Age in medieval plagues and pandemics: Dances of Death or Pearson's bridge of life?

Death has long obsessed humanity. In times of plague and pandemic even more so. Medieval man saw four horsemen of the apocalypse, and of them, Death by disease was gathering the greatest harvest. How randomly did he gather? And how random is the death toll in later pandemics? **James Hanley** and **Elizabeth Turner** look at Karl Pearson's visualisations of mortality.

In October 1347 a trading ship from the Crimea with its crew dead and dying drifted into a harbour in Sicily, and black rats leapt ashore. The European phase of the Black Death had begun.

At the time they called it the Great Mortality, subsequently the "Great Pestilence" or the "Great Plague". Today we call it the "Black Death" and consider it as perhaps the deadliest pandemic ever to have struck humanity.

In the countryside, peasants dropped dead in the fields; in towns, the sick died too fast for the living to bury. A monk in Ireland, the last survivor of his monastery and himself awaiting death, listed the names of those who had perished and left space at the end for his own name in the hope that a passing stranger would add it[1].

Tilled fields returned to wilderness for lack of men to farm them. Whole villages disappeared for ever from the map. To an awestruck mankind, it really did seem that the end of the world had come.

In trying to convey its horror to later generations the 14th-century historian Froissart, who usually confined himself to describing the chivalrous exploits of knights in armour, summed it up simply and terrifyingly: "One-third of the world died". He may have been underestimating.

Not surprisingly, given the primitive statistical systems of the time, estimates of the actual death toll from the Black Death vary widely, from 30% to 60% of a population that spread from China to Iceland. For Europe, with an estimated population of 80 million, that means 25–50 million deaths. The most recent estimates, based on a synthesis from the best localised epidemiologic sources in England, France, Spain and Italy, are at the upper end of this range. Given this virulence, and the fact that the plague was new and was striking a population that had yet to develop any natural immunity to it, one might reasonably assume that the Black Death killed without discrimination, regardless of age, sex or frailty.

That indeed was how it was seen at the time. Paintings and woodcuts depicted the "Dance of Death" – Death as a skeleton indiscriminately carrying off old and young, rich and poor, kings and commoners. A good life, a healthy life, a clean-lived life was no protection: the medieval folk-conception was of Death as one who obeys no rule of time, of place, of age, of sex, or of household. Five hundred years later a young Karl Pearson (1857–1936) viewed two of the 67 images painted inside the roof of the Spreuer Bridge in Lucerne, depicting Death's blindness to beauty and riches. In his 1897 essay on *The Chances of Death*[2] he traced the "idea of Death as the lawless one, the one who strikes at random" back to this early medieval tradition[3]. The message in those pictures of dancing Death was indeed clear: Death, in plagues and pestilence, was random.

The message since then has been tested. Horrox[4] studied many contemporary accounts to see if the Black Death took more of the young or of the old, but found "no firm evidence that the 1346–1353 plague was age-specific". However, Benedictow[5] provides evidence of "supermortality" among women and children. They died in greater numbers than the men. He ascribes this in part to their spending more time indoors, closer to the infectious rat fleas. He also explains the rather surprising *inverse* relation between plague mortality rates and population density – the countryside was hit worse than the towns – by the lower ratio of humans to co-resident rat colonies in urban than rural environments. More country households shared their homes with an entire rat colony, whereas several urban homes might be ruled by one territorial rat colony.

"Palaeo-demography" is another tool that can examine the role of age and frailty in succumbing. The skeletal remains of those buried in Black Death cemeteries should reveal the age distribution of the death toll: if Death was truly indiscriminate this distribution should resemble the (pyramid-like) shape of the living population just before the plague – many young, fewer adults, and fewer still who had reached old age. Margerison and Knüsel[6] found that the age-at-death distribution of those buried in the Royal Mint site, London, a Black Death cemetery of 1349, "coincides generally with what one would expect from" an age-indiscriminate Death. But DeWitte and Wood[7] compared the same skeletal remains with contemporary non-epidemic samples from two medieval Danish towns, and concluded the Black Death was selective with respect to pre-existing health conditions – in other words, it took more of the frail than of the strong - although probably it was not as strongly selective for frailty as death in normal times. It took many of the strong as well.
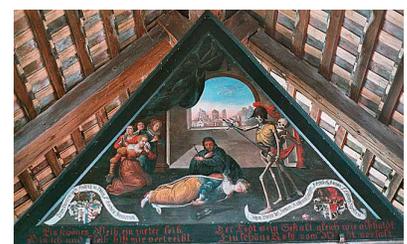
Dance of Death paintings under the roof of Spreuer Bridge in Lucerne. From all-about-switzerland.info[3]

After the Black Death

As centuries passed, views of mortality began slowly to change – and statistics began slowly to creep in, to inform those views and their cultural and artistic representations. Plagues, however, continued. The London Bills of Mortality were begun after plague outbreaks in 1592 and 1603. Collected by parish clerks, the information was published weekly and tracked trends in the number of deaths. The cause of death was being recorded by the time of the Great Plague of London in 1665, but the age at death was not included until the following century. Moreover, several authors have argued that many of the plague deaths were reported under another cause. "Searchers" went round to each house to collect the information on the cause of each death, and, since a plague house was forcibly quarantined, the searchers were frequently lied to. Thus, accurate age-specific mortality information on the 1665 plague is limited to a few locations and circumstances, such as the village of Eyam in Derbyshire, where in a heroic voluntary quarantine approximately 80% of the population died.

One of the more vivid verbal depictions of the force of mortality (which today we know as the hazard function – see below) is found in Thomas Addison's allegorical essay, "The Vision of Mirza", in 1711[8]. In it, he describes a "Bridge of Human Life", with "multitudes of people passing over it" and with "passengers dropping through innumerable concealed trap-doors". He specifically describes the relationship between age and death: he tells us that these trap-doors "were set very thick at the entrance, grew thinner towards the middle and multiplied and lay closer together towards the end". Those who survive one age – one arch in the bridge – face a new, and different, probability (hazard) of death at the next age.

So death is no longer random. Childhood and old age are the dangerous times; we may with luck avoid the less closely spaced traps of middle life. But only those who have avoided all the previous trap-doors reach the ones at the far end of the bridge.

The epidemiologist and founder of medical statistics, William Farr (1807–1883), suggested that Addison's essay may have been inspired by his having seen Edmond Halley's lifetable, one of the first truly data-based mortality tables, based on data from the city of Breslau. We cannot tell whether Addison's description of a "multiplicative in age" mortality rate model is based on a formal statistical analysis or is merely figurative. In 1825, the actuary Benjamin Gompertz (1779–1865) found that the logarithms of the age-specific mortality rates were indeed linear over much of the human age-span. He expressed this multiplicative form as a formal law of mortality.

We can return to Karl Pearson contemplating the Lucerne Dances of Death. In his 1897 essay he was also preoccupied with the role of age in

Medieval woodcut depicting the Dance of Death. From Plate II of the Chances of Death[2]

mortality statistics. His data gave the age distribution of English male deaths during the period 1871–1880. In these data, spanning a decade when Pearson himself was aged 14–23, he did not see Death indiscriminately carrying off old and young, rich and poor. Instead he saw considerable statistical order. Nevertheless he remembered the medieval imagery, and he did not reject it, but adapted it. Pearson did concede that the medieval images were probably inspired by the mortality patterns observed during plagues; and he conveyed his alternative vision through a very similar image of his own Bridge of Life.

A cohort of a thousand starts across the Bridge of Life; as they advance, the throng is more and more thinned. Just as the hazards of Addison's Bridge of Life are represented by trap-doors, so the hazards of Pearson's are represented by Death as a marksman. Five "Deaths"

are posted at different stages (ages), and with different skewness of aim and different weapons of precision they fire at the human target, till none remain to reach the end of the causeway. For more details of this and of Addison's and Gompertz's work, see Turner and Hanley[9].

He conveyed this imagery, and his mixture model, to his readers using a drawing rendered by his wife Maria; this drawing also served as a frontispiece to his collection of essays.

Technically, he was fitting a five-component mixture model to mortality data; students of statistics will be able to convert this density function into a hazard function, and to work out mathematically the chances of surviving to a certain age. One of the counterintuitive aspects of the hazard function is that a frail 99-year-old stands a greater chance of reaching 100 than does a healthy young man. The mathematics of the hazard function can be complex (though it is explained admirably in a recent article in *Significance* by Byron Jones)[10], but Pearson's visualisation of it makes it clear. Before he can reach the far end of the bridge the young man must overcome many hazards – hazards which the 99-year-old has already successfully overcome.

Pearson thus modernised the medieval cultural images of "Death as the lawless one, the one who strikes at random" to one of Death who obeys strict laws.

The role of age in cholera mortality

So what are those laws obeyed by death? In epidemics later than the Plague it is possible to know more about who is being taken and who is being spared.

Frontispiece, by Maria Pearson, to Karl Pearson's book *Chances of Death*[2]
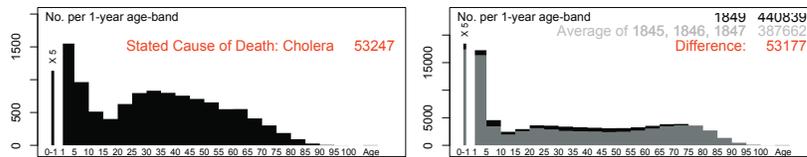
Figure 1. The age-specific numbers of cholera deaths for the year 1849, based on Farr's report, are shown on the left. The age-specific average numbers of deaths due to all causes for the years 1845–1847, along with those for 1849, are shown on the right, and based on data available in the online Human Mortality Database[12]

By the time of the 1848–49 cholera epidemic in England and Wales, the Births and Deaths Registrations Act of 1836 was in place. In addition, William Farr had produced his "statistical nosology" which listed and defined 27 fatal disease categories to be used by local registrars when recording causes of death. Thus, in a special report completed by Farr in 1852[11], he was able comprehensively to document mortality in the epidemic specified by age.

Figure 1 uses these data and data from the Human Mortality Database[12] to examine the 1849 distributions of cholera-specific deaths that year and at the peak of the epidemic and all-cause deaths in non-epidemic years (1845–1847). The similar age distributions of the 1849 cholera deaths (left) and excess all-cause deaths in 1849 over the average in the non-epidemic years suggest that the cholera Death did not discriminate on the basis of age; but there was some sparing, not of the very young, but of those aged 10–25 years. We can speculate on reasons for this. Some of those in this age-range had lived through the cholera outbreak of 1832 and through subsequent smaller ones documented in the beginning of Farr's 1852 report and had therefore acquired some immunity.

The role of age in influenza mortality

The "Spanish Flu" pandemic began in early 1918, and ended in mid-1920. Estimates of total worldwide number of influenza deaths vary widely, but the number is generally believed to exceed the (approximately) 16 million deaths in World War I. We estimated the age pattern by comparing the age-specific numbers of deaths from all causes in the peak influenza year, 1918, with the numbers in adjacent years.

We focus on the 12 countries in the Human Mortality database with age- and sex-specific numbers of deaths for each year from 1912 onwards. In some of these countries, differences between the numbers of deaths in 1918 and 1917 reflect not just influenza mortality, but also deaths from World War I or civil war. To separate these, we also examine inter-year differences separately in females and males, as well as differences from 1912–1913 numbers. Because of the limited space, some of these are only shown on the authors' website.[13]

The 1917–1918 comparisons are shown in Figure 2. They clearly show that most of the

influenza deaths must have been in young adults. If the cholera Death spared some of the young, the influenza Death singled them out.

This singling out is more evident in England if we limit our 1917–1918 comparisons to females (top left panel compared to bottom left panel). The 1912–1913 vs. 1916 comparisons on the website also document the equally large numbers of deaths from war in just one year in the male populations of these three countries.

Pandemics have not gone away. In H1N1 we may be facing another, although the 2009-2010 winter period has proven less severe than anticipated. Even so, H1N1, like its predecessors, too has proven not to discriminate. Government advice, as at December 2009, was quite right to include men and women over 65 and children between 6 months and five years as priorities for immunisation.

In his essay, Pearson conceded that the notion of Death as the one who strikes at random probably arose "at a time when men were face to face with the terrible mortality of the plague"; but he noted that this "widespread and deeply-rooted traditional representation of the random action of death" (and in particular, Death's blindness to *age*) [remained so] "for more than four centuries". The notices in doctors surgeries today urging high-risk age-groups to consider vaccination are signs that death, even in

pandemics, is more selective than the medieval peasant supposed.

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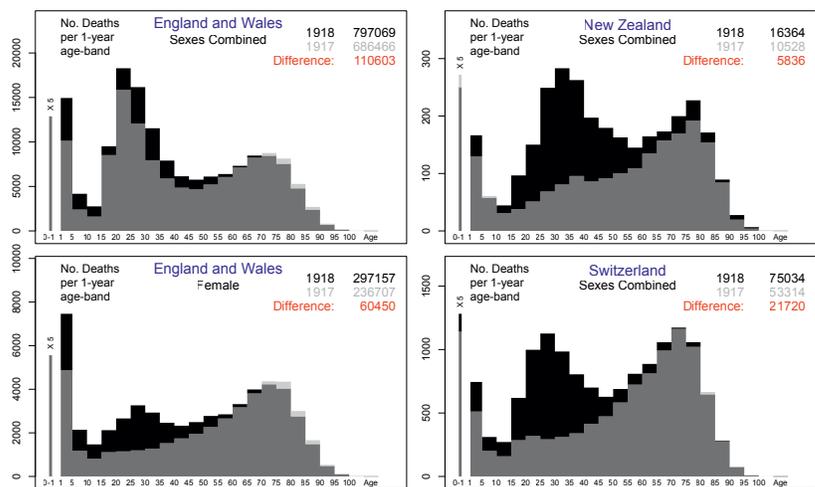
Figure 2. Deaths from all causes in 1918, the peak year of the Spanish Flu pandemic, compared to 1917. In the case of Switzerland, and of women in England and Wales, the excess deaths are entirely due to disease, not war. Data from the Human Mortality Database[12]