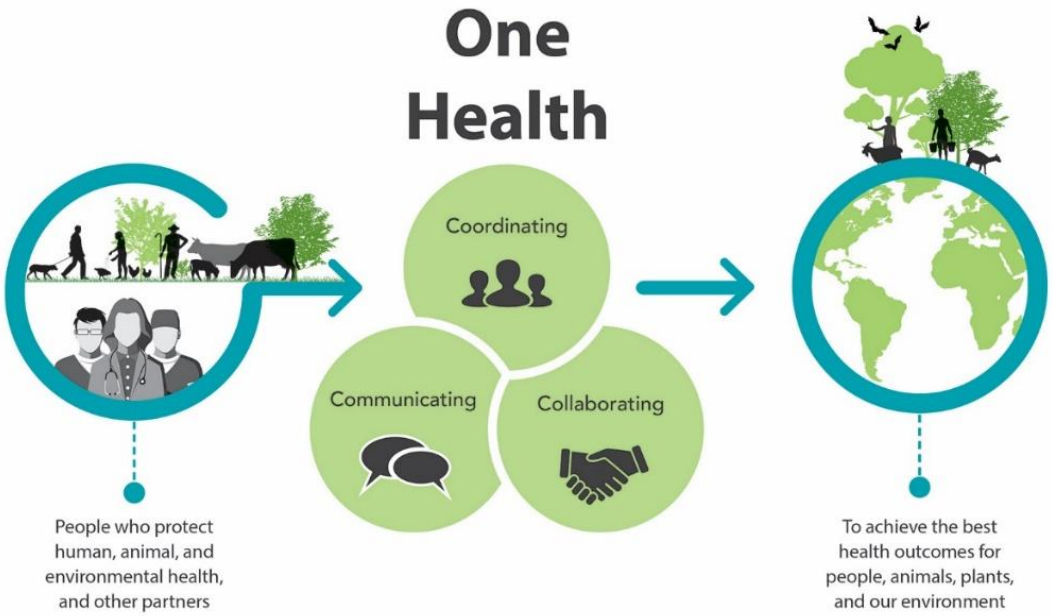
  human – animal - environment

- **One health**

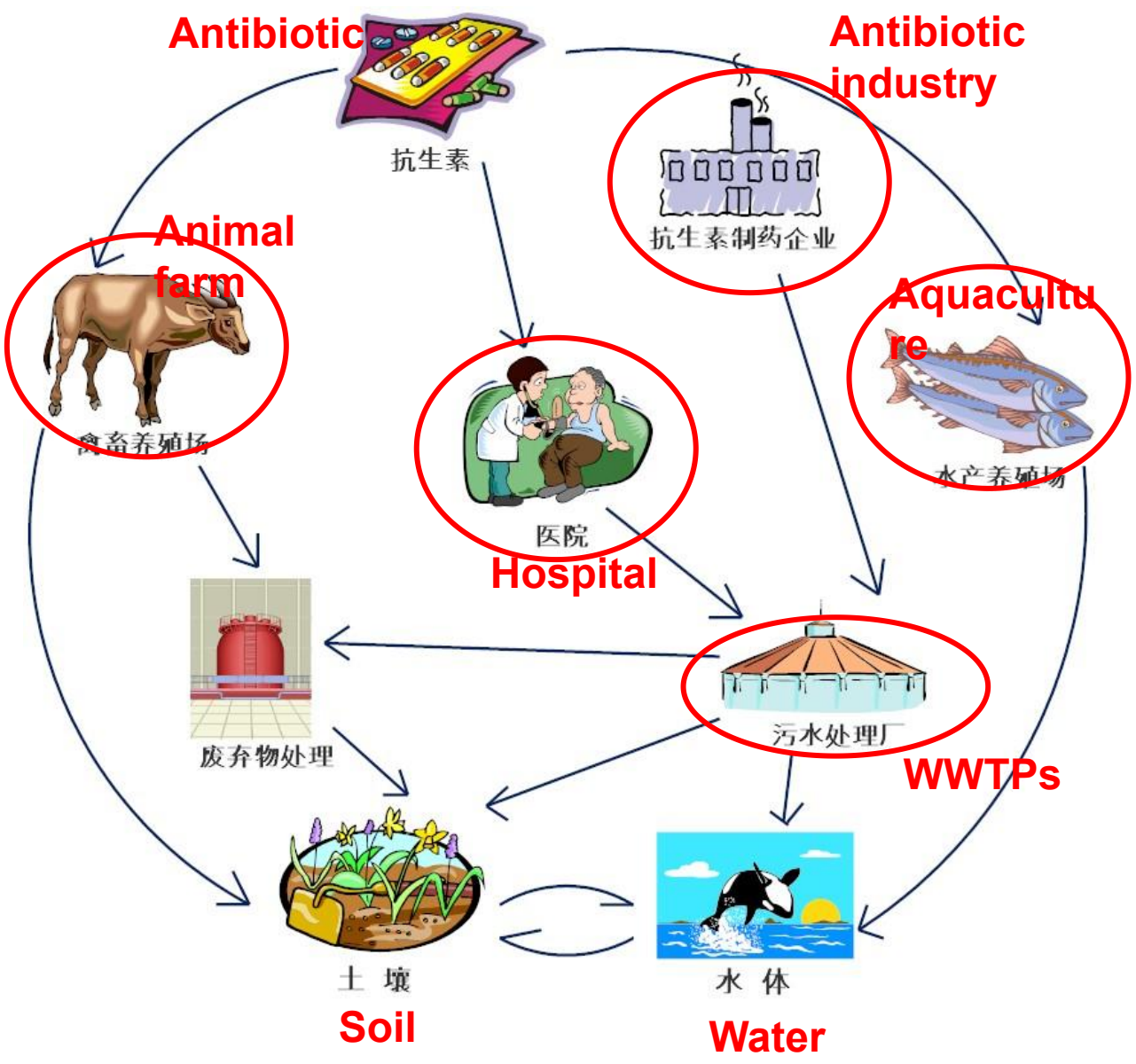
  human – animal – environment health



Threatening human health



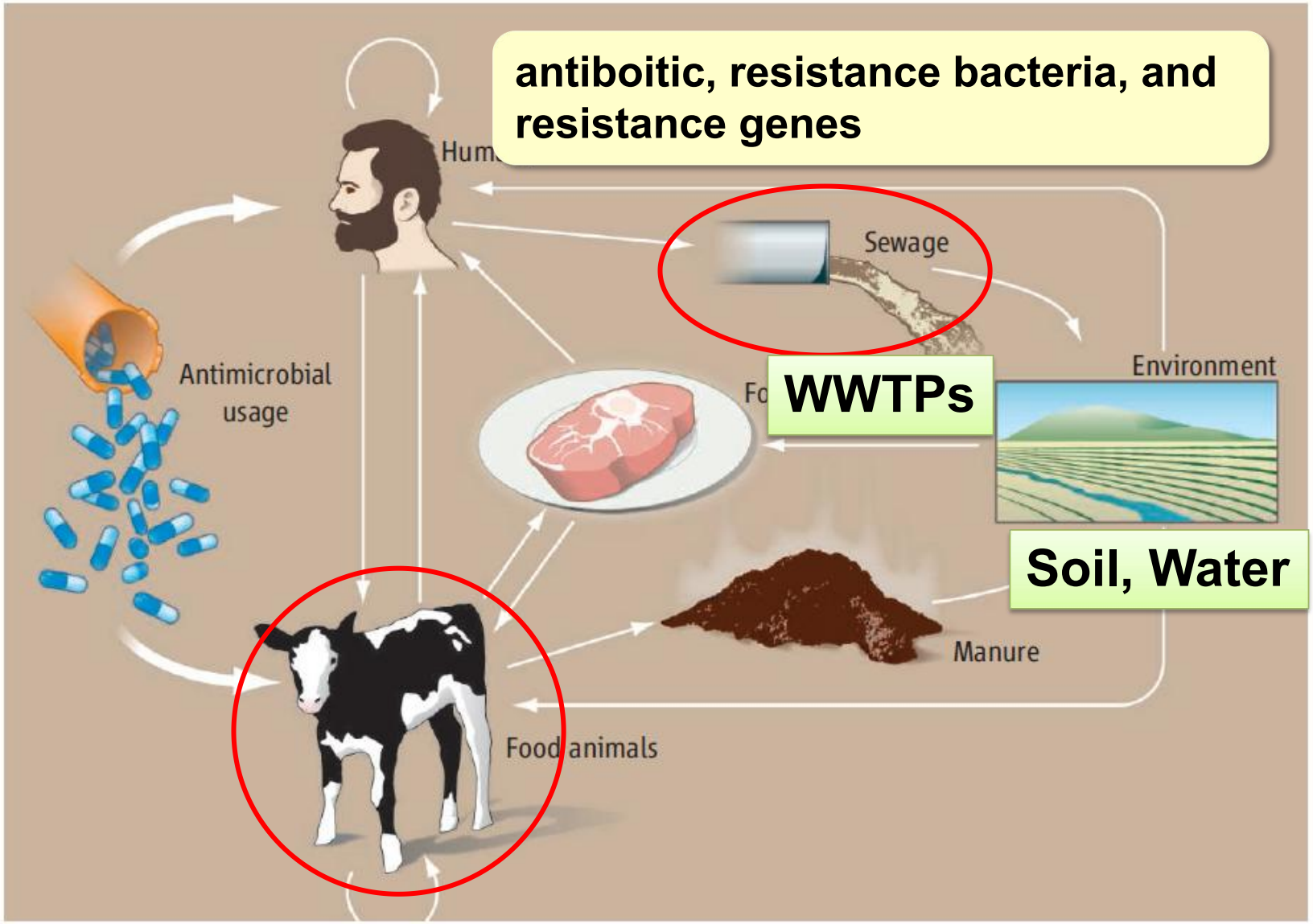
ARGs – biological contaminant



- Transmission
- Proliferate
- Exchange

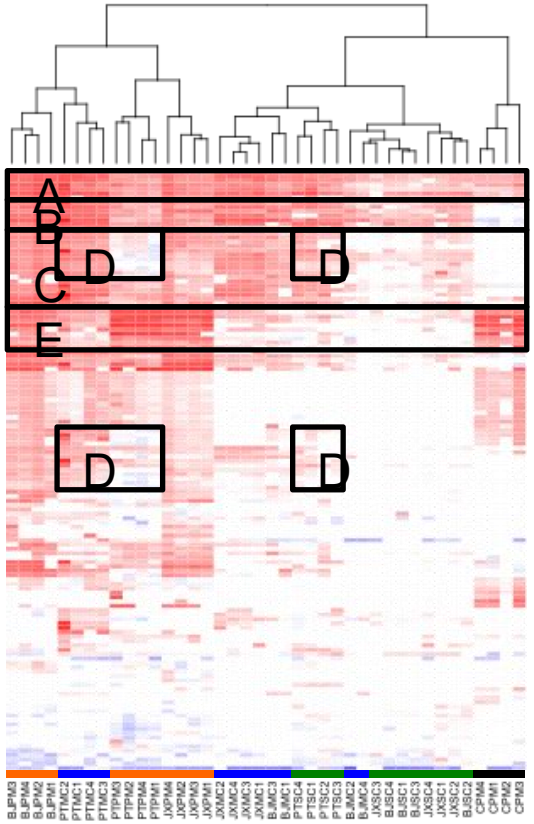
- Distribution and spread

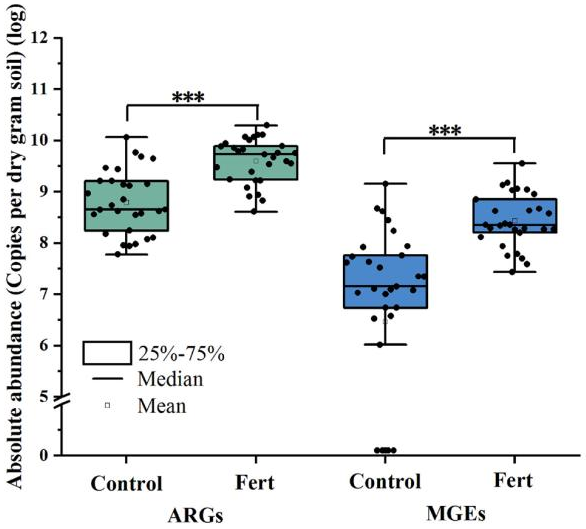
Hotspots: WWTPs, Livestock farms

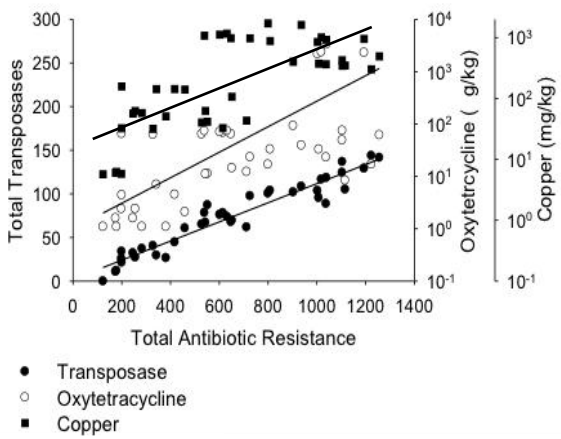


Woolhouse and Ward, 2013, Science 341: 1460-1461

Livestock farms







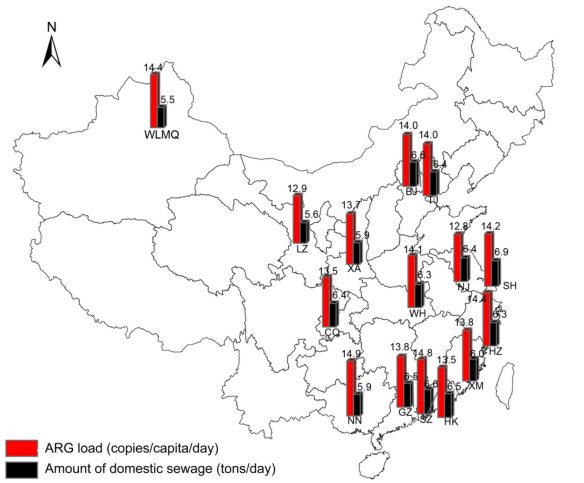
- Detect diverse ARGs in swine farms
- Application of manure or manure compost lead to enrichment of ARGs in soil
- Metals and antibiotics

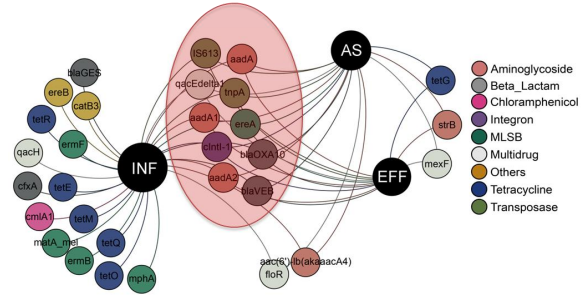
Zhu et al. PNAS, 2013

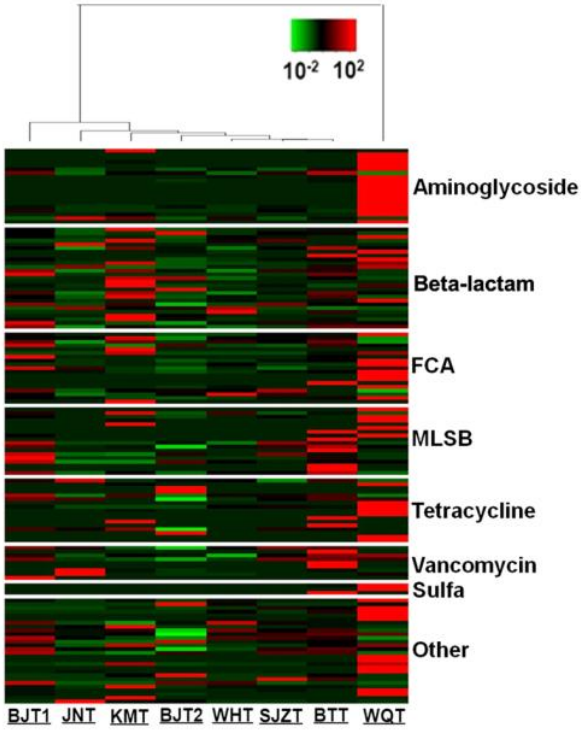
Su et al. EI, 2014

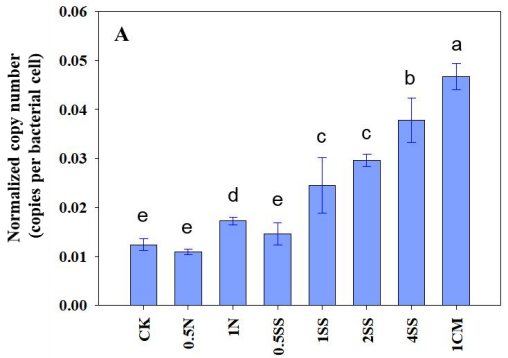
Pu et al., JHM, 2020

WWTPs









- Spatial and temporal Distribution of ARGs in urban sewage in China
- Discharge of effluent and sludge lead to enrichment of ARGs in soil

Su et al. Microbiome, 2017

Wang et al. EST 2014
An et al. AEM, 2018

Chen et al., Environment International, 2016
Chen et al., ES&T, 2017

- **Anthropogenic factors**

  is the major factor influencing ARG profiles in estuaries

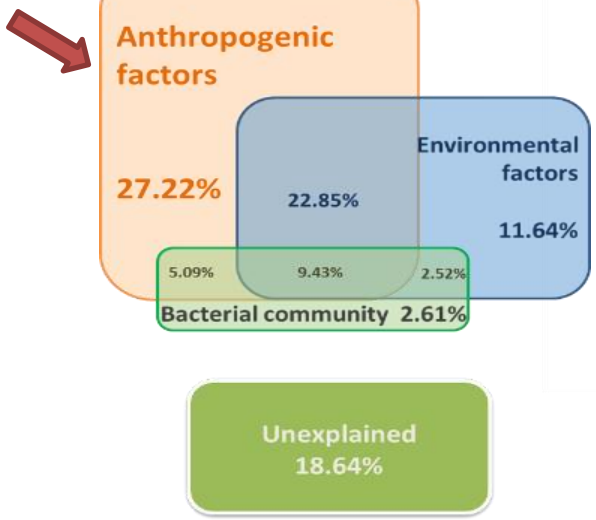
nature microbiology

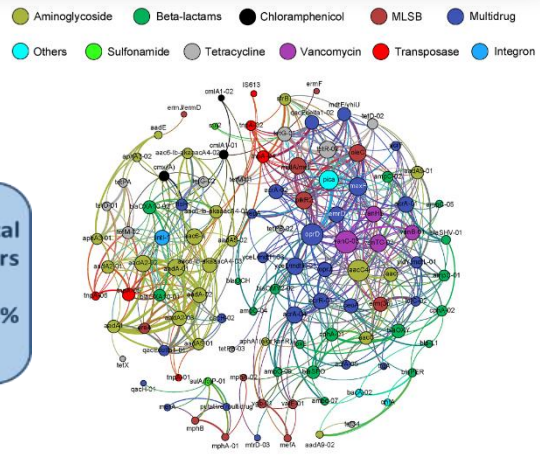
ARTICLES

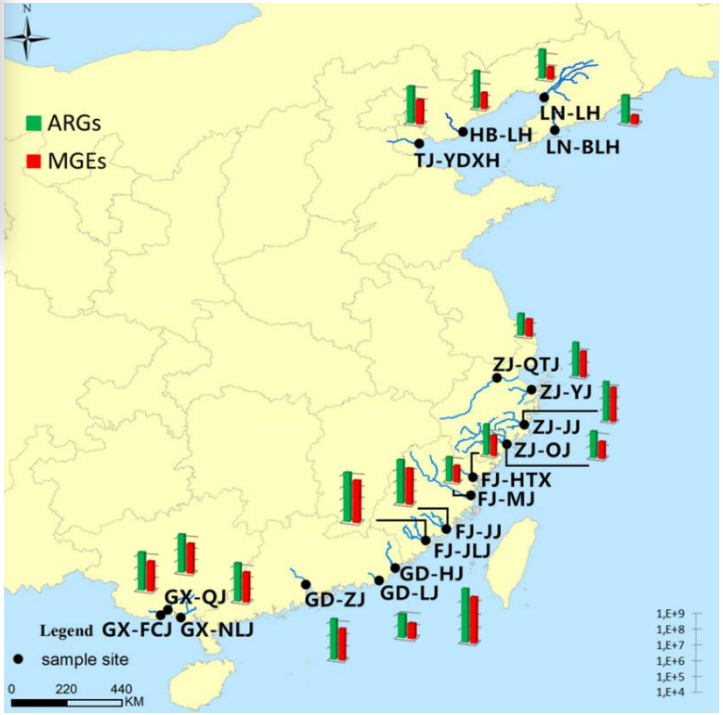
PUBLISHED: 30 JANUARY 2017 | VOLUME: 2 | ARTICLE NUMBER: 16270

Continental-scale pollution of estuaries with antibiotic resistance genes

Yong-Guan Zhu[1,2*†], Yi Zhao[1†], Bing Li[3], Chu-Long Huang[1], Si-Yu Zhang[2], Shen Yu[1], Yong-Shan Chen[1], Tong Zhang[4], Michael R. Gillings[5] and Jian-Qiang Su[1*]



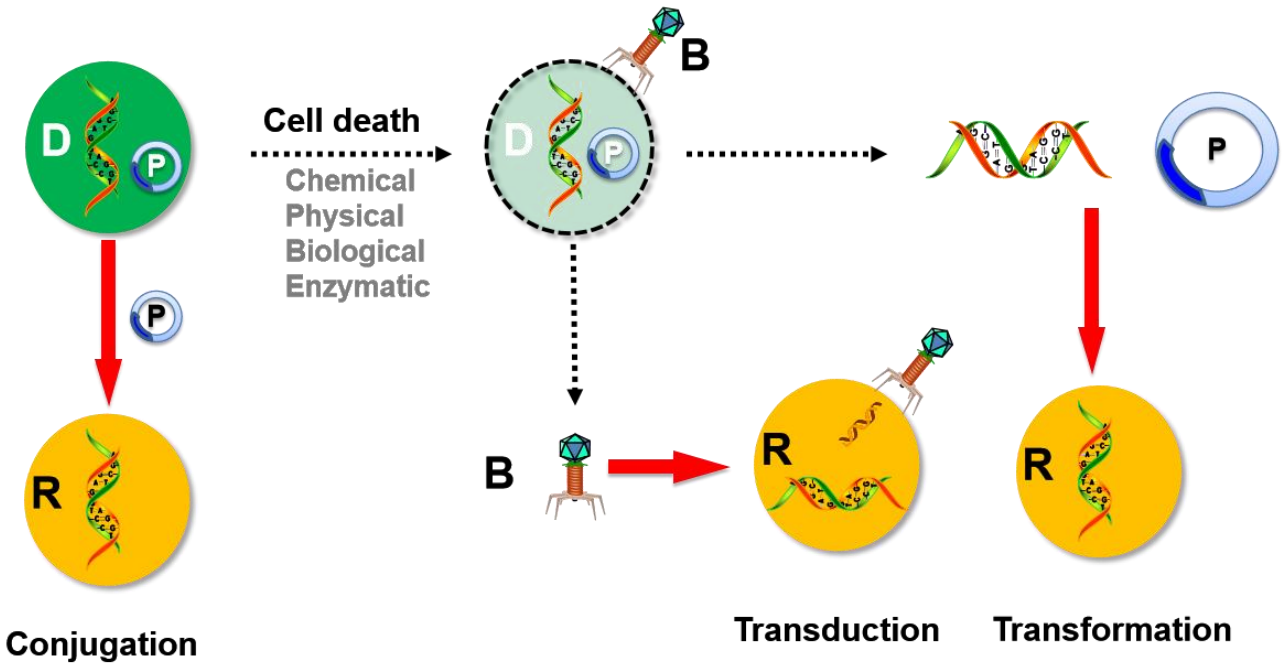




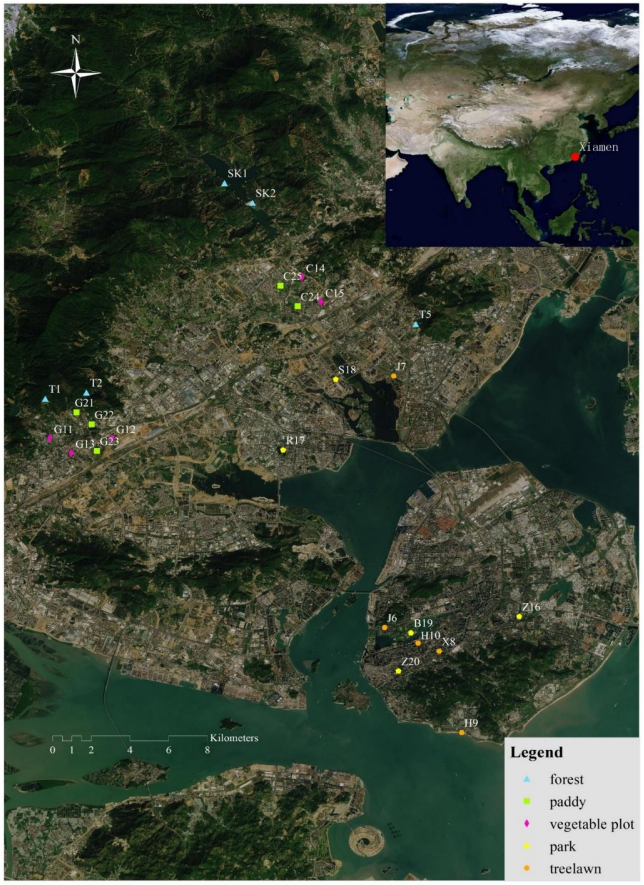
Zhu et al., Nature Microbiology, 2017.

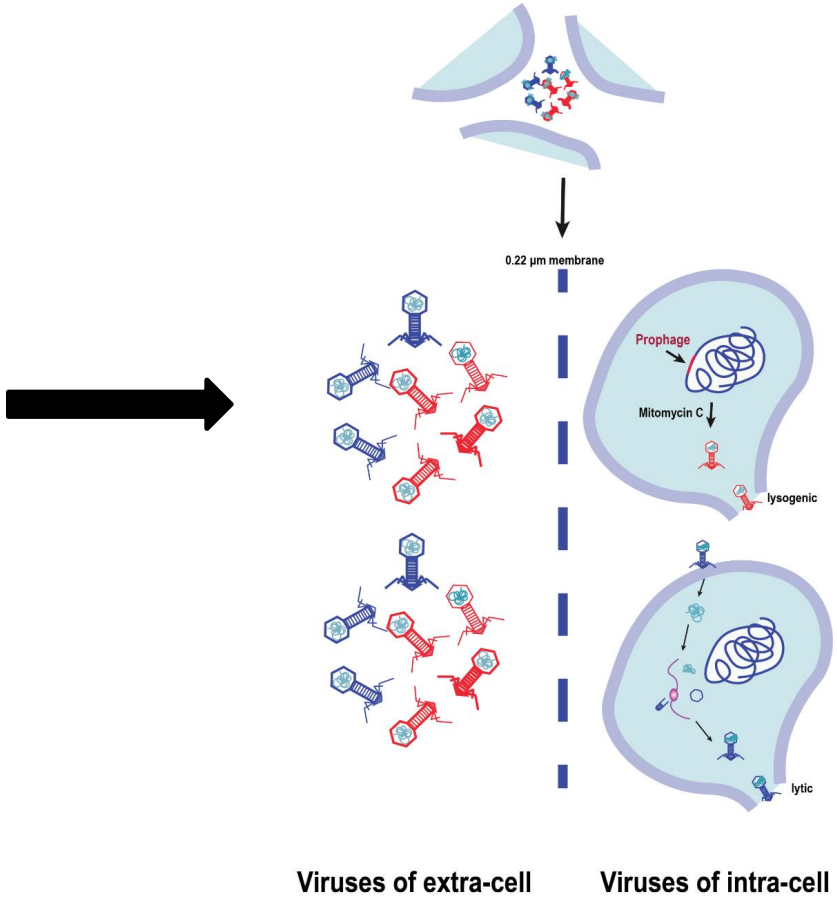
Questions

- Input of exogenous ARGs or proliferation of indigenous ARGs?
- What is the major MGEs for the transfer of ARGs, Plasmid or Phages?



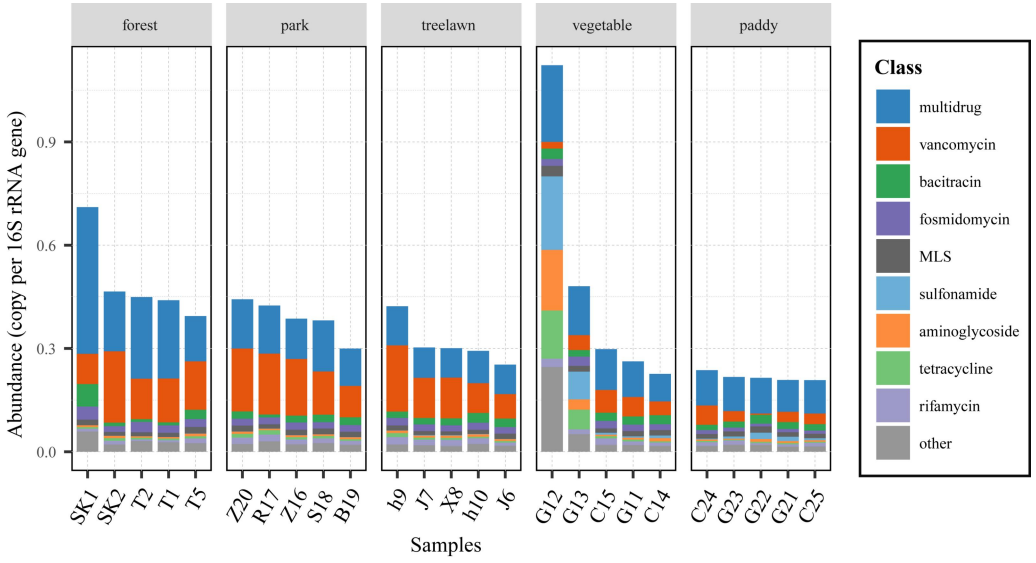
- Metagenomic and viromic sequencing

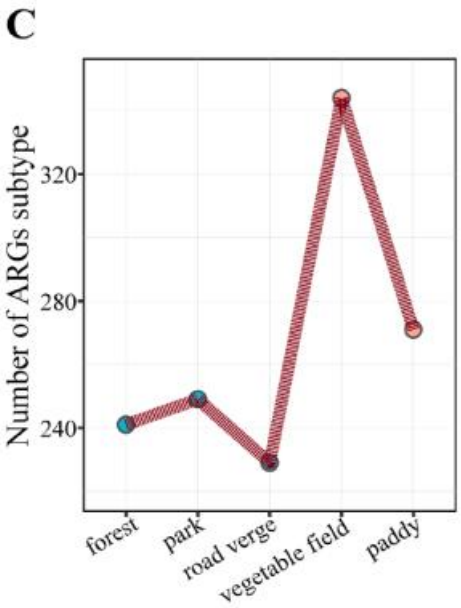




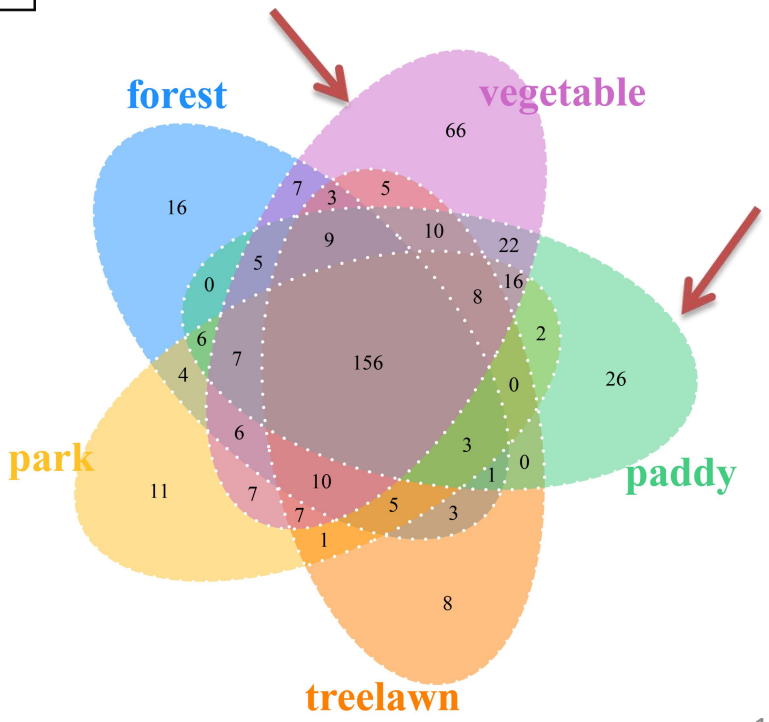
- **Forest**
- **Agriculture: vegetable soil, paddy soil**
- **Urban soil: park soil, road verge soil**

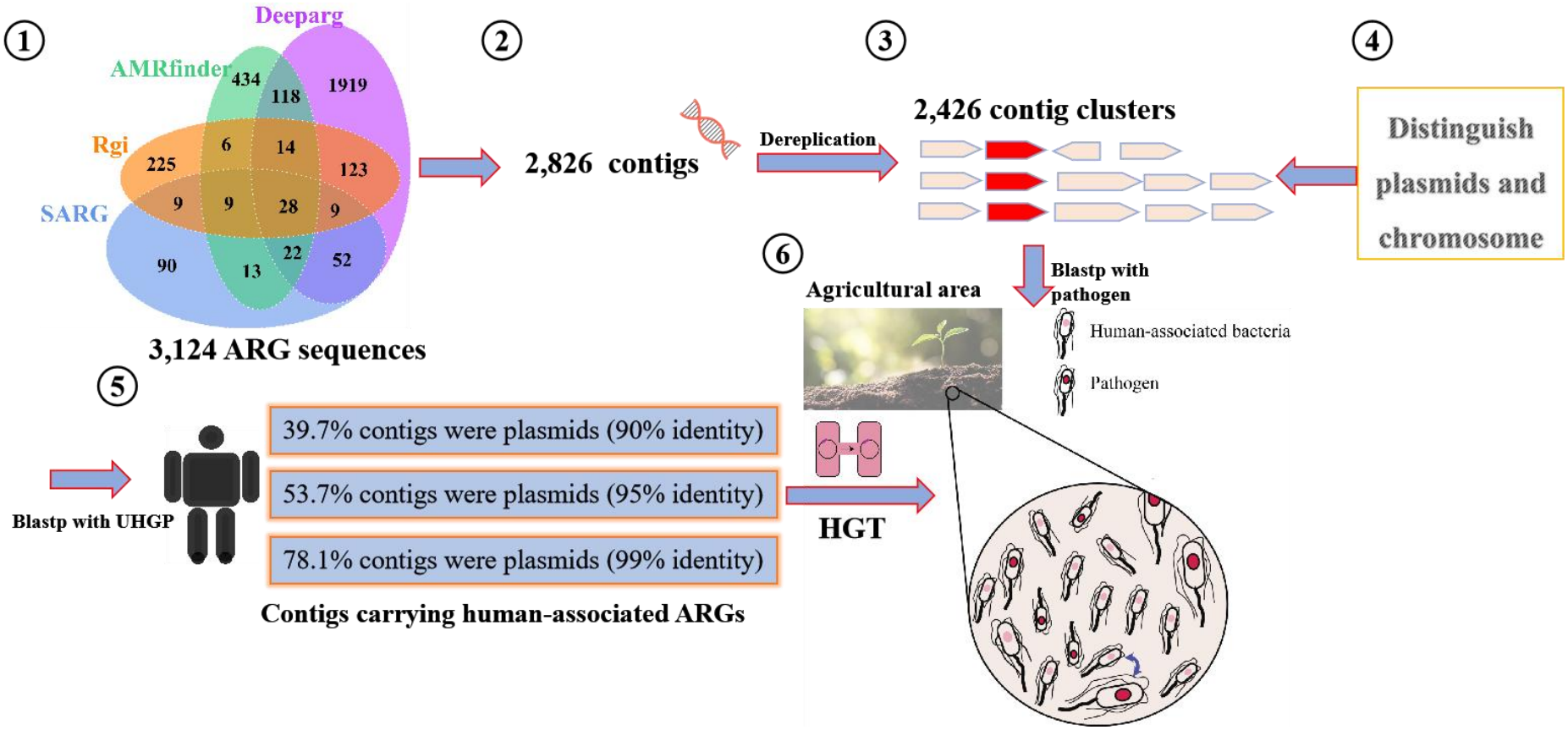
➢ ARG diversity and abundance





- Higher diversity in AG
- More unique ARGs in AG



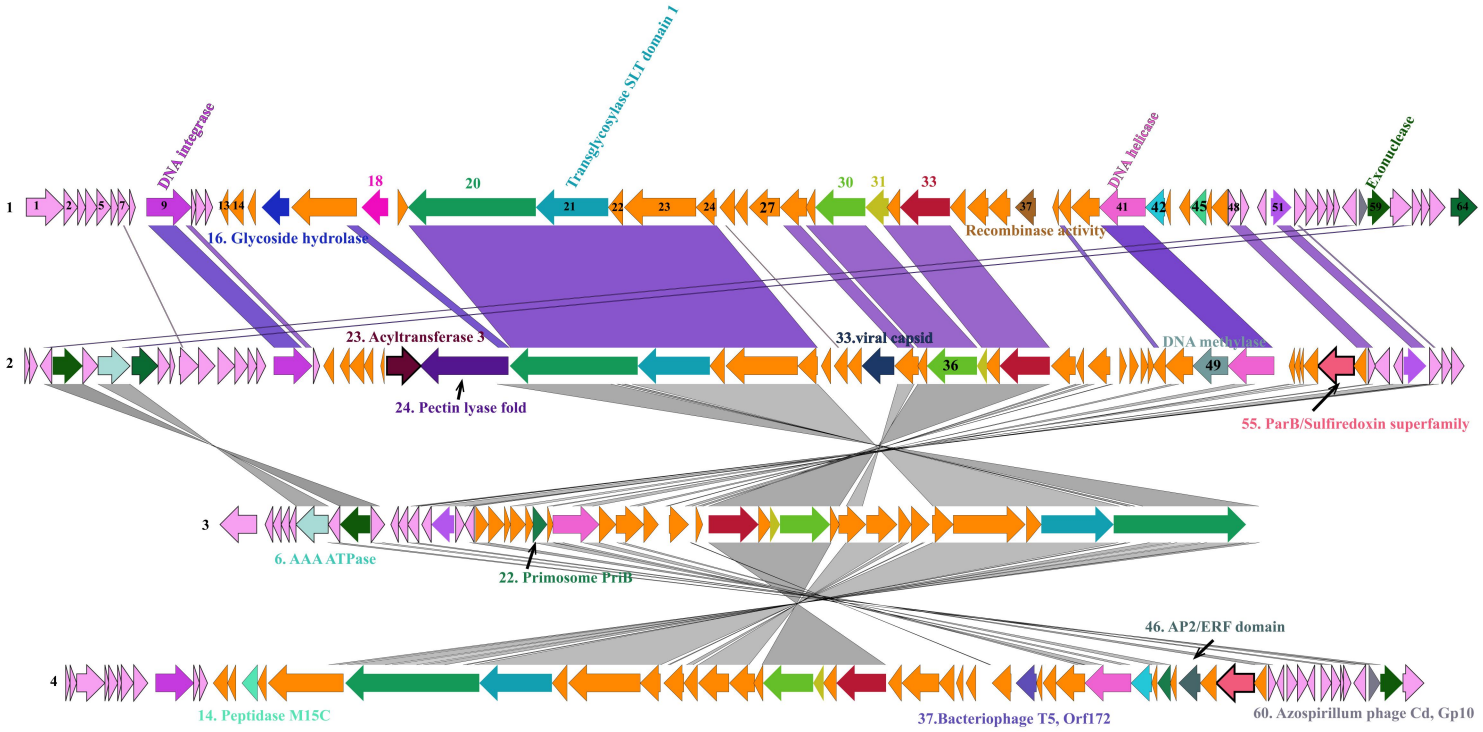


- **Metagenome assembling: 2426 contigs, 3124 ARGs， 15% plasmid**
- **Pathogen related: 32 contigs， 43 ARGs， 80% plasmid**
- **All from agricultural soil**

Clinical relevant ARG-carried plamids

➢ Phage encoded ARGs?

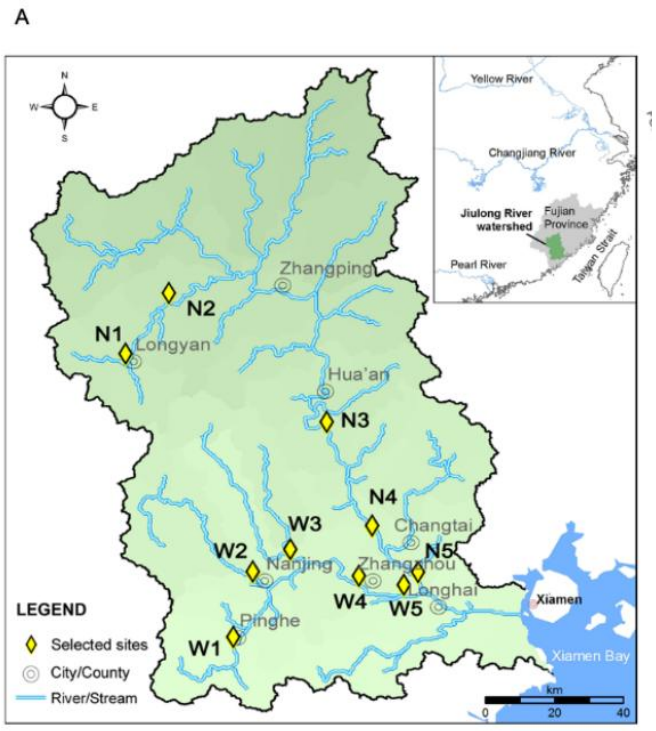
- 59626 phage genomes from soil virome
- 2,622,088 genes
- **Only 17 ARGs，soil phages rarely carry ARGs**



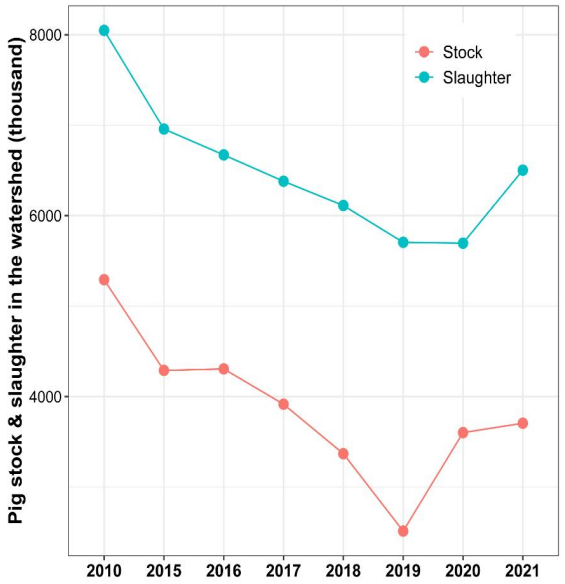
Liao et al., NC 2022， EI，2022

Reduction of ARGs

- Livestock farming is the major factor
- Restriction on Livestock farming - reduce ARGs?
- From 2010, gradually closure of farms near waterbodies



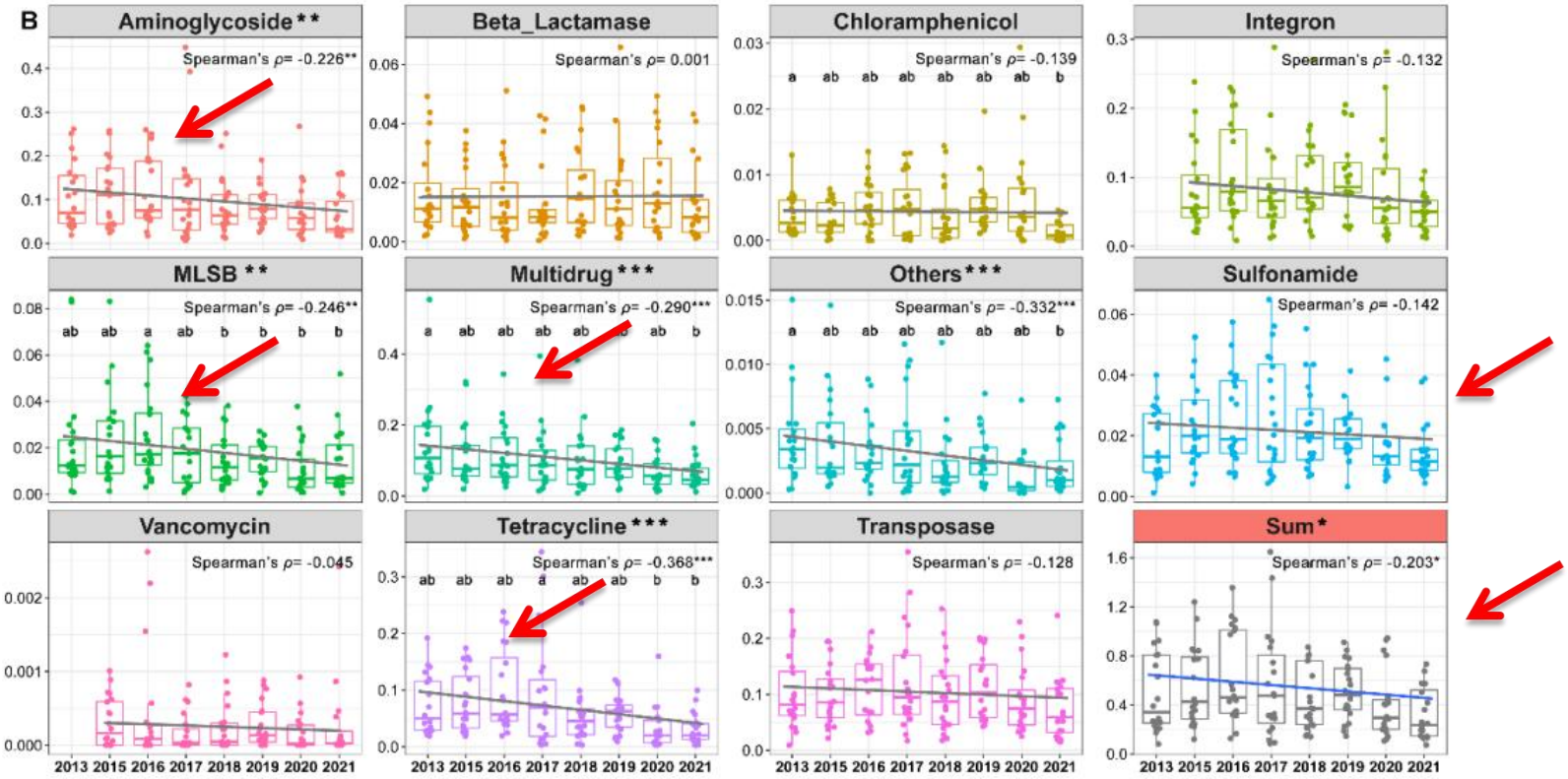
Jiulong River
Drinking water source

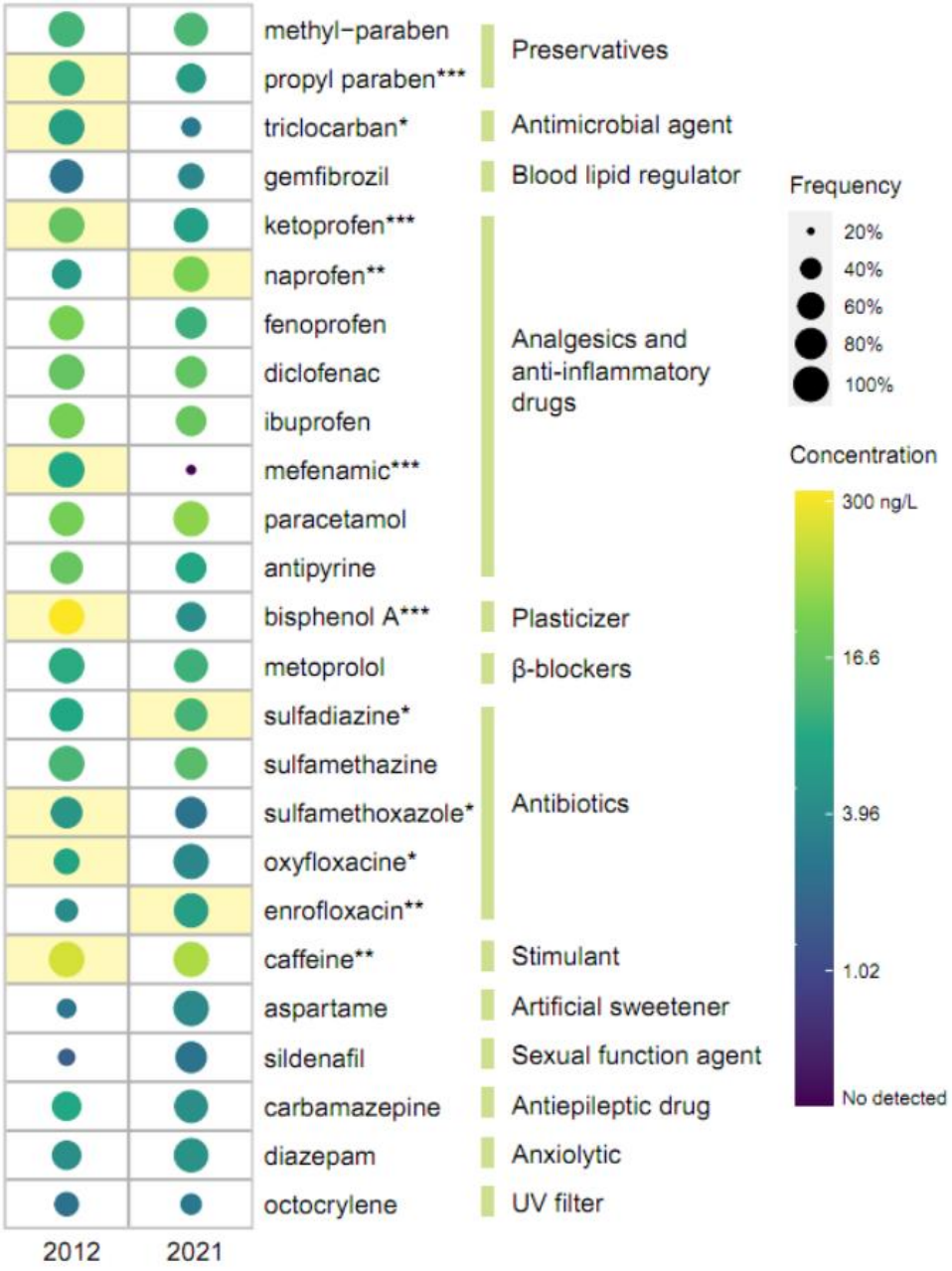


Decline in the pig stock and slaughter

Reduction of ARGs

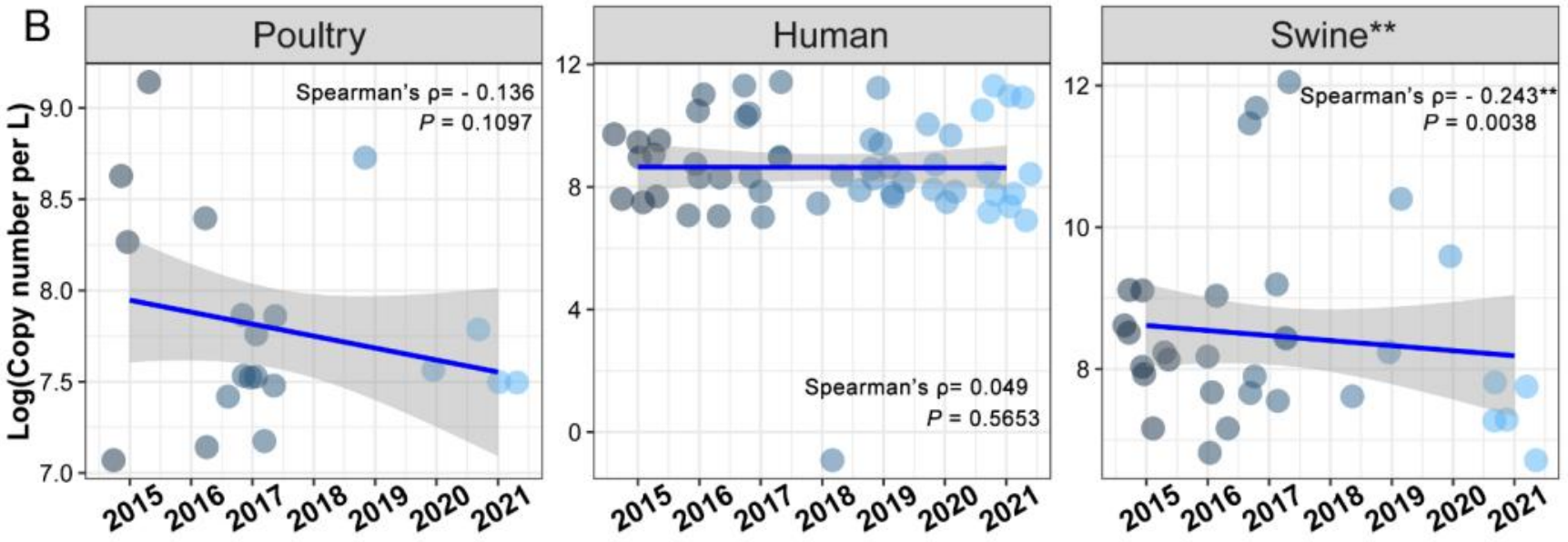
- Nine-year surveillance
- Reduction of total ARG abundance
- Aminoglycosides, Macrolides, Tetracyclines, Sulfonamides, and multidrug





- Antibiotic residues and other PPCPs remain at a similar low level
- Selection of ARGs by these chemicals may not be the major reason

- Decline in swine and poultry fecal indicators
- Human fecal indicator remain at a similar level



- Reduction of ARGs in the river should be attributed to less input of ARGs from animal waste

Unpublished data

Tackle AMR in the environment

- Promote awareness and incorporate environmental considerations into National Action Plans on AMR
- Improve environmental surveillance and monitoring systems
- Evaluate the impact of chemical pollutants on the evolution and spread of AMR
- Develop or optimize technology for wastewater treatment and waste treatment to reduce AMR
- Translate current knowledge into environmental legislation

Thank you for attention