Chapter 5
Misconceptions About the Bioarchaeology of Plague

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Introduction

Bioarchaeological and paleomicrobiological research is yielding important new information about past epidemics, and much of this research has generated considerable public interest. Historical plague epidemics including the medieval Black Death (*c.* 1346–1352, the first outbreak of the Second Pandemic of bubonic plague) have, in particular, attracted the attention of researchers and the general public because of their extraordinarily high mortality levels and the important effects they had (or are purported to have had) on demographic, social, economic, and political conditions in affected populations in Eurasia and Africa. Bioarchaeological reconstructions of temporal trends in mortality, survivorship, and skeletal markers of physiological stress during the medieval period have made it possible to assess earlier conditions that might have shaped patterns of vulnerability to a new disease, patterns of selective mortality during the epidemic, and changes in demographic and health conditions in its aftermath (Castex and Kacki 2016; DeWitte 2014, 2015; DeWitte and Wood 2008; Rubini et al. 2016). Analyses of mortuary practices during historical plague epidemics, particularly patterns of burials in mass interments or burial grounds created specifically for plague burials, provide insights into how people in the past planned for or responded to catastrophic mortality (Castex 2008; Grainger et al. 2008; Kacki et al. 2011; Signoli et al. 2002). Mortuary practices also reflect beliefs people in the past held regarding the mechanisms of disease transmission. For example, the relatively high proportion of coffin burials in the East Smithfield Black Death cemetery in London (Gilchrist and Sloane 2005; Sloane 2011) was consistent with orders issued in many cities to use coffins to prevent corruption from rotting plague victims (Creighton 1891). Paleomicrobiological research has clarified the identity and phylogeny of the causative pathogen of past

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plague epidemics, *Yersinia pestis*, and genomic sequencing and array-based analyses are creating opportunities to examine the molecular biology and disease ecology of historical strains of the disease (Bos et al. 2011, 2016, 2015; Devault et al. 2014; Haensch et al. 2010; Raoult et al. 2000; Schuenemann et al. 2011).

Rich documentary, archaeological, bioarchaeological, and climatological data from the medieval period allow us to reconstruct in great detail the biological, social, and environmental contexts that existed before, during, and after the Black Death. Detailed reconstructions of the contexts of the Black Death and of its variable effects on human populations are invaluable not only for improving our understanding of this particular outbreak, which was one of the most important disease epidemics in human history, but also for allowing us to generalize about contemporary conditions for which there are parallels in the medieval period. Research on past epidemics, including historical plague outbreaks, therefore has the potential to yield benefits for living populations, several of which are described by DeWitte (2016) and are discussed in more detail below.

The findings from research on disease in the past are often reported in the popular media (see examples below). Such reporting should, in theory, be welcome because it increases the likelihood that the results of this work will reach the public and scholars outside of our own fields, which is crucial for reasons that are outlined below. Unfortunately, the content or broader implications of our work are not always reported in the media accurately or in ways with which we agree. This is frustrating as it might spread misconceptions among people who will not engage with our research further and who thus misconceive what we do and why it matters. Importantly, inaccurate media reporting has the potential to interfere with implementing potential benefits of our research and might negatively affect future research. In this paper, I focus on research on the Black Death and other historical plague epidemics as an example of how bioarchaeological and paleomicrobiological work has been and can be misinterpreted and to explore the potential negative outcomes of media misconceptions. I also suggest strategies that bioarchaeologists in general might use in an effort to combat and correct these misconceptions.

Bioarchaeology and Paleomicrobiology of Plague

My research on medieval skeletal samples (*c.* 1000–1539 AD) has focused on the context of the initial emergence of the fourteenth-century Black Death in London, patterns of variation in risk of mortality during the epidemic, and changes in health and demography in the surviving population of London. I have applied hazard analysis-based approaches, which are arguably more efficient and informative ways to assess skeletal data compared to conventional life table-based approaches (Konigsberg and Frankenberg 2002; Milner et al. 2008; Wood et al. 2002). I have used these approaches to assess mortality patterns in relatively large skeletal samples from London that date to one of the three time periods: 1000–1250 AD (pre-Black Death), 1349–1350 AD (Black Death), and 1350–1539 (post-Black Death).

The Black Death assemblage is from the East Smithfield cemetery, a burial ground established explicitly for and used only during the epidemic in London (Grainger et al. 2008). The other assemblages reflect attritional, non-epidemic mortality and contain a combination of lower and higher status individuals, clergy and lay individuals, both sexes, and all age groups. These skeletal collections, though subject to the sources of bias inherent to all archaeological skeletal samples (see Milner et al. 2008), provide better representations of the once-living medieval population than are available from existing documentary sources from that period, which are biased in general toward wealthy men. Thus this work, as is true of more generally of many bioarchaeological studies, provides the opportunity to challenge interpretations about medieval plague that have been based entirely on documentary evidence.

Black Death Selectivity

The results of my work and that of my colleagues have challenged the often-made assumption that the Black Death was an indiscriminate killer. This assumption of nonselectivity is understandable given the extraordinarily high levels of mortality during the epidemic, which ranged from 30% to 60% and resulted in tens of millions of deaths within a very short time. This assumption is also the foundation for the hypothesis that Black Death burial grounds provide “snapshots” of once-living populations (e.g., see Chamberlain 2006; Margerison and Knüsel 2002), i.e., samples that are much more representative of living populations than we typically expect from skeletal assemblages that accumulate under normal mortality conditions and are subject to the complicating phenomena of heterogeneous frailty, selective mortality, and demographic non-stationarity (Milner et al. 2008; Wood et al. 1992). However, rather than finding consistent signals of uniform risks of mortality, our results suggest that older adults faced higher risks of mortality during the epidemic than younger adults, as is typically observed under conditions of normal, non-crisis mortality (DeWitte 2010). My colleagues and I also compared individuals with and without a variety of skeletal stress markers (e.g., enamel hypoplasia, cribra orbitalia, short adult stature, periosteal new bone formation), which indicate exposure to a variety of physiological stressors, in both the East Smithfield Black Death cemetery and a non-epidemic medieval cemetery sample. We found that in both mortality contexts, people of all ages who experienced physiological stressors at some point before (in some cases decades before) the arrival of the epidemic were subsequently more likely to die during the Black Death compared to their age peers who lacked these stress markers and thus presumably avoided exposure to physiological stress or endured the stressors without producing skeletal markers (DeWitte and Hughes-Morey 2012; DeWitte and Wood 2008). This suggests that the Black Death, like non-epidemic causes of medieval mortality, disproportionately killed frail individuals. These findings suggest that we should not assume indiscriminate (nonselective) mortality under catastrophic (or, for that matter, normal) conditions. It should be noted that other researchers, who have focused on fourteenth-century plague burials in England (Hereford), Spain, and France, have found that the age distributions in plague burials mimic those of living populations, which suggests reduced selectivity with respect to age during the epidemic compared to non-epidemic mortality conditions (Castex and Kacki 2016; Gowland and Chamberlain 2005; Margerison and Knüsel 2002). The variation in these findings might be the result of differences in analytical approaches or, in some cases, perhaps reflect spatiotemporal variation in the effects of medieval plague.

*Pre-Black Death Trends (*c. *1000–1350 AD)*

More recent bioarchaeological work indicates that adult survivorship declined and risks of adult mortality increased in London before the Black Death across the period from 1000 to 1250 AD (DeWitte 2015). Assessment of fertility proxies [the proportion of individuals above the age of 30 divided by those above the age of 5, D_{30+}/D_{5+}, a ratio that is strongly negatively associated with birth rates (Buikstra et al. 1986)] suggests that the estimated changes in survivorship and mortality were not an artifact of increases in fertility across the pre-Black Death time period [such attempts to control for fertility are necessary in bioarchaeology given that changes in fertility can alter age-at-death distributions even if age-specific mortality does not change (Milner et al. 1989; Paine 1989; Sattenspiel and Harpending 1983)].

Historical evidence dating from the late thirteenth century through the mid-fourteenth century reveals general declines in life expectancy from 1276 though the time of the Black Death (at least for adult males—i.e., the demographic predominantly represented in medieval documentary data) (Jonker 2003, 2009; Russell 1948). Thus, it appears from the historical evidence that the trends estimated from the bioarchaeological data did not reverse just before the Black Death. That is, demographic conditions in England began deteriorating at least as early as the first half of the thirteenth century and continued to do so until the epidemic began. These negative demographic changes occurred in the context of climatic changes that produced repeated famines (DeWitte 2015). Temperatures in England peaked at the end of the twelfth century (during the Medieval Warm Period) and then dropped rapidly from the thirteenth to fifteenth centuries (Brooke 2014; Galloway 1986). The cooler temperatures in the thirteenth and fourteenth centuries contributed to repeated, widespread famines (Farr 1846). These famines were accompanied by severe declines in England's economic conditions (Campbell 2005, 2010). For example, between 1200 and 1300, real wages declined, while prices increased (Campbell 2010; Clark 2005; Farmer 1988). In an effort to raise funds at the beginning of the Hundred Years' War (1337–1453), King Edward III of England more than quadrupled the country's annual tax burden between 1337 and 1341 (Campbell 2016). Population growth and simultaneous increases in taxes, rent, and grain prices in the twelfth to thirteenth centuries created stark social inequalities, notably with respect to food availability. Food crises in preindustrial populations appear to have disproportionately affected mortality risks within lower socioeconomic strata (Hayward et al. 2012). Given the negative effects of malnutrition on immunocompetence (Scrimshaw et al. 1968), the confluence of climate change-driven famine, the interaction of famine and disease, decreasing real wages, and increasing social inequities might have substantially, negatively affected health in the pre-Black Death period.

Longevity (life expectancy) and mortality are commonly used as measures of general population health for contemporary populations (Gage 2005). As detailed above, there is documentary evidence that life expectancy declined from the end of the thirteenth century until the Black Death. This, combined with the downward trends in survivorship and increasing risks of mortality estimated from the skeletal data, suggests that health in general declined before the Black Death emerged in the fourteenth century. Such declining health might have exacerbated vulnerabilities to a new disease at the eve of the Second Pandemic of plague (DeWitte 2015). One of the defining characteristics of the Black Death was its extraordinarily high mortality. The medieval epidemic killed 30–60% of the population of Europe, a level which was unmatched by any subsequent outbreaks of plague. For example, three major plague epidemics occurred in London in the 1600s (including the Great Plague of London in 1665), each of which killed about one-fifth of the city's population at the time (Cummins et al. 2016). More recently, but still prior to antibiotic treatments, outbreaks of the Third Pandemic of plague in India in the early twentieth century killed no more than 2–3% of affected populations (Plague Research Commission 1907). This level of mortality, while certainly horrifying in terms of absolute numbers of people killed, is substantially lower than that of the Black Death. The high mortality levels of the Black Death appear not to be explained by a particularly virulent strain of *Y. pestis* in the medieval period. Comparison of the strain of *Y. pestis* that caused the Black Death (assembled from endogenous *Y. pestis* sequences isolated from individuals buried in the East Smithfield cemetery) and modern reference strains of the disease has yielded no evidence that there was a genetic variant unique to the fourteenth-century strain that rendered it more deadly than modern stains (Bos et al. 2011). Rather than having been caused by some factor intrinsic to the pathogen itself, the extraordinarily high mortality levels of the Black Death may be more appropriately attributed to weakened immune responses of people debilitated by years of famine-induced nutritional stress. Worsened by stark social inequities, the epidemic became vastly more deadly than it might have been, had it struck a more robust or resilient population.

Post-Black Death Trends (c. *1350–1539 AD)*

By killing large numbers of people of all ages who were in relatively poor health, the medieval epidemic might have powerfully shaped patterns of health and demography in the surviving population, producing a post-Black Death population that differed, at least over the short term, from the population that existed before the epidemic. Bioarchaeological analyses reveal that following the epidemic (at least from 1350 to 1539 AD), adult survivorship was higher and adult risks of mortality were lower than they were in the pre-Black Death population. This suggests that health in general improved following the Black Death (DeWitte 2014). As with the study of pre-Black Death demographic trends, these post-epidemic trends do not appear to be artifacts of differences in fertility between the pre- and post-Black Death populations.

There are several possible mechanisms that might have produced these positive changes. The Black Death might have shaped population patterns by altering exogenous factors that affected health and demography, such as improved standards of living, including better, more nutritious diets for people of all socioeconomic strata. In some regions of Europe, including England, there is evidence from historical documents that standards of living improved following the Black Death as a result of the depopulation that occurred during the epidemic. The huge loss of life during the Black Death disrupted the pre-epidemic conditions of a population that was too large relative to the available resources (under the existing system of agriculture) and economic inertia (Bridbury 1973; Campbell 2016; Epstein 2000). The medieval system of serfdom was no longer sustainable following the Black Death in the face of the resulting severe shortage of laborers. There was a major redistribution of wealth as wages increased dramatically at the same time that prices for food, goods, and housing decreased (Bailey 1996). As a result, housing and diet improved for people of all social status levels (Dyer 2002; Hatcher 1977; Poos 1991; Postan 1950; Rappaport 1989; Stone 2006). Diet plays an important role in determining immunocompetence and health in general. Poor nutritional status during development of the immune system can have permanent negative effects on immunocompetence, and nutritional status can also have immediate (though potentially reversible) immune suppressive effects throughout an individual's life (McDade 2005; Scrimshaw 2003; Spencer 2013). Therefore, improvements in diet after the Black Death may have had substantial positive effects on general levels of health in the latter half of the medieval period. Elevating diet quality for lower status individuals to the level previously enjoyed by higher status people might have meant that a much larger proportion of the post-Black Death population of England was in generally good health or at least was at lower risk of poor health outcomes associated with malnutrition compared to the pre-Black Death population.

Alternatively, improvements in survivorship and mortality after the Black Death might indicate that the epidemic acted as an agent of natural selection. Given that people of all ages, including reproductive-aged individuals, with relatively high frailty were at elevated risks of mortality during the Black Death, the epidemic might have affected genetic variation with respect to disease susceptibility or immunocompetence and thus acted to reduce average levels of frailty in the surviving population. Post-Black Death demographic changes might also represent a short-term "harvesting" effect of the epidemic [i.e., an increase in mortality among people with compromised health (Sawchuk 2010)]. The observed improvements in the post-Black Death period might also reflect migration into the city, specifically the introduction of large numbers of healthy people to London after the epidemic.

Teasing apart and identifying the possible mechanisms that drove demographic changes and, by inference, improvements in general health in the aftermath of the Black Death awaits further research.

Paleomicrobiology of Plague

Burials from historical plague epidemics provide the means for directly examining the responsible pathogen, *Yersinia pestis* (the same bacterium that causes bubonic plague today). Thus far, ancient DNA studies have isolated *Y. pestis* DNA from burials dating to the Bronze Age (Rasmussen et al. 2015), the sixth-century Plague of Justinian (Wagner et al. 2014; Wiechmann and Grupe 2005), the Black Death (Bos et al. 2011; Haensch et al. 2010; Raoult et al. 2000; Schuenemann et al. 2011), and later outbreaks of plague in the fourteenth-century (Bos et al. 2016), the seventeenth-century (possibly the Great Plague of London *c.* 1665–1666) (Bos et al. 2017), and the eighteenth-century Great Plague of Marseille (Bos et al. 2016; Drancourt et al. 1998).

These paleomicrobiological studies have been crucial for resolving long-standing debates regarding the identity of the causative agent of historical plague epidemics. The cause was previously in doubt because, among other reasons, there are differences between the symptoms of modern plague and those described during historical plague epidemics, and the medieval disease spread much more rapidly than has been observed in outbreaks caused by *Y. pestis* in the nineteenth to twenty-first centuries (Scott and Duncan 2001; Twigg 1984). Not only have ancient DNA studies found *Y. pestis* DNA in historical plague burials, but a draft genome of fourteenth-century *Y. pestis* assembled from authentic endogenous pathogen DNA from East Smithfield has, as mentioned above, revealed that the Black Death was caused by a strain that differed very little from strains circulating today. Furthermore, ancient DNA studies have suggested that the earliest known plague pandemic (the Plague of Justinian) and the Second Pandemic (which began with the Black Death) were the result of independent introductions of the disease from rodent reservoirs in Asia, but that plague in contemporary populations is likely derived from strains that circulated during the Second Pandemic (Bos et al. 2016; Wagner et al. 2014).

Benefits to Living People

As is true of other topics studied by bioarchaeologists (e.g., interpersonal and structural violence, the effects of environmental change, migration), research on disease in the past has the potential to improve our understanding of phenomena that people experience today in ways that may yield tangible benefits to them now or in the future. These benefits include revealing how the diseases that currently affect humans originally spread to, within, and between human populations. This research also clarifies the environmental, biological, social, economic, and political contexts that favor the emergence, epidemicity, and endemicity of disease. Further, it reveals the biological, social, economic, and political consequences of disease and how these consequences have varied across time and space. All of this is important for understanding how and why new diseases may emerge or reemerge and affect us in the future; this, in turn, can contribute to prevention, surveillance, and control measures.

Research on past diseases can reveal patterns of socially or biologically determined variation in risk of morbidity and mortality during epidemics, and, ideally, this knowledge can motivate us to implement strategies to reduce the devastating effects of disease epidemics in the future. For example, as described above, research on the medieval Black Death suggests that the epidemic disproportionately killed frail people, including those who experienced nutritional deprivations in childhood. These results suggest that we should expect such variation in risk of mortality, regardless of the context (DeWitte and Wood 2008). By identifying who might be most vulnerable during epidemics and which factors most significantly affect negative health outcomes or risk of mortality or simply by highlighting the possibility that variation in risk might exist in general, research on past epidemics can help motivate us to take measures to reduce morbidity and mortality in the face of future threats, such as reducing social inequalities in access to food and other resources and making concerted efforts to improve childhood health and nutrition globally.

Paleomicrobiological research can clarify how humans and the causative pathogens of past and present epidemics have coevolved and may provide data that are useful for predicting future genetic changes in pathogens (Anastasiou and Mitchell 2013). Detailed reconstruction of ancient pathogen genomic sequences also provides data that could aid in the development of vaccines and drug therapies (e.g., Ifeonu et al. 2016; Moriel et al. 2010; Seib et al. 2009; Sette and Rappuoli 2010). Genomic data from contemporary pathogens has been used to identify antigens for vaccines (Giuliani et al. 2006; McKevitt et al. 2003; Moriel et al. 2010), and the drug ST-246, developed using pathogenic orthopoxvirus genomic data, was used to treat a child who developed life-threatening eczema vaccinatum after exposure to the smallpox vaccine (Vora et al. 2008; Yang et al. 2005). Ancient DNA research can contribute valuable data on pathogen sequence variation that might prove similarly useful in the future. For example, the identification of antibiotic-resistance genes in ancient bacterial DNA isolated from an eleventh-century Andean mummy informs about the evolution of antibiotic resistance in the pre-antibiotic era. It might contribute to the development of treatments and prevention of infection in the future (Santiago-Rodriguez et al. 2015; see also D'Costa et al. 2011).

Media Reporting on the Bioarchaeology and Paleomicrobiology of Plague

The results of many bioarchaeological and paleomicrobiological studies of historical plague epidemics have been reported in the popular media following publication in professional journals or presentation at professional conferences. Public dissemination of these findings is crucial if the potential benefits of research on past diseases are to be realized. For example, efforts to use the Black Death as a case study to inspire further research or to motivate efforts to mitigate disasters in living populations will not come to fruition if our work is only read by a small, exclusive audience of bioarchaeological experts. Furthermore, dissemination of our findings to the public is important, given that in many cases such research is made possible by federal funding or other public funds. Even if members of the general public are not actively choosing to support our specific research projects, they arguably have the right to access these results. Media reporting of bioarchaeological plague research also contributes to legitimizing anthropological research in the public's eye and thus strengthens or expands public support.

Public dissemination of research also facilitates multi- and interdisciplinary research, as it can forge connections among scholars with relevant expertise who might otherwise be unaware of each other's work. For example, media reporting of my research brought it to the attention of risk management experts, scholars who are far outside my own field, whom I would not interact with under normal circumstances (e.g., at professional conferences), and with whom I have little overlap from a conventional perspective. This led to a publication (DeWitte et al. 2016) that brings together our disparate research interests and applies the insights gained from research on past diseases to planning efforts in living populations. As in this case, media reporting provides us with new perspectives and can spark creative, interdisciplinary "out of the box" thinking.

Because there is widespread fascination with the Black Death, the interest that my work and that of other bioarchaeologists and paleomicrobiologists has sparked in the popular press does not come as a complete surprise. However, I did not (perhaps naïvely) anticipate the ways in which the results of my own work would be reported (see Fig. 5.1). In many cases, the headlines and text of articles in the popular media were fairly accurate representations of the substance of my findings, if perhaps lacking in nuance, which is quite understandable given the space limitations of media venues and their presumably primarily nonspecialist readership. For example, our evidence that suggested that risks of mortality varied during the Black Death led to headlines such as "Clues to Black Plague's fury in 650-year-old skeletons" (Bakalar 2008) and "Black Death was Selective" (Moskowitz 2008). Recent research indicating that survivorship was elevated and risks of mortality were lower in the post-Black Death population of London than in the pre-Black Death population was reported with such headlines as, "Study suggests improved survivorship in the aftermath of the medieval Black Death." This was the headline of a PLOS press release on May 7, 2014, which was reposted on various websites, such as www.eurekaalert.org and sciencenewsline.com. While this headline might not necessarily effectively grab every reader's attention, it certainly clearly reflects the findings. This research was also reported in an online article with the arguably problematic headline, "Black Death: The upside to the plague killing half of Europe," written by Alex Berezow for Realclearscience.com (May 12, 2014) and reposted by several other news websites, such as Forbes.com. This and other sensationalized accounts presented the Black Death as ultimately good for affected

Fig. 5.1 Selected headlines reporting bioarchaeological and paleomicrobiological research. Modified from Eugen Holländer (1921) *Die Karikatur und Satire in der Medizin: Medico-Kunsthistorische Studie von Professor Dr. Eugen Holländer*, 2nd Edition (Stuttgart:Ferdinand Enke), Fig. 79 (p. 171)

populations because it disproportionately killed frail individuals or produced a better balance between population size and resources. These and similar headlines heightened my concern about media representations of bioarchaeology.

From an anthropological and public health perspective, one of the most important findings from bioarchaeological research on the Black Death is the observation that poor health conditions, including compromised health in childhood, in the pre-Black Death population, potentially influenced by the stark socioeconomic disparities preceding the epidemic, might have favored high epidemic mortality. As detailed above, bioarchaeological and historical evidence indicates that there was a long downward trend in survivorship and increases in risks of mortality prior to the Black

Death, and these changes occurred in the context of climatic changes and increasing social inequities in access to resources. Subsequently, during the Black Death, people who had skeletal indicators of exposure to physiological stressors at some point before the epidemic (including during childhood) faced elevated risks of morality during the epidemic itself compared to those who appeared relatively healthy. The dramatic estimated differences between the pre- and post-epidemic populations might largely reflect poor general health conditions prior to the Black Death that were presumably mediated, at least in part, by socioeconomic status.

Furthermore, reduced social inequities (e.g., in dietary quantity and quality) following the Black Death might have promoted improved general health. That is, the demographic and health outcomes we can observe from the skeletal remains and historical documents following the Black Death were likely driven partly by changing socioeconomic conditions. As is true of all diseases, the Black Death did not occur within a vacuum, and there were almost certainly factors totally independent of the disease itself that amplified human mortality levels. Therefore, we should primarily be concerned with the conditions, particularly those that still exist today or that have the potential to reemerge in the future, that might have made these populations vulnerable to massive mortality when exposed to a new disease. We should also be concerned with the mechanisms by which diseases dramatically shape human populations, not by themselves, but as one component within a larger syndemic [i.e., the synergistic interactions, often in the context of disparate social conditions, of multiple diseases or health problems that exacerbate their negative outcomes (Singer 2010)]. Ideally this information will allow us to enact changes so that such disasters can be avoided or mitigated in the future.

It is not my goal to deny that improved survivorship following the Black Death was a positive outcome for those who experienced improved health and thus longer lives. I acknowledge that this perspective defines "positive outcomes" only in terms of demography and, largely by inference, health, thus totally ignoring possible psychosocial stressors and other factors that medieval people themselves might not have viewed as positive in the aftermath of the Black Death. Setting aside the difficult issue of assessing health and self-ascribed well-being solely using human skeletal remains (Reitsema and McIlvaine 2014; Temple and Goodman 2014; Wood 1998), of primary concern to me is the apparent tendency of some journalists and other consumers of this research to move from a perspective of viewing the outcomes of the Black Death as positive to framing the Black Death itself as "good" because it created conditions such as reduced population size relative to resources that made improvements in health possible. Media emphasis on the perceived "benefits" of the Black Death and on the characterization of the Black Death as having been "good" for the affected populations diverts attention from the insight that decreased social inequities in access to food or other resources might have resulted in lower mortality rates during the epidemic. This undermines the potential for this insight to motivate efforts to reduce social inequities today.

Numerous studies have revealed the myriad ways that socioeconomic status affects health outcomes associated with infectious disease, chronic disease, violence, pollution, and other factors. For example, diseases such as cardiovascular disease, diabetes, cancers, and infectious diseases are more prevalent in low socioeconomic status groups, and pathogen burdens are also higher for people of low socioeconomic status in contemporary populations (Cavigelli and Chaudhry 2012). In many countries socioeconomic status is strongly, positively associated with life expectancy and negatively associated with risks of mortality (Cavigelli and Chaudhry 2012; Phelan et al. 2010; Robertson et al. 2013). The negative effects of inequality are not limited to individuals of low socioeconomic status. Studies have found spillover effects of inequality on general population health resulting, for example, from environmental degradation and pollution (Cushing et al. 2015).

The negative health effects of low socioeconomic status and economic inequality in general might appear unresolvable given current conditions of staggering global inequality. According to a recent report by Oxfam (Hardoon 2017), the current combined wealth of just eight men is estimated to be equivalent to that of the poorest half of the world's population (approximately 3.6 billion people). The existence of such extreme global social inequalities is shocking, and unfortunately the observed trend in recent history has been one of increasing inequalities. However, according to the Oxfam report, conditions of poverty for hundreds of millions of people worldwide could be remedied with increased taxation, reduced spending on military, and other measures. So, what we are faced with today are conditions of stark social inequalities, as was the case before the Black Death, but with the theoretical means to do something to improve conditions for the poor. Perhaps a greater understanding of the effects of inequality on mortality during the Black Death, a disease that people find fascinating, might inspire the *will* to resolve global economic inequalities and, as a consequence, health disparities. But, this is possible only if the general public and policy makers have a clear understanding of the social and economic context of the Black Death.

In addition to potentially interfering with the beneficial implementation of knowledge about the role of social inequality at the time of the Black Death, framing the epidemic as "beneficial" also fails to acknowledge that any positive outcomes of the epidemic were certainly not worth the huge cost of millions of human deaths. Without explicit statements to this effect, however, media reporting of the "benefits" of the Black Death might lead people to view my colleagues and I who study the epidemic, and other bioarchaeologists by extension, as callous scientists, impervious to the loss of life and psychosocial trauma associated with disease and other crises in the past and present. This might negatively influence further research on disease in the past, if, for example, people are reluctant to support funding the work of scholars whose worldview they perceive as distasteful.

As with bioarchaeological research, ancient DNA studies of past plague epidemics have been reported in the popular media to both good and bad effect (see Fig. 5.1). For example, the discovery of *Y. pestis* DNA in burials dated to the Great Plague of London (1665–1666) led to straightforward, accurate reporting with headlines such as the following: "DNA from ancient skeletons reveals cause of London's Great Plague" (Senthilingam 2016). Similarly, the publication of a draft genome of fourteenth-century *Y. pestis* (Bos et al. 2011) led to a report that "Scientists solve DNA puzzle of the Black Death" (Wade 2011). At the other end of the sensationalism spectrum, evidence of *Y. pestis* DNA in sixth-century Plague of Justinian burials was reported with the headline, "Scientists revive ancient plague that wiped out half of Europe" (Scientists revive ancient plague 2011). According to that article, "Scientists have brought the world's first known plague—responsible for killing more than 25 million people—back from the dead." Reader comments accompanying the online article express alarm that scientists would risk "reviving" a deadly disease. One commenter encouraged others to read the original article, which makes clear that the researchers succeeded in reconstructing the genome of sixth-century *Y. pestis*, but they have not produced an actual living, infectious organism capable of causing disease in people today. However, this comment is outnumbered by those expressing outrage and alarm regarding the apparent hubris displayed by the scientists involved in the ancient DNA research. It is possible that the patently false idea that ancient DNA researchers would purposefully "revive" a pathogen that had such extraordinarily dire consequences in the past and risk unleashing it onto living populations would fan the flames of distrust of scientists among some readers, leading to future refusal to engage with scientific research and undermine efforts to support it financially.

We literally cannot afford to be complacent about the effects that peoples' perceptions of our research might have on funding opportunities. This is increasingly crucial in light of widespread antiscience sentiment in the USA and elsewhere, as most recently highlighted by the antiscience and anti-intellectualism rhetoric used during the 2016 US presidential campaign. Both President Trump and Vice President Pence have a record of dismissing the findings of scientific research and perpetuating misconceptions about, among other things, evolution and climate change, two phenomena that in many cases inform or are the focus of bioarchaeological research (Kaplan 2016). At the time of writing (January 20, 2017, the day of the US Presidential Inauguration), it remains unclear how Trump's views on science and those of his Cabinet members and advisors will shape the funding of and engagement with scientific research, but there is widespread concern among scholars about the future of science in the USA under the new administration (Tollefson et al. 2016). Ominously, on the first day of President Trump's administration, information about climate change was removed from the official White House website. Under President Obama's administration, the website had provided information about steps that had been taken and that were planned to combat climate change (DiChristopher 2017). With respect to disease research, this is particularly troubling given the possible links between climate change, famine, and the emergence of the Black Death and its devastating consequences. Further, it is alarming that an anti-intellectual computer scientist is being considered for the role of President Trump's science advisor (Kaplan 2017).

The current relatively small proportion of US government spending that is allocated to nondefense scientific research (see, e.g., Hourihan and Parkes 2015) must be vigilantly defended. Tangible threats to this funding include the recent effort to substantially cut funding to the National Science Foundation Directorate for Social, Behavioral, and Economic Sciences (SBE; the directorate that includes the Biological Anthropology, and Archaeology and Archaeometry programs) via the

Fiscal Year 2016 Commerce, Justice, Science and Related Agencies (CJS) Appropriations bill (H.R. 2578). This bill was ostensibly motivated in part by views held by government officials (and presumably at least some of their constituents) that social science research is wasteful and frivolous (e.g., Trager 2015). Further, President Trump reportedly plans to defund the National Endowment for the Humanities (NEH) (Bump 2017), which has supported archaeological and bioarchaeological research. These past, current, and potential future threats require us to combat misperceptions of our research, not only to reduce the chances of hostility on the part of the general public and their elected officials toward bioarchaeological research but also so that they will be well-informed advocates for its support in the future.

Addressing Misconceptions About Bioarchaeological Research

Bioarchaeologists have a responsibility to address misconceptions about our studies and to prevent them to whatever extent is possible. In cases of unanticipated responses to our research results, we can take a post hoc corrective approach: we should stay alert to how our work is disseminated and digested and make efforts to publish clarifications or corrections both formally and informally (e.g., on social media) as needed. For example, I co-authored an article for a public health audience with experts on risk management (DeWitte et al. 2016) in part to respond to the media framing of the Black Death as beneficial (DeWitte 2014). Our article highlights the economic stagnation, repeated famines (that might have increased heterogeneity in frailty in the population), and rising social inequities that existed in medieval Europe in the period before the Black Death and that might have contributed to its deadly effects. The Black Death was an acute shock that triggered or accelerated changes that might not have been possible otherwise, given the inertia that characterized the social, economic, and political conditions prior to the epidemic. Our emphasis is on the relevance of understanding the circumstances before the Black Death and the changes in its aftermath to the field of resilience management. Though the necessity of and opportunity for economic reorganization following the Black Death yielded changes with apparent positive health outcomes, we should not rely on disasters to promote positive change. Instead, we argue, we can use what we know about the context of the Black Death to identify conditions (such as persistent poverty) that diminish our capabilities to prepare for, absorb, and recover from crisis events.

Taking a post hoc approach requires us to be vigilant. We need to actively seek out media reporting of our research and online discussions of our work (e.g., on Facebook and Twitter) and contribute in ways that correct misunderstandings and clarify the context and implications of our findings. One easy way to maintain vigilance is to use services such as Google Alerts or TalkWalker Alerts, free online tools that notify you when selected keywords (such as your name or words relevant to your research) are mentioned online. Join Facebook and Twitter, if you do not already belong, so that you can be notified when other users post notices of or otherwise comment on your work and follow discussions on public or private Facebook groups relevant to our field. For example, the BioAnthropology News page on Facebook is a public group whose members (of which there are over 19,000 as of June 11, 2018) and administrators regularly post newly published research or media interpretations thereof, often generating lively discussion among bioanthropological researchers, undergraduate students, and interested non-experts. This and other Facebook groups provide us with opportunities to respond quickly and directly to people who are intrigued (positively or negatively) by our work, including direct dissemination of articles and other writings via private message.

Alternatively, we can be more proactive about preventing misconceptions. When we craft our papers and other texts, we should scrutinize them prior to publication with an eye toward the "sound bites" they might generate in the popular media—i.e., what possible attention-grabbing headlines might be inspired by our research? Along these lines, I find it helpful to enlist the aid of friends, family, and colleagues who are non-experts and are not nearly as invested and engrossed in the research as I am to act as a test audience to gauge how a member of the general public might respond to my work. If we can imagine plausible interpretations of our findings that are inconsistent with what we want emphasized, we should strive to make much more explicit what the appropriate or important interpretations and inferences really are.

For those employed at institutions with cooperative public relations offices, we should work with affiliated staff to write press releases about our research and thus help preemptively shape the inferences that will be made by journalists. It is also crucial to agree to talk to journalists when they request interviews and to accommodate, as much as is reasonable, their typically narrow windows of opportunity to respond to inquiries. Requests for interviews may present an additional burden added to our numerous existing service commitments, particularly when, as if often the case in my experience, journalists prefer to conduct interviews over the phone or in person rather than via e-mail, thus limiting the flexibility of responding to such requests. However, planning in advance of the actual publication can make it easier to respond to media inquiries. This planning could include scheduling time for talking to journalists and thinking about how to respond to questions they are likely to ask. In my experience, there is a great deal of overlap in the questions that different journalists ask. When I interact with journalists with respect to my Black Death research, I am always asked variations on some or all of the following questions: "What data do you collect from human skeletons? Were any of your findings surprising or unexpected? Why is this work important? How might this research help people today? Were some people immune to the Black Death? Is it possible that an epidemic as devastating as the Black Death could occur again in the future? How should we prepare for epidemic diseases now?" Scholars might find it useful to script responses to commonly asked or anticipated questions to have at hand in order to efficiently respond to interview requests by journalists. These tactics are certainly worth the effort if they result in media portrayals of our work that are consistent with our perspectives, motivations, and interpretations.

Similarly, we can shape the message we want disseminated by writing about our research, in a way that is accessible to the general public, on our personal or professional websites. Alternatively, we should reach out to science bloggers and encourage them to write posts or host guest posts that we write about our research. There are several widely read bioarchaeological blogs that can provide ideal platforms for our research, including one (http://www.poweredbyosteons.org/) written by Kristina Killgrove (who also contributes bioarchaeological news items to Forbes.com and MentalFloss.com; see Chap. 14).

Bioarchaeologists can also prevent and correct misconceptions about our work by taking advantage of opportunities to engage with the general public in relatively informal ways. This can make more people aware of our research and the value of bioarchaeology so that they might be more likely to consult us (either directly or by reading our publications) in the future if they have questions about health and disease in the past. One mechanism for doing this is contributing to the production of a TED-Ed video lesson (https://ed.ted.com/). These short (3–4 min) animated video lessons are designed to be accessible to high school and undergraduate students, as well as teachers and anyone else interested in the featured topics. The videos are accompanied by relevant questions to test understanding and additional resources such as links to relevant websites, news articles, and other TED-Ed videos with related content for those who want to learn more. Scholars can propose their own ideas for these lessons or nominate other scholars to be asked to participate in their production. My own TED-Ed lesson (https://ed.ted.com/lessons/the-past-present-and-future-of-the-bubonic-plague-sharon-n-dewitte) on the effects of the Black Death and the ancient DNA analyses of the responsible pathogen has been viewed over 550,000 times as of June 11, 2018. Though the short TED-Ed video is certainly not sufficient to fully educate people about Black Death bioarchaeology and paleomicrobiology, it has exposed many people to my work for the first time, leading some to read my publications. To my knowledge, the video has been shown in undergraduate anthropology and history courses at several institutions. This has resulted in a far larger number of people with a wide variety of educational backgrounds and academic interests who are now familiar with my Black Death research than would be possible solely through the dissemination of my peer-reviewed publications. Wide exposure of my research in this way also has the potential to more generally forge an association in peoples' minds between bioarchaeology and disease research. I hope this contributes to more people in the general public viewing bioarchaeologists appropriately as the experts that we are on these matters and affording our research the consideration and weight that it deserves.

On a smaller scale, we can reach the general public by giving talks designed for non-specialist audiences in continuing education courses, local museums, and other venues outside the academy. It has been a humbling experience to give such talks and realize in the process how many people have never heard of bioarchaeology, but it has also been encouraging to see how enthusiastic they are about it once they do learn about the field. I hope that the excitement I have seen in audiences compels them to read more about bioarchaeological research and to be supportive of funding of our work via federal and private foundation grants. Furthermore, not only do these types of talks enhance our ability to reach a diverse audience and inform them about what we do, but they also benefit us as scholars. These interactions with the general public drive us to think carefully about how to make our research relevant and interesting to non-experts. Success in engaging with the general public and convincing people of the value of bioarchaeological research in turn improves our ability to write compelling grant applications that are reviewed by scholars outside our own fields or by funding agencies, such as the National Science Foundation, that prioritize clear descriptions of the broader implications, including potential societal benefits, of our work.

Conclusion

Bioarchaeologists are engaged in research that is relevant far beyond our field and is often of great interest to other scholars and the general public. This includes research on disease; interpersonal violence, warfare, and structural violence (Chaps. 3 and 11); climate change (Chap. 6); colonial contact (Chap. 4); diet (Chap. 7); migration (Chap. 8); identity formation and family dynamics (Chap. 9); and socioeconomic health disparities. In addition to improving our understanding of both variation and shared human experiences throughout time, bioarchaeological research can benefit living people. Our work has the potential to interest an even larger audience than that which currently exists and to affect human behavior and policy decisions in positive ways if we make greater efforts to engage with the general public and ensure that our findings and the inferences thereof, which are relevant to contemporary issues, are represented accurately.

Unfortunately, bioarchaeological research is sometimes distorted in the popular media, thereby potentially warping public perceptions not only of our findings but also of the value of our field of inquiry in general. For example, research results on the medieval Black Death have been presented in the popular media as evidence that the epidemic was ultimately good for the affected populations. This distracts from the much more important and useful insight that extremely high Black Death mortality and differences in health and demography between the pre- and post-Black Death populations might have been driven by dramatic social inequities in access to resources. Such distraction is unfortunate, given that this finding might help motivate efforts to reduce social inequities in contemporary populations as part of a broader effort to reduce risks of mortality from diseases now and in the future. Similarly, reporting of ancient DNA analyses of historical plague outbreaks has created the false impression that the participating researchers have "revived" the pathogen that caused past epidemics. This misconception might engender public mistrust of researchers who specialize in ancient biomolecule analysis and provoke unjustified fears that the work we do poses a risk to public health.

In some cases, it might be possible to prevent future misconceptions about bioarchaeological research if we are carefully attuned to the inferences that can plausibly be made from our findings and craft our publications, press releases, and responses to journalists in ways that prevent off-target or blatantly wrong interpretations. We are also fortunate to have at our disposal numerous means of widely disseminating our research, and correcting misconceptions thereof, beyond conventional scholarly publications, which may not reach all potentially interested readers and which are not always easily accessible to or affordable for those outside of the academy. These nonconventional platforms include social media such as Facebook and Twitter, and YouTube, all of which are free to use and that allow us to reach people of various educational backgrounds and interests throughout the world. However, we need to harness those means more effectively so that *our* messages (as opposed to the messages produced by others based on our findings) are broadcast widely and accurately and thus have maximum impact with respect to furthering knowledge and benefiting the public.

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