Disease emergence and health transitions in the last millennium

L Donaldson

ABSTRACT - For most of the first millennium, average expectation of life was only 30 or 40 years. The beginning of the 20th century saw the start of improvements, which by the century's end meant that a baby boy could expect an average 75 years of life, a baby girl even longer. The successes of the 20th century were not products of advances in medicine alone, but consequences of the great sanitary reforms that fuelled the public health movement in late Victorian Britain. However, health challenges also grew and changed: the rise in so-called modern epidemics (coronary heart disease, cancer, accidents and mental illness); the ageing of the population; the containment of the costs of rapid technological advances; the marked and intractable inequalities in health status between rich and poor, and between North and South.

The dawn of a new millennium sees many of these health problems carried over from the late 20th century, whilst communicable diseases, once thought conquered, continue to pose a serious threat to human health because of their global significance. This paper traces progress in the health of the population and identifies some of the key challenges for medicine in the 21st century.

Health in the doldrums

Looking back over the last millennium it is difficult to imagine the scale of the devastation and human misery inflicted by the great epidemic diseases on millions of people in cities, towns and countries around the world. As many as 137 million people are estimated to have died from three major epidemics of the plague in the 6th, 14th and 17th centuries, whilst in the 14th century one third of the populations of Europe and Asia is known to have died from the bubonic plague. Boccaccio's poigniant prose on the plague of Italy in The Decameron reflects those forbidding times:

How many valiant men, how many fair ladies, breakfasted with their kinsfolk and that night supped with their ancestors in the other world?

In the 18th and 19th centuries, cholera was a major cause of several pandemics. Until the early 1800s, cholera was a disease that appears to have been virtually confined to India. By the late 1820s, rail and steamship travel had allowed Asiatic cholera to migrate: by the winter of 1830/31 it had reached the eastern half of Russia; the following winter the cities of Eastern Europe were under siege; and by the spring of 1832, the Americas were also affected. Worldwide, thousands were ill and dying and mass panic ensued.

In 1831, Sunderland was the fourth largest port in the country as measured by tonnage. One of its imports was flax, which arrived from Riga on the Baltic. In response to the outbreak of cholera in Riga, the British government extended a 15 day quarantine regulation for ships from Russia, to cover ships from the Baltic and Germany as well. Regulation was left to the local authorities to enforce; some did, but in Sunderland the narrowness of the River Wear made quarantine difficult to control. The quarantine station was sited at Deptford, a mile or so upriver from Sunderland Bridge. This area was crowded with ships and at night crew members were reported to have gone ashore at will. This is probably how cholera came into the town. One of the first recorded deaths from cholera in England was that of twelve-year-old Isabella Hazard, who died on 17 October 1831, depicted as the 'blue girl' in the Lancet (Fig 1). Thus, cholera introduced through the port of Sunderland brought about a major epidemic in Victorian England, leaving tens of thousands in the towns and cities dead in its wake.

Smallpox and tuberculosis raged throughout England during the 16th and 17th centuries and were responsible for huge numbers of deaths; for example, around the mid 1500s tuberculosis accounted for about 20% of all deaths in England, with the greatest numbers found in London.

As a result of these great scourges, life expectancy at birth did not rise above thirty years for 300 years after records began in 1541.

Starting to make an impact

Whilst there was an understanding of the need for quarantine and isolation, for most of history there was little understanding of the causes of disease. In Victorian times it was believed to come from a 'miasma' – an invisible vapour arising from graveyards and rotting vegetation. Then came the emergence of the 'germ theory' of disease. The germ theory of disease was developed through the work of scientists such as Louis Pasteur and Robert Koch. Pasteur showed that there were bacteria in the air by observing their growth in sterile culture media. The germ theory of disease causation was based on a simple relationship between the causative agent and the host, which formed the foundation.
of the biomedical model of disease. The theory dispelled myths and superstitions around disease that had stood for centuries.

This development led to the rise of public health as a preventive science with practical applications. The path to intervening to prevent diseases like cholera was marked in 1842 by the publication of the *Report on the sanitary condition of the labouring population of Great Britain*, written by the redoubtable Edwin Chadwick, a major figure in public health reform. Chadwick was instrumental in drawing attention to the need for sanitary measures to aid disease prevention. A few years later, The Public Health Act of 1848 laid the foundations for many of the improvements in health that occurred during the last century.

Earlier, the work of Edward Jenner*, often described as 'a country physician' in Berkeley, Gloucestershire, had laid the foundations for one of the greatest ever health interventions. Towards the end of the 18th century, he discovered that a mild illness to which milkmaids were particularly prone protected against smallpox. History shows that Jenner drew, with the point of a clean lancet, serum from the cowpox pustules on the hand of a milkmaid, Sarah Nelmes. She had acquired the cowpox infection naturally. Using the point of the same lancet, Jenner made two incisions on the arm of James Phipps, the seven-year-old son of a labourer of his acquaintance. The boy was then exposed to smallpox and did not acquire it. The discovery of cowpox saved millions of lives around the world. Later, when polio incidence rose dramatically around 1945, the scientific community responded rationally by taking wild polio virus, growing it in cell culture to produce an inactivated vaccine and subsequently attenuating it to produce oral polio vaccine. The former was introduced into the United Kingdom in 1956 and the latter in 1962 (Fig 2). The result has been the virtual disappearance of polio from countries wherever the vaccine was introduced and high coverage has been achieved.

These two vaccines illustrate the vital role that immunisation has played in the conquest of disease. As a result of Jenner's discovery, smallpox was eventually eradicated in the late 20th century and as a result of sustained international commitment, poliomyelitis is well on its way to extinction. A further strand of enlightenment in the approach to communicable diseases was the recognition by Semmelweiss and others that postoperative and puerperal sepsis were linked to poor hygiene, and could be avoided by the introduction of antiseptic techniques, notably Lister's use of carbolic spray in his operating theatre (Fig 3).

It was only in the late 19th century that the health status of the

![Fig 1. 'Blue girl' in the Lancet.](image-url)
population began to change. The major sanitary reforms in Victorian England laid the foundations for the greatly increased expectation of life at birth that marked the end of the 20th century. Apart from improvements in life expectancy, there was a large reduction in infant and childhood mortality (Table 1).

**Communicable diseases: the eternal enemy**

Despite the triumphs of the last two centuries and the continued reduction worldwide of vaccine-preventable diseases, communicable diseases continue to pose threats and challenges for the health of the population.

Influenza was a major cause of death, and particularly so in the influenza pandemic of 1918–1919, which killed at least 25 million people worldwide in one year and around 228,000 in Britain.

One of the greatest challenges in the 20th century came from the new and emerging infections. Human immuno-deficiency virus and the acquired immune deficiency syndrome (HIV/AIDS) represent one of the more striking examples. AIDS was recognised clinically in the early 1980s when the first few cases were reported in the United States and the United Kingdom. Current scientific thinking suggests that HIV originally developed from a simian immunodeficiency virus (SIV) possibly in chimpanzees and that this was transmitted to humans in west central Africa in the 1920s or 1930s. One of the most popular theories among scientists is that this cross-species transmission occurred during the hunting and butchering of animals, the so-called 'cut hunter' theory.

The Joint United Nations Programme on HIV/AIDS (UNAIDS) has estimated that nearly 34 million people worldwide were living with HIV/AIDS at the end of the 20th century, the majority of them in sub-Saharan African countries. In 1999 alone, over 2 million people died of AIDS and some 5 million adults were newly infected, as were over half a million children under 15 years old. The trend in HIV infection will have a profound effect on future rates of infant, child and maternal mortality, life expectancy, and economic growth.

Treatment for people with HIV and AIDS includes combinations of antiretroviral drugs that not only prolong life but also improve quality of life. Figure 4 shows that in the United Kingdom the number of people with HIV/AIDS increased steadily during the final two decades of the 20th century, while the number of deaths decreased after the introduction of new therapies in the mid 1990s.

Another lesson from communicable diseases in the 20th century was to recognise how important it is to remain vigilant and be prepared to think the unthinkable when seeking to assure maximum protection of public health. The story of how a new human disease, variant Creutzfeldt-Jakob disease (vCJD), arose from poor animal hygiene leading to

---

**Table 1. Changes in the health status of the population in the 20th century.**

| Expectation of life at birth (years) | Males | Females |
|-------------------------------------|-------|---------|
| 1900                                | 44.1  | 47.8    |
| 1998                                | 75.1  | 80.0    |

| Infant mortality                    |       |         |
|-------------------------------------|-------|---------|
| 1846                                | Approx 160 per 1000 live births |         |
| 1999                                | 5.7 per 1000 live births        |         |
the occurrence of bovine spongiform encephalopathy (BSE), is an object lesson in this respect. Other events at the very end of the 20th century also emphasised the importance of vigilance and good surveillance. An unexpected number of dead crows in the city of New York in the summer of 1999 was the first unrecognised indication that a potentially fatal infectious organism previously unknown in the Western hemisphere had emerged in the United States. Human cases of viral encephalitis began to be seen in August 1999 in New York City and later in neighbouring counties in New York State. The infection was first thought to be due to St Louis encephalitis (SLE), a virus transmitted by mosquitoes, which occurs in the southeastern states of America but not usually in New York.

Zoo birds as well as crows had been dying before and during the outbreak. A virus similar to SLE was found in tissues from the birds, but the virus more closely resembled one called West Nile Virus (WNV). WNV is known to have caused human epidemics in Israel, Europe and South Africa since the early 1950s but never in the Western hemisphere. New tests on the patients’ samples confirmed the virus was the same. The link between the birds and the human cases was made.

By the end of 1999, 62 people had been confirmed as having West Nile Fever and seven had died. The American crow was the major casualty; 861 birds died. Mosquito control measures were carried out in the outbreak areas by spraying with a synthetic pyrethroid insecticide.

It is still not known how the virus was introduced to North America; an infected traveller or imported birds may have played a role.

Even in the middle of the 20th century, communicable diseases were still bringing about a relatively large number of deaths compared with the position at the end of the century (Table 2). Vaccines did much to reduce mortality and morbidity in childhood. Leaving aside newly emergent infectious diseases like HIV/AIDS, which caused major morbidity and mortality in the 20th century, trends in infectious disease occurrence in the population of the United Kingdom reflect changes in human behaviour and lifestyle.

As more and more people travelled abroad, both to and from the United Kingdom, imported diseases such as malaria increased. Whilst they have not yet posed a major threat to the British population, there is an ever present risk that infectious diseases, endemic in certain distant countries, could be imported. For example, the viral haemorrhagic fevers (e.g. Lassa fever) can be spread from person to person, yet only affect a small number of individuals who travel to the endemic areas of West Africa.

In that part of the world however, infection is quite common and is transmitted mainly by contact with excreta of the natural host (rat), or person to person by contact with body fluids.

Other lifestyle changes such as eating out, together with lapses in standards of food hygiene or production accounted for an increase in population morbidity from food-borne diseases in the last two decades of the 20th century.

Whilst the advent of antibiotics in the 20th century did much to counteract morbidity and mortality from communicable diseases, the final decades of the century demonstrated that this success had a serious downside. About 9% of inpatients had a hospital acquired infection at any one time, equivalent to at least 100,000 infections a year. The effect of infection varied from mild discomfort to prolonged hospital stay, permanent disability, and even death for a small number of patients.

This was compounded by the major growth of antibiotic resistant organisms. When penicillin, the first true antibiotic, was introduced in 1946, 5% of staphylococcal infections were resistant to it. By 1952, this had risen to 85%. In 1997, the first staphylococci partially resistant to vancomycin, the drug usually kept in reserve for treating...
highly resistant strains, were reported from Japan\textsuperscript{13} and then America\textsuperscript{14}. Some infections are spread by person to person contact, some are derived from the patient's own flora, whilst others may result from contact with a contaminated environment. Antibiotic resistance is a particular problem on intensive care units, where infection is common and antibiotics frequently prescribed. Resistance to antibiotics is not confined to hospitals, but is emerging in the community as well; for example, \textit{Streptococcus pneumoniae} and multi-drug resistant tuberculosis (MDRTB).

For two human generations antimicrobial agents have altered expectations of life and death but antibacterial drug resistance will remain a major challenge for the foreseeable future, and policies to combat it\textsuperscript{15} must be rigorously implemented.

**The rise of chronic diseases**

The second half of the 20th century saw a major shift in the burden of disease from the communicable disease, which had dominated the rest of recorded history, to the so-called modern epidemics. Diseases such as coronary heart disease, cancer, stroke, mental illness and injury became common causes of premature death and chronic illness.

Mortality from coronary heart disease (CHD) peaked during the 1970s and remained the most important cause of premature death, chronic ill health and disability in the United Kingdom for the remainder of the 20th century. Mortality from it in this country was worse than in many parts of Western Europe, and internationally the pattern differs markedly:

- the rate of coronary heart disease is increasing in Central and Eastern Europe
- the rate of coronary heart disease is decreasing in the wealthy countries of Europe, North America and Australasia
- the rate of coronary heart disease in Japan is comparatively low and is declining
- in wealthy countries, coronary heart disease is more common in the lower socio-economic groups
- in the UK and USA, the decline in coronary heart disease has occurred at a faster rate in the higher socio-economic groups.

In 1900, cancer was the cause of about 5% of all deaths, whereas in 1999 that figure had risen to around 24%. In this 24%, lung and breast cancer were the most common cancers. Decreases in mortality from cancer at different sites (Fig 5)\textsuperscript{16} reflect true reductions in their occurrence and in some cases improved survival.

The realisation that against a background of steadily increasing health during the 20th century there were marked inequalities in health status came in the early 1980s\textsuperscript{17}. For example, in the middle of the last century a professional person had about a one and a half times greater chance of dying of coronary heart disease than someone in an unskilled manual occupation. At the end of

![Image]

**Disease emergence and health transitions in the last millennium**

**Death rates risen by 40% or more over the last 20 years**

- +61% Lung cancer in women over age 65
- +53% Malignant melanoma
- +45% Oesophageal cancer in men
- +40% Prostate cancer in men over age 75

**Death rates fallen by 40% or more over the last 20 years**

- -47% Lung cancer in men under age 75
- -50% Cervical cancer
- -50% Cancer in children
- -52% Stomach cancer
- -57% Uterine cancer
- -73% Testicular cancer

**Fig 5. The change in annual death rate in the UK from different cancers between 1979 and 1999\textsuperscript{16}.**

The 20th century the gap was a factor of almost three in the opposite direction (Fig 6). However, this is only one of many health inequalities. Overall, at the end of the 20th century, 17,000 premature deaths in Britain would have been avoided each year if the death rates of all men of working age had been the same as those in professional and managerial jobs\textsuperscript{18}. The gradient applied to almost all causes of death.

Before the 20th century, little was known about the health detriment incurred by certain lifestyles such as smoking, faulty diet, lack of exercise, substance abuse, and excess alcohol consumption. These links were systematically established through high quality epidemiological research\textsuperscript{19,20}.

Late in the 20th century, understanding of diseases like circulatory disease had moved beyond purely attributing causation to specific risk factors. The importance of social and economic determinants of poor health and inequalities\textsuperscript{21,22} produced a fundamental shift in approaches to the promotion of population health. Creating opportunities for better health through strategies in education, environment and employment, coupled with local inter-agency programmes as well as encouraging people to change their lifestyle was the public health response to the challenges of the late 20th century. Just as a similarly broad-based public health effort had tackled the problems of Victorian England.

**Conclusions**

After 19 centuries in the last millennium in which people were at the mercy of the great communicable disease scourges of humankind, the early 20th century saw the tide
beginning to turn, and by the end of the century in Britain expectation of life had virtually doubled. The health challenges of the first decades of the 21st century echo those of the last years of the 20th century: tackling deep-seated health inequalities, remaining vigilant in the fight against communicable diseases and harnessing the benefits of science, research and technology for health care.

References

1  www.humanities.ccny.cuny.edu/history/plague/decameron.htm.
2  Milburn JE, Miller ST (eds). Sunderland River, town and people: a history from the 1780s. Sunderland: Thomas Reed Printers Ltd, 1988.
3  Dreyer F, Whitehead M (eds). Health inequalities: decennial supplement: DS series no. 15. London: The Stationery Office, 1998.
4  Donaldson LJ, Donaldson RJ. Essential public health. Reading: Petroc Press, 2000.
5  Chadwick E. Report on the sanitary condition of the labouring population of Great Britain. (Flinn MW, ed). Edinburgh: Edinburgh University Press, 1965.
6  Fisher RB. Edward Jenner. London: André Deutsch Limited, 1991.
7  Krause RM. Emerging infections. New York: Academic Press, 1998.
8  Centre for Disease Control and Prevention. Update on acquired immune deficiency syndrome (AIDS). Morb Mortal Wkly Rep 1982;31:507-8, 513-14.
9  Weiss RA, Wrangham RW. From Pan to pandemic. Nature 1999;397:385-6.
10  Maxwell R. An unplayable hand. BSE, CJD and British government. London: King’s Fund Publishing, 1997.
11  Committee on the Microbiological Safety of Food. The microbiological safety of food: parts I and II: the report of the Committee on the Microbiological Safety of Food to the Secretary of State for Health, the Minister of Agriculture, Fisheries and Food, and the Secretaries of State for Wales, Scotland and Northern Ireland. London: HMSO, 1990.
12  National Audit Office. The management and control of hospital acquired infection in acute NHS trusts in England. London: The Stationery Office, 2000.
13  Hiramatsu K, Hanaki H, Ino T, Yabuta K, et al. Methicillin-resistant Staphylococcus aureus clinical strain with reduced vancomycin susceptibility. J Antimicrob Chemother 1997;40:135-6.
14  Centre for Disease Control and Prevention. Staphylococcus aureus with reduced susceptibility to vancomycin – United States 1997. Morb Mortal Wkly Rep 1997;46:765–6.
15  Interdepartmental Steering Group on Resistance to Antibiotics and other Antimicrobial Agents (chaired by Dr Pat Troop). UK antimicrobial resistance strategy and action plan. London: Department of Health, 2000.
16  Department of Health. Saving lives: our healthier nation. London: The Stationery Office, 1999.
17  Department of Health and Social Security. Inequalities in health: report of a research working group (The Black Report). London: HMSO, 1980.
18  Marmot M, Shipley MJ, Rose G. Inequalities in death – specific explanations of a general pattern? Lancet 1984;1:1003–6.
19  Doll R, Hill AB. A study of aetiology of carcinoma of the lung. Br Med J 1952;2:1271-86.
20  Lerner DJ, Kannel WB. Patterns of coronary heart disease morbidity and mortality in the sexes: a 26 year follow up of the Framingham population. Am Heart J 1986;111:383–90.
21  Wilkinson RG. Unhealthy societies: the afflictions of inequality. London: Routledge, 1996.
22  Acheson D. Report of the Independent Inquiry into Inequalities in Health. London: The Stationery Office, 1998.

Address for correspondence: Professor L Donaldson, Chief Medical Officer, Department of Health, Room 111 Richmond House, 79 Whitehall, London SW1A 2NS. E-mail: Liam.Donaldson@doh.gsi.gov.uk