Avoid Infection, and While You’re At It, Have a Demographic Transition

or

Allocating Energy: What Social Activists Know About Metabolism

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for

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370-380 Shanks Hall
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OUTLINE

1. TEETH AND METABOLISM

2. MICROBES TO METABOLISM

3. SOLUTIONS TO PROBLEMS
1, WHAT HAVE TEETH GOT TO DO WITH IT?
Perturbation to enamel and dentine formation at birth, the “neonatal line”

Carious enamel (42 days)

FOR INSTANCE, A BABY TOOTH
A QUICK REFRESHER ON ENAMEL STRUCTURE AND, YES, ITS RELATION TO METABOLISM!

The number of increments between striae is called the "repeat interval".
ENAMEL STRIAE OF RETZIUS

Striae of Retzius
RELATIONSHIP BETWEEN STRIAE OF RETZIUS REPEAT INTERVAL AND BMR (ml O2/h) AMONG PRIMATES

Striae of Retzius Repeat Interval

Basal Metabolic Rate (log)

Callithrix pygmaea, Callithrix jacchus, Saginus oedipus

Callimico goeldii, Leontopithecus rosalia, Aotus sp., Saimiri sciureus

Erythrocebus patas, Hylobates lar

Pongo pygmaeus

Papio anubis

Alouatta palliata

Pan troglodytes

Homo sapiens sapiens

r = 0.90, p < 0.001
RELATIONSHIP BETWEEN STRIAE OF RETZIUS REPEAT INTERVAL AND BMR (W) AMONG PRIMATES PLUS RAT AND ELEPHANT

$r = 0.99, p < 0.001$
2. THE HUMAN ECONOMIC PRODUCTION SYSTEM
FROM MICROBES TO METABOLISM

THE MAIN ELEMENTS

- ENERGY, METABOLISM & GROWTH
- MICROBES AND METABOLIC ADAPTATION
- ECONOMIC STOICHIOMETRY
The metabolic theory of ecology posits that the metabolic rate of organisms is the fundamental biological rate that governs most observed patterns in ecology (Allen, 2002; Brown, 2004).

The Energetic-Equivalence Rule reflects mechanistic connections between individual metabolic rates, rates of energy flux by populations, and the partitioning of available energy among species in a community. (Allen, 2002; Brown, 2004)
YOU CAN ONLY EAT SO MUCH!

NEUROBIOLOGY OF THE REGULATION OF FOOD INTAKE IN HUMANS

Batterham, 2007
ORGAN MASSES FOR THE AVERAGE HUMAN

Expected

Brain

Gut & Fat

Liver

Kidney

Heart

Observed

Brain

Gut & Fat

Liver

Kidney

Heart

100%
GROWTH LAW IN THE CONTEXT OF FINITE METABOLIC SUPPLY AND DEMAND

AS A YOUNG GIRL SHE NEEDS ENERGY FOR

✓ GROWTH
✓ MAINTENANCE
✓ ACTIVITY

WHEN GROWN SHE NEEDS ENERGY FOR

✓ MAINTENANCE
✓ ACTIVITY

AS A MOTHER SHE NEEDS ENERGY FOR

✓ REPRODUCTION
✓ MAINTENANCE
✓ ACTIVITY

Semana Santa, Seville
RESUMPTION OF CHILDBEARING IS LINKED TO METABOLIC BALANCE

CHANGES IN THE ENERGY BALANCE OF BREAST-FEEDING WOMEN

Valeggia, 2003
WHAT IS COMPLEXITY?

The world is indeed made of many highly interconnected parts on many scales, the interactions of which result in a complex behaviour that requires separate interpretations of each level... New features emerge as one moves from one scale to another, so it follows that the science of complexity is about revealing the principles that govern the ways in which these new properties appear. These principles include, for instance, self-organization, self-adaptation, rugged energy landscapes, and scaling (e.g. power-law dependence) of the parameters and the underlying network of connections.

They are open systems which require exchanges of energy, materials, and/or information from extrinsic sources to maintain highly organized states far from thermodynamic equilibrium.

They are historically contingent, so that their present configurations reflect the influence of initial conditions and subsequent perturbations.

They are often nested within other complex systems, giving rise to hierarchical organizations that can be approximated by fractal geometry and dynamic scaling laws.

Nekola, 2007; Vicsek, 2002
Maternal care:

(i) mother’s sleeping proximity to infant
(ii) parental response to infant crying
(iii) bodily contact in early infancy

Quinlan, 2007
A MOTHER’S ENERGY FLOW WHEN MICROBIAL AND HUMAN SYSTEMS COLLIDE

MOTHER’S ENERGY

- REPRODUCTION
- MAINTENANCE ACTIVITY
- LIFE
- OTHER (MICROBIAL)

TARGET

- BABY
  - GROWTH MAINTENANCE ACTIVITY
- LIFE
  - HOUSEHOLD
  - SOCIAL ACTIVITIES
  - EMPLOYMENT
- OTHER (MICROBIAL)
  - INFANT/CHILD MORBIDITY
  - OWN MORBIDITY
  - REALLOCATION TO NEW BABY

REDISTRIBUTION OF MOTHER’S ENERGY
MIGHT BIRTH RATES IN THE PRESENCE OF HIGH LEVELS OF INFECTIOUS DISEASE RELATE TO REDUCED EMPLOYMENT AND NATIONAL PRODUCTION?

A POWER LAW!

Ordinary least-squares regression of log transformed data on linear scales.

\[ r = -0.884 \quad (p < 0.01) \]

\[ n = 47 \text{ countries} \]
OSMOSIS AND MATERNAL METABOLIC BALANCE

MATERNAL METABOLIC ENERGY DEVOTED TO HUMAN BIOMASS PRODUCTION IN THE FACE OF INFECTIOUS DISEASE

A MESH MAINTAINS ENTROPY GRADIENT (WHAT COULD THIS FILTER BE?)

MATERNAL METABOLIC ENERGY DEVOTED TO NATIONAL PRODUCTION IN THE FACE OF INFECTIOUS DISEASE
**A POLICY, RURAL INFRASTRUCTURE AND HEALTHCARE FILTER?**

“The growing disparity between India’s urban economy, with its white-hot annual growth rate of around 9%, and its sagging rural economy yoked with massive unemployment, is of profound concern. India, with more than 1.1 billion people, remains the country with the largest number of poor people, 70% of whom live in rural areas. Moreover, the percentage of gross domestic product the government spends on rural infrastructure has been steadily declining since the late 1980s. According to the World Bank, improving the accessibility and quality of education, health care and basic infrastructure such as water, electricity, sanitation and roads are among India’s biggest challenges.”
ECONOMIC STOICHIOMETRY

the availability and distribution of metabolic resources for nations

Example | Urban–rural differentials in selected health indicators in sub-Saharan Africa

<table>
<thead>
<tr>
<th>Health indicator</th>
<th>Urban environment</th>
<th>Rural environment</th>
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<tbody>
<tr>
<td></td>
<td>25%</td>
<td>Median</td>
</tr>
<tr>
<td>Infant mortality rates: deaths per 1,000 in &gt;1 year of age cohort in the 10 years before survey; n = 59, 1988–2002</td>
<td>60.0</td>
<td>74.7</td>
</tr>
<tr>
<td>Childhood mortality rates: deaths per 1,000 in 1–4 year age cohort in the 10 years before survey; n = 59, 1988–2002</td>
<td>41.8</td>
<td>57.3</td>
</tr>
<tr>
<td>Nutritional status: maternal body mass index; n = 40, 1992–2002</td>
<td>22.5</td>
<td>22.9</td>
</tr>
<tr>
<td>Morbid events: percentage children (&lt;3 years) ill with fever during the two weeks preceding the survey; n = 54; 1988–2002</td>
<td>29.9</td>
<td>35.1</td>
</tr>
<tr>
<td>Vaccine coverage: percentage children (12–23 months) who received bacille Calmette-Guérin, measles, three doses of diphtheria–pertussis–tetanus and polo vaccines by the time of the survey; n = 58; 1988–2002</td>
<td>46.5</td>
<td>57.9</td>
</tr>
<tr>
<td>Physical access to health services: average distance to a health facility in km; n = 6; 1999–2002</td>
<td>14.5</td>
<td>16</td>
</tr>
<tr>
<td>Use of insecticide-treated nets (ITN): percentage of households with ITN; n = 7; 1999–2002</td>
<td>30.9</td>
<td>32.9</td>
</tr>
</tbody>
</table>

For each indicator the number of demographic and health surveys and date range are given. The median and interquartile range (shown as 25 and 75 percentiles) are given. All data for sub-Saharan Africa from national Demographic and Health Surveys (see the Online links box), accessed 1 September 2004.
NATIONAL PRODUCTION AND THE COMPLEXITY OF PRODUCT SPACE

Hidalgo, 2007
In these illustrations, yellow squares mark products successfully exported. The industrialized countries' products occupy the highly connected core of world trade. Goods from Southeast Asia and the Pacific region cluster in the garment industry and in electronics, while products exported from sub-Saharan Africa and Latin America are mostly peripheral.
TO THE FINAL QUESTION, IS THERE A RELATIONSHIP BETWEEN INFECTIOUS MATERNAL METABOLIC BURDON, INFECTIOUS DISEASE, AND NATIONAL PRODUCTION?
The link between infectious disease, human biomass production and GDP.

Ordinary least-squares regression of log transformed data on log scales.

Major Infectious Diseases: degree of risk:
- VERY HIGH
- HIGH
- INTERMEDIATE
- LOW

Birth Rate / 1000 (log)

Gross Domestic Product per Capita (log)

r = -0.884 (p < 0.01)
slope = -0.38
n = 47 countries
AN IDEA EXPRESSED IN MAPS:
MALARIA DEATHS BY

Total Fertility Rate

Gender Inequality

nd-gi = no data-gender inequality
3. SOLUTIONS: THE KERALA PHENOMENON
Kerala's per capita GDP of 11,819 INR is significantly higher than the all India average.

The service sector (tourism, public administration, finance, transportation, and communications) were 63.8% of GDP in 2002–2003, while agricultural and fishing industries made up 17.2% of GDP.
Kerala is home to 3.44% of India's people; at 819 persons per km², its land is three times as densely settled as the rest of India.

Till 1971, Kerala had the highest population growth rate in India and thereafter it showed a declining trend.

Today, Kerala's rate of population growth is India's lowest, and human development indices—elimination of poverty, primary level education, and health care—are among the best in India.

<table>
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<tbody>
<tr>
<td>0-14</td>
<td>42.6</td>
<td>40.3</td>
<td>35.0</td>
<td>29.6</td>
</tr>
<tr>
<td>15-59</td>
<td>51.6</td>
<td>53.5</td>
<td>57.5</td>
<td>59.8</td>
</tr>
<tr>
<td>60+</td>
<td>5.9</td>
<td>6.2</td>
<td>7.5</td>
<td>10.6</td>
</tr>
</tbody>
</table>
THE KERALA PHENOMENON

Low birth rate and death rate along with higher female life expectancy and low infant mortality due to:

➢ Wide network of health infrastructure and manpower.
➢ Social factors like women’s education, general health awareness.
TODAY WE KNOW THAT SCALE-FREE NETWORK ARCHITECTURES LAY AT THE HEART OF NATURAL SYSTEMS AND SOLUTIONS TO VEXING PROBLEMS.

Few nodes with many connections, while remaining nodes have reduced connectivity with other nodes. (obey power law)
The Spread of Behavior in an Online Social Network Experiment

Damon Centola

How do social networks affect the spread of behavior? A popular hypothesis states that networks with many clustered ties and a high degree of separation will be less effective for behavioral diffusion than networks in which locally redundant ties are rewired to provide shortcuts across the social space. A competing hypothesis argues that when behaviors require social reinforcement, a network with more clustering may be more advantageous, even if the network as a whole has a larger diameter. I investigated the effects of network structure on diffusion by studying the spread of health behavior through artificially structured online communities. Individual adoption was much more likely when participants received social reinforcement from multiple neighbors in the social network. The behavior spread farther and faster across clustered-lattice networks than across corresponding random networks.

3 SEPTEMBER 2010 VOL 329 SCIENCE
Patients with TB must take their drugs every day for six to eight months to eliminate infection, but often stop as soon as they feel better. With mobile phones now more common in poor countries, the researchers have come up with an idea. A text message reminds patients to take their pill. On opening the pill wrapper they get a code that gives them three minutes’ free call time. “It’s the first attempt to approach poverty research in a scientific, controlled, experimental way,” Nilima Gurlanji.

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“India boasts the fastest-growing mobile-phone market in the world. One-fifth of its 218 million mobile-phone users live in rural areas and the country’s service providers are rapidly expanding wireless coverage to villages.” (Fairless, 2007)
“Once the scourge of the developing world, infectious diseases such as malaria, tuberculosis and AIDS can now be fought with cheap drugs. But as people in poorer nations live longer and adopt Western habits, non-communicable diseases such as heart disease, diabetes and cancer have become the main killers — and paying for their treatment has become a thorny problem.”

(Hayden)

**INDIA SPURNS CANCER PATENTS**

India now surpasses the United States in terms of annual cancer deaths, and wants to find ways to treat the disease cheaply. But this desire runs counter to the goals of drug makers, who see middle-income nations as central to their growth plans.

By Erika Check Hayden

Once the scourge of the developing world, infectious diseases such as malaria, tuberculosis and AIDS can now be fought with generic drugs. But as people in poorer nations live longer and adopt Western habits, non-communicable diseases such as heart disease, diabetes and cancer have become the main killers — and paying for their treatment has become a thorny problem.

The first of the recent rejections occurred on 27 July, when an Indian federal board of patent officials revoked a patent on a slightly modified version of the breast cancer drug lapatinib, sold as Tykerb by London-based pharmaceutical firm GlaxoSmithKline. Then, on 4 August, Swiss drug company Roche reported that a patent office in the city of Kolkata, a hub of the national patent system, would not grant patents on a version of the company’s drug trastuzumab, sold as Herceptin. Indian officials allowed other patents that will protect both drugs from generic competition until 2019. But the rulings will stop the companies from extending their patent protection beyond that date, opening a window for manufacturers of generic drugs to the market.

“We think the answer is to make the price of drugs really cheap.”

But drugs for non-communicable diseases — particularly cancer — will be much trickier to negotiate. “There’s no easy compromise that’s going to arise around non-communicable diseases the way that we saw around HIV,” says Thomas Bollyky, a lawyer with the Council on Foreign Relations in New York who fought for affordable HIV medicines in the 1990s.

In India, a $15,000 course of trastuzumab can cost more than ten times the average annual wage. And there are no older, off-patent drugs that could serve as an alternative, because none of them target the specific type of breast cancer as well as trastuzumab.

Yet drug makers are reluctant to cut prices in middle-income countries such as India, China and Brazil, which are projected to account for much of the industry’s growth in the near future (see “Drug money”). Although Africa’s ability to pay for HIV drugs was never going to be high, some people in middle-income countries can afford expensive medicines. Drug makers do not want to erode that market through lower-cost drugs, even if the vast majority of people in need cannot pay, says James Love, director of Knowledge Ecology International, a non-governmental organization in Washington DC that advocates for social justice in access to knowledge.

A number of ideas to skirt the impasse have been floated, but none are simple. Drug makers argue that governments of middle-income nations should broaden insurance programmes and access to health care. They also argue that drugs will become more affordable as economies grow and people earn more money. By reducing support for intellectual property, India is undermining incentives for drug development and forcing cheap drugs. But as people in poorer nations live longer and adopt Western habits, non-communicable diseases such as heart disease, diabetes and cancer have become the main killers — and paying for their treatment has become a thorny problem.

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(Hayden)
The rural diaspora coupled with infectious disease and poor national production affects the mortality landscape in unexpected ways.

“Postseismic investigations reveal that structural collapse is typically attributable to shoddy construction resulting from poverty and ignorance, or to covert avoidance of building codes by contractors.” (Bilham & Gaur)
Many thanks to:

Virginia Tech

and for

Thinking Out of the Box

Phi Beta Kappa Mu of Virginia Chapter