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Every generation needs a new revolution: 200 years in the history of longevity

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The huge increase in life expectancy enjoyed by people in the industrialized world since 1800 is among the most remarkable facts in human history. No one living in 18th century Europe could have foreseen that a lifespan of more than 70 years would be possible for the majority – indeed almost everyone. Nor could they have imagined that the prospects for survival would improve so rapidly.

Essential ingredients

Thomas Jefferson's remark that "every generation needs a new revolution", made in the early 1800s, is still an inspiration for every new generation. A look back over 200 years of human longevity shows that a revolution in health is possible in the space of a single human generation. But while some developing countries, notably China, have taken advantage of the earlier European experience, others are still trying to escape pre-industrial levels of mortality, with persistently high death rates among children. The preventive and curative methods needed to cut mortality – including antibiotics, clean water, sanitation and vaccination – are mostly simple to use and widely available. The reason why they have not been used universally is that they are merely essential ingredients, not the complete recipe for a long and healthy life.

The story of rising longevity begins in England – ground zero for the industrial revolution. Figure 1 is a reconstruction of life expectancy in England over seven centuries. The data are sketchy for the 14th and 15th centuries, when life expectancy from birth was about 30 years. There were ups and downs between about 1550 and 1800, but life expectancy remained trapped between 30 and 40 years (1). Not until the early 1800s did life spans steadily increase, reaching 70 in England by around 1950. The only marked periods of decline were the years of the two world wars.

Why did life expectancy remain constant and low for so long, and how did it double in less than 200 years? Long periods of stasis in populations are a sign of regulation, or negative feedback. When life expectancy goes up, there is some compensatory force that brings it back down. When it goes down, there is some process that brings it back up.

The best-known exponents of the idea of population regulation were the economic historians Thomas Malthus and David Ricardo. At the end of the 18th century, Malthus suggested that human populations would be regulated by their food supply. The problem, as he expressed it, was that populations grow geometrically (1, 2, 4, 8…), but the food supply increases only arithmetically (1, 2, 3, 4…). Under this regime, people inevitably grow hungry. This is a simplistic view, but there are numerous ways in which negative feedback could affect longevity – by acting directly on mortality or indirectly through fertility. Wherever death rates have shown a sustained decline, largely through improved nutrition and the control of infectious diseases, birth rates have also dropped soon after. This sequence of events has, in most countries, launched a "demographic transition" from high birth and deaths rates in small populations towards low birth and death rates in large populations. Contraceptive methods invented in the 20th century have made the control of fertility relatively easy (and given more control to women), but families have for centuries adjusted the number of children born to compensate for others that have died.

Technological advances

The English population broke free of negative feedback around 1800 by taking a gigantic step in innovation – switching from an organic to an inorganic economy, from an economy based on agriculture to one based on coal (4). The accelerating increase in life expectancy was tracked by growth in income, and the two are likely to have been a mutually reinforcing, positive feedback process (Figure 1).

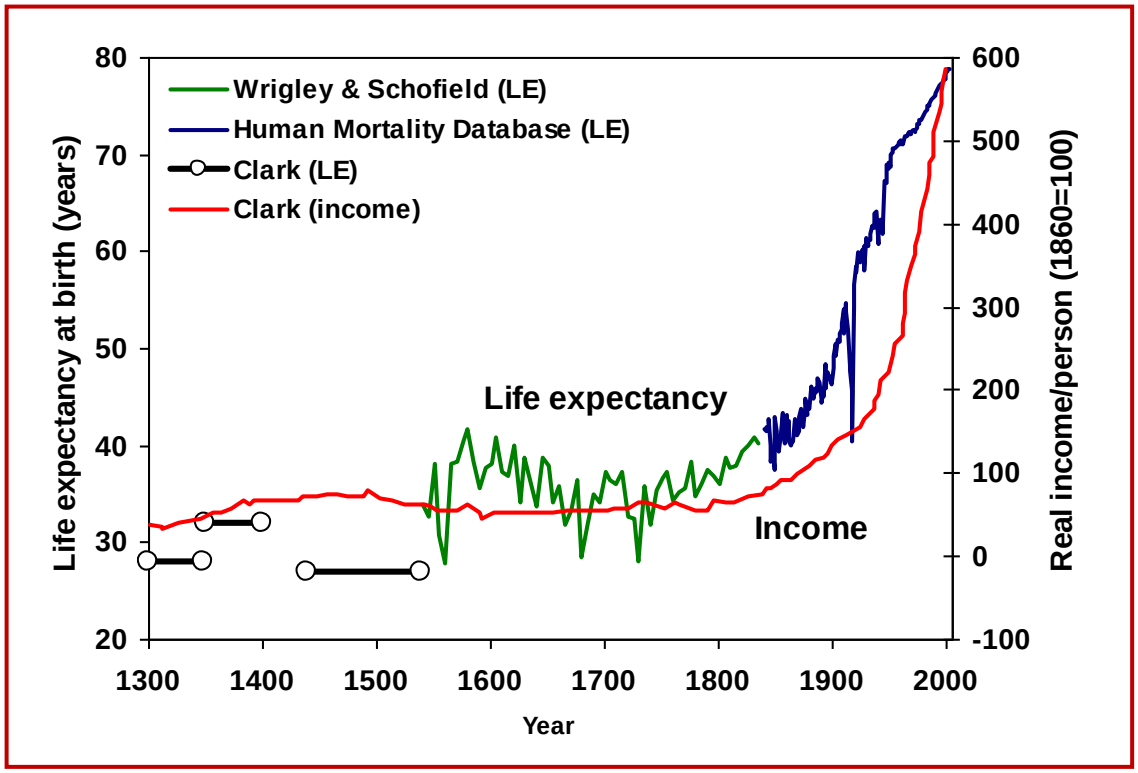

Figure 1. Life expectancy from birth in England (and Wales) was under 40 years up to about 1800 (black, green), then more than doubled between 1800 and 2000 (blue) (1-3). Income per person (red) also increased sharply after 1800.

Accompanying and following this switch, three technological developments generated three successive revolutions in health. First, better agricultural productivity improved nutrition. Prior to the 18th century in England, there was typically a 20-30% excess in food production each year, with a similar fluctuation in yield. The upshot was that some farming communities in some years lived on the edge of starvation. As farming technology improved, generating bigger surpluses in yield, famines became fewer, and there were none in the 20th century. In terms of Malthus's simple model, new technology allowed the food supply to grow geometrically, like the population. So production could now satisfy reproduction.

The second set of events together constituted the "sanitation revolution". Even though the pathogens that caused diseases such as cholera were unknown in the mid 19th century, pioneering epidemiological studies found that a supply of clean water and the removal of human waste could prevent and control epidemics. Large-scale public health measures probably added to the positive feedback processes that led to rapid reductions in mortality. In the "malnutrition-infection complex", diarrhoea leads to poor food absorption, which leads to lower resistance to infection, which leads to more diarrhoea. This is a downward spiral that can be converted to a powerful upward spiral, with the potential to sharply reduce mortality.

The third revolution was in microbiology. Although inoculation had been carried out for centuries to prevent, for instance, smallpox and leishmaniasis, vaccination science did not flourish until the late 19th century. At the same time new methods were invented to culture and identify bacteria, like Mycobacterium tuberculosis. Spectacular cure rates of bacterial diseases were achieved with the discovery of antibiotics in the first half of the 20th century.

These technological advances in agriculture, public health and microbiology led to a doubling of life span in England within 200 years. But the success was not purely technological; it depended on having the institutions, capital and skilled labour to exploit the technology. John Snow and Edwin Chadwick were the leading sanitation revolutionaries of 19th century England, but the application of their ideas could not take full effect without political and legal instruments, including the Public Health Act of 1848.

The life expectancy for people born in England today is approaching 80 years. Although there must be an upper limit to human life span, there is no indication that we are close to that limit yet. The maximum average life span recorded in the best-performing countries has been growing linearly by 1 year in every 4 years since the middle of the 19th century, with no sign of a slow-down. The pinnacle of longevity is currently occupied by Japanese women, who in 2006 had a life expectancy at birth of 86 years. If longevity continues to grow at the same pace, most babies born since 2000 in wealthy countries will reach their 100th birthdays (5).

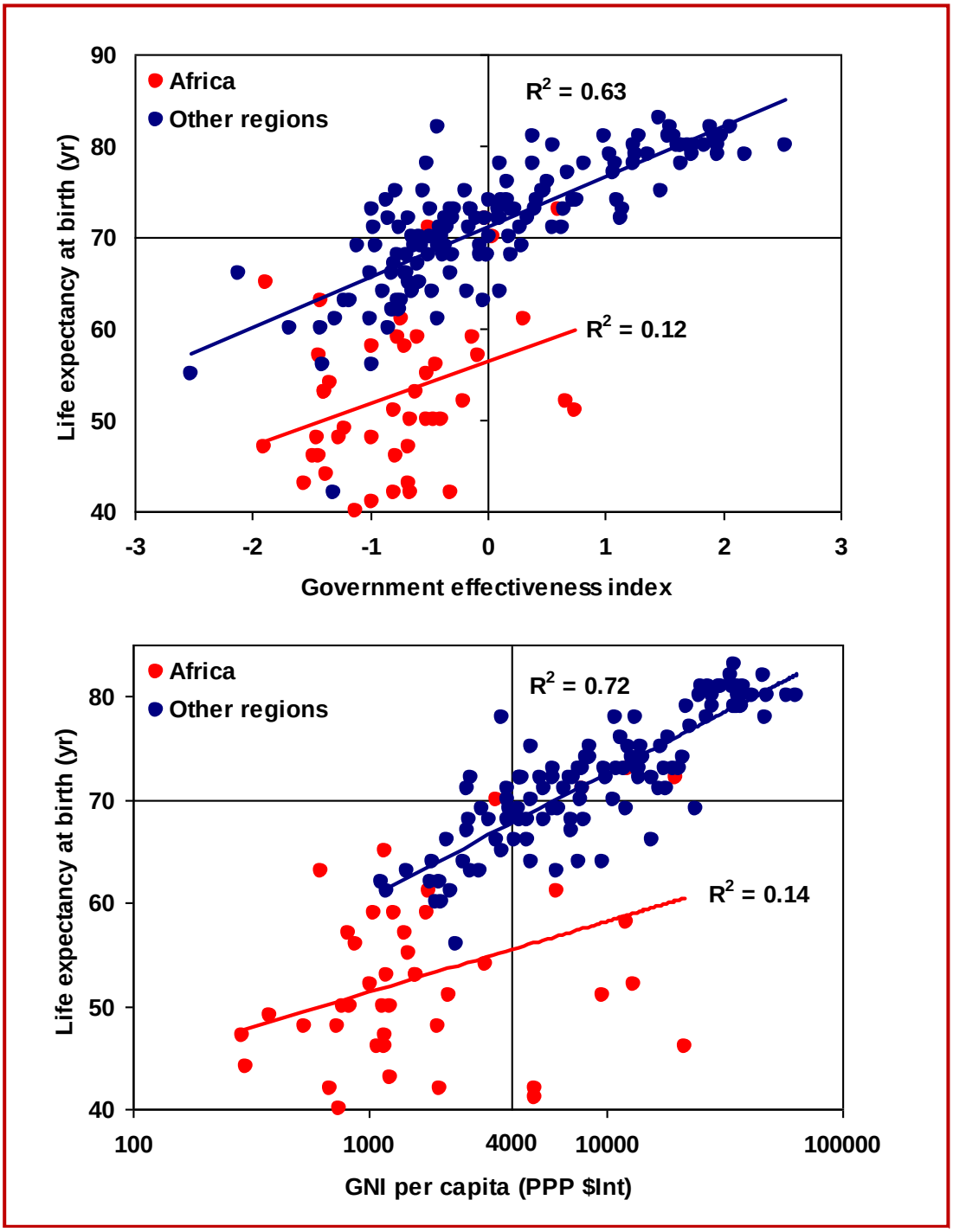

Figure 2. Government effectiveness (top) and gross national income per capita (bottom) are strongly associated with life expectancy countries outside Africa (each point represents a different country) but weakly associated with life expectancy in Africa. Life expectancies are WHO estimates for 2006 (7). Government effectiveness is from Kaufmann et al (8) and 2008 estimates of GNI (PPP $Int) are from the World Bank (9).

The accumulation of wisdom that led to increased life spans during the industrial revolution has since allowed much faster improvements in health as knowledge and technology have diffused worldwide. In England, the growth in life expectancy reached a maximum of 4.2 years per decade in first half of the 20th century. In comparison, life expectancy in sub-Saharan Africa grew at 3.3 years per decade between 1960 and 1990 but was then reversed by 3.3 years in the 1990s, largely due to the spread of HIV/AIDS. However, the pacesetter is no longer England in the first half of the 20th century but rather China in the second half. Life expectancy in China increased by a staggering 25 years in the 25-year period from 1950 to 1975. This pathway to immortality was not of course sustainable, and it slowed markedly after the death of Mao Tse Tung in 1976. Moreover, sharp reductions in mortality have brought other adverse consequences to China. The need to cut the number of births, and to adjust socially and economically to a rapidly ageing population, have been felt acutely in China (6).

Although people born in England have expected to live beyond 70 years for half a century, only about half of the world's countries have now reached that mark, with the poorest performers mostly in Africa (Figure 2). The relatively short life spans in today's low- and middle-income countries are still mostly attributable to deaths from infectious diseases (7). Among the 60 million deaths that occurred in 2004, about 10 million were children under 5 years old, three-quarters of them living in Africa and South-East Asia. Three million died within a month after birth. Another 4 million died from respiratory infections and diarrhoea. And underpinning many of these immediate causes of death was malnutrition. The vast majority of these deaths could have been avoided with cheap and simple preventive methods and treatments.

Economic development

Why, then, have African and South-East Asian countries not been able to emulate China's success? The answer is that technical know-how and medicines are necessary but not sufficient for good health. Unless public health can be conducted in the style of a military campaign (like polio vaccination), specific health interventions (such as tuberculosis treatment) need strong public health systems, and public health systems need the institutions (democracy, governance, law, infrastructure), capital and skilled labour to administer them.

Measures of institutional performance and governance, such as government effectiveness, are positively associated with life expectancy (Figure 2, top). This association does not prove that life expectancy depends on good governance. It does, however, show that the great majority of countries that score less than zero on government effectiveness (especially in Africa) have not yet achieved life expectancies of at least 70 years. Good governance is evidently a prerequisite for good health for the majority.

The association between life expectancy and income is more profound still (Figure 2, bottom). Income per capita is a somewhat better predictor of longevity than government effectiveness. But the key point is that practically no country with an average annual income per capita under $4000 has achieved a life expectancy of 70 years. The few exceptions (Figure 2, top left quadrant), mainly Cuba and Vietnam, prove the rule. These former communist countries have not followed the mainstream of health development, and they have a limited role as models for others. There are, of course, countries with incomes in excess of $4000 that also have not reached or maintained life expectancies above 70 years. Outstanding among them are Botswana and South Africa, which have high prevalence rates of HIV infection and AIDS.

The implication of Figure 2 is that good health has to be founded on a minimal level of economic development and all the factors that go with that, including government effectiveness. This is not to say that selected interventions driven by government or external aid, cannot work. But it does suggest that specific interventions have not, on their own, altered the larger picture of improving health, as measured by longevity.

For countries where birth and deaths rates are still high, the simplistic prescription for good health runs as follows. Introduce cost-effective methods to cut mortality, mainly from infectious diseases. Then, with growing confidence that their children will survive, families will choose to reduce fertility. The upshot is that today's children become young adults with few dependants, and cash in the "demographic dividend" on the road to health and wealth.

But that road has been open for a while, and not taken. To follow it now, people living in the poorest countries will need their own new revolutions. Technological breakthroughs are highly desirable, but not enough. Essential too are the right public and private institutions to stimulate both health and wealth, because long life for the majority is incompatible with widespread poverty.

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Note: From 2006-9 the author was Gresham Professor of Physic in the city of London, and this article is based on his inaugural lecture. The author alone is responsible for the views expressed in this article, which do not necessarily represent the decisions, policy or views of WHO.

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