Global One Health and Role of –Omics in Strengthening Integrated Capacity to Address Food- and Waterborne Diseases

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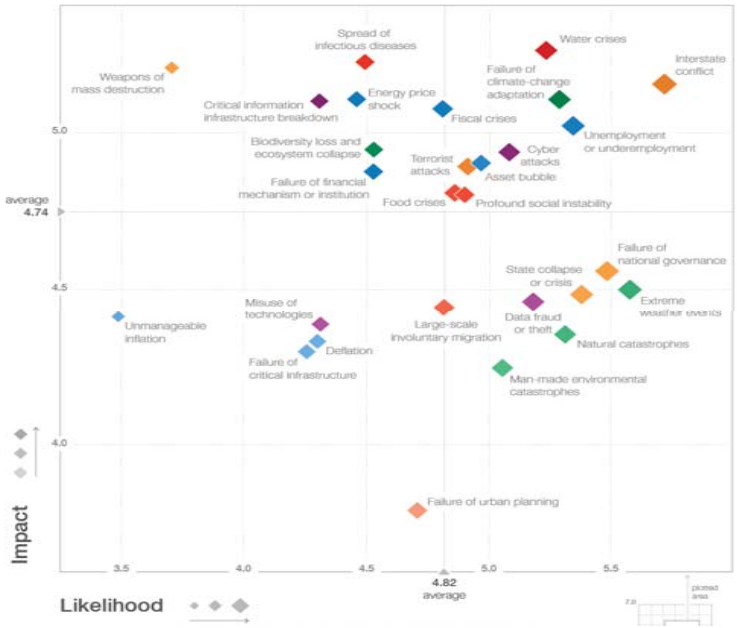
Global Water Food Safety Summit
November 19-21, 2019 (College Park, MD)

Role in the changing global dynamics.

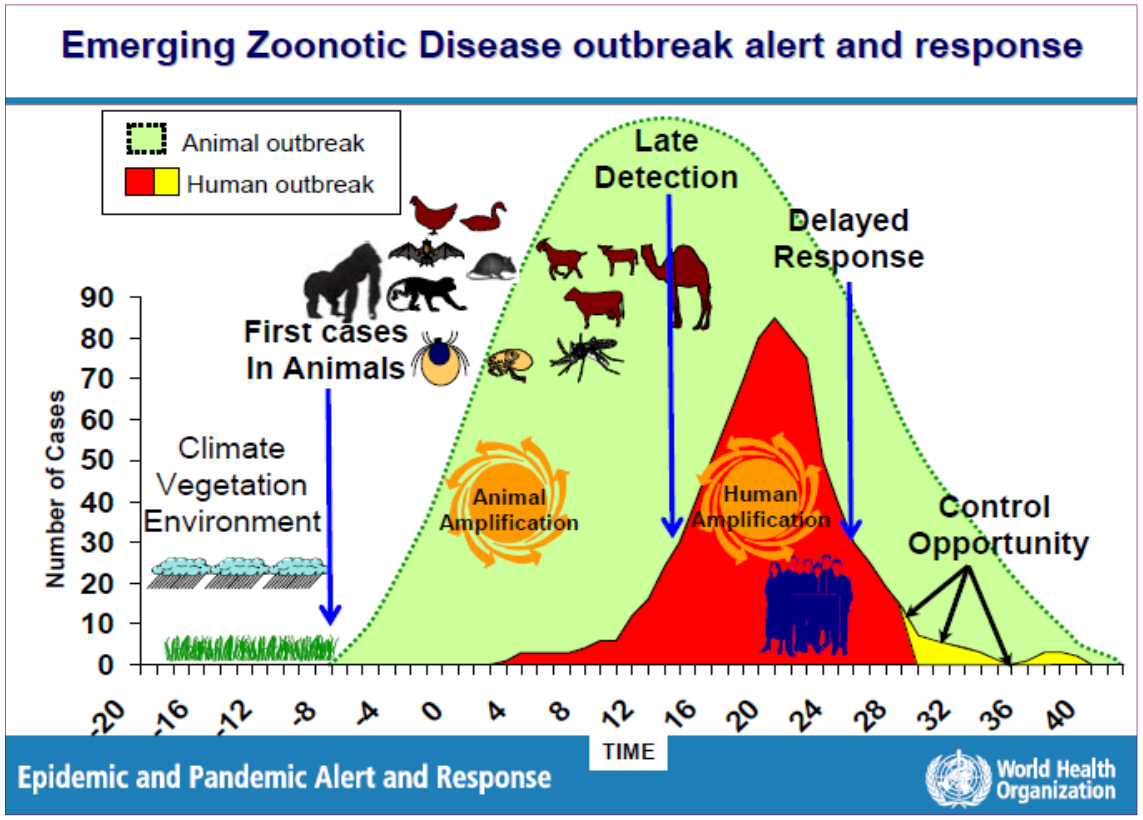
The Global Risk

- Spread of infectious diseases;
- **Water crises**;
- Failure of climate change adaptation;
- Global travel;
- Man-made environmental catastrophes;
- Biodiversity loss and ecosystem collapse;
- Large-scale migration, conflict, refugees

Consequences – Very complex, wider in spectrum.



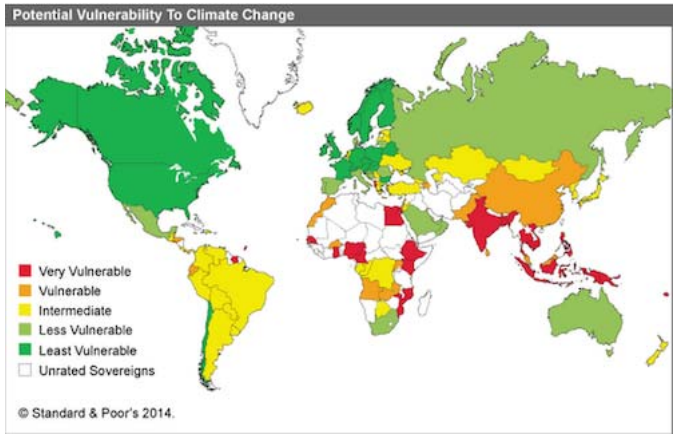
Global Risk Forum, 2016

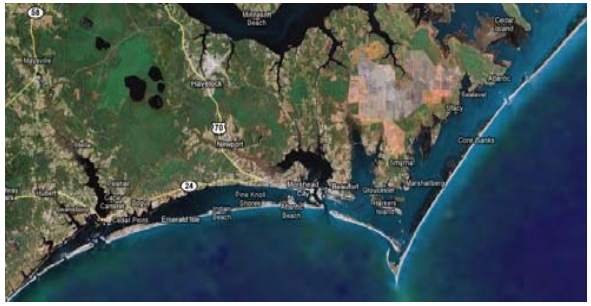

Emerging Zoonotic Disease outbreak alert and response
Animal outbreak
Human outbreak
Late Detection
Delayed Response
First cases In Animals
Climate Vegetation Environment
Animal Amplification
Human Amplification
Control Opportunity
Number of Cases
90
80
70
60
50
40
30
20
10
0
-20
-16
-12
-8
-4
0
4
8
12
16
20
24
28
32
36
40
TIME
Epidemic and Pandemic Alert and Response
World Health Organization

An expanded paradigm

http://resources.nationalacademies.org/widgets/Food-origins/flashfile/Food%20origins.html?keepThis=true&

Climate change and water-borne diseases





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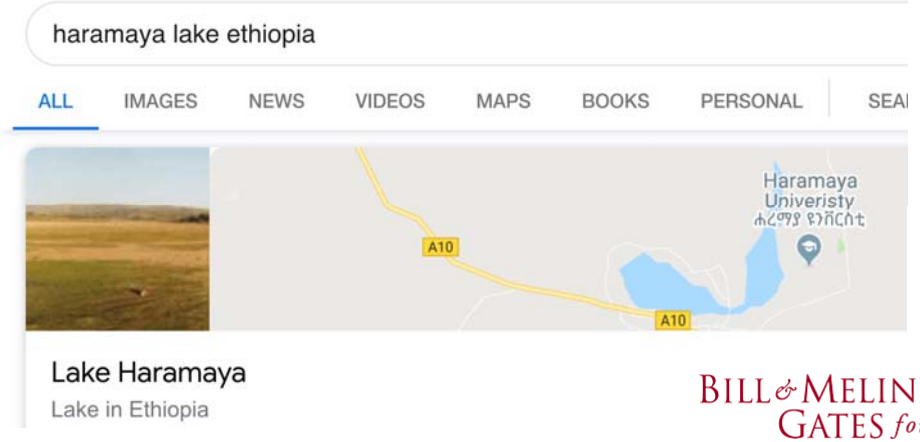
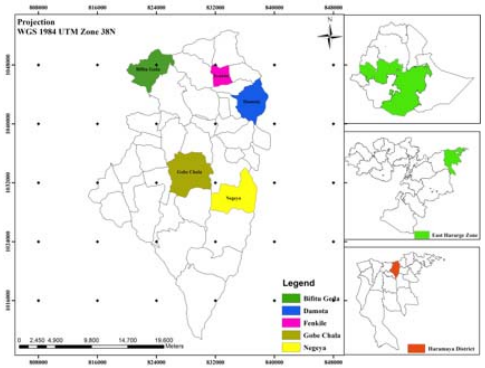
Environmental Enteric Dysfunction (EED)

Impact of water availability on sanitation- Foodborne Pathogens

- Reduced colonization by *Campylobacter*, in children, improve sanitation and hygiene to reduce the prevalence of Environmental Enteric Dysfunction (EED) and thus childhood stunting.
- Haramaya University, Eastern Ethiopia and UFL (USA)

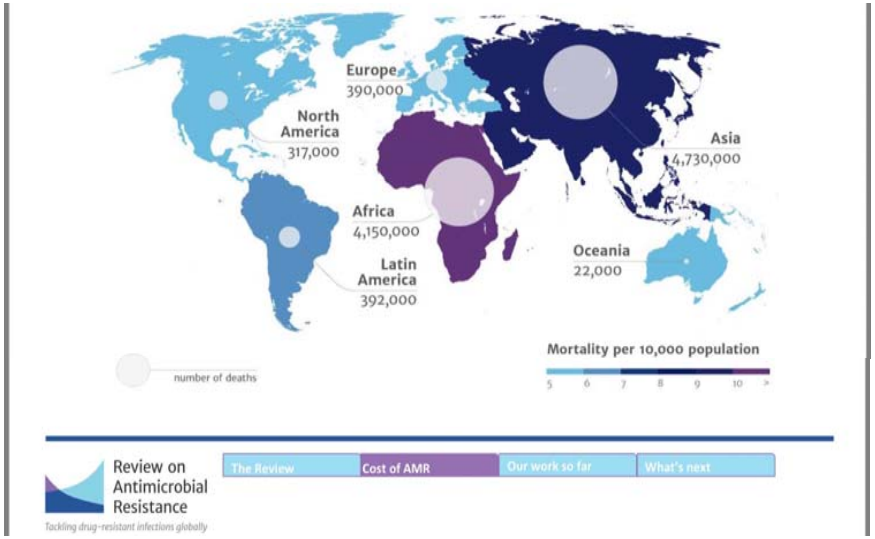


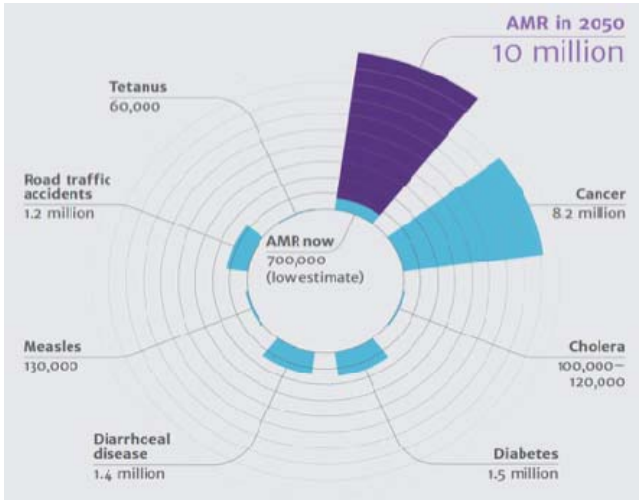
BILL & MELINDA GATES foundation



The Added Burden of Antimicrobial Resistance (AMR)

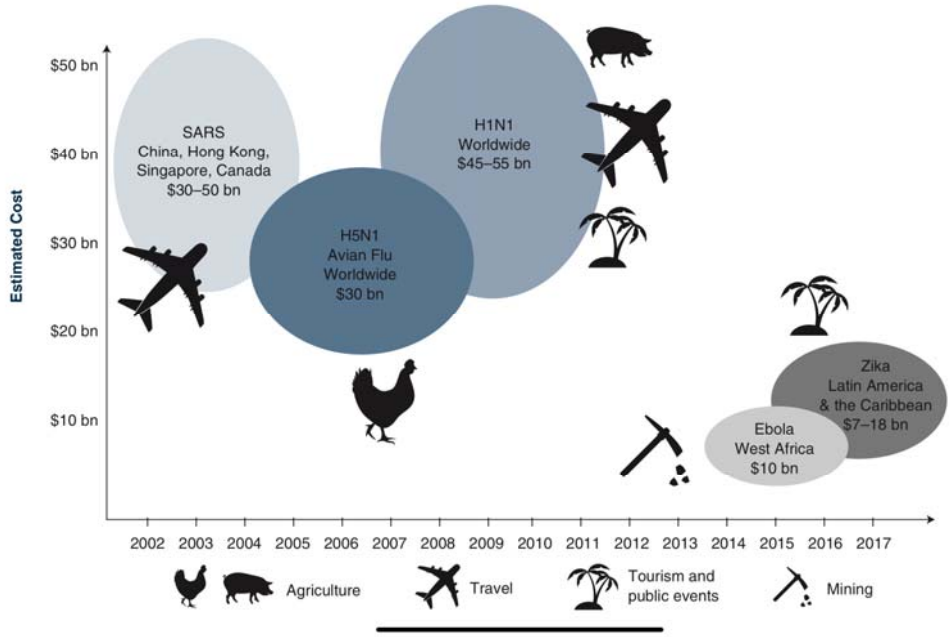
Global Public Health ~~priority~~ Crisis





Cumulative economic impact of AMR, > $100 Trillion by 2050.

Economic Impact of One Health issues- Zoonotic Food-Water- and vector-borne Diseases



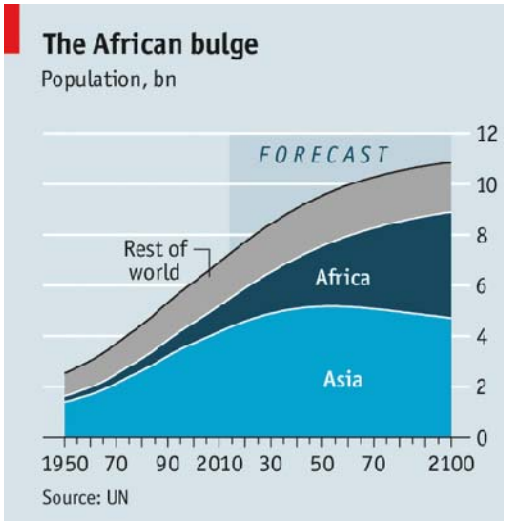
"As a physician, the issue of antimicrobial resistance—or AMR—is very familiar to me. …The problem goes beyond hospitals. Antimicrobial resistance crosses boundaries of nations, sectors, and even species—affecting livestock, crops, and wildlife...

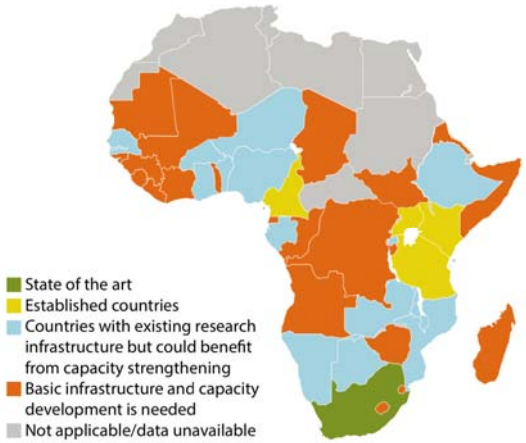
The World Bank is coordinating efforts across agricultural, environmental, and health sectors under the umbrella of One Health—"

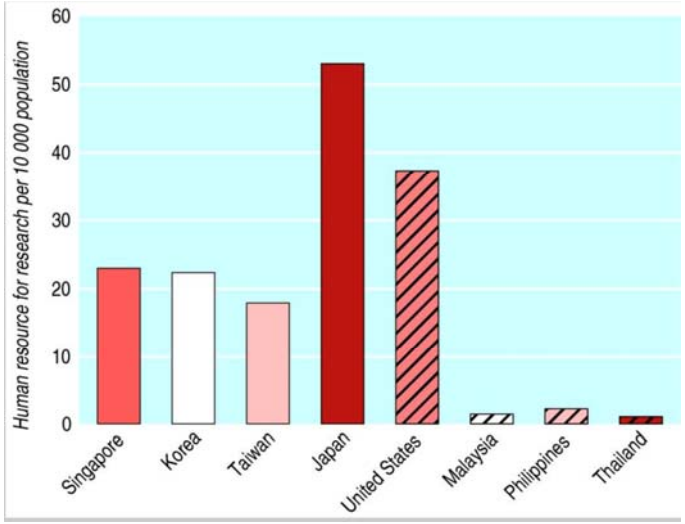
Dr. Jim Yong kim, 2014
President (Former)

WORLD BANK GROUP

Population, Global Preparedness on Research Capacity







Sitti-Amorn et al., BMJ (2000)

Demand for Animal Source Food (ASF) and water is increasing at high rate.

Global investment on Health Research

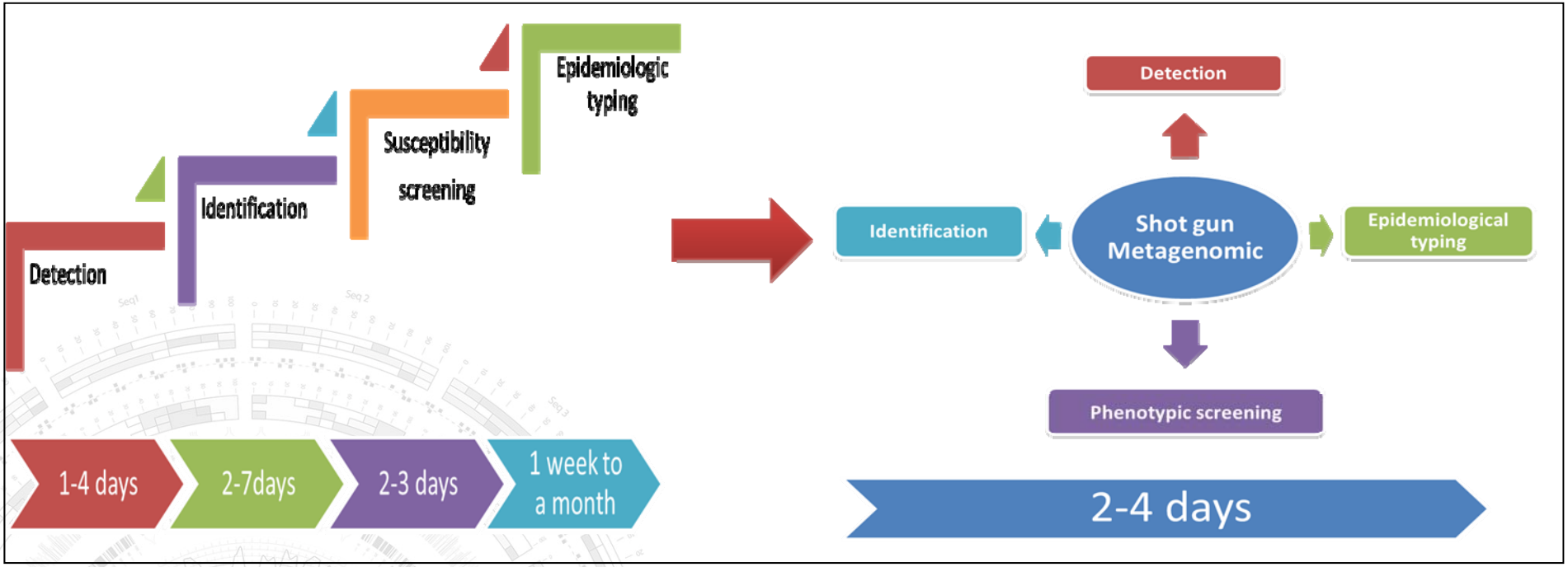
Name of funder	Type of funder	Total Amount Invested (US$)
US National Institutes of Health (NIH)	Government	5,795,734,228
Bill & Melinda Gates Foundation	Private foundation	2,530,342,885
Aggregate Pharmaceutical and Biotechnology Company Respondents	Private	2,037,077,360
European Commission: Directorate-General for Research and Innovation*	Government	567,311,143
United States Agency for International Development (USAID)	Government	416,278,263
US Department of Defense (DOD) including DOD Defense Advanced Research Projects Agency (DARPA)	Government	403,029,646
The Wellcome Trust	Charity	361,225,501
UK Department for International Development (DFID)	Government	348,154,635
UK Medical Research Council (MRC)	Government	270,742,509
Institut Pasteur	Private foundation	161,012,834
Dutch Directorate General of International Cooperation	Government	128,593,178
Australian National Health and Medical Research Council	Government	100,613,706
Grand total		13,120,115,888

Disease area	Total Amount Invested (US$)	% of total funding allocated
HIV/AIDS	5,488,168,543	43.5%
Malaria	2,709,915,003	21.5%
TB	2,508,349,300	19.9%
Dengue	781,191,533	6.2%
Kinetoplastids*	706,168,846	5.6%
Helminths (Worms & Flukes)	352,659,673	2.8%
Leprosy	42,627,803	0.3%
Trachoma	19,653,909	0.2%
Buruli Ulcer	17,429,734	0.1%
Grand Total	**12,626,164,344**	**100%**

-Omics and associated technologies provides efficient, high-throughput solutions

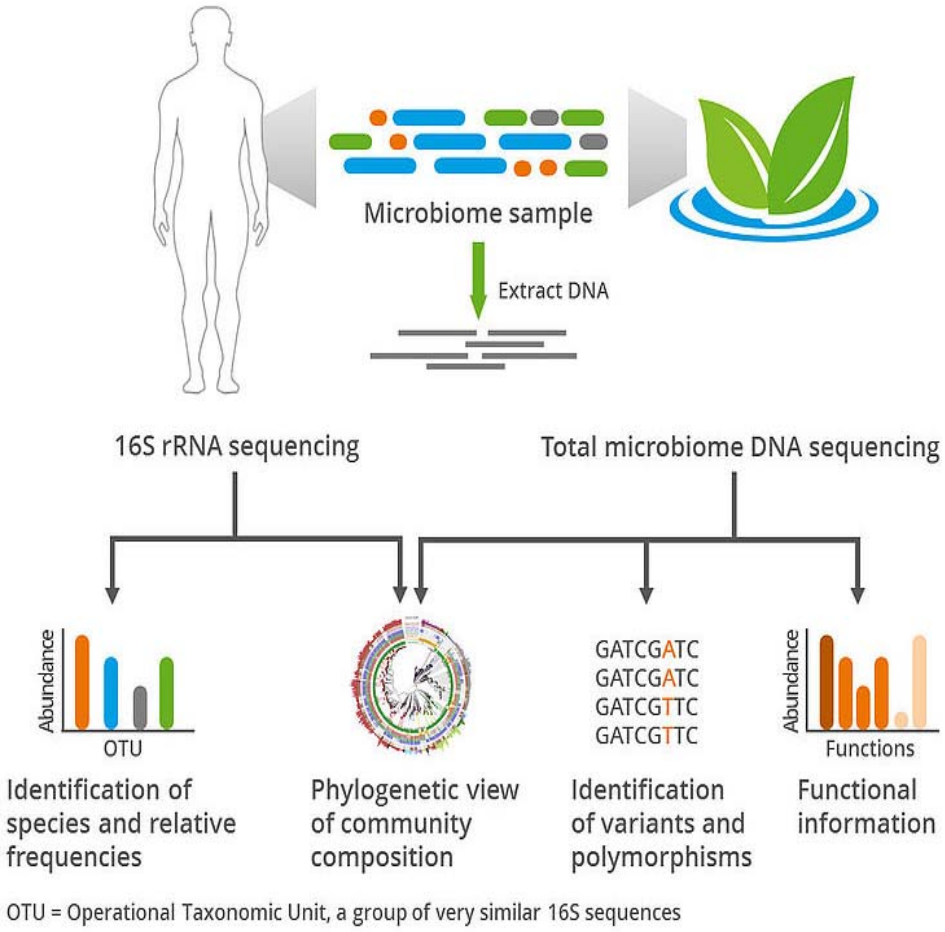
- Genomics
- Proteomics
- Metagenomics
- Transcriptomics
- Metabolomics
- Meta-metabolomics etc.

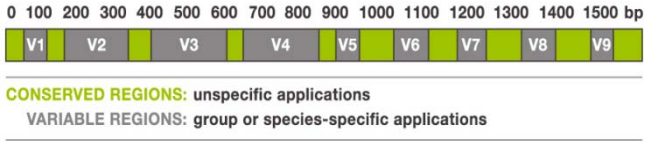
Need for innovative and cost-effective systems



- Many tests for one pathogen
- One test for all pathogens

Ghanem and El-gazzar,2017





https://www.gatc-biotech.com/en/expertise/targeted-sequencing/16s-rrna-analysis.html

1. Microbial Identification
2. Outbreak / source tracking
3. Rapid, Point-of-care detection
4. Antibiotic Resistance
5. Virulence / Hypervirulence

GenomeTrakr

Basic Data Flow for Global WGS Public Access Databases

DATA ACQUISITION

Sequence and upload genomic and geographic data

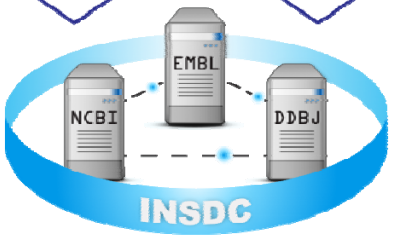
GENOME TRAKR

Other distributed sequencing networks

DATA ASSEMBLY, ANALYSIS, AND STORAGE

International Nucleotide Sequence Database Collaboration (INSDC)
Shared Public Access Databases

- *NCBI – National Center for Biotechnology Information*
- *EMBL – European Molecular Biology Laboratory*
- *DDBJ – DNA Databank of Japan*

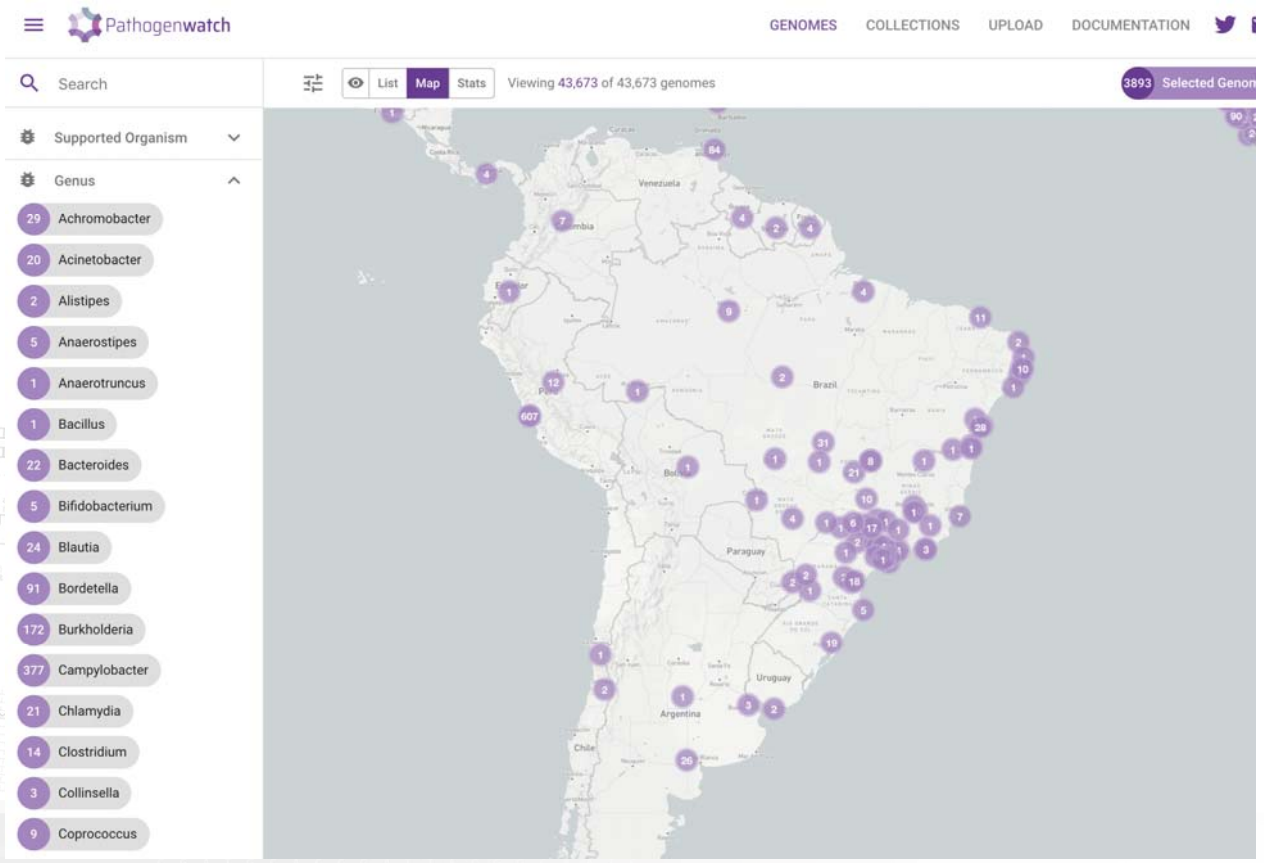


PUBLIC HEALTH APPLICATION AND INTERPRETATION OF DATA

- *Find clinical links*
- *Identify clusters*
- *Conduct traceback*
- *Develop rapid methods*
- *Develop culture independent tests*
- *Develop new analytical software*

11/2014 State, Local, Federal, and Foreign Public Health Agencies Academia/Industry

Portable data and visualization



Vision

Capable professionals and institutional systems that support and advance a healthy, enduring global community

Compelling Global Challenge

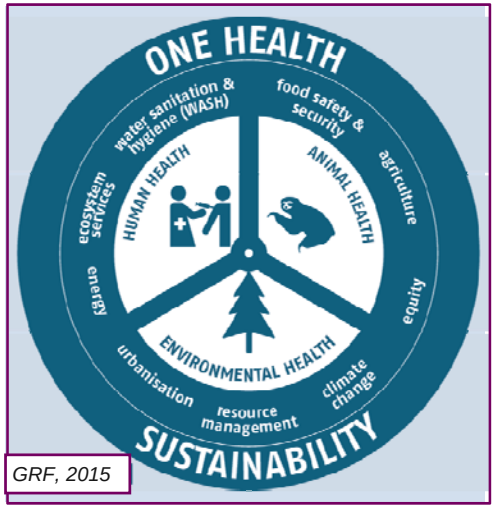
Integrated approach to build capacity, to mitigate diseases and associated hazards; influence science & policy at the interface between & among humans, animals, plants and the environment- ***Global One Health****.*

Integrated approach is essential for the sustainability of our planet.

Challenge- **How do you build capable professions; influence policy and sustain impact?**

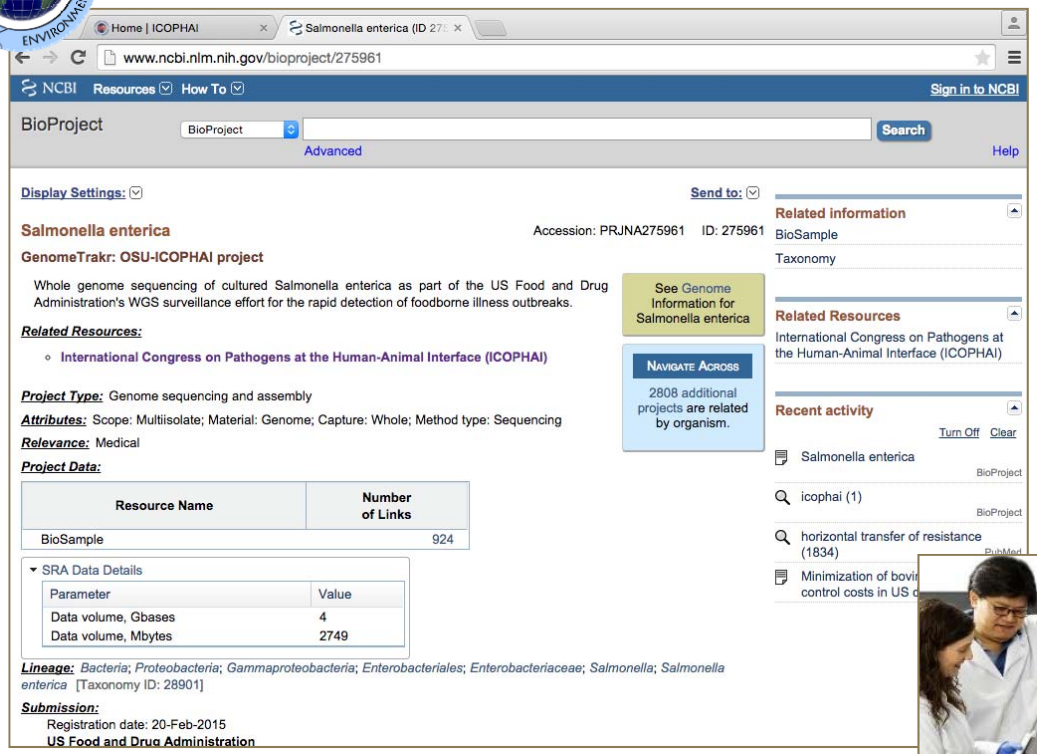
Global One Health- Capacity Needs

- **Food and water safety**
- Re-emergence: multi-drug resistance (MDR), hypervirulent,
- Vector-borne Diseases
- Chemical hazards: antibiotics, pesticides...
- Biodefense and biosecurity
- Malnutrition and environmental enteric dysfunction (EED)
- Interaction and chronic outcomes (cancer)
- Lives and livelihood
- International trade
- Sustainability



GRF, 2015

ICOPHAI GenomeTrakr Partnership



<u>1000+ MDR *Salmonella* submitted to FDA CFSAN</u>

- Brazil (104)
- Ethiopia (401)
- Kenya (86)
- Mexico (63)
- Tanzania (64)
- Thailand (60)
- U.S. –OSU (247)

E. Coli

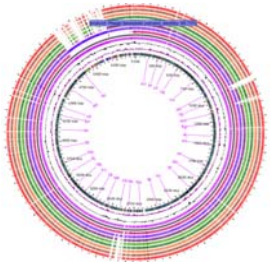
- Eastern Africa

Campylobacter

- Ethiopia

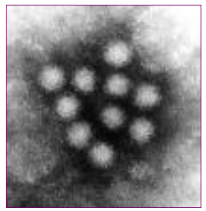
Building Capacity- NIH-GID/ Research Training Program (OHEART)

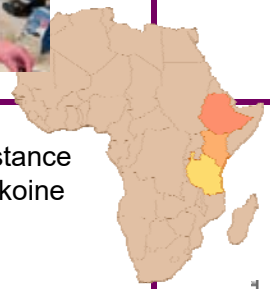
Molecular Epidemiology of MDR *Salmonella* in Tanzania (Julius Medardus)



FOGARTY

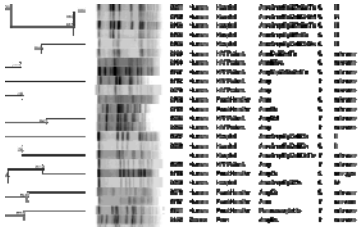
Enteric caliciviruses in pigs and cattle (Zufan Sisay – Addis Ababa University, Ethiopia)





Molecular Typing and Antimicrobial Resistance of *Campylobacter* (Isaac Kashoma – Sokoine University of Agriculture, Tanzania)

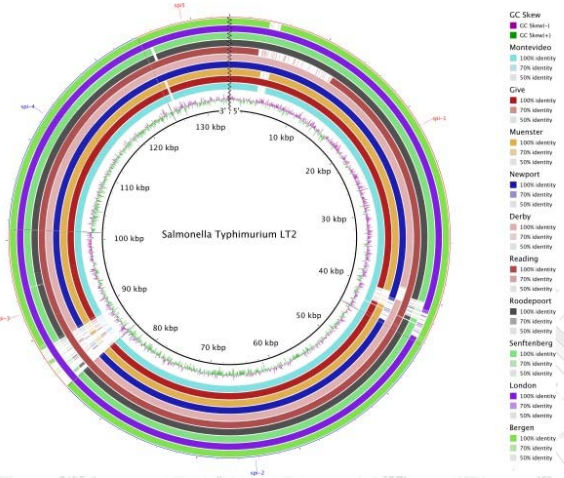
NIH

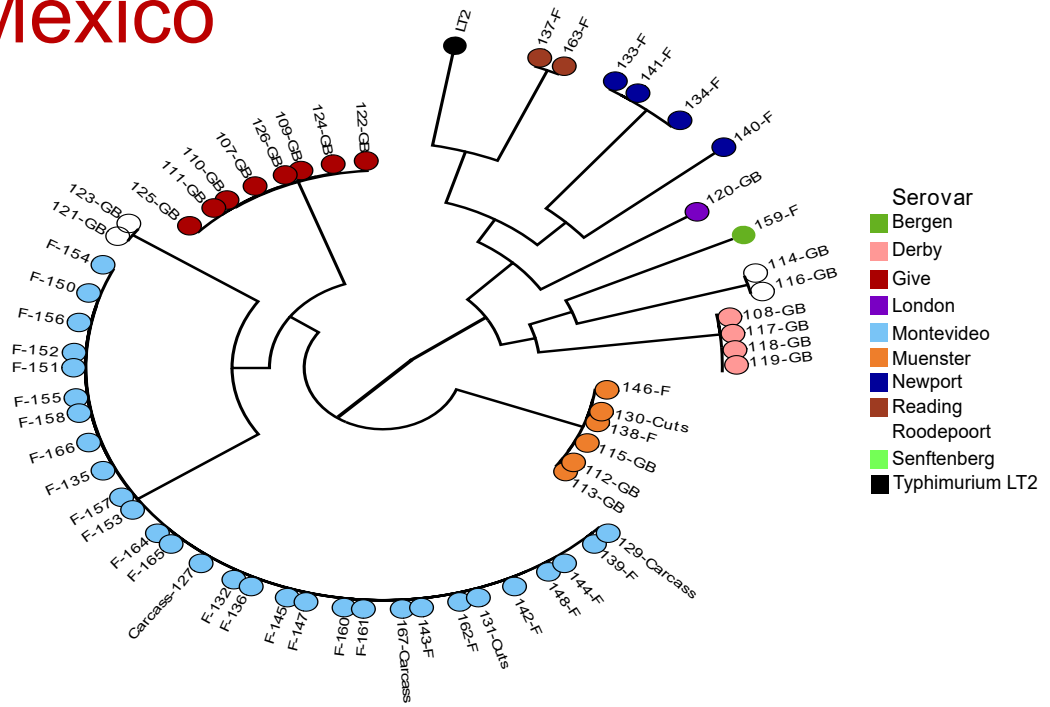


MRSA among HIV, Hospital and Food handler cohorts (Benear Obanda – Kenya Medical Research Institute, KEMRI)

Salmonella WGS- Mexico

- Blast Atlas
- SNP- based phylogeny





Distribution of strains per isolation site:

Mexico City: samples 107-119

Guadalajara City: samples 120-126

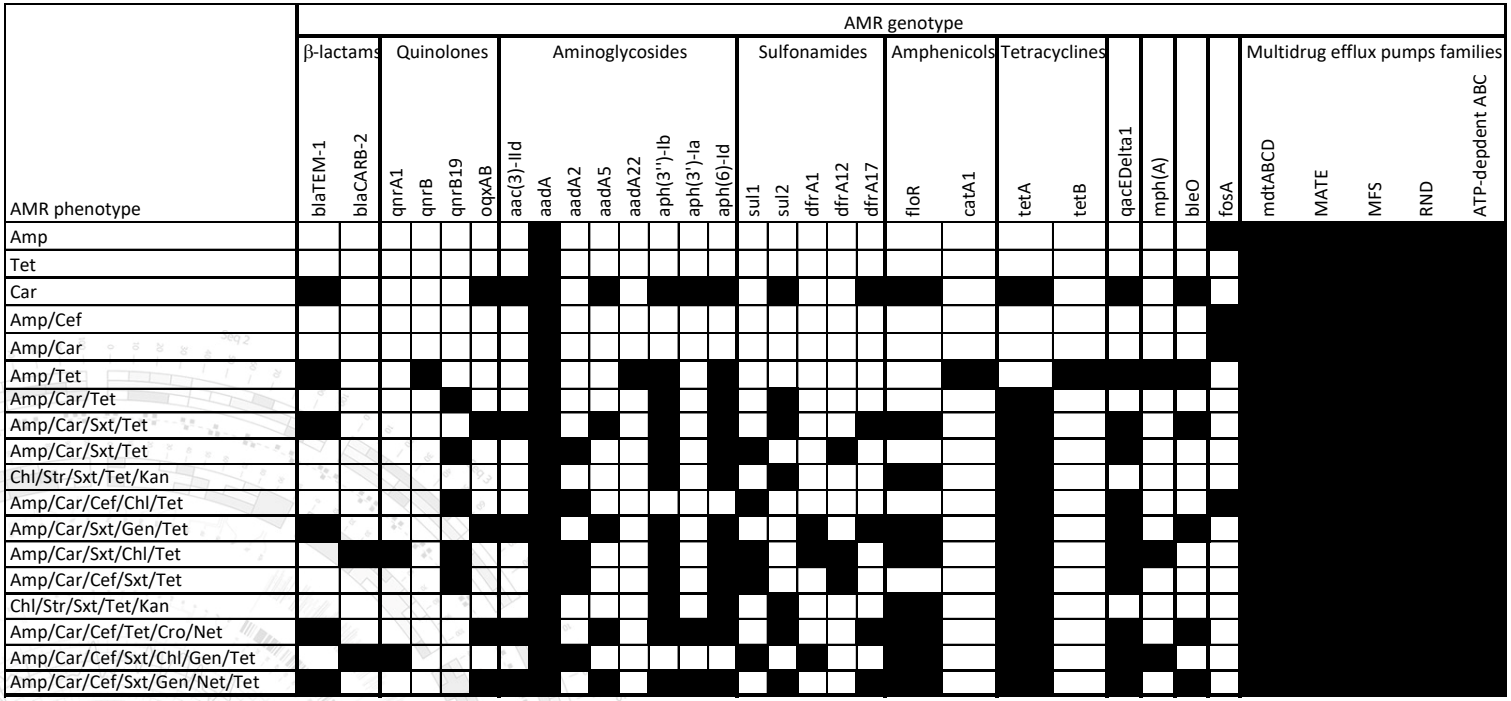
Mexicali City: samples 127-167

Antimicrobial Resistance and Virulence

Culture of a multiresistant bacterium

- Increasing prevalence of antibiotic resistant strains
- Special case of directed evolution
- Acquire AMR genes or virulence-associated genes from the environment.
- Often independent of serotype or gene markers
- NGS comprehensively and unambiguously track AMR and virulence-associated genes

Identify and correlate- AMR phenotype/ genes

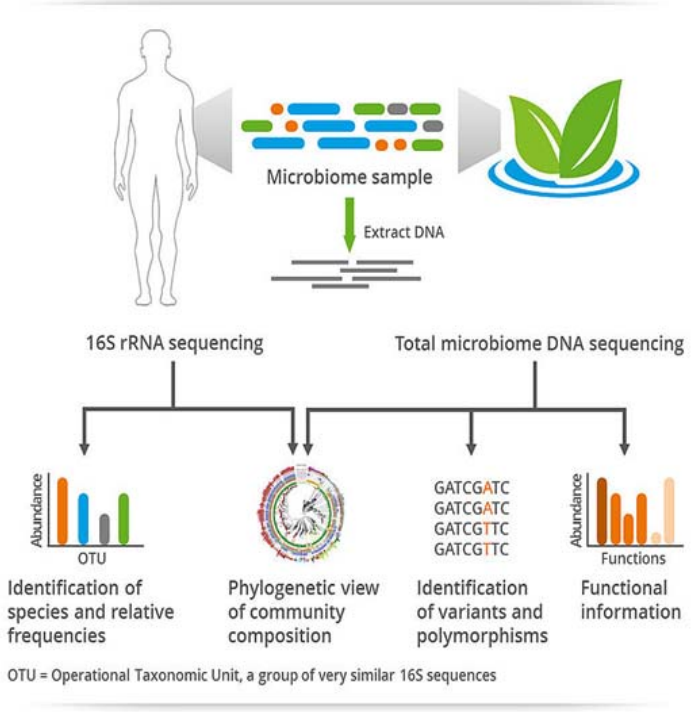


Amp, ampicillin; **Amx,** amoxicillin; **Amc,** amoxicillin clavulanic acid; **Car,** carbenicillin; **Cro,** ceftriaxone; **Cef,** cephalotin; **Ctx,** cephotaxime; **Cip,** ciprofloxacin; **Pef,** pefloxacin; **Amk,** amikacin; **Kan,** kanamicin; **Gen,** gentamicin; **Str,** streptomycin; **Net,** netilmicin; **Sxt,** trimethoprim-sulfamethoxazole; **Chl,** chloramphenicol; **Nit,** nitrofurantoin; **Tet,** tetracycline

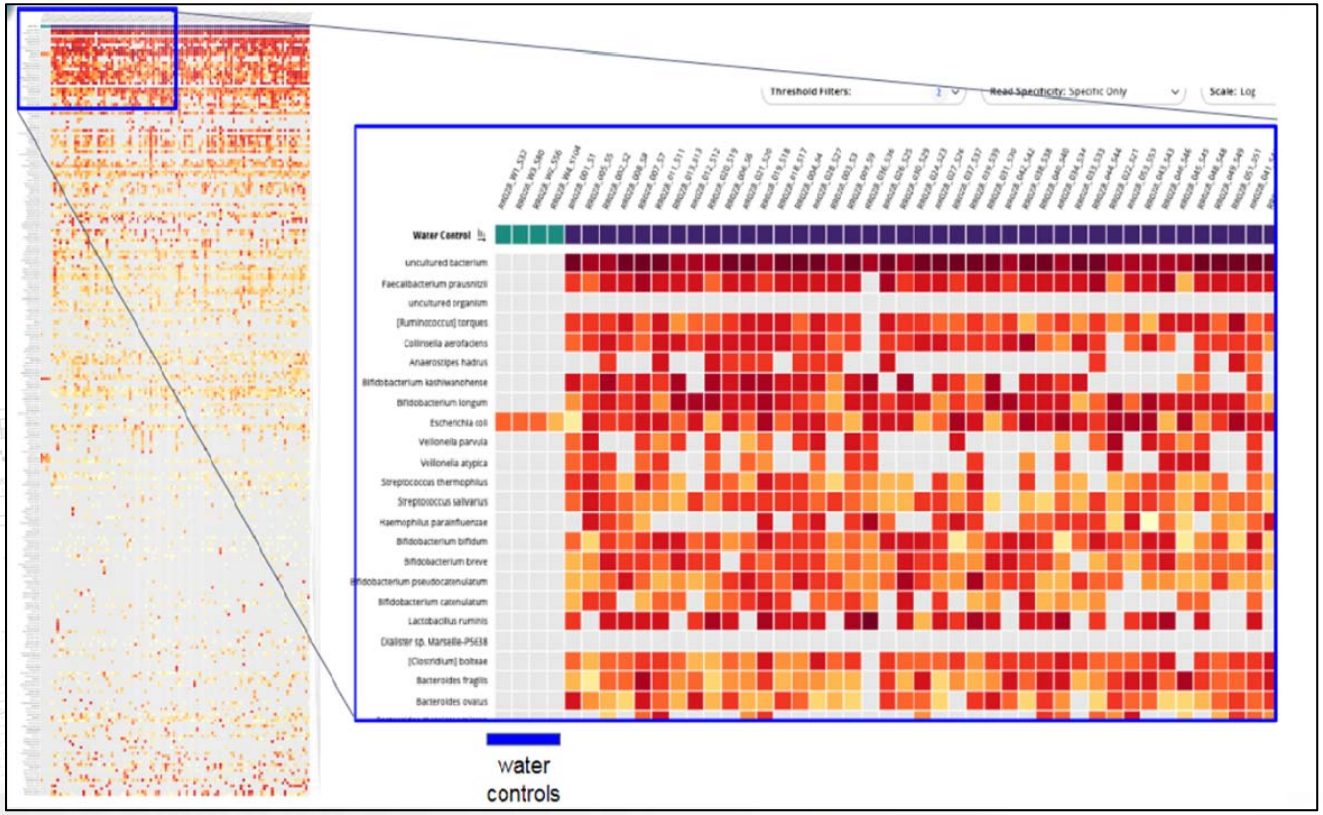
■ Gene present □ Gene absent

Shotgun Metagenomics

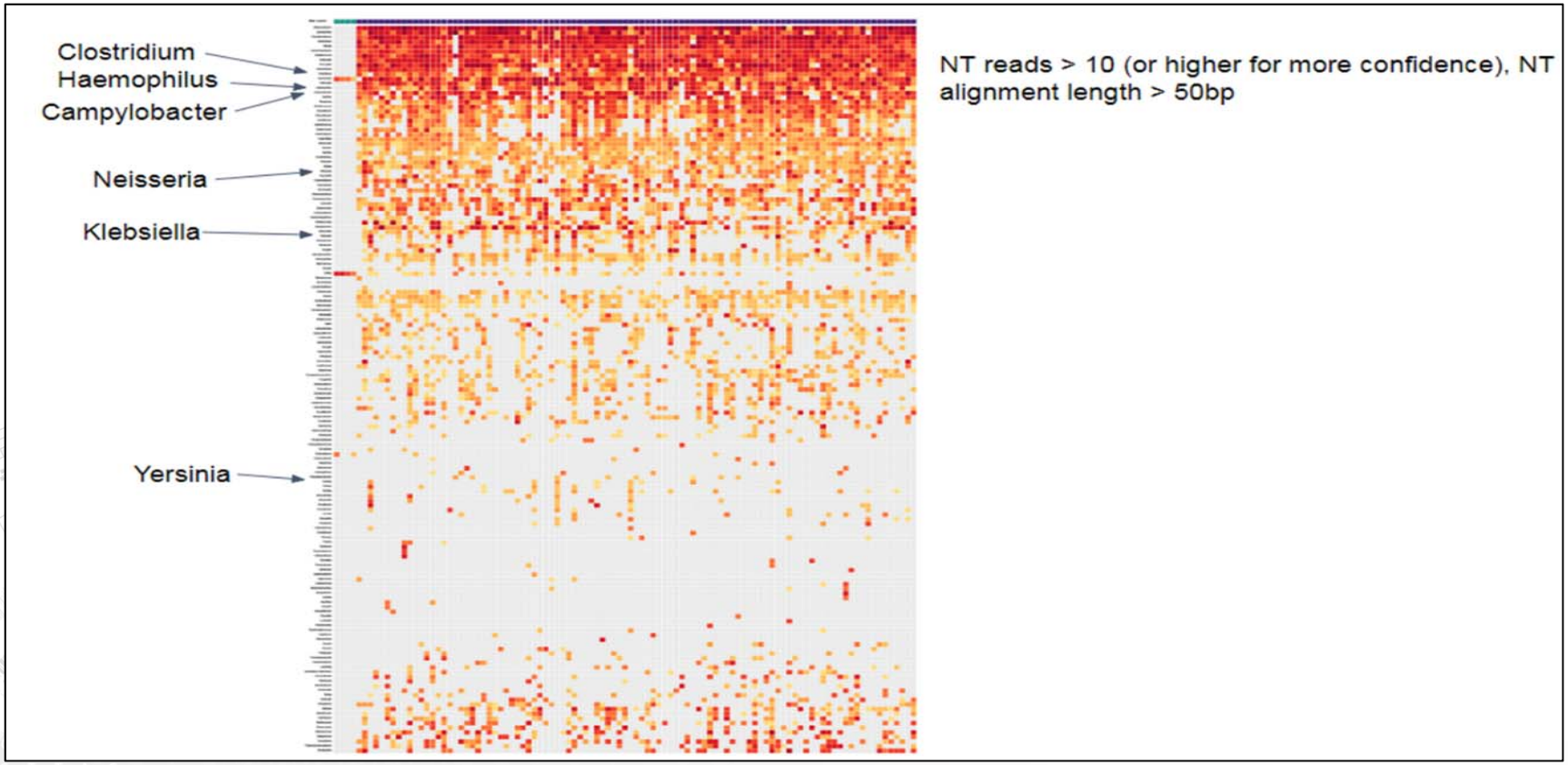
- Comprehensive sampling all genes in all organisms in a complex sample
- Metabolic pathways and gene function
- Evaluation of bacterial diversity
- Detect the abundance of microbes in various environments
- Studying unculturable microorganisms



Campylobacter Genomics and Enteric Dysfunction (CAGED)



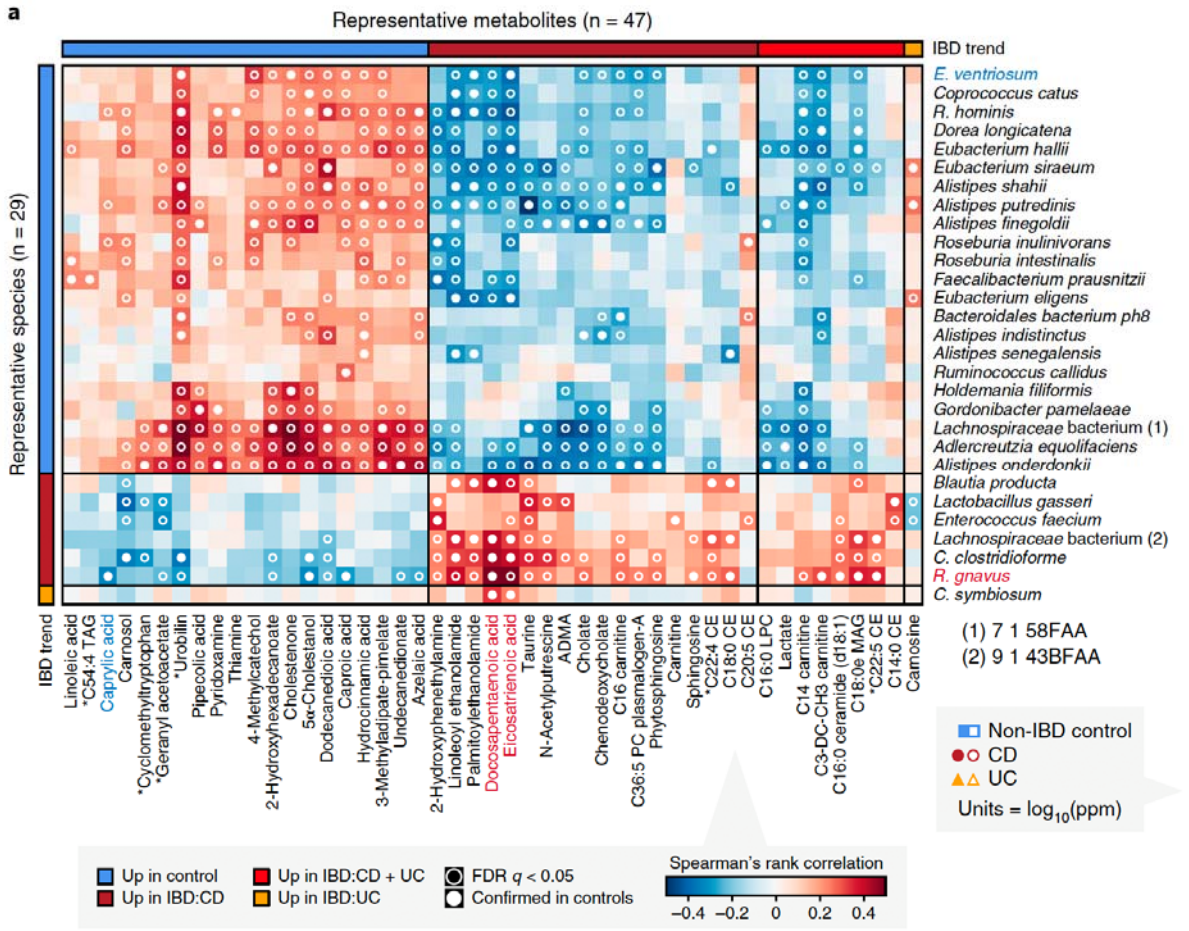
CAGED- Identification of multiple bacteria



Metabolomics

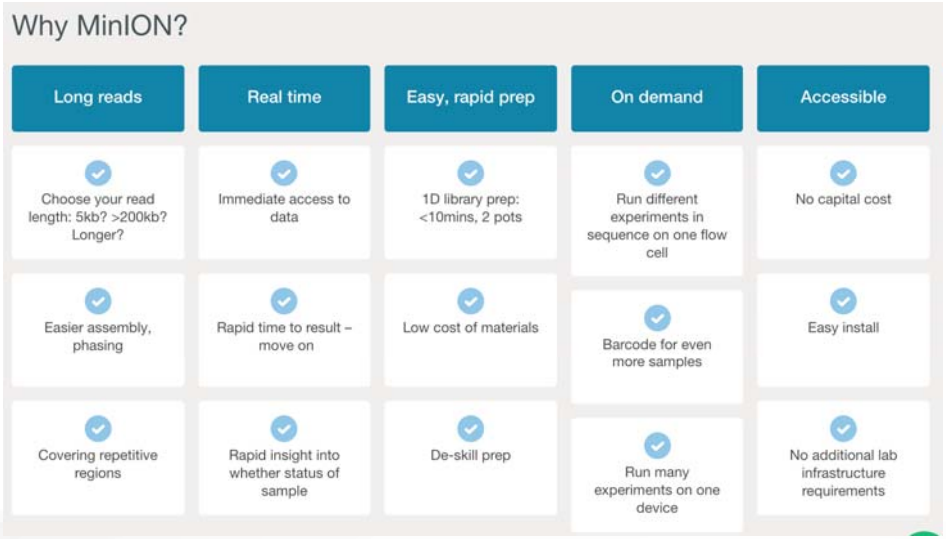
IBD associated Microbes and Metabolic profiles

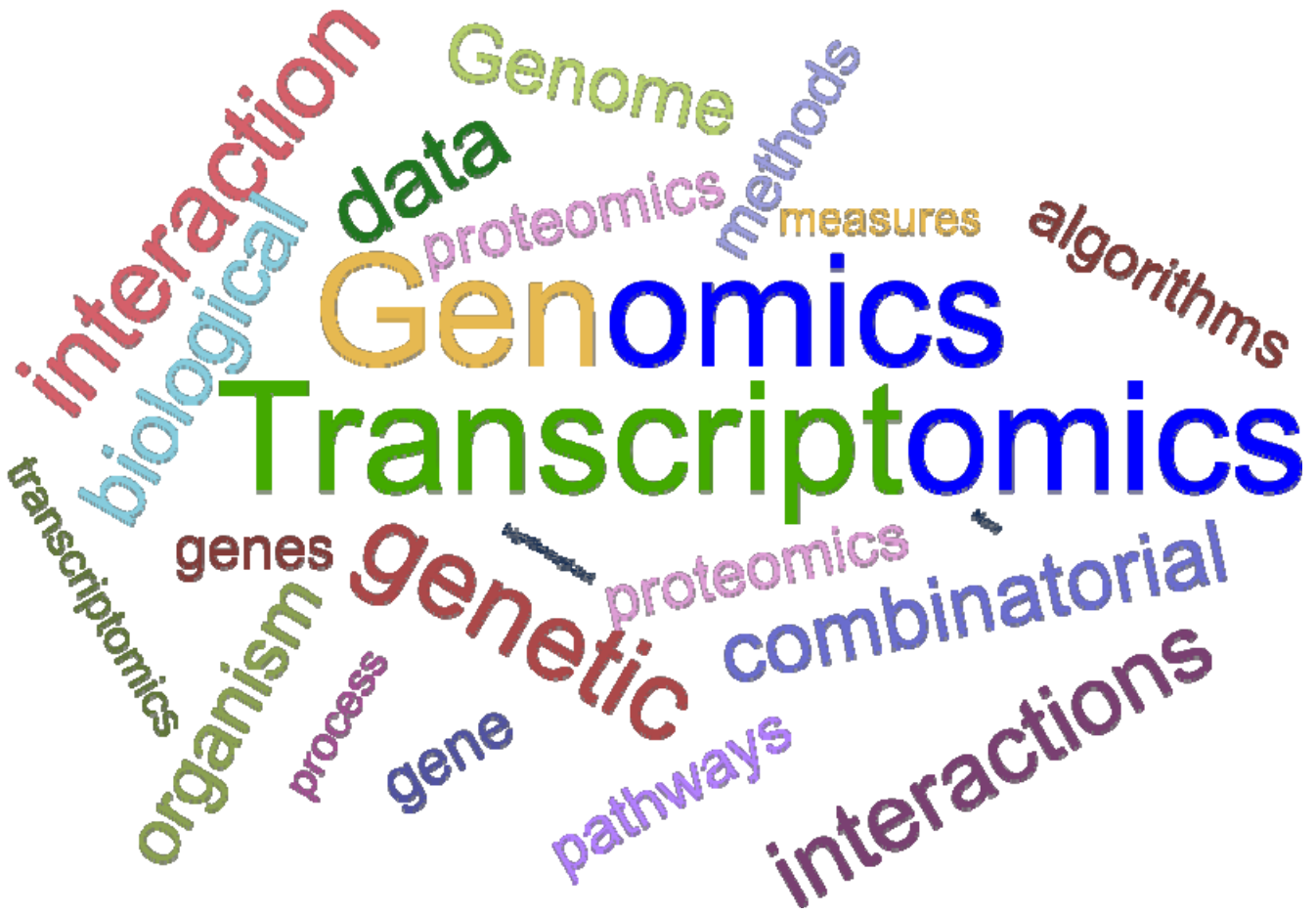
Fransoza et al., 2019

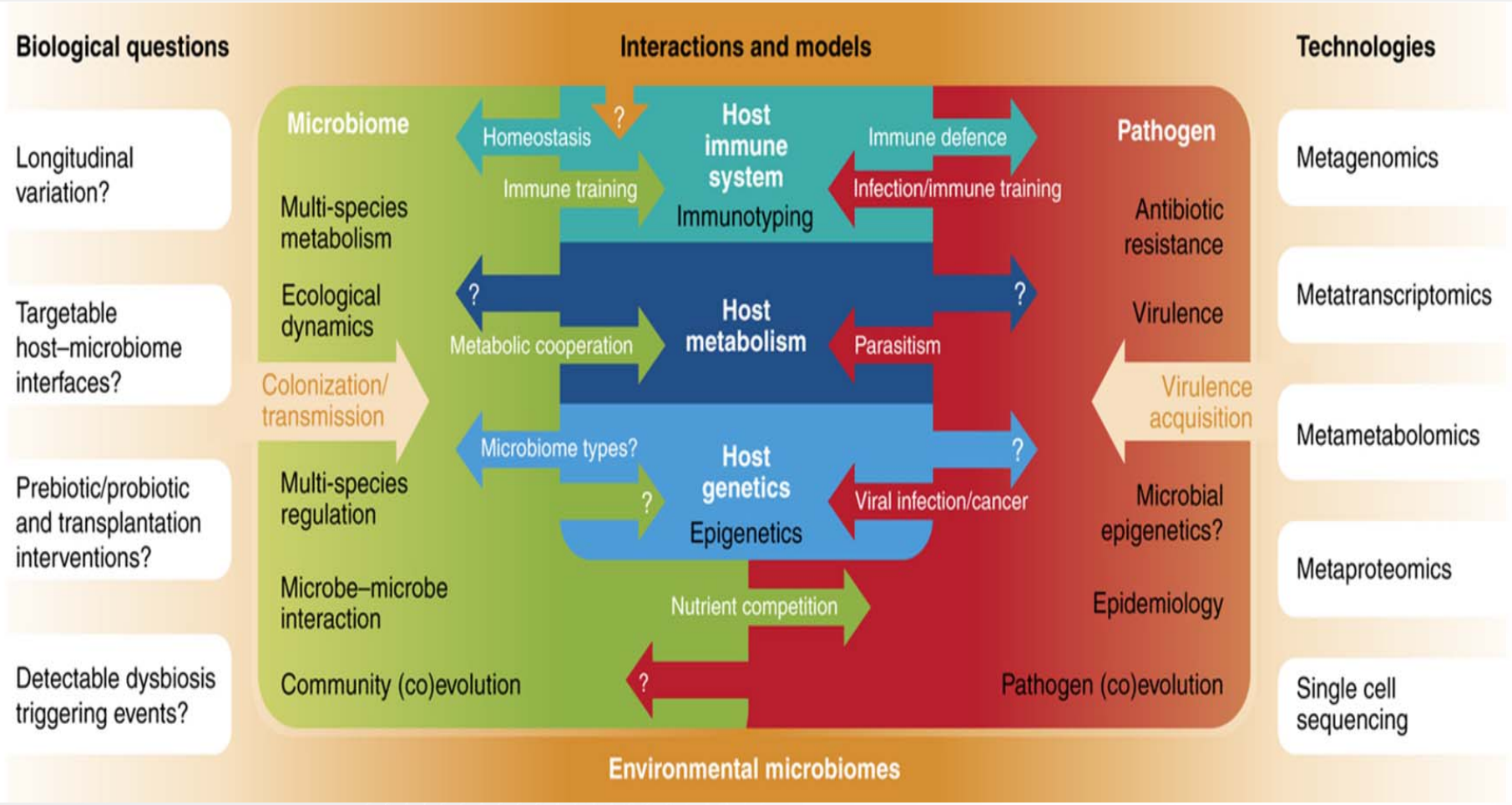


Global context

- Oxford Nanopore (Minion)
- Portable
- Very long read length
  - Easier bioinformatics
  - Quality? V. short reads
- Complement with Illumina
- No capital cost
  - Catch?




interaction
Genome
data
methods
biological
proteomics
measures
algorithms
Genomics
Transcriptomics
transcriptomics
genes
genetic
proteomics
combinatorial
organism
process
gene
pathways
interactions


Biological questions
Interactions and models
Technologies
Longitudinal variation?
Targetable host–microbiome interfaces?
Prebiotic/probiotic and transplantation interventions?
Detectable dysbiosis triggering events?
Microbiome
Multi-species metabolism
Ecological dynamics
Colonization/ transmission
Multi-species regulation
Microbe–microbe interaction
Community (co)evolution
Homeostasis
Immune training
Host immune system
Immunotyping
Immune defence
Infection/immune training
Pathogen
Antibiotic resistance
Virulence
Metabolic cooperation
Host metabolism
Parasitism
Virulence acquisition
Microbiome types?
Host genetics
Epigenetics
Viral infection/cancer
Microbial epigenetics?
Nutrient competition
Epidemiology
Pathogen (co)evolution
Environmental microbiomes
Metagenomics
Metatranscriptomics
Metametabolomics
Metaproteomics
Single cell sequencing

Training for Transformative Impact

Molecular Epid.

Environmental Health

Food Safety

Data Analytics

Geospat. Epid.

NIH

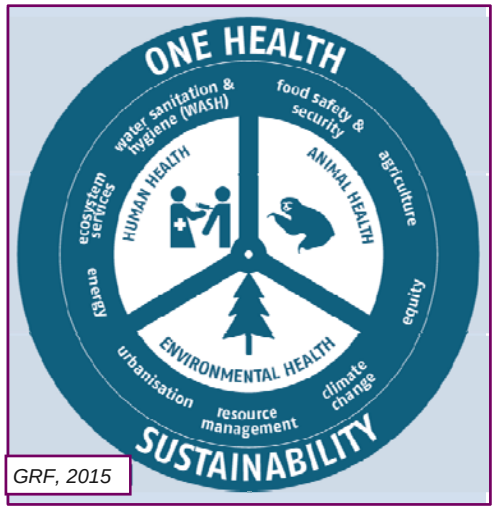
FOGARTY

Bringing multi-disciplinary teams/ Global One Health knowledge-sharing

PATHOGEN ANIMAL HUMAN ENVIRONMENT (OPHA)

Take Home Message

- Water/ Food- Key conduits for One Health;
- Integrated approaches- addressing biological and chemical hazards
- Lack of capacity and harmonization of research and surveillance is critical;
- Genomics+ play key role;
- Resource mobilization to address Global Water and Food Safety is key for success;
- FDA and global partners leadership is needed.



GRF, 2015

Thank You!
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Muchas Gracias!
谢谢
Asante Sana!
شكرا جزيلا
Merci Beaucoup!
Благодаря ти
Terima Kasih
நன்றி
Muito Obrigado!
תודה רבה
Vielen Dank!
Murakoze!
ขอบคุณมาก

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