An introduction to the history of infectious diseases, epidemics and the early phases of the long-run decline in mortality[†]

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This article, written during the COVID-19 epidemic, provides a general introduction to the long-term history of infectious diseases, epidemics and the early phases of the spectacular long-term improvements in life expectancy since 1750, primarily with reference to English history. The story is a fundamentally optimistic one. In 2019 global life expectancy was approaching 73 years. In 1800 it was probably about 30. To understand the origins of this transition, we have to look at the historical sequence by which so many causes of premature death have been vanquished over time. In England that story begins much earlier than often supposed, in the years around 1600. The first two 'victories' were over famine and plague. However, economic changes with negative influences on mortality meant that, despite this, life expectancies were either falling or stable between the late sixteenth and mid eighteenth centuries. The late eighteenth and early nineteenth century saw major declines in deaths from smallpox, malaria and typhus and the beginnings of the long-run increases in life expectancy. The period also saw urban areas become capable of demographic growth without a constant stream of migrants from the countryside: a necessary precondition for the global urbanization of the last two centuries and for modern economic growth. Since 1840 the highest national life expectancy globally has increased by three years in every decade.

At time of writing when several billion people are in 'lock-down' the history of infectious diseases has a new relevance. Much important historical work on how epidemics and infectious disease were brought under control, the escape from premature death, and the sources of the spectacular long-term improvements in life expectancy over the last two centuries has been published or reviewed in the *Economic History Review*, an academic journal published since 1927 by the Economic History Society.

The Economic History Society and the publisher of the *Review*, Wiley, are therefore pleased to make available a free virtual issue of the *Economic History Review* consisting of a selection of articles and book reviews on the history of disease, epidemics and long-run improvements in life expectancy.[1] This introduction is intended to give a brief general introduction to the long-term history of disease and mortality decline, primarily with reference to English history (which is particularly well documented) before 1900. This is necessarily a somewhat simplified account and suggestions for further reading can be found in the footnotes.[2] The topic may seem morbid, but is a fundamentally optimistic one.

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[1] Please note that the special issue has been put together in a limited time, and some articles and book reviews that could or should have been included may have been missed. We apologise in advance to any authors whose work has been inadvertently omitted.

[2] For a superb and very accessible general introduction to the history of disease and patterns of mortality before the nineteenth century, which probably makes the best place to start further general reading, see Walter and Schofield, 'Famine, disease and crisis mortality'. In this special issue, see Kunitz, 'Speculations', for an overview of the origins of the decline in mortality in Europe. For an excellent start to further reading on long-run declines in mortality, see the editors' introduction to Schofield et al., eds., *Decline of mortality.* For a more recent and global overview, see Davenport, 'Patterns of death'. For book-length overviews see Riley, *Rising life expectancy*; Fogel, *Escape from hunger*; Mercer*, Infections*. It has not always proved possible to provide precise

The world we have escaped

In 2019 global life expectancy was approaching 73 years. In 1800 it was probably about 30.[3] This is arguably the most important single historical change of the last two hundred years. In 1800 no country in the world had a life expectancy much above about 40. The highest figures for territories reported by the World Bank in 2018 were 84.9 in Hong Kong, 84.9 in Japan and 84.1 in Macau (table 1). Today most people in rich countries like the UK die of degenerative diseases or complications arising from them, such as cancer, heart disease, diabetes and dementia. Pneumonia, usually arising as a complication from an underlying chronic disease, is the only infectious disease which is still a major cause of death in rich and middle-income countries. In the past the majority of people everywhere died from infectious diseases and only a minority of people lived long-enough to succumb to degenerative diseases. Even in major famines, before the twentieth century, most deaths were from infectious diseases, triggered by the changes in behaviour induced by famine conditions.[4]

Today in rich and middle income countries most deaths occur amongst the elderly, while deaths in infancy and childhood are increasingly rare. Covid-19, with the possibility of sudden infection leading to serious illness and even death (in a small percentage of cases) for adults who are neither elderly nor frail sounds a faint echo of an earlier world, in which death from infectious disease, at any age, was an ever-present risk. Whilst life expectancy and infant mortality rates vary considerably around the world today, nowhere in the world has a life expectancy as low as, or an infant mortality rate as high, as late Victorian Britain, which then had one of the world's highest life expectancies.[5] In 2018 the infant mortality rate (the number of deaths in the first year per thousand live births) ranged from as low as one per thousand in Finland, two in Japan, Singapore and Sweden, and four in the UK to as high as 85 in the Central African Republic, with a mean of 53 across sub-Saharan Africa.[6] In England and Wales between 1876 and 1900, then one of the most affluent nations on earth, 149 infants out of every thousand born, died in the first year of life. Table 1 compares life expectancies around the world in 2018 with Britain in 1900.

Rank	Country	Life Expectancy	Rank	Country	Life Expectancy
1	Hong Kong	84.9	33	Germany	81.0
2	Japan	84.2	45	Lebanon	78.9

references to discussions in monographs, or to check that my characterisation of these discussions is correct in all details.

[3] Davenport, 'Patterns of death.'

[4] On the inter-relationships between famine and disease in this special issue, see Appleby 'Disease or famine?'; Post 'Famine, mortality, and epidemic disease'; Appleby 'Famine, mortality, and epidemic disease'. In Walter and Schofield, eds., *Famine, disease and the social order*, see Walter and Schofield, 'Famine, disease and crisis mortality'; Dupâquier 'Demographic crises'; Weir, 'Markets and mortality'. More generally see Ó Gráda, *Famine: a short history*; Alfani and Ó Gráda, eds., *Famine in European history*.

[5] For overviews of mortality in Victorian Britain, see Woods and Shelton, *Atlas of Victorian mortality*; Woods, *Victorian England and Wales*.

[6] World Bank Data: https://data.worldbank.org/indicator/SP.DYN.IMRT.IN, accessed 6.4.2020. Elsewhere in 2018 rates were 4 in Cuba, 6 in the USA, 7 in China and 30 in India with a global average of 28.9. In England the infant mortality rate fluctuated from between around 150 and 200 per thousand live births across the seventeenth and early eighteenth centuries. (Wrigley et al., *Reconstitution* (1997), p. 224, table 6.3) In historical terms these rates were not high. In parts of Southern Germany, where custom militated against breast-feeding, infant mortality rates could be 400 per thousand or higher. (Knodel, *Demographic behaviour*; Brown and Guinnane, 'Infant mortality decline', pp. 1–2; Guinnane and Ogilvie, 'Demographic system', pp. 97–104.) On infant mortality more generally, see Wrigley et al., *English population history*, pp. 214–79; Garrett et al., eds., *Infant mortality.*

3	Macau	84.1	46	Cuba	78.7
5	Switzerland	83.6	49	United States	78.5
6	Spain	83.3	69	China	76.7
7	Singapore	83.1	142	India	69.4
8	Italy	82.9	164	Afghanistan	64.5
10	Norway	82.8	181	Zimbabwe	61.2
11	Israel	82.8	193	South Sudan	57.6
12	Australia	82.7	200	Central African Republic	52.8
29	UK	81.4	N/A	England and Wales 1900	46.3

Table 1. *Life expectancy for selected countries in 2018 and UK in 1900*
Note: Life expectancy for both sexes combined.
Modern life expectancies: World Bank Data: https://data.worldbank.org/indicator/SP.DYN.LE00.IN Accessed. 14.4.2020 England and Wales in 1900: Human mortality database.

Strikingly, the top three places and seventh place are taken by high-income parts of East Asia, which also appear to have been very successful in containing Covid-19 down to the time of writing. Switzerland, Spain, Italy and Norway lead the European pack in terms of life expectancy. Britain is in 29th place with Germany at 33. The United States in 49th place, as is well known, is a global stand-out for poor performance relative to GDP per capita, despite massive *average* expenditures on health, as a result of gross inequalities in access to health care. Cuba, with far lower income levels, is just ahead of the US in 46th place as a long-lasting legacy of a very different approach to the provision of healthcare. China in 69th place has achieved a life expectancy only 1.8 years lower than the US, and, unless the US reforms its health-care system profoundly, can be expected to overtake the US in the not-too-distant future.[7] India in 142nd place has a life expectancy 7.3 years lower than China. The bottom 34 places in the global rankings are almost all taken by poverty-stricken countries in sub-Saharan Africa. But even the Central African Republic, at the very bottom of the table in 200th place, with an estimated life expectancy of 52.8 in 2018 still looks better than the UK in 1900 with a life expectancy of 46, and far better than England in the early eighteenth century with a life-expectancy in the mid-thirties.

The fundamental nature of this change is clear if we look at mortality before 1900. As a result of work over several decades at the Cambridge Group for the History of Population and Social Structure by Tony Wrigley, the late Roger Schofield, Jim Oeppen and the late Ros Davies, we have secure knowledge of the long run trends in mortality and life expectancy in England (but not Wales or Scotland) over nearly five centuries – far longer than for any other country on the planet.[8] Figure 1 shows long run trends in national life expectancy from the 1540s through to the present.

[7] Note, however, that in general the relationship between national life-expectancies and average incomes (GDP per capita) in the modern world is characterised by what is termed a 'Preston curve' (named after Samuel Preston who first observed the pattern) which rises very sharply at lower averages incomes and then flattens out at higher average incomes. The pattern is apparent in table 1 with only modest differences in life expectancy in the rich world countries at the top of the table, but large differences among poor and middle-income countries.
[8] Wrigley and Schofield, *Population history of England*; Wrigley et al., *English Population History*. These two books are the foundation stones for our understanding of mortality and population trends in England between the mid-sixteenth century and the early nineteenth century and major landmarks in quantitative history. However, both books are long and quite dry, technical and densely written. Whilst written with exceptional clarity they are not light reading for the faint-hearted. For an excellent introductory textbook, which has the additional merit of covering an exceptionally long time period, see Hinde, *England's population.*

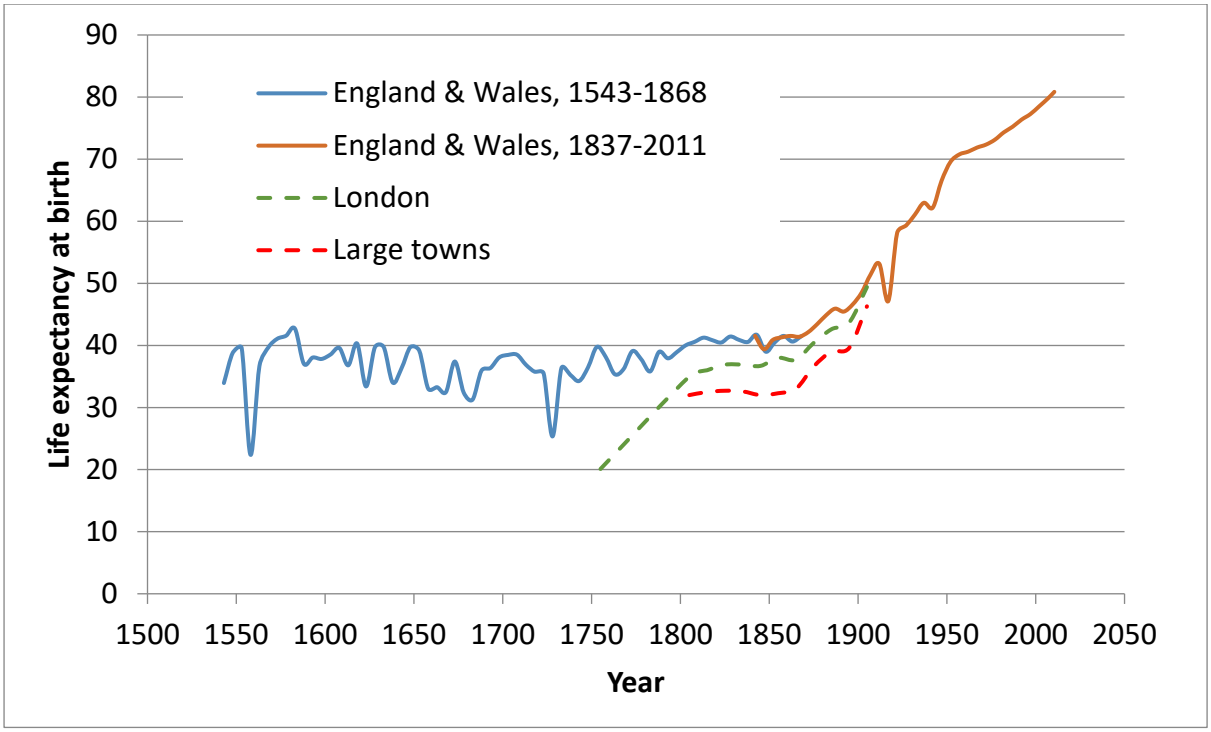


Figure 1: *Estimates of long-run life expectancy at birth in England 1543–2011*

Note: The data underling this figure derive for England & Wales 1543–1868 from Wrigley et al., *Population history of England*; the later nationwide series is from the Human mortality database. The urban and London series are from Woods, *Victorian England and Wales*.

The blue line shows the national estimates for England and Wales made by Wrigley and his colleagues while the brown line derives from official data produced by the state from the inception of the civil registration of deaths in 1837. The dashed green line shows the estimates made by the late Bob Woods for London and the dashed red line shows Woods' estimates for other large English towns.[9]

The spectacular long-run increase in life expectancy visible in figure 1, which Richard Easterlin has termed the mortality revolution, has been brought about by fundamental shifts in the cause of death.[10] To understand the origins of this transition in England, we have to look at the historical sequence by which so many causes of premature death have been vanquished over time. That story begins much earlier than figure 1 might lead the reader to suppose, in the years around 1600.[11] The rest of this introduction is structured as follows. Section I presents a broad overview of patterns of death in the world we have (largely) escaped, including a discussion of the much higher rates of mortality in urban areas than in the countryside. Section II discusses the first two 'victories' in the escape from premature death, first over famine, and second over plague. Section III discusses economic changes whose negative influences on mortality meant that despite victories over famine and plague life expectancies were either falling or stable between the late sixteenth and mid eighteenth centuries. Section IV turns to the decline in mortality and the increase in life expectancy from the eighteenth century. Section V contains a brief discussion of lessons for the present.

[9] Woods, *Victorian England and Wales*.
[10] Easterlin, *Growth triumphant.*
[11] We know much less about the long-term history of mortality in Ireland, Wales or Scotland, in essence because the surviving source material is very poor compared to that for England for the early modern period, itself partly a reflection of relative levels of economic development. Nonetheless, on the medieval period, in this special issue, see Hatcher et al., 'Monastic mortality'. See also Campbell, *Climate, disease and society*.

A broad overview of patterns of death in the world we have escaped

Table 2 summarises causes of death in Britain, in 1850, 1900 and in 1939 and globally in 2012 distinguishing high and low-income countries. It can readily be seen that in the nineteenth century, approaching half of all deaths were from infectious disease and that non-communicable conditions were far less important than in rich countries today. Between 1848 and 1872 tuberculosis was the leading cause of death in Britain, accounting for 15.0 per cent of all deaths. Bronchitis was ascribed responsibility for 6.7 per cent of all deaths, scarlet fever and diphtheria for 5.7 per cent and diarrhoea and enteritis for 4.4 per cent. By contrast heart disease, strokes etc., accounted for only 5.8 per cent and cancer for a mere 1.7 per cent of recorded causes of death.[12] Because so many people died at relatively young ages relatively few people lived long enough to develop life-threatening heart disease or cancer.

Causes	England and Wales 1850 %	England and Wales 1900 %	England and Wales 1939 %	High-income countries 2012 %	Low-income countries 2012 %
Infectious diseases:	44.7	35.8	14.5	6.0	38.6
Non-respiratory	26.2	18.2	3.7	2.6	28.2
Respiratory	18.5	17.6	10.8	3.4	10.4
Maternal conditions	0.9	0.8	0.4	0.02	1.7
Neonatal conditions	6.0	3.7	3.7	0.34	9.3
Non-communicable	44.8	56.1	76.5	87.3	40.3
Injuries	3.6	3.6	4.9	6.4	10.1
Total	100	100	100	100	100
Total deaths	368,995	587,830	498,968	1,1671,361	5,696,969
Life expectancy	43	46	64	79	62

Table 2: *Distribution of causes of death in England and Wales 1850-1939 and in high and low income countries in 2012.*

Note: The infectious diseases category excludes infectious causes of maternal and neonatal mortality; the non-communicable diseases category includes deaths due to nutritional deficiencies. High (Gross National Income per capita ≥ $12,476) and low-income ≤ $1,025) groups are as defined by the World Bank in 2012.

Sources: Davenport, '*Annual deaths by cause*'; ONS, 2006; WHO Global Health Observatory; Human mortality database.

Figure 2 shows what demographers call 'survivorship curves', one from England (omitting large towns where mortality was worse) in the 1640s and one for England as a whole in 2016 (in which the population was overwhelmingly urban). What these curves show, for every thousand live births, is how many people, on average, were still alive at each age.[13] So, the line for 2016 shows that 97 per cent of those born were still alive at 50. Deaths in infancy and childhood are so low as to be virtually invisible. After 50 the curve steepens but over 50 per cent of those born are still alive at 80. By contrast, in a sample of English villages and small market towns in the 1640s, whose population histories have been

[12] Charlton and Murphy, *Health of adult Britain*. Note that 'old age' was also a leading cause of death in the nineteenth century. Deaths once classified as 'old age' are today generally classified into more precise causes. This means that causes of death such as cancer, dementia and heart-disease were, to some degree, under-reported in the nineteenth century.

[13] More technically, what the curve shows is how many people would survive to a given age for every 1,000 life births if the cohort experienced the average age specific mortality rates of the period in question.

reconstituted, 30 per cent of all children born died before their tenth birthday. Mortality in the first year of life (termed infant mortality by demographers) was especially severe. Less than half of those born made it to their 45th birthday. It is not true, as is often supposed, that low *average* life expectances, meant that there were no old people in the past, but they did make up a much smaller part of the population. Over 15 per cent of those born reached the age of 60. Mortality was especially concentrated in the first five years of life, but those who survived to five had about a 50 per cent chance of making it to 50. Something under five per cent survived past their 80th birthday to enter the age group so vulnerable to Covid-19 today.

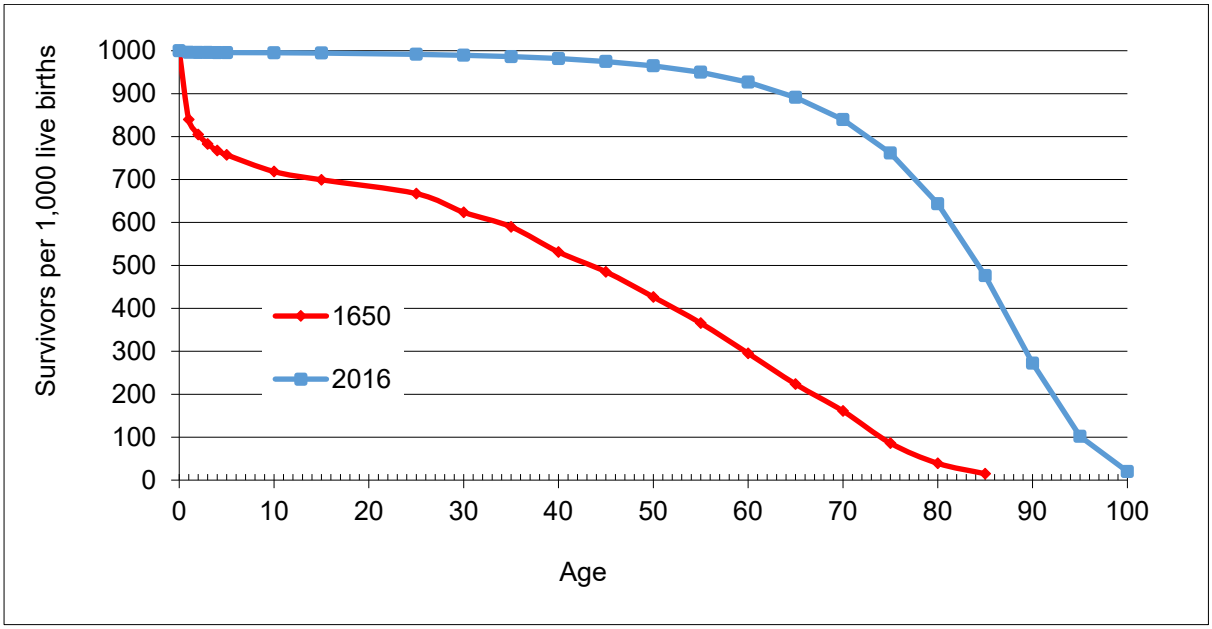


Figure 2: *Cohort survival curves for England 1650 and 2016*
Note: The data for 1650 are based on a sample of reconstituted parish populations in 1650–9: Wrigley et al, *English population history*. The 2016 data is from the Human mortality database.

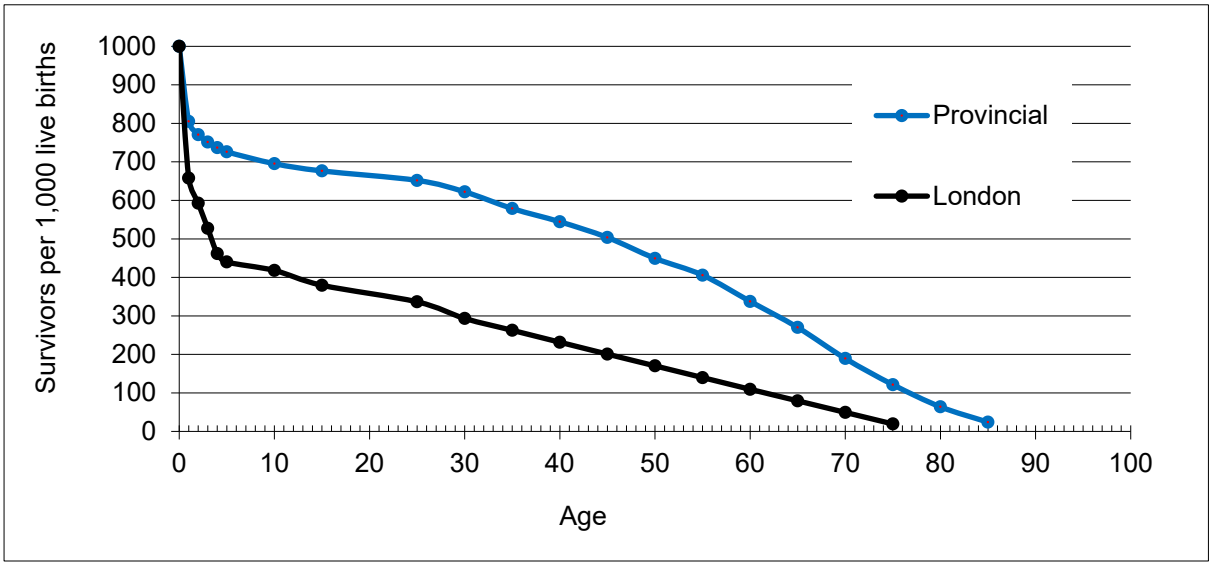
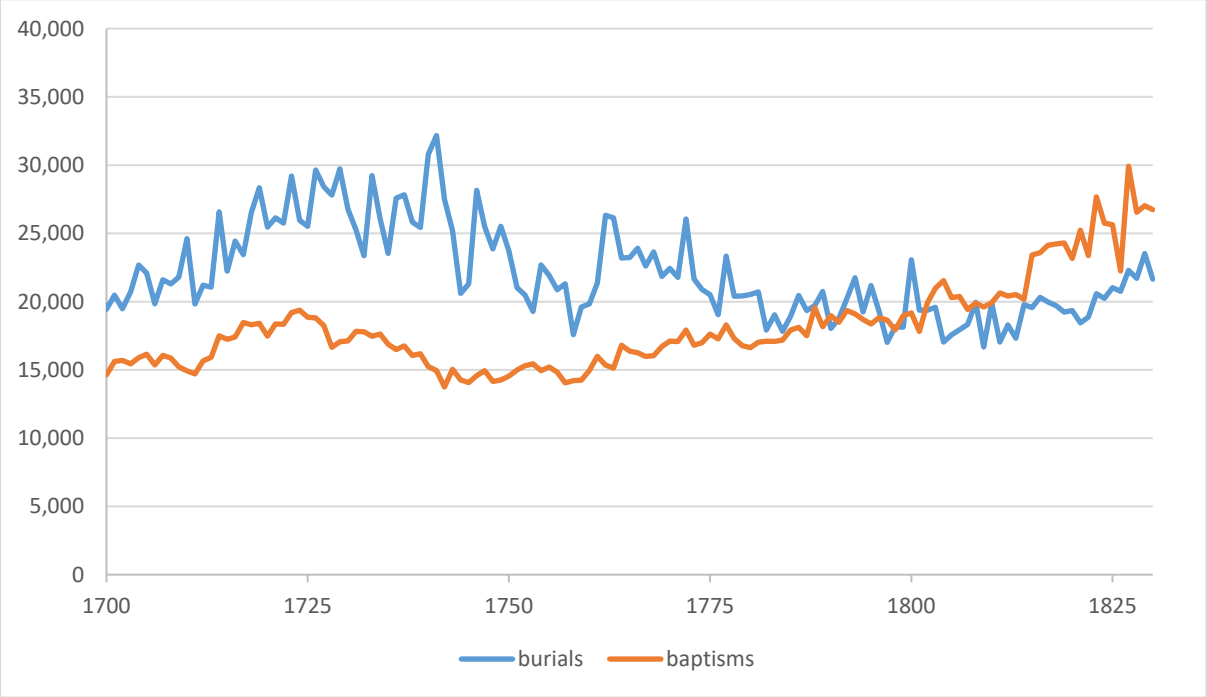


Figure 3: Cohort survival curves, London and England in the 1730s
Note: London data is based on a sample of Quakers in 1730–39, drawn from Landers, *Death and the metropolis*. The provincial data is derived from the parish reconstitutions for 1730–39 in Wrigley et al., *English population history*.

The differences between these two curves are largely explained by rising living standards, public health measures and medicine, which amongst other things, reduced the direct and indirect effects of infectious diseases. Aside from plague, differences in mortality by social class appear to have become significant only in the nineteenth century, initially as a result of reductions in the most lethal and socially non-selective infectious diseases, and increasing residential segregation.[14] Later, as knowledge on how to avoid death improved, social class differences widened.

Figure 3 shows two more cohort survival curves, this time for the 1730s. The blue line relates to the same sample of villages and small towns across England and shows little variation from the pattern in the 1640s shown in figure 2. The black line shows the cohort survival curve for two groups of Quakers living in London, estimated by John Landers.[15] It is most unlikely that Quakers experienced worse mortality than most Londoners. As can be seen, however bad things were in small towns and in the countryside, things were far worse in London (also visible in figure 1) which was much larger than any other English city. Less than half of those born lived to see their fifth birthday, and 80 per cent failed to make it to 45. Mortality was much more severe than in the countryside because of the greater concentration of people; the higher level of interconnectedness with other places both internally and internationally; and because sanitary conditions were even worse than in rural areas. This produced an even greater prevalence of infectious diseases in London than in the countryside and in small towns.[16]



[14] On the emergence of social class differences in mortality, see Smith and Oeppen, 'Place'; Jaadla et al., 'Infant and child mortality.'

[15] Landers, *Death and the metropolis*.

[16] On urban mortality in the early modern period, see Galley, 'Urban demography', in this special issue. For book length surveys see Landers, *Death and the metropolis* on London and Galley, *Early modern towns* on York, then the second city. On urban mortality in nineteenth century Britain Woods, 'Population redistribution', argued for major improvements in urban mortality across the nineteenth century. This view was challenged by Szreter and Mooney, 'Urbanization and mortality', republished in this special issue, which argued for worsening mortality in second quarter of the nineteenth century. Woods restated his case in Woods, *Victorian England and Wales*. For a further rejoinder to Szreter and Mooney, see Davenport, 'Urbanization and mortality', republished in this special issue.

Figure 4: *Recorded burials and baptisms in the London Bills of Mortality 1675–1830*
Note: Data from Marshall, *Mortality*, pp. 67, 70–1.

In the early modern period, as figure 4 shows, mortality was so bad in London that deaths consistently exceeded births. London could only sustain its population because of continuous immigration of healthy young adults from the countryside. Many of these migrants lacked the immunities of their London born adult peers, just as we lack immunity to Covid-19, and would therefore have died earlier than the London-born who had survived to the ages at which migrants arrived.[17] Even those small towns for which we have evidence had mortality rates which were so high that population could only be sustained by constant in-migration. Infant mortality in small market towns in the early eighteenth century was as high as levels in Manchester in the nineteenth century, where urban conditions appeared so shocking to Fredrik Engels, whose *Condition of the English Working Class*, (1845), which described conditions in the city's slums, continues to colour perceptions of the Industrial Revolution to this day.

Everywhere in the world, until the late nineteenth century, urban mortality was higher than rural mortality. In Europe and North America in the eighteenth century, the excess of deaths over births in urban areas was the norm. Whether this was generally true in the medieval period and in the ancient world, or in Asia is not yet clear. Yet by 1800, as figure 4 shows, London, which was by then the largest city in Europe and on the way to becoming the largest city the world had ever seen, achieved a balance between births and deaths, and in the early nineteenth century births came to exceed deaths. The trend towards an excess of births over deaths appears to have been a general feature of urban centres in England and at least some cities elsewhere in the late eighteenth and early nineteenth centuries.[18] Thus by 1800 the beginning of the mortality revolution was underway.

Without this epidemiological transition, the massive urbanisation that took place first in nineteenth-century Britain, before spreading across Europe, North America and Japan, and in more recent times to all inhabited continents, would not have been possible.[19]

Escape from famine and plague

In England, the earliest success in the escape from premature death was the escape from 'the spectre of famine',[20] which occurred a century earlier than in most of Western Europe and a quarter of a millennium before Ireland.[21] In 1314/15 the 'Great Famine', sparked by the worst

[17] At the time of writing there is ongoing uncertainty as to the extent to which Covid-19 confers immunity on survivors.

[18] Davenport, 'Urbanization and mortality', in this special issue.

[19] The centrality of this demographic precondition to modern urbanization has not been widely noted by economic historians or economists. For two notable exceptions, see de Vries, *European Urbanization*; and Kuznets, *Modern economic growth*, p. 60, who also explicitly identified this transition as a precondition for modern economic growth

[20] On famine in England, in this special issue, see Appleby, 'Disease or famine?'; Hoyle, 'Famine'; Kelly and Ó Gráda, 'Living standards and mortality'. For a highly readable account of famine and its early disappearance in England see Appleby, *Famine.* The best introduction to the decline of famine in England remains Walter and Schofield, 'Famine, disease and crisis mortality'. See also: Walter, 'Social economy of dearth'. For an excellent overview of famine across Britain, see Hoyle, 'Britain'.

[21] On Europe, in this special issue, see Post 'Famine, mortality', on the post-Napoleonic famine in Europe in 1816–17, triggered by the 1815 explosion of the Tambora volcano in what is now Indonesia (believed to be most powerful volcanic eruption of the last ten thousand years), and Appleby 'Comment'. See also Post's subsequent book on the same episode, *The last great subsistence crisis*, and his *Food shortage*, on the harvest shortfalls across Europe in the 1740s. For a very accessible long-run overview of famine in history, see Ó Gráda, *Famine: a short history.* On famine in Europe, see Alfani and Ó Gráda, eds., *Famine in European history*. In Ireland, the 'Great Famine' of 1845–49, sparked by the failure of the potato crop (caused by the plant pathogen, *phytophthora infestans*, or potato blight), led to the deaths of perhaps a million people out of a pre-

weather (for grain crops) of the last thousand years, ravaged much of Europe. In England it is estimated to have led to the deaths of 10–15 per cent of the population. In the second half of sixteenth century, as population began to rise for the first time since the Black Death (1348–1349 in England), England experienced a number of famines, but these were minor compared with the Great Famine and the most severe of these are estimated to have killed 'only' 1–2 per cent of the population.[22] The famine of 1597–8, was the last which affected large parts of the country and led directly to creation of a universal nation-wide set of poor laws to support the poor and which came eventually to provide a cradle-to-grave welfare system.[23] The famine of 1623–4 was largely confined to upland villages in the north and west of the country which specialised in livestock production, and appears to have been the last geographically extensive famine in England.[24] When bad weather caused major harvest shortfalls across north-western Europe in the 1690s, it is estimated that perhaps 10 per cent of the population died in both France and Scotland. Strikingly, England, which shared in the bad weather and poor harvests, escaped famine entirely, due to some combination of improved agriculture, an effective welfare system and better functioning inter-regional markets. It is very unlikely that in any of these famines large numbers of people starved to death. Responses to harvest failure triggered epidemics and most excess mortality was from infectious diseases.[25]

The first pathogen successively defeated by human action in Europe was plague (*Yersinia pestis*, a bacterial infection, now treatable with antibiotics),[26] which had revisited Europe periodically since the Black Death first reached Europe in 1347. The plague had visited Europe before, in the Plague of Justinian 541–542, and recurrences down to the mid-eighth century which may have weakened the Roman Empire.[27] The Black Death is now believed to have killed between one third and two thirds of Europe's population between 1347 and 1352.[28] Plague, a vastly more lethal pathogen than Covid-19 with case fatality rates which may have been between 60 and 90 per cent, was probably defeated by the development of relatively simple but stringent surveillance and quarantine measures.[29] In Europe, systematic quarantine, cordons sanitaire and public health measures, including contact tracing, were first developed in the Renaissance.[30] England was a laggard in adopting

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famine population of about 8 million and the emigration of another million. The Westminster government under the influence of a laissez-faire ideology played a major contributory role in turning a harvest failure into a human catastrophe. On the Irish Great Famine, see Ó Gráda, *Black '47*; idem, *Ireland's Great Famine*; Kennedy et al., *Mapping the Great Irish Famine*; Clarkson and Crawford, *Famine and disease in Ireland*.

[22] The most detailed statistical analyses of mortality crises in England, covering 1541–1871, remain those by Wrigley and Schofield, 'Short-term variation' (chapter 8) and Lee, 'Local mortality crises', both in Wrigley and Schofield, *Population history of England.* See also, in this special issue Kelly and Ó Gráda, 'Living standards and mortality', which is of particular value for extending the analysis back to the medieval period.

[23] On the Old Poor Law, from a large literature, see Healey, *First century of welfare*; Snell, *Annals*.

[24] On the geography of the famine of 1623–4, see Lee, 'Local mortality crises', figure 10A.7, p .676. A number of historians have recently claimed to identify famines in early eighteenth century England via statistical analyses. Contemporaries do not appear to have reported these episodes, in contrast to earlier famines, for which contemporary commentaries do survive. The early eighteenth century was characterised by a vibrant print culture and a vastly higher level of surviving social commentary than earlier periods, so it is most unlikely that any widespread famine could have occurred without contemporaries noticing and published comment.

[25] On the relationship between epidemics and famine see, in this special issue, Appleby, 'Disease or famine?'; and Post, 'Famine, mortality', For an excellent introduction to these issues Walter and Schofield, 'Famine, disease and crisis mortality'; Dupâquier, 'Demographic crises'; Weir, 'Mortality and markets'.

[26] Though there is some evidence that antibiotic resistance may be emerging in plague. (Alfani and Murphy, 'Plague', p. 319.)

[27] Alfani and Murphy. There is also evidence for plague long before the Roman Empire: Cell Press, 'Neolithic.'

[28] Alfani and Murphy, 'Plague', p. 318.

[29] On case fatality rates, see Alfani and Murphy, 'Plague'. For a contrary hypothesis downplaying the role of human action, see Alfani and Murphy, 'Plague', citing Alfani, 'Epidemiological hypothesis'.

[30] On this see Cippola, *Cristifano and the plague*; idem, *Faith, reason and plague*; idem, *Fighting the plague.*

measures developed on the continent. In the seventeenth century there were four plague epidemics in Britain. In London these are estimated to have killed 23, 20, 8 and 18 per cent of London's population, which rebounded each time as a result of rapid post-epidemic in-migration from the countryside.[31] But the epidemic of 1665–6 was the last (aside from some inconsequential outbreaks in the twentieth century).[32] From the 1730s plague also ceased to be a significant feature in most of Europe, though it lingered longer in Russia and in South-Eastern Europe, where states were weaker and where exposure to endemic reservoirs of plague was probably more extensive.

Globalisation, urbanisation, trade and the worsening of mortality in the early modern period

The disappearance of famine and plague from early modern England did not, however, lead to any long-term decrease in overall mortality or increase in the expectation of life. One reason for this was that England was urbanising across the late sixteenth, seventeenth and eighteenth centuries, though not so rapidly as it was to do in the nineteenth century. Population levels rose nationally over much of the period, a higher share of the population came to live in towns, and the urban population was increasingly concentrated in larger towns. Urbanisation was accompanied by increased internal and international trade, while the European expansion across the Atlantic initiated by Columbus in 1492 led to what Emanuel Le Roy Ladurie memorably termed 'l'unification microbienne du monde', the microbial unification of the world, an event, or process, whose consequences are still very much with us.[33] This intensified the circulation of disease vectors and introduced new pathogens to the 'old world' as part of the 'Columbian exchange'. [34] As a result of these demographically negative and interconnected processes, although famine and plague had disappeared, national life expectancy flat-lined for a century from 1650 to 1750 (figure 1) at levels lower than had prevailed in the less urbanised late sixteenth and early seventeenth centuries.

Higher populations, urbanisation and increased local and global interconnections through trade led to many pathogens becoming permanently present, or endemic, in populations, especially urban populations, rather than raging through periodically as introduced epidemics. This process of endemicization had three key effects. First, all other things being equal, it tended to increase the general level of mortality. Second, diseases which were immunising, came to be predominantly childhood diseases, increasing the chances of dying in childhood, but decreasing the chances of dying at later ages, for those who survived childhood. Third, it made annual patterns of mortality more stable.

[31] Slack, *Impact of plague*, p. 151.

[32] Two articles in this special issue make an ideal introduction to the disappearance of plague in England: Appleby, 'Disappearance of plague', and Slack's critical response, 'Disappearance of plague'. Those who only have time to read one of these should read Slack's piece. For further reading Slack's chapter on plague in Walter and Schofield provides an excellent overview of measures adopted to combat plague including quarantine and contact tracing. The standard work on plague in England remains Slack's very readable *Impact of plague*. For a shorter more recent account with global scope, see Slack, *Very short introduction*. On London, see Cummins et al., 'Living standards and plague in London', in this special issue. On plague in the Ottoman territories, see Varlik, *Early modern Mediterranean world.* For an excellent general overview of plague between late antiquity and 1800, see Alfani and Murphy, 'Plague'. Also in this special issue see Schofield, 'Last visitation', on Sweden.

[33] Le Roy Ladurie, 'L'unification du monde'.

[34] Crosby, *Columbian exchange;* McNeil, *Plagues and People*; Crosby, *Ecological imperialism*.

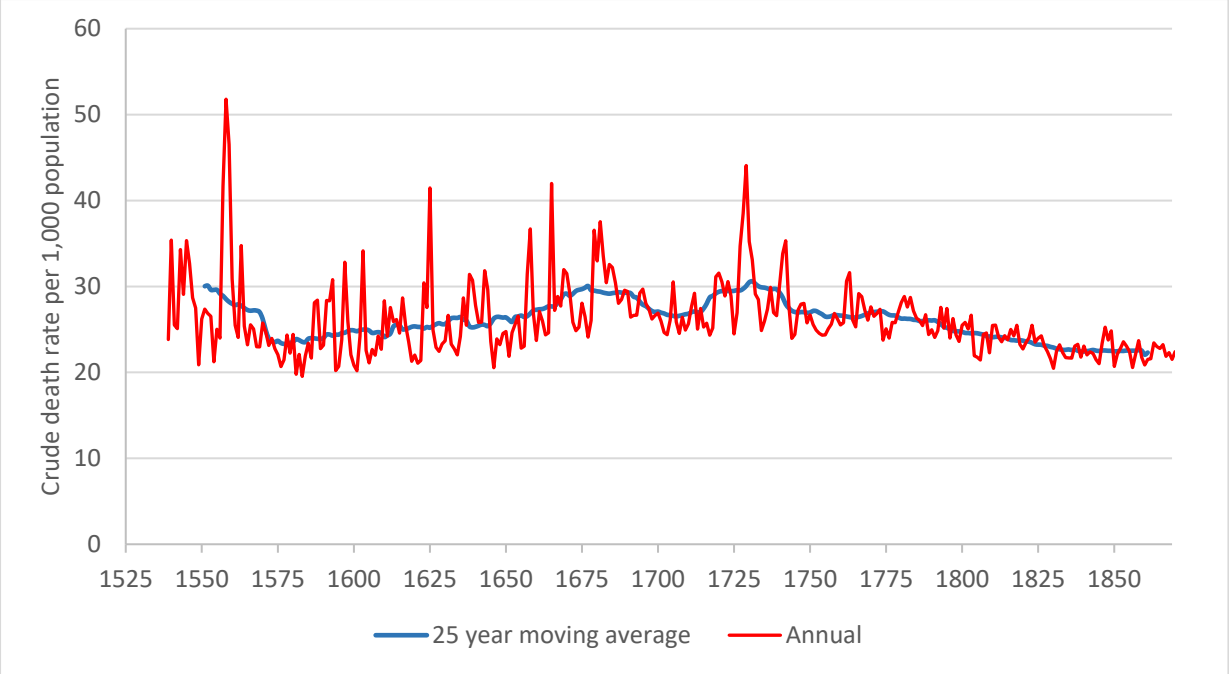

Figure 5: Crude death rate (deaths per thousand population) 1543–1869
Note: Data from Wrigley and Schofield, *Population history*.

The progress of endemicization can be seen very clearly in figure 5 which shows in red the *annual* crude death rate (deaths per thousand people) and in black the 25 year moving average. This is the average of 25 years centred on the year plotted, which is one way of representing the long-run background level. In 1558 there were 52 deaths for every thousand people in the population, but across the 25 years centred on 1558 there were 29 deaths per year on average. So, in this epidemic year deaths were over 80 per cent above normal.[35] In the plague year 1625, mortality was 65 per cent above the 25 year average, and in 1665, the last significant outbreak of plague in England, it was 52 per cent above average. The frequency of epidemics in the sixteenth, seventeenth and early eighteenth century is evident. In the 200 years between 1551 and 1749, mortality was 10 per cent or more above the average in 37 years, or one year in five. For Covid-19 to be this severe in Britain today, deaths from the disease would probably have to go far above 100,000 in a single year.[36]

Annual variation was evidently much lower in the second half of the eighteenth century than in the first half of the century. Mortality was ten per cent above average in only three years in the second half of the century compared with seven years in the first half. By the early nineteenth century annual fluctuations were generally very modest. Between 1800 and 1869 only in one year, 1847, was mortality 10 per cent or more above trend. This is unmistakeable evidence of endemicization. Death had become more predictable and was increasingly concentrated in childhood years. Even during the epidemics of 'Asiatic' Cholera

[35] On the mortality crisis of 1556–60, see Zell, 'Fisher's 'flu', republished in this special issue.
[36] Note that a high proportion of deaths from Covid-19 are likely to be of people who would have died later in the year in question or in 2021 and 2022. In recent years UK deaths have generally fluctuated between about 560,000 and about 610,000. So around 58,000 extra deaths would be required to increase the mortality rate by 10%. But if say half of COVID-19 deaths were of people who would have died in 2020 anyway, then it would take a total of 116,000 deaths attributable to Covid-19 to increase the overall annual mortality rate by 10%.

in 1831/2, 1848/9, 1854 and 1866 with case fatality rates of 20–25 per cent or even 50 per cent, overall mortality increases were modest in nature by comparison with earlier periods.[37]

The improvement in life expectancy since the eighteenth century

Despite ongoing urbanisation overall life expectancies began to rise from the middle of the eighteenth century. One major factor was increasing control over smallpox, which was probably the leading cause of death in mid-eighteenth century England, but only a minor cause of death by the mid nineteenth century. This did not begin with Jenner's famous discovery of the world's first vaccine in 1796 and publication of the results in 1798, important as this was. Long-before this, in 1718, a different technique had been introduced into England from the Ottoman Empire, by Lady Mary Wortley Montagu, whose husband had been the British ambassador in Constantinople. The procedure, termed inoculation, involved administering a small dose of smallpox to the patient via an incision in the skin. In most cases this would lead to a very mild infection and confer immunity. Unfortunately, in a small minority of cases it proved fatal.

Given the prevalence of smallpox, inoculation was widely, but not universally adopted, after 1760. Inoculation and the use of quarantine seems to have been widespread in southern, but not northern England, with mass inoculation carried out by parish poor law authorities who also provided 'pest-houses' in which to isolate the sick. In the more interventionist South, the fatality rate from smallpox was probably somewhere between 25 and 50 per cent of the level in the less interventionist North. Autonomous mutation of the virus that led to greater infectiousness in the late eighteenth century, together with poor law practices in the rural south, from where most London migrants originated, were probably conjointly responsible for the major reduction in smallpox mortality in London amongst adult migrants.[38] This contributed to the spectacular decline in the excess of deaths over births that occurred over the last three decades of the eighteenth century. [39] John Landers also inferred that more widespread breast-feeding of infants conferred considerable protection from infection, based on the evidence of London Quakers.[40] Vaccination played a major role after 1798. The trend towards an excess of deaths over births appears to have been a general feature of urban centres in England and at least some cities elsewhere in the late eighteenth and early nineteenth centuries.[41]

[37] Modern epidemiological studies suggest a case fatality rate of 20–25% for cholera. Contemporaries reported 50%, a figure some historians have also suggested.

[38] The evidence suggests a seventeenth century mutation increasing infectiousness and a late eighteenth century mutation suggesting increased virulence. (Davenport et al., 'Geography of smallpox'; Davenport et al., 'Decline of adult smallpox'; Duggan et al., 'Seventeenth-century Variola'.

[39] In this special issue, see: Davenport et al., 'Decline of adult smallpox'; Razzell, *Conquest of smallpox*; Davenport et al., 'Reply'. The account presented here follows Davenport et al., with which Razzell disagrees. For an earlier book-length presentation of Razzell's more optimistic views on the impact of inoculation, see Razzell, *Conquest of smallpox*.

[40] Landers, *Death and the metropolis.*

[41] Davenport, 'Urbanisation and mortality', in this special issue.

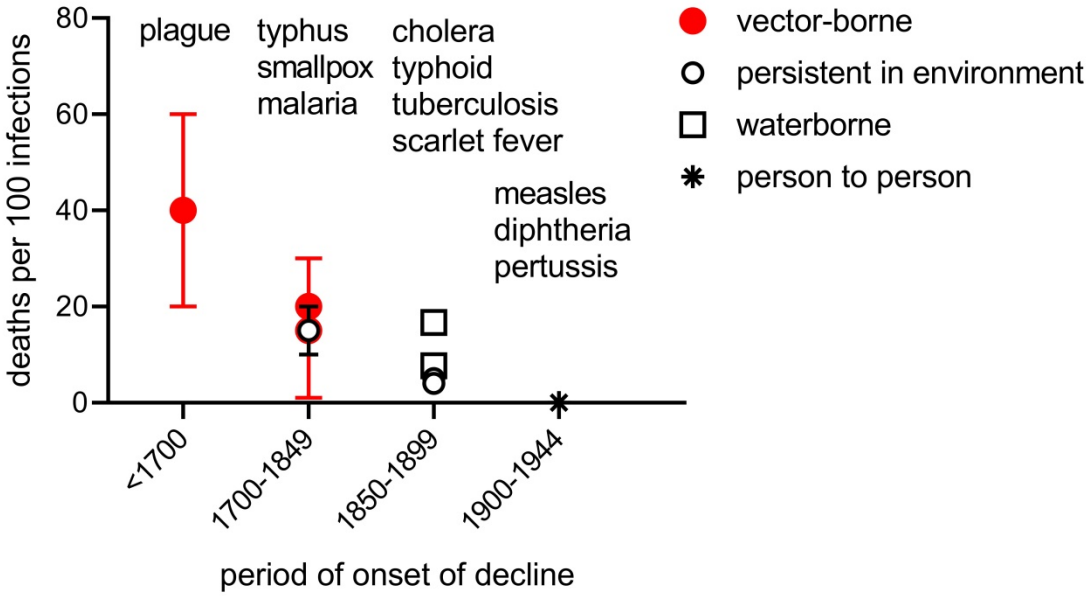

Figure 6: *Major diseases that declined before 1945 in England*
Source: Davenport and Smith, 'Early history of public health'. Note these death rates derive from modern epidemiological studies, not from historic outbreaks which may have been different for a variety of reasons.

Figure 6 indicates the broad periods in which major infectious diseases were brought under control, down to the 1940s when antibiotics first came. The most virulent diseases were those which were most easily dealt with.[42] Alongside smallpox, the big killers that declined rapidly across the eighteenth and early nineteenth centuries were malaria and typhus.[43] It was the decline of these diseases, combined with the earlier disappearance of famine and plague, which drew the era of major epidemics to a close. Malaria is not associated with England today, but in areas of extensive marshy wetland, such as the fens in Cambridge, Norfolk and Lincolnshire, suffered from endemic malaria. Drainage of wetlands, aimed at agricultural improvement, were probably largely responsible for the decline in malarial mortality in England.[44]

The second half of the nineteenth century saw major reductions in waterborne diseases as a consequence of widespread improvements in water supply and sewerage, much of it delivered by newly-empowered local governments. [45] Most of the long-run improvements to life expectancy in Britain have occurred since 1900, with the largest improvements occurring in the first half of the twentieth century (figure 1). Rising living standards and public health interventions played a major part in this. Mortality from tuberculosis and measles, for example, declined enormously, and this probably reflected

[42] Davenport and Smith, 'Early history of public health'.
[43] On typhus, see Mercer, *Infections*, chapter 6. On the remarkable declines in slave mortality in transatlantic voyages in the light eighteenth century by the provision of clean water, improved diets, simple sanitary and quarantine measures, a century before the systematic development of public health programmes and the germ theory of disease, see Haines and Ralph, 'British slave trade', in this special issue. On typhus, see Kunitz, 'Speculations', in this special issue.
[44] Dobson, *Contours.* Dobson suggested that drainage may have reduced malaria through a variety of mechanisms that included reductions in mosquito habitats, and reductions in contacts between humans and mosquitoes. For example, increases in cattle densities, associated with drainage, may have provided an alternative source of food for mosquitoes. Cattle do not act as hosts for malarial parasites, so any switch from humans to cattle would have reduced the prevalence of malaria-carrying mosquitoes.
[45] In this special issue, on late nineteenth century sanitary improvements and mortality decline in Germany, see Gallardo-Albarrán, 'Decline of mortality'.

improving nutritional status and reduced residential crowding (in which fertility declines also played an important role).

The period after about 1950 is where medicine came to make large contributions. This saw the widespread use of antibiotics and mass vaccination campaigns against a whole series of infections. Smallpox became the first, and to date only, disease to be eradicated from the human population on a global basis. This was achieved as a result of a sustained and co-ordinated global eradication programme initiated by the World Health Organisation (WHO) in 1959. Initially poorly funded, the programme was intensified in 1967 and the last non-laboratory case of smallpox was in 1977 with the disease officially considered eradicated in 1980.

During the twentieth century the declining number of deaths from infectious diseases in the UK was accompanied by the sustained growth of deaths from cancers, heart disease and other chronic diseases. In Scotland the annual death rate from cancers grew steadily from around 70 per thousand in 1890 to a little over 250 per 100,000 people around 1980.[46] In the third quarter of the nineteenth century cancer accounted for only 1.6 per cent of ascribed causes of death, and heart disease, strokes etc. for 5.8 per cent. By 2007 the corresponding figures were 27.6 and 34.7 per cent.[47] High modern rates of death from cancer and other chronic diseases are not, as is often thought, simply the negative consequence of industrial life-styles, though smoking and air pollution have played a role and continue to do so. Rather, the primary cause is the declining incidence of death from infectious diseases, allowing more and more people to live long enough to succumb to cancer, heart disease, or dementia. Death remains inevitable. Reducing one cause of death inevitably leads to an increase in other causes, typically at later ages. The dominance of non-communicable disease as a cause of death today is a measure of our success in extending human life by reducing deaths from infectious disease. In more recent decades, deaths from cancer and heart-disease have also begun to fall.

Globally, improvement to human life expectancy has been remarkably steady over the period since 1840. Jim Oeppen and Jim Vaupel, in an overview of long-run global progress published in 2002, graphed life expectancy over time for the country with the highest life expectancy on the planet at each date. This served to indicate what could be achieved by 'best practice' at each date. Remarkably, this produced a dead-straight line, with best-practice global life expectancy rising around three years every decade for sixteen decades.[48] Over the following decade global best-practice life expectancy continued to grow at the same fixed increment of three years per decade.[49]

Lessons from history?

Can we learn anything from history at the present time? The lessons of history are at least as numerous as historians and predictions about the future are notoriously unreliable whoever makes them. Nonetheless, I will make a small number of observations.

First, like the 1918 flu pandemic, Covid-19 is likely go down in history as a short-term interruption to long improvements in life expectancy, and it is most unlikely that the improving trend in global life expectancy will not resume within a few years.

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[46] Anderson, '1911–1990', p. 373, figure 6.

[47] Charlton and Murphy, *Health*. Some of this shift may have been caused by the inadequacies of cause of death reporting in the nineteenth century, however, there is no doubt that the bulk of this shift was real, large and sustained.

[48] Oeppen, and Vaupel, 'Broken', *Science*, pp. 1029-1031. Note that micro-states like Andorra were excluded from the analysis.

[49] Personal communication, Jim Oeppen (2015); Roser et al., 'Life expectancy'.

Second, there is no road back to some older safer world before the current era of globalisation. That older world was far more deadly than ours in every country in every month of every single year. Nor can we turn back the clock on global inter-connectedness. At least as far back as the Plague of Justinian in the sixth century, epidemics have crossed the Eurasian landmass. From the late sixteenth century, European expansion led to the microbial unification of the world, laying the foundations for truly global pandemics. This cannot be reversed, nor would it be desirable to do so.

Third, whilst COVID-19 is highly infectious, when seen in historical context, it has a low case-fatality rate. The best estimates are currently somewhere in the range 0.5 to 1 per cent, and perhaps two-thirds of deaths Covid-19 are of people who would have died very soon anyway. This may be a significant overestimate, but is considerably lower than the 1918 flu pandemic which killed around 50 million people with an average case-fatality rate of around 2.5 per cent.[50] The case-fatality rate of Covid-19 does not begin to compare with vanquished diseases like plague, smallpox or cholera. The Black Death may have had a case-fatality rate of between 60 and 90 per cent and struck down people of all ages both healthy and not; it also does not appear to have conferred long-lasting immunity on survivors. By the late eighteenth century, smallpox had a case-fatality rate of perhaps 20–30 per cent, but did at least confer life long-immunity. In the nineteenth century, cholera probably had a case-fatality rate of between 25 and 50 per cent, killing many of its victims within 24 hours. When the HIV pandemic struck in the 1980s, before the development of retroviral drugs, the case-fatality rate was over 80 per cent, though death took some years to eventuate. However, HIV spread relatively slowly and it rapidly became clear how to minimise the risks, although the insidious and culturally-charged nature of its transmission made it more difficult to detect transmission patterns. As a result, outside sub-Saharan Africa, and high risk groups elsewhere, most notably gay men, prostitutes and intravenous drug users, the mortality impact of HIV was limited despite the case-fatality rate.[51] In 2020, we could easily have been confronted with something as infectious as Covid-19 but far more virulent, though it should be noted that there is an evolutionary trade-off for many pathogens between infectiousness and virulence.[52]

Fourth, sooner or later, another pandemic will occur, and if we are unlucky, it may be far more virulent than Covid-19 but just as infectious. Experts, much derided in recent times, have always known that the world remained vulnerable to novel pathogens or new more lethal strains of old pathogens, but most of the world's governments were *both* woefully underprepared *and* either unable or unwilling to start making adequate preparations during January and February and in some cases into March. COVID-19 may provide a wake-up call to national governments to be better prepared in the future, and to fund international agencies, not least the chronically underfunded World Health Organisation (WHO), at much higher

[50] Note that the case fatality rates for Covid-19 will vary with the age structure and underlying health of the population and with the quality of health services available. The range of 0.5% to 1% derives from middle-income and rich countries with strong healthcare systems but large elderly populations. At the time of writing we do not know much about case fatality rates in countries with unhealthy populations and weak healthcare systems, but these countries typically have much younger populations.

[51] In parts of sub-Saharan Africa, where heterosexual transmission was widespread, life expectances fell by more than ten years, temporarily reversing gains made over several decades.

[52] For pathogens which are dependent on direct transmission between humans, if the human host is rendered prone and unable to move around and the capacity to infect a new host is vitiated. This is why Ebola, for instance, probably does not pose a global health risk. It is so deadly that it has limited capacity to spread. As a result there is some tendency for pathogens to evolve away from extreme virulence. However, this does not apply to the same extent to diseases which do not rely on human-human transmission, like bubonic plague or malaria.

levels, but this is by no means guaranteed.[53] It might even make the world more realistic about the risk of business as usual and failing to take decisive and timely action against the looming existential threat of climate change. Again, this is merely a possibility and is certainly not a prediction.

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[53] The annual budget for the WHO is currently about $2.2bn. For comparison, Mount Sinai Hospital in New York has an annual budget of $2.1bn.

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