Economic Aspects of Disease
Epidemiology

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Resources for the Future
Economic Epidemiology

Mathematical conceptualization of the interplay between economics, human behavior and disease ecology to improve our understanding of

– the emergence, persistence and spread of infectious agents

– optimal strategies and policies to control their spread
Overview

- Individual response and disease
- Incentives of institutions (to invest in hospital infection control)
- Malaria subsidy
Individual response and disease

- Vaccinations
  - Insufficient incentives to vaccinate prevent attainment of herd immunity thresholds

- Drug resistance
  - Insufficient incentives to make appropriate use leads to ineffective drugs and increasing prevalence

- Testing
  - Private testing behavior adds to public information on disease prevalence
Rational epidemics

- Prevalence response elasticity
  - Hazard rate into infection of susceptibles is a decreasing function of prevalence (opposite of epidemiological model predictions)
  - Application to HIV
  - Application to Measles
When should governments intervene?

- Disease prevalence increases adoption of public programs
- Impact of public program may be zero if prevalence has already reached an individual’s threshold prevalence
- Paradoxically, the role of government subsidies is lowest when prevalence is highest since individuals will protect themselves regardless
Figure 3: Survival in State Government Spending

Philipson, NBER, 1999
Public price subsidies

- Can price subsidies or mandatory programs achieve eradication?
  - Increase in demand by folks covered by the program lowers the incentives to vaccinate for those outside the program

- Do monopolistic vaccine manufacturers have an incentive to eradicate disease?
  - Market for their product would disappear with eradication

Geoffard and Philipson, Int Econ Rev, 1997
Disease Complementarities

- Incentive to invest in prevention against one cause of death depends positively on probability of dying from other causes.
- Intervening to prevent mortality not only prevents a death but also increases incentives for the family to fight other diseases.
FIGURE 1: Kaplan-Meier Survival Curve to Age 2

Dow et al, Am Econ Rev, 1999
Does the theory fit the facts?

- Do individuals actually observe prevalence?
- Why don’t we see prevalence responsiveness at work everywhere?
- Importance of observational learning (herd behavior)?
Stoneburner and Low-Beer, Science, 2004
ON THE ANTIBACTERIAL ACTION OF CULTURES OF A PENICILLIUM, WITH SPECIAL REFERENCE TO THEIR USE IN THE ISOLATION OF B. INFLUENZÆ.

ALEXANDER FLEMING, F.R.C.S.

From the Laboratories of the Inoculation Department, St. Mary's Hospital, London.

Received for publication May 10th, 1929.
Thanks to PENICILLIN
...He Will Come Home!
Superbugs
The Bacteria Antibiotics Can’t Kill

By Sheryl Gay Stolberg
The Bug Wars

In the battle of bad bacteria vs. antibiotics, the drugs usually lose.

Intermittent disease gives rise to a starring demonstration of evolution in action. The fittest bacteria—the ones that survive an antibiotic onslaught—transfer their resistance to new generations and across species. Their ability to fight back usually strengthens with each mutation, allowing them to thwart even the most intelligently designed drugs. Over the past 60 years, deadly bugs like Staphylococcus aureus, Streptococcus pneumoniae, and Escherichia coli have evolved to withstand medicines like penicillin, tetracycline, and chloramphenicol. To scientists and toxicologists alike, a tank attack—precisely targeted drug-delivery systems and bacteria-killing nanobots—may be the only answer.

Start 

Infopac

Behind Enemy Lines: A Look at Resistance Tactics

Genetic mutations enable bacteria to adapt to new threats. Here are three ways they evolve to combat antimicrobial agents.

CARRIERS

A bacterium's protein Connor makes it difficult for the antibiotic to kill it. (These are the bacteria we need to avoid for the sake of public health.)

ROBOLOCKS

The cell membranes change to keep the antibiotic out. (Bacteria like methicillin and penicillin are affected by this way.)

DISSIMULATION

A mucous protein covers the path of the antibiotic. (This is how E. coli and other spirochetes protect themselves.)

How 10 main antibiotics are described.
BusinessWeek

SPECIAL REPORT TELECOM'S POWER PLAYERS INVESTING MUTUAL FUNDS 1ST QUARTER STARS

APRIL 6, 1998 A PUBLICATION OF THE McGRAW-HILL COMPANIES $3.95

WAR against the MICROBES

How drug makers are fighting back against a global resurgence of infectious disease.

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DR. DAVID SHLAES OF WYETH-AYERST

www.businessweek.com America Online, Keyword: BR
Fig 1. Selected antimicrobial-resistant pathogens associated with nosocomial infections in ICU patients, comparison of resistance rates from January through December 2003 with 1998 through 2002, NNIS System. CNS, Coagulase-negative staphylococci; 3rd Ceph, resistance to 3rd generation cephalosporins (either ceftriaxone, cefotaxime, or ceftazidime); Quinolone, resistance to either ciprofloxacin or ofloxacin. *Percent (%) increase in resistance rate of current year (January-December 2003) compared with mean rate of resistance over previous 5 years (1998-2002): [(2003 rate – previous 5-year mean rate)/previous 5-year mean rate] × 100. **“Resistance” for E. coli or K. pneumoniae is the rate of nonsusceptibility of these organisms to either 3rd Ceph group or aztreonam.
Optimal infection control

Infection dynamics are given by

\[
\dot{X} = \beta(c)X(1 - X) - \sigma(X - \kappa)
\]

Equilibrium prevalence is given by

\[
\bar{X}(c) = \frac{S(c) - 1 + \sqrt{(S(c) - 1)^2 + 4\kappa S(c)}}{2S(c)}
\]

Smith, Levin, Laxminarayan (PNAS, 2005)
Objective

Minimize costs of infection control and infections

\[ c + D\tilde{X}(c) \]

Local minima, if they exist, are solutions to

\[ 1 + D\tilde{X'}(c) = 0 \]

Smith, Levin, Laxminarayan (PNAS, 2005)
Total Costs, $c + DX$

Daily HIC Expenditures, $c$

Smith, Levin, Laxminarayan (PNAS, 2005)
Implications for policy

- Dutch experience: frequency of MRSA infections is < 0.5% after an intensive “search-and-destroy” campaign, compared with 50% in some areas
- In Siouxland (Iowa, Nebraska, S. Dakota), an epidemic of VRE was reversed
- Regionally coordinated response to epidemic
- Does this explain higher prevalence of ARB in areas with high concentration of health care institutions?
Global spread of chloroquine-resistant strains of *P. falciparum*
WHO has established 126 sentinel surveillance sites in 35 African countries that monitor the efficacy of locally used antimalarial drugs by following up patients in clinics. According to standard protocol (13, 14), results are expressed as (i) early treatment failure (ETF); (ii) late clinical failure (LCF); in the future, late parasitological failure (LPF) will be considered as well. Treatment failure for policy change as shown here consists of the sum of ETF+LCF.

Note: The box indicates the 25th/75th percentile, the line limits lower/upper values, and where the lines cross, the median.
1 in $10^{12}$ parasites resistant to drug A

One in 10 to 100 patients

1 in $10^{12}$ parasites resistant to drug B

One in 10 to 100 patients

1 in $10^{24}$ parasites resistant simultaneously to drug A and drug B

Such a parasite would arise once in every 10,000 to 100,000 years

Nick White
Global subsidy for Artemisinin Combinations (ACTs)

- Global subsidy for artemisinin drugs
- Make ACTs as cheap as chloroquine
Central Recommendation

Within five years, governments and international finance institutions should commit new funds of US $300-$500 million per year to subsidize co-formulated ACTs for the entire global market to achieve end-user prices that are comparable to the current cost of chloroquine.
What would a subsidy do?

- Save lives and lower burden of malaria
- Discourage monotherapy by lowering price of ACTs
- Stimulate the ACT market and allow for lower prices by ensuring a stable demand
- Maintain the impetus to produce new antimalarial drugs
Why a global subsidy?

- Allow ACTs to flow through both public and private sector channels
- Give the international community leverage to discourage production of monotherapies
- Minimize administrative costs of subsidy
- Minimize incentives for counterfeit drugs, diversion and smuggling of ACTs
Could a subsidy increase the likelihood of resistance?

- Possible if the effect of a subsidy on lowering monotherapies is less than effect on increasing ACT use (and overuse)
- Depends on how ACT use and Artemisinin/partner drug monotherapy change in response to the subsidy

### EXHIBIT 4
Sensitivity Analysis With Respect To Demand Elasticity For The Six Scenarios For Ten-Year Planning Horizon And One Million Population

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Deaths averted (compared with scenario A)</th>
<th>Treatment cost per death averted ($)</th>
<th>Subsidy cost per death averted ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elasticity -2</td>
<td>Elasticity -4</td>
<td>Elasticity -2</td>
</tr>
<tr>
<td>B</td>
<td>2,939</td>
<td>7,732</td>
<td>846</td>
</tr>
<tr>
<td>C</td>
<td>5,246</td>
<td>8,939</td>
<td>1,245</td>
</tr>
<tr>
<td>D</td>
<td>3,703</td>
<td>6,724</td>
<td>1,443</td>
</tr>
<tr>
<td>E</td>
<td>5,485</td>
<td>12,665</td>
<td>444</td>
</tr>
<tr>
<td>F</td>
<td>8,141</td>
<td>17,379</td>
<td>802</td>
</tr>
</tbody>
</table>
Main findings

- Regardless of the degree of responsiveness of antimalarial consumption to price, a subsidy to ACT would save lives even if it hastened the arrival of parasite resistance to artemisinin-based drugs.
- A delay in instituting a subsidy for ACTs would exacerbate resistance would lead to faster resistance to ACTs.
- A global subsidy for multiple ACTs is likely to be far more effective in delaying the onset of resistance and saving lives than reliance on a single or even a limited number of combinations.
EXTENDING THE CURE

Policy responses to the growing threat of antibiotic resistance

www.extendingthecure.org
Antimalarial Strategies Project

- Would treating with more than one ACT combination delay emergence of resistance substantially?
- What is the optimal spatial scale for heterogeneity?
- How do these benefits compare with other strategies such as sequential use or cycling?
Opportunities – if you are interested in

- Modeling malaria
- Drug resistance
- Optimization models
Closing thoughts

- Epidemiological models take little or no account of economic constraints or incentives faced by individuals or institutions.
- Economic models mostly ignore the spatial and temporal dynamics of disease.