D-LAB HEALTH
SP 725
Jose Gomez-Marquez
Infectious Diseases in Global Health

- Scope and magnitude of the problem
- What can we do?
- Framework for designing solutions and interventions
- Examples and case studies.
The Burden of Disease

Disability Adjusted Life Years

The sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.
Infectious Diseases in Global Health

<table>
<thead>
<tr>
<th>Disease</th>
<th>Deaths (millions)</th>
<th>DALYs* (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory Infections</td>
<td>3.96</td>
<td>94.50</td>
</tr>
<tr>
<td>Diarrheal Diseases</td>
<td>1.80</td>
<td>61.97</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>2.78</td>
<td>84.46</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>1.57</td>
<td>34.74</td>
</tr>
<tr>
<td>Malaria</td>
<td>1.27</td>
<td>46.49</td>
</tr>
</tbody>
</table>

Source: WHO Death & DALY Estimates Report for 2002

http://www.bvgh.org/LinkClick.aspx?fileticket=agnG6vPYW_o%3D&tabid=91
Courtesy of BIO Ventures for Global Health. Used with permission.
Infectious Diseases in Global Health

Cause the greatest burden of disease. Each year >10 million children under 5 years die from preventable or treatable diseases.

- {Respiratory infections + diarrheal diseases} kill ≈ {AIDS + TB + Malaria}
- Each year 2-3 million children die from acute diarrheal illnesses (ADI) including rotavirus, enterotoxigenic *E. coli* (ETEC) and Shigella. Some 60% of the deaths from diarrhea occur in 10 developing countries.
- Nearly 40 million people (including 2.3 million children) are currently living with HIV/AIDS - 63% live in Africa.
- > 2.4 billion people (40% of global population) in over 100 countries are at risk for malaria. 300-400 million cases of acute malaria each year.
- Multidrug-resistant or MDR-TB is in every country worldwide - resistant to at least isoniazid and rifampicin, the two principal first-line drugs.
Neglected Diseases

- 1 billion people affected.
- ½ million deaths annually.
- Lymphatic filariasis patients lost 20% productive working days each year. 1/3rd of S. Africa’s workforce is HIV-positive.
- Repeated bouts of childhood diarrheal infections are associated with malnutrition and growth stunting and diminishing mental development in children.

Box 1. The Thirteen Neglected Tropical Diseases in Africa and Their Major Etiologic Agents

| Protozoan Infections          |  |
|------------------------------|  |
| African trypanosomiasis      | Trypanosoma gambiense, T. rhodesiense |
| Kala-azar (visceral leishmaniasis) | Leishmania donovani |

| Helminth Infections          |  |
|------------------------------|  |
| STH Infections               |  |
| Ascariasis                   | Ascaris lumbricoides |
| Trichuriasis                 | Trichuris trichiura |
| Hookworm infection           | Necator americanus |

| Schistosomiasis              |  |
|------------------------------|  |
| Urinary schistosomiasis      | Schistosoma haematobium |
| Hepatobiliary schistosomiasis| Schistosoma mansoni |

| Lymphatic filariasis         | Wuchereria bancrofti |
| Onchocerciasis               | Onchocerca volvulus |
| Dracunculiasis               | Dracunculus medinensis |

| Bacterial Infections         |  |
|------------------------------|  |
| Trachoma                     | Chlamydia trachomatis |
| Leprosy                      | Mycobacterium leprae |
| Buruli ulcer                 | Mycobacterium ulcerans |

(Modified from [3])

Infectious Diseases in Global Health

- **Neglected Diseases:**
- 1 billion people affected and ½ million deaths annually.

African Sleeping Sickness

- Model of a extremely variant pathogen
- Tse-tse fly
- Trypanosoma brucei

Image: US NIH.

Courtesy of Louis De Vos. Used with permission.
Focus Areas for Designing Solutions

- Diagnosis
- Therapy – Medicines, Compliance/Adherence.
- Prevention – Vaccines.
- Management – Monitoring/Surveillance
- SYSTEMS
The D-Lab Health Design Cycle

Elements for Device Design Success

Select the Appropriate Device Attributes

Global Health Innovation Compass

Invent using Design Toolkit Strategies
## Attributes for Medical Devices

<table>
<thead>
<tr>
<th>Essential</th>
<th>Enhancing</th>
<th>Long-Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SAFE</td>
<td>• Mobile</td>
<td>• Local Mfg</td>
</tr>
<tr>
<td>• Accurate</td>
<td>• Connected</td>
<td>• Local Innovation</td>
</tr>
<tr>
<td>• Robust</td>
<td>• Smart</td>
<td></td>
</tr>
<tr>
<td>• Longevity</td>
<td>• Plug n’ Play</td>
<td></td>
</tr>
<tr>
<td>• Cheap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reliable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Reusable/Disposable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Global Health Innovation Compass

<table>
<thead>
<tr>
<th>Inexpensive/ Appropriate</th>
<th>Expensive/ Appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inexpensive/ Not Very Appropriate</td>
<td>Expensive/ Not Very Appropriate</td>
</tr>
</tbody>
</table>

Program Goal X Level of Pushing the Status Quo

Net Resources Expended (Time & Money – Resulting Impact)

Image credits: Glucose meter (upper left & right) public domain/Wikipedia. iPhone (upper right) courtesy of For Inspiration Only on Flickr. Farmer (lower left) courtesy of Lon@Queta on Flickr. Vaccination clinic (bottom center) courtesy of cambodia4kids.org on Flickr. Drawings of cellphone and hospital by MIT OpenCourseWare.
Diagnostics

Photos removed due to copyright restrictions.
Various medical diagnostic tools.
Malaria

- Model for a multi stage infectious disease
- Anopheles mosquito
- Plasmodium vivax,
- Plasmodium falciparum

Courtesy of the WEHI-TV. Used with permission.
Diagnosis of Malaria

Image: US CDC
Diagnosis of Pneumonia

- Chest X-ray
- Viral vs. Bacterial:
  - Complete blood count
  - Sputum stain
  - Fluid from lungs
- Developing Countries:
  - Treat all pneumonias in children with antibiotics
  - Has reduced mortality
  - May encourage antibiotic resistance
Diagnosis of Tuberculosis

- Skin test (PPD)
- Serum test
- Chest X-ray
  - Shows nodules in active TB
- Sputum
  - Acid-fast bacilli
Direct Fluorescence Assay

- Collect nasal secretions
- Spin down cells
- Place cells on slide
- Immerse in alcohol
- Apply solution containing antibodies which bind to viruses
- Antibodies are coupled to fluorescent dye
- Examine with fluorescence microscope
Microfluidics Applications

- Diagnostics/Management
  - Point of Care (POC)
  - Disease Surveillance

Various images of microfluidic devices removed due to copyright restrictions.
Sample Pre-processing for Diagnostics

**Step 1**
Use lancet to take blood from finger, and put into straw

**Step 2**
Open SNAP Device, and load with:
- Straw (containing blood sample)
- Blister Pack
- Waste and Sample Containers

**Step 3**
Close device, lock, and attach bicycle pump

**Step 4**
Pressurize device to 60 psi to push blood and buffer through straw

**Step 5**
Pull and rotate. Pressurize to push ethanol through straw.

**Step 6**
Pull and rotate. Pressurize to push water through straw.

**Step 7**
Open device to remove DNA solution and dispose of waste

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**SNAP**
Simple Nucleic Acid Processing

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D-LAB HEALTH
Directly Observed Therapy (DOT)

- A health care worker watches and helps as the patient swallows anti-TB medicines in his/her presence.
- DOT shifts responsibility for cure from patient to health care system
- Requires political commitment, accurate diagnosis, quality drugs, observation, follow up
- DOT works well in many developing countries
Compliance by “electronic” pills

A Wireless Pharmaceutical Compliance Monitoring System Based on Magneto-Inductive Sensors

Xueliang Huo, Student Member, IEEE, and Maysam Ghovanloo, Member, IEEE

Fig. 1. (a) Schematic diagram of the wireless magnetic PCM system (MagNeTrace) consisting of a magnetic tracer incorporated with the medication, a detector necklace, and a data delivery device. (b) Rendered cross section of the neck demonstrating the position of the sensor modules around the esophagus, as well as the detection zone, where the proposed PCM system looks for the passage of the tracer.

Fig. 3. (a) PNI MicroMag2 two-axis sensor module. (b) PNI magneto-inductive sensor on a U.S. penny. (c) Prototype MagNeTrace detector necklace consisting of three MicroMag2 sensor modules and a control unit. (d) Sample waveforms recorded at 11 samples/s from three X-axis and three Z-axis sensors while passing a magnetic tracer through the artificial neck, resembling ingestion (DIG). Sensor counts are proportional to the measured magnetic field strength [19].
The Cold Chain for Vaccines

Vaccines must be stored at 2-8 deg C

5% Waste

75-83% Waste

Waste = Thermally Damaged Vaccines

Image by MIT OpenCourseWare.
The Real Cost of Needles

Image removed due to copyright restrictions.
Photo of young boy at a trash dump in Nairobi, holding a scavenged hypodermic syringe.

1/3 of vaccine injections in the developing world are UNSAFE.

This leads to:
- **250,000** cases of HIV
- **Millions** of cases of hepatitis
Standard Immunization Team

Drug Preparation

Doctor Gives Shot

Patient Registration

Biohazard Disposal

6 Physicians and Aides

200 Patients In-Clinic

70 Patients In the Field

Sources: USAID, Becton Dickinson
Aerovax Man

1 LOW SKILLED VOLUNTEER

650 PATIENTS IN THE FIELD

62% SAVINGS

Sources: Aerovax, MIT Analysis
Oral Rehydration Therapy

- 1975 WHO and UNICEF:
  - 90 mM sodium
  - 20 mM potassium
  - 80 mM chloride
  - 30 mM bicarbonate
  - 111 mM glucose
- Packet of ORT: 10 cents
- ORT in the U.S.

Photo of Pedialyte® products removed due to copyright restrictions.
Preventing Malaria

- Pregnant women and infants should sleep under insecticide treated nets
  - 25% reduction in low birth weight babies
  - 20% reduction in infant deaths
  - Cost: $1.70 (Retreatment: 3-6 cents)

Image: US Department of State / Timothy Ziemer
Preventing Neonatal Infections

Incubadoras Modulares
Infection Management

- Disease surveillance
Infection Management

- Disease surveillance
Infection/Disease Surveillance

- Google FluTrends

Image removed due to copyright restrictions.


How do we get there?

Design Strategies

- Hybridization
- Vintage Technologies + Smart Design/Tech = New Solutions
- Taking the improvisation and engineering solutions
- Bottom up observation
- Be trendsetting, not trendy
- Context shifting
- Distributed Systems
- Crowd sourcing
The Stage & the Actors

Policy & Aid
- WHO
- UNICEF
- Multilateral aid agencies
- MSF
- Red Cross

Solution Side
- PATH
- FIND
- Rice, Duke,
- MIT
- CIMIT
- MedMondiale
- IAVI*
- OneWorld Health*

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