Neglected Tropical Diseases

Infection, modelling and control

Robert Smith?

Department of Mathematics and Faculty of Medicine
The University of Ottawa
NTDs

- A group of bacterial and parasitic infections endemic in tropical climates
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• Affect rural areas in the developing world
• More than 1 billion people infected
• Transmission cycles perpetuated by
  – environmental contamination
  – poor standards of living
  – lack of hygiene.
The diseases

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Neglect

- These diseases are neglected at the
Neglect

• These diseases are neglected at the
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• Attention to disease in endemic areas usually focuses on
  – HIV/AIDS
  – malaria
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  – novel emerging infections.

The “big three”
Common features

• Ancient
Common features

- Ancient
- Chronic
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- Ancient
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- Disfigurement and disability
Common features

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- Disfigurement and disability
- Impair growth and development in children
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Common features

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- High disease burden, low mortality (530,000 per year).
Measuring the impact

- DALYs (Disability-Adjusted Life Years)
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  – measure the number of years of life lost from premature death/disability
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- DALYs (Disability-Adjusted Life Years)
  - measure the number of years of life lost from premature death/disability
- These are likely underestimates, especially for NTDs.

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Proportion of DALYs

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- Childhood & vaccine preventable diseases
- Other infectious and parasitic diseases
- STDs excluding HIV
- HIV/AIDS
- TB
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- Other infectious and parasitic diseases
Categories

- Core group of 13 tropical infections
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• Protozoan
Categories

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<td>Praziquantel</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>Interrupt transmission cycle, yearly mass drug admin</td>
<td>Vector control, yearly mass drug admin</td>
<td>Safe water, health education</td>
<td>Molluscide, yearly mass drug admin.</td>
</tr>
</tbody>
</table>
Protozoans

<table>
<thead>
<tr>
<th>Disease</th>
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<td>Blood, lymph, spinal fluid, central nervous system</td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
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<td>Tsetse flies</td>
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<td></td>
<td>blood, bone</td>
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</tr>
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<tr>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Treatment</td>
<td>Amphotericin B,</td>
<td>Nifurtimox, Benznidazole, Pacemakers/transplant</td>
<td>Pentadmine, Suramine, Melarsoprol, Eflornithine</td>
</tr>
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<td>Control</td>
<td>Case detection &amp; management, vector control</td>
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<td>Disease</td>
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<tr>
<td>Clinical</td>
<td>Disfiguring skin infection, amputation</td>
<td>Tuberculoid</td>
<td>Lepromatous</td>
</tr>
<tr>
<td>manifestation/</td>
<td></td>
<td>Loss of sensation, skin</td>
<td>Disfigure-ment, bone invasion</td>
</tr>
<tr>
<td>impairment</td>
<td></td>
<td>lesions</td>
<td></td>
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<tr>
<td><img src="image1" alt="Buruli ulcer" /> <img src="image2" alt="Leprosy" /> <img src="image3" alt="Trachoma" /></td>
<td><img src="image4" alt="Tuberculoid" /> <img src="image5" alt="Lepromatous" /></td>
<td><img src="image6" alt="Irreversible visual impairment, blindness" /></td>
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<td><strong>Control</strong></td>
<td>Amputation</td>
<td>Multidrug treatment</td>
<td>facial hygiene, surgery</td>
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Management and control

- Prevention/treatment exists for most NTDs
Management and control

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  - cheap and effective chemical pharmaceuticals are available for some NTDs
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• Not available to the people at risk
  – access and distribution difficulties
• Lack of healthcare infrastructure
  – lack of R&D for existing and novel pharmaceuticals
  – treatments may be toxic
• Inadequate funding.
What can help

- Availability and access to health care
What can help

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- Clean living conditions
What can help

• Availability and access to health care
• Clean living conditions
• Clean drinking water
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• Adequate nutrition
What can help

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- Adequate nutrition
- Education
What can help

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• Gender equality
What can help

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- Non-discrimination
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- Pharmaceutical research and development
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- Pharmaceutical research and development
- Overhaul of drug patent systems
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• Clean living conditions
• Clean drinking water
• Adequate nutrition
• Education
• Gender equality
• Non-discrimination
• Pharmaceutical research and development
• Overhaul of drug patent systems
• Identification/targeting of vulnerable groups.
Organisation

- Public-private partnerships have had considerable success
Organisation

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- Eg Guinea worm disease has been almost entirely eradicated, despite no biomedical intervention

![Graph showing decline in Guinea worm eradication cases](Source: World Health Organization)
Organisation

- Public-private partnerships have had considerable success
- Eg Guinea worm disease has been almost entirely eradicated, despite no biomedical intervention
- These relationships need to be strengthened.
Mathematical models

• Have contributed to many advances in disease control and management
Mathematical models

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- Eg

\[
\begin{align*}
\frac{dS_{H}}{dt} &= -\alpha m S_{H} I_{V} + \nu I_{H} \\
\frac{dI_{H}}{dt} &= \alpha m S_{H} I_{V} - \nu I_{H} - \delta I_{H} \\
\frac{dY_{V}}{dt} &= \lambda_{V} N_{V}(t) - \rho \lambda_{V} N_{V}(t - \tau) - \mu_{V} Y_{V} \\
\frac{dS_{V}}{dt} &= \rho \lambda_{V} N_{V}(t - \tau) - a c S_{V} I_{H} - \mu_{V} S_{V} \\
\frac{dI_{V}}{dt} &= a c S_{V} I_{H} - \mu_{V} I_{V}
\end{align*}
\]
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    - emergency preparedness.
Advantages of models

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• Modellers need to be clear about limitations
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• However, models depend critically on the assumptions used to construct them

• Modellers need to be clear about limitations

• Policy analysts need to be better educated about the power of models.
Modelling

• Provides greater understanding of existing control strategies without costly experiments
Modelling

- Provides greater understanding of existing control strategies without costly experiments
- Can find control/eradication thresholds
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  – a reliance on a model’s conclusion that does not consider its assumptions.
NTD modelling so far...

• Only sleeping sickness has received any substantial theoretical modelling
NTD modelling so far...

- Only sleeping sickness has received any substantial theoretical modelling
- No models for the Buruli ulcer
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• Models that do exist are usually limited to one lab and its collaborators per NTD
NTD modelling so far...

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- Only one for Guinea worm
- Models that do exist are usually limited to one lab and its collaborators per NTD
- A diversity of voices is urgently needed.
A modelling success story

- The West African River Blindness Control Program was hailed as a success due to integrated modelling and control efforts
A modelling success story

• The West African River Blindness Control Program was hailed as a success due to integrated modelling and control efforts
• Modelling predicted that 14 years of vector control would reduce the risk to less than 1%
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- Models were refined using subsequent data to include treatment
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• Modelling predicted that 14 years of vector control would reduce the risk to less than 1%
• Helped convince donors that control was feasible
• Models were refined using subsequent data to include treatment
• Modelling retained a prominent role in subsequent policy discussions.
Future directions for modelling

• More mathematical models are urgently needed
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• Existing control efforts need to be optimised
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- Existing control efforts need to be optimised
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  - eg potential vaccines
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- Fill in potential gaps in knowledge
  - eg routes of transmission.
Specific problems

- Adapting malaria pesticide models for vector control in Chagas’ Disease
Specific problems

• Adapting malaria pesticide models for vector control in Chagas’ Disease
• Modelling access to resources across geographically difficult terrains
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- Modelling access to resources across geographically difficult terrains
  - eg distance to hospitals, swamps, mountains, road networks
- Categorise the cost to developing economies of disabling NTDs
- Model NTD research funding
- Co-infection models
  - with other NTDs and the big three.
Summary

• NTDs require immediate attention
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• NTDs extract an enormous price in
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• NTDs extract an enormous price in
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  – promotion of poverty
Summary

• NTDs require immediate attention
• NTDs extract an enormous price in
  – suffering
  – lack of economic development
  – promotion of poverty
• Mathematical models can be used to inform policy at minimal cost.
Conclusions

- NTDs are the low-hanging fruit of disease modelling
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• A great many problems could be solved, relatively easily, by harnessing the power of mathematical modelling
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• NTDs are the low-hanging fruit of disease modelling

• A great many problems could be solved, relatively easily, by harnessing the power of mathematical modelling

• The price — political and otherwise — for such a huge improvement in the quality of life for 1/6 of the world’s population is tiny.
Key References


http://mysite.science.uottawa.ca/rsmith43