Global One Health and Role of –Oomics 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.
An expanded paradigm

http://resources.nationalacademies.org/widgets/Food-origins/flashfile/Food%20origins.html?keepThis=true&
Climate change and water-borne diseases
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)
The Added Burden of Antimicrobial Resistance (AMR)
Global Public Health priority Crisis

Cumulative economic impact of AMR, > $100 Trillion by 2050.
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)
Demand for Animal Source Food (ASF) and water is increasing at high rate.
# Global investment on Health Research

## Table: Health Research Funding Details

<table>
<thead>
<tr>
<th>Name of funder</th>
<th>Type of funder</th>
<th>Total Amount Invested (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US National Institutes of Health (NIH)</td>
<td>Government</td>
<td>5,795,734,228</td>
</tr>
<tr>
<td>Bill &amp; Melinda Gates Foundation</td>
<td>Private foundation</td>
<td>2,530,342,885</td>
</tr>
<tr>
<td>Aggregate Pharmaceutical and Biotechnology Company Respondents</td>
<td>Private</td>
<td>2,017,077,160</td>
</tr>
<tr>
<td>European Commission: Directorate-General for Research and Innovation*</td>
<td>Government</td>
<td>567,311,443</td>
</tr>
<tr>
<td>United States Agency for International Development (USAID)</td>
<td>Government</td>
<td>416,278,263</td>
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<tr>
<td>US Department of Defense (DOD) including DOD Defense Advanced Research Projects Agency (DARPA)</td>
<td>Government</td>
<td>469,029,646</td>
</tr>
<tr>
<td>The Wellcome Trust</td>
<td>Charity</td>
<td>361,225,501</td>
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<tr>
<td>UK Department for International Development (DFID)</td>
<td>Government</td>
<td>348,154,635</td>
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<tr>
<td>UK Medical Research Council (MRC)</td>
<td>Government</td>
<td>270,742,509</td>
</tr>
<tr>
<td>Institut Pasteur</td>
<td>Private foundation</td>
<td>161,012,814</td>
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<tr>
<td>Dutch Directorate General of International Cooperation</td>
<td>Government</td>
<td>128,593,178</td>
</tr>
<tr>
<td>Australian National Health and Medical Research Council</td>
<td>Government</td>
<td>106,613,706</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td></td>
<td>13,120,115,588</td>
</tr>
</tbody>
</table>

## Table: Disease Area-wise Funding Allocation

<table>
<thead>
<tr>
<th>Disease area</th>
<th>Total Amount Invested (US$)</th>
<th>% of total funding allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV/AIDS</td>
<td>5,488,168,543</td>
<td>43.5%</td>
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<tr>
<td>Malaria</td>
<td>2,709,915,003</td>
<td>21.5%</td>
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<tr>
<td>TB</td>
<td>2,508,349,300</td>
<td>19.9%</td>
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<tr>
<td>Dengue</td>
<td>781,191,533</td>
<td>6.2%</td>
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<tr>
<td>Kinetoplastids*</td>
<td>706,168,846</td>
<td>5.6%</td>
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<tr>
<td>Helminths (Worms &amp; Flukes)</td>
<td>352,659,673</td>
<td>2.8%</td>
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<tr>
<td>Leprosy</td>
<td>42,627,803</td>
<td>0.3%</td>
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<tr>
<td>Trachoma</td>
<td>19,653,909</td>
<td>0.2%</td>
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<tr>
<td>Buruli Ulcer</td>
<td>17,429,734</td>
<td>0.1%</td>
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<tr>
<td><strong>Grand Total</strong></td>
<td>12,626,164,344</td>
<td>100%</td>
</tr>
</tbody>
</table>
-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
1. Microbial Identification
2. Outbreak / source tracking
3. Rapid, Point-of-care detection
4. Antibiotic Resistance
5. Virulence / Hypervirulence

OTU = Operational Taxonomic Unit, a group of very similar 16S sequences

Basic Data Flow for Global WGS Public Access Databases

DATA ACQUISITION
Sequence and upload genomic and geographic data

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
ICOPHAI GenomeTrakr Partnership

1000+ MDR *Salmonella* submitted to FDA CFSAN
- Brazil (104)
- Ethiopia (401)
- Kenya (86)
- Mexico (63)
- Tanzania (63)
- Thailand (60)
- U.S. –OSU (247)

**E. Coli**
- Eastern Africa

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

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)

MRSA among HIV, Hospital and Food handler cohorts (Beneear 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

- 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

<table>
<thead>
<tr>
<th>AMR phenotype</th>
<th>β-lactam</th>
<th>Quinolones</th>
<th>Aminoglycosides</th>
<th>Sulfonamides</th>
<th>Amphenicols</th>
<th>Tetracyclines</th>
<th>Multidrug efflux pumps families</th>
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<td>Amp</td>
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Amp, ampicillin; Amx, amoxicillin; Amc, amoxicillin clavulanic acid; Car, carbenicillin; Cro, ceftriaxone; Cef, cephalotin; Ctx, cefotaxime; Cip, ciprofloxacin; Pef, pefloxacin; Amk, amikacin; Kan, kanamycin; 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

- Clostridium
- Haemophilus
- Campylobacter
- Neisseria
- Klebsiella
- Yersinia

NT reads > 10 (or higher for more confidence), NT alignment length > 50bp
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?

### Why MinION?

<table>
<thead>
<tr>
<th>Long reads</th>
<th>Real time</th>
<th>Easy, rapid prep</th>
<th>On demand</th>
<th>Accessible</th>
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</thead>
<tbody>
<tr>
<td>Choose your read length: 5kb? &gt;200kb? Longer?</td>
<td>Immediate access to data</td>
<td>1D library prep: &lt;10mins, 2 pots</td>
<td>Run different experiments in sequence on one flow cell</td>
<td>No capital cost</td>
</tr>
<tr>
<td>Easier assembly, phasing</td>
<td>Rapid time to result – move on</td>
<td>Low cost of materials</td>
<td>Barcode for even more samples</td>
<td>Easy install</td>
</tr>
<tr>
<td>Covering repetitive regions</td>
<td>Rapid insight into whether status of sample</td>
<td>De-skill prep</td>
<td>Run many experiments on one device</td>
<td>No additional lab infrastructure requirements</td>
</tr>
</tbody>
</table>
Training for Transformative Impact

- Molecular Epid.
- Environmental Health
- Food Safety
- Data Analytics
- Geospat. Epid.
Bringing multi-disciplinary teams/Global One Health knowledge-sharing

September 15-17, 2011 UN Conference Center, Addis Ababa, Ethiopia
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.
Thank You!
አንደስጥንአንድ
Muchas Gracias!
谢谢
Asante Sana!
 شكرا جزيلا
Merci Beaucoup!
Благодаря ти
Terima Kasih
நன்௣
Muito Obrigado!
רבجا רבע
Vielen Dank!
Murakoze!
ขอบคุณมาก