Future Infectious Disease Threats to Europe

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We examined how different drivers of infectious disease could interact to threaten control efforts in Europe. We considered projected trends through 2020 for 3 broad groups of drivers: globalization and environmental change, social and demographic change, and health system capacity. Eight plausible infectious disease threats with the potential to be significantly more problematic than they are today were identified through an expert consultation: extensively drug-resistant bacteria, vector-borne diseases, sexually transmitted infections, food-borne infections, a resurgence of vaccine-preventable diseases, health care–associated infections, multidrug-resistant tuberculosis, and pandemic influenza. Preemptive measures to be taken by the public health community to counteract these threats were identified. (*Am J Public Health.* 2011;101:2068–2079. doi:10.2105/AJPH.2011.300181)

The 2009 pandemic influenza A (H1N1) virus is perhaps exemplary of what is to be expected from a 21st-century pathogen. It is zoonotic, with a genome of human, swine, and avian elements whose reassortments may have been facilitated by intensive agricultural practices[1]; its initial worldwide spread strongly correlated with global air traffic patterns[2]; its emergence led to moral panic as the World Health Organization declared a pandemic[3]; public consensus about whether it was safe or necessary to vaccinate was lacking[4,5]; and its principal medical products, vaccines and antivirals, appear to have been unevenly distributed across the world.

The 2009 influenza A (H1N1) pandemic may not have had the catastrophic impact initially feared, but its consequences were nonetheless significant. There were more than 18 000 laboratory-confirmed deaths worldwide,[6] and the number of attributable deaths may be several orders of magnitude higher: estimates for the United States alone, provided by the US Centers for Disease Control and Prevention, range from 8700 to 18 000 deaths. The number of estimated hospitalizations was in the hundreds of thousands and estimated cases in the millions.[7] Furthermore, because young people were particularly vulnerable to the virus,[8] the disease burden in terms of years of life lost has been substantial.[9]

The pandemic serves as the latest addition to a long list of recent examples of the emergence and spread of infectious diseases, which currently account for roughly 20% of the global burden of disease.[10] Malaria, HIV, and tuberculosis; novel diseases such as severe acute respiratory syndrome[11]; resurgent vector-borne diseases such as dengue[12] and chikungunya[13]; and drug-resistant microbes quickly come to mind when considering emerging and reemerging infectious diseases (EIDs), but they are not alone.

A 2005 study suggested that 177 human pathogens have been labeled as emerging or reemerging, of which more than half (58%) are zoonotic agents.[14] A separate study reported that 335 new diseases emerged between 1940 and 2004 and that the frequency of emergence has risen significantly over time, with a peak coinciding with HIV in the 1980s.[15] The northeastern United States, Western Europe, Japan, and southeastern Australia have been identified as emerging disease "hot spots"; socioeconomic factors (human population density, agriculture, antibiotic drug usage), alongside environmental factors, are hypothesized as key drivers of EIDs in these regions, and this notion has been widely corroborated by the literature.[16–19]

In a period of rapid global change, it is reasonable to expect that the conditions amenable to the transmission of EIDs will, in some instances, be created or exacerbated. To thoroughly assess how this might affect disease transmission dynamics, it has been advocated that a wider range of methodological approaches be incorporated into epidemiological research and that EIDs and human health be viewed from a broader, social–ecological systems perspective.[20–22] This could also help guide public health prioritization activities.

Under the premise that Western Europe is indeed an EID hot spot and that the European Union (EU) is highly connected to other global EID hot spots, the European Centre for Disease Prevention and Control (ECDC) conducted a foresight project to ascertain how the European Union's social–ecological context might change over the coming decade and what this might mean for infectious disease control in the European Union by 2020. Eight plausible threat scenarios were formulated on the basis of an analysis of how exacerbating (and not mitigating) EID drivers could interact.

METHODS

Foresight involves the identification and monitoring of possible developments or changes surrounding a given issue, as well as the development of tools, such as scenarios, to inform strategic planning, research prioritizations, policymaking, and so forth.[23] Foresight has been increasingly incorporated into government workflows across the world,[24,25] including the health sector,[26] but relatively few projects have focused on EIDs. The most notable exception would be the comprehensive UK government foresight project on the detection and identification of infectious diseases, which looked at plant, animal, and human diseases in the United Kingdom and sub-Saharan Africa 10 and 25 years into the future (the project was conducted during 2004–2006) to identify needs and opportunities for the development of disease identification and monitoring technologies and strategies.[27–29]

Our principal objective was to identify plausible scenarios of infectious disease threats facing the European Union by 2020. Rather than being developed as accurate predictions of

the future, these scenarios are primarily intended to inform, broaden, and improve decision-making by anticipating key factors that could influence future developments, thus incorporating perspectives on future developments into current activities and strategies.[30] Plausible scenarios should have a reasonable probability of occurring, as opposed to possible scenarios (which might consider any imaginable scenario, regardless of likelihood) or probable scenarios (which might be more heavily based on extrapolations of the present situation).[31]

Thus, our intention was to identify plausible threats in 2020 on the basis of current knowledge about disease as well as about changing social–ecological contexts. We developed the scenarios for this study by initially identifying and analyzing key disease drivers and then exploring how these drivers could interact to create new threats or exacerbate current ones.

Expert Consultation

To initiate the study, ECDC hosted a 2-day expert consultation in Stockholm in July 2008 at which experts in human health, animal health, and environmental health from 13 different countries, as well as the US Centers for Disease Control and Prevention, the European Commission, and the European Medicines Agency, worked alongside technical staff from ECDC. These experts identified and organized disease drivers on the basis of the following question: what are the key social, economic, and environmental drivers that will influence disease transmission globally and in the European Union by 2020? Drivers were defined as biological, environmental, social, or economic factors that influence the evolution, transmission, or distribution of infectious diseases. They may lead to the creation of new diseases, or they may act as threat multipliers by exacerbating existing trends. Participants reconvened to a plenary session to debate a final set of drivers to be used in scenario development.

Subsequently the experts developed a series of narrative scenarios by considering how these drivers might interact and what the consequences could be for the spread and control of infectious diseases in the European Union by 2020. Small teams of experts working with the set of drivers were given the charge of conceiving fictional newspaper captions that outlined different disease scenarios. Each caption was required to describe key constituents, such as the relevant drivers, diseases, and transmission pathways, as well as rough estimates of morbidity and mortality. All scenarios developed in the group work were then discussed in a plenary session.

Scenario Refinement

A panel of disease-specific researchers at ECDC prioritized the drivers and selected scenarios for further refinement according to the following criteria: plausibility of the scenario, potential severity of the scenario in terms of burden of disease, and relevance of the scenario to multiple EU member states. Scenarios related to the intentional transmission of infectious disease (i.e., bioterrorism) were excluded; we have assessed the risks of bioterrorism from research that could be readily applied to inflict significant harm to the public, the environment, or national security (dual-use life science research) elsewhere.[32,33] At the same time, the long list of drivers identified in the workshop was further organized, with some drivers being assembled and collapsed into broader categories. For each remaining category of drivers, the literature was reviewed to strengthen the scientific basis of the approach.

The search strategy for the academic literature involved searching according to the following parameters: category of driver *and* infectious disease *and* Europe/European Union. Papers were limited to those published in English between 1995 and April 2010, as well as to those focusing on humans. Literature and relevant books released in English in the preceding 10 years from national or international governmental or nongovernmental organizations anywhere in the world were scanned. Data pertaining to specific categories of drivers, rather than connecting drivers to infectious diseases, and publications with data projections through to 2020 or beyond were of particular interest.

The literature review was then used to develop an interpretation of what the social–ecological context in the European Union could be like in 2020. Final versions of the scenarios were revised and reviewed by panels of disease-specific ECDC experts, as well as, in some instances, experts who had attended the workshop. An additional focus of this round of reviews was to identify strategies to mitigate these scenarios.

RESULTS

To identify and classify factors relevant for our study, we created 3 broad groupings of macro-level drivers relevant for understanding the emergence of disease within Europe as well as Europe's capacity to cope with such diseases regardless of their origins. These groupings were as follows: globalization and environmental change drivers, social and demographic drivers, and public health system drivers (Table 1). Under each grouping, a wider range of more detailed drivers were considered in the development of the scenarios.

A vision of the European social–ecological context by 2020 provided the essential backdrop for the disease threat scenarios identified. This vision, as illustrated in the organization diagram presented in Figure 1, was based on published environmental and socioeconomic projections derived from assumptions that are consistent with what is already known but do not incorporate any major surprises (e.g., the collapse of current political or trading systems or a rate of climate change much more rapid than anticipated). Despite this, and although we are looking only roughly a decade into the future, there are nonetheless significant uncertainties in all published projections. Thus, although the discussion here is somewhat biased toward the probable, the consideration and integration of so many variables, with so many underlying assumptions, renders our overall vision rather more plausible than probable.

It is important to stress that those aspects of disease drivers that could help create or magnify infectious disease threats, as opposed to those that could mitigate these threats, are given particular attention here, in line with the objectives of this project. Furthermore, although many more factors could have been detailed, we describe only drivers relevant to the scenarios selected from the expert consultation.

Globalization and Environmental Change

Climate change and land use. The current rate of climate change appears to be approaching or

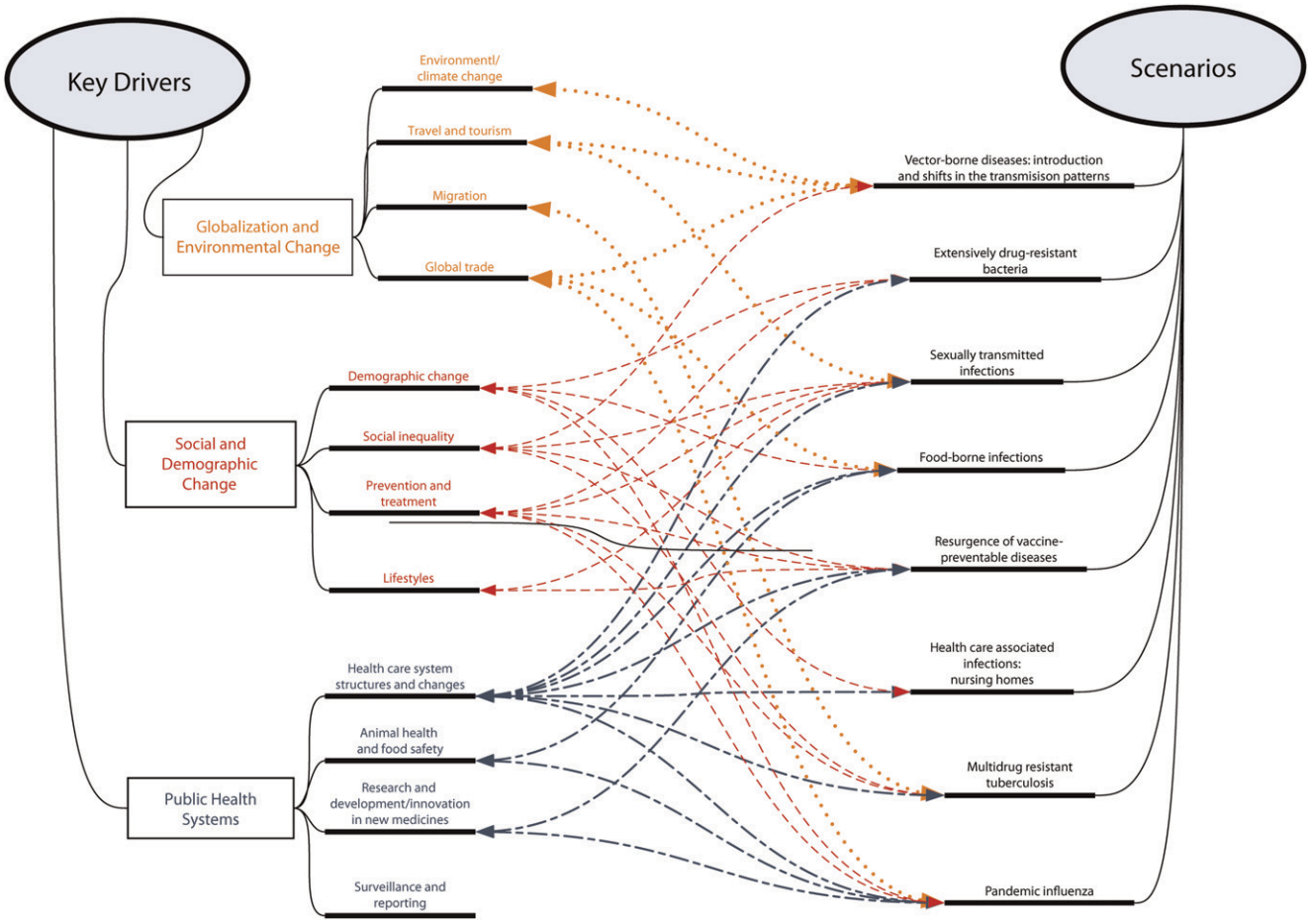
TABLE 1—Key Drivers of Emerging Infectious Diseases in the European Union

Driver	Examples of Links to Infectious Disease Spread or Control
Globalization and environmental change	
Environmental/climate change	Global climate change is projected to increase precipitation in Northern Europe and drought in Southern Europe. An increase in outbreaks of food- and water-borne disease and shifts in the host ranges of European vectors (e.g., ticks, mosquitoes) are possible. Habitat destruction, land use, pesticide application, pollution, and host density are other factors influencing vector distribution.
Travel and tourism	Open borders across EU member states adhering to the Schengen Agreement and global growth in international travel will lead to increased human mobility and, concomitantly, increased possibilities for disease transmission (e.g., importation and autochthonous transmission of chikungunya in Italy in 2007).
Migration	Population movement within and between EU member states and beyond poses particular challenges for local health care systems. Migrant populations are often vulnerable to infectious diseases and may also be, in some circumstances, unable to fully access health care systems in host countries.
Global trade	Continued intensification of global trade can lead to exportation and importation of health threats, ranging from contaminated livestock food products to the accidental exportation/importation of disease vectors.
Social and demographic change	
Demographic change	Population aging is associated with greater health vulnerabilities and public expenditures.
Social inequality	Disadvantaged groups suffer disproportionately from infectious diseases. The recent financial crisis may further exacerbate social inequalities, which have already increased both within and between European countries in past decades. Risk reduction can be achieved through health education and health promotion for marginalized and vulnerable groups (e.g., safe sex education, food hygiene).
Prevention and treatment	Decreases in the credibility of public health authorities and distrust in prevention efforts (e.g., childhood vaccination programs) can result in an upsurge of infectious diseases. Adherence to treatment regimes and good prescription practices are cornerstones of infectious disease control programs.
Lifestyles	Among certain groups, rates of participation in health education and health promotion programs targeting high-risk behaviors (e.g., intravenous drug use or unprotected sex with multiple partners) are low.
Public health systems	
European health care system structures and changes	Poor distribution of general practitioners, hospital beds, medicines, diagnostics, insurance coverage, and so forth exacerbates the burden of infectious diseases. Cross-border health care will be mandated in the EU, potentially complicating service provision.
Animal health and food safety	Livestock and intensive agricultural practices are prime drivers of emerging and reemerging infectious diseases. Food safety regulations and measures are essential for infectious disease control.
R&D/innovation in new medicines	The sparse R&D pipeline targeting infectious diseases, most notably for novel antibiotics, is a cause for concern. Innovation has thus far not kept pace with microbial evolution. The availability and affordability of new diagnostics and vaccines will also be important.
Surveillance and reporting	Systematic ongoing collection, collation, and analysis of infectious disease data and timely dissemination of this information are essential for rapid response as well as for guiding public health intervention strategies.

Note. EU = European Union; R&D = research and development.

even exceeding the upper boundary of the Intergovernmental Panel on Climate Change projections.[34] Between 1906 and 2005, the global mean surface temperature increased by 0.74°C (SD=0.18),[35] and during the 20th century, annual precipitation increased by 10% to 40% in Northern Europe and decreased by up to 20% in Southern Europe.[36] An intensification of water scarcity in Southern Europe as periods of drought become more frequent and prolonged is among the more concerning projected impacts.[37] This might particularly affect agriculture. Irrigation currently accounts for more than 60% of water use in some parts of Europe,[38] and projections suggest a 20% increase in the total area under irrigation in Southern Europe by 2020.[36]

By the 2020s, climatic changes will have also increased the risk for more frequent and severe winter flooding in Northern Europe and flash floods across most of Europe.[37] Warmer lake and river temperatures may affect water quality and thus increase the health risks of water used for drinking or bathing.[39,40] Climate change could also lead to shifts in the distribution range and frequency of vector-, food-, and water-borne diseases in Europe.[41] Phenological phasing and habitat suitability for many disease vectors and reservoirs may be influenced by climate change as well, as appears to have



Note. Infectious disease drivers are grouped into 3 categories and connected to the 8 scenarios developed in the expert consultation. The connections shown reflect those used to develop the scenarios, but they are by no means a comprehensive network of possible interactions between drivers and disease scenarios.

FIGURE 1—Interactions between disease drivers and scenarios: European Union.

occurred during the northward expansion of bluetongue virus[42] and of the disease-transmitting tick *Ixodes ricinus*.[43]

Land-use patterns (e.g., intensive agricultural practices, deforestation, irrigation, and road construction) are another important anthropogenic determinant of infectious disease spread.[44] Agriculture already accounts for roughly 55% of all land area in the European Union,[45] and it has been suggested that the area for agricultural land use will further increase through 2030, principally in Eastern Europe.[46] Meanwhile, urbanization and urban sprawl have encroached agricultural and semi-natural areas in Europe,[47] and this trend is expected to continue. One consequence is that wildlife may increasingly need to find new habitats, sometimes in urban or abandoned environments.

Travel, tourism, and trade. Although the recent financial crisis may have temporarily slowed global travel and trade, it is anticipated that both will have grown by 2020. Nearly 1.6 billion international flight arrivals worldwide are predicted for 2020, up from 800 million in 2005.[48] Similarly, 519 million international tourist arrivals to Western Europe are predicted for 2020, up from an estimated 412 million in 2010.[49]

Meanwhile, global trade has increased substantially in the past few decades, creating myriad opportunities for the spread of disease pathogens, vectors, and reservoirs.[50] From 2000 to 2008, the value of merchandise imports and exports in the 27 EU member states (hereafter EU-27) both increased by an average annual rate of 12% (excluding intra-EU trade).[51] Agricultural trade is of particular interest. In 2008, the EU-27 imported roughly $173 billion worth of agricultural products.[51] Global per capita demand for food consumption is projected to increase through to 2030 (although per capita increases are much less for industrial than for developing nations)[52]; this should contribute to the continued growth of intensive agriculture practices in the form of increased production and trade of animal products and food crops in most regions of the world.

Migration. In the coming decade, migration rates could be driven by factors such as poverty, climate change, rapid urbanization, and conflict.[53,54] Meanwhile, from 2015 onward the European Union will be dependent on migration for population growth.[55] By 2020, an additional influx of 20 million net migrants (the difference between the influx of immigrants and "natural" population increases or decreases) is projected in the EU-27.[56]

There are currently an estimated 214 million international migrants worldwide,[57] and migrants make up 8.8% of the EU population. In 2006 alone, 3.5 million people immigrated to EU member states. Roughly 40% were from other EU member states; of the remaining 60%, most were from Asia (16%), the Americas (15%), and Africa (13%).[58] Migrants are a very heterogeneous group, with a wide range of health determinants, vulnerabilities, and needs.[59] Migrants from countries with a high prevalence of infectious diseases tend to be disproportionately affected by these diseases, but the risk of disease spread from migrant to host populations is thought to be low.[60,61] Migration also tends to both follow and reinforce existing trade and travel networks between migrants' home and adopted countries,[62] further increasing global interconnectedness.

Social and Demographic Change

Demographic change. The population of the EU-27 is expected to reach 514 million by 2020 (as compared with approximately 500 million today), but population growth rates are slowing, and population decreases are even projected by the mid-2030s.[55] Some regions, notably Central Europe, eastern Germany, southern Italy, and northern Spain, will already be facing significant population declines by 2020, meaning that they will probably also be dealing with associated challenges such as low income levels, high unemployment, and lower government revenues.[63]

By 2020, 103 million people 65 years old or older will live in the EU-27, 29 million of whom will be 80 years old or older. The old-age dependency ratio for the EU-27 (the relative ratio of the elderly population to the working-age population) will have increased from 25% in 2008 to 31% by 2020 (and toward 50% by 2050).[64] As this ratio increases, further economic burden is placed on a society through increased demand for health and other public expenditures and, simultaneously, decreased tax revenues resulting from a smaller labor market.

Social inequalities. The recent financial crisis has strained the public finances of many industrialized countries. Public debt as a share of gross domestic product (GDP) has recently risen drastically in many European nations, just as they are beginning to face substantial age-related expenditures (as just discussed). Projections suggest that debt-to-GDP levels will continue to rise dramatically through to 2020 unless governments begin to curb their expenditures.[65] Yet, austerity measures designed to restore government finances could lead to budget cuts for social safety nets and public health systems, and the pressure to reduce budgets could be significant because health expenditures as a share of GDP have increased significantly across the member countries of the Organisation for Economic Co-operation and Development in recent years.[66]

Although budget cuts do not necessarily worsen the quality of health systems, a key risk is that programs that particularly benefit vulnerable groups will be cancelled.[67] Social inequalities, therefore, would be further exacerbated. However, inequalities within regions or nations have widened even during more prosperous times. Despite substantial economic growth in the past few decades, income gaps between rich and poor have widened in many industrialized countries.[68] Vulnerable groups suffer disproportionately from infectious diseases in every EU member state,[69] and countries with higher wealth and lower income inequalities have been observed to have a lower incidence of certain infectious diseases, as seen with tuberculosis.[70] Thus, for example, the current economic downturn could lead to a rise in tuberculosis rates in some of the countries of Central and Eastern Europe.[71]

Prevention, treatment, and lifestyles. This set of drivers is particularly challenging to predict, quantify, or extrapolate into the future; yet, social trends can have a substantial impact on public health. The sociodemographic context in Europe in 2020 involves not only population aging but also a lower frequency of marriage, delayed childbirth, smaller household sizes, and increased population mobility. Sexual networks will become increasingly global as a result of migration, tourism, and human trafficking.[72] Public trust (or lack thereof) in health authorities is another important issue,[73] perhaps particularly since the publication of the Wakefield paper (subsequently retracted), which falsely suggested a link between measles, mumps, and rubella vaccines and autism.[74] Just as low vaccination coverage may prevent herd immunity from developing for many infectious diseases, failure to adhere to full treatment regimes increases the likelihood of drug resistance.

Public Health Systems

Public health systems and effective infectious disease control require financing, skilled professionals, the availability of preventative medicines and diagnostics, and effective reporting, monitoring, and surveillance. In the wake of the financial crisis, public health budget cuts may be the most critical element over the following decade. Yet, other issues are important as well. European health care systems already face substantial shortages in qualified medical personnel, and this problem is likely to intensify with population aging,[75] another consequence of which is that higher levels of primary care may be needed in nursing homes and other old-age facilities.

European health care systems will also face the challenge of providing cross-border health care to citizens from other EU member states.[76] This could be hindered by a lack of effective medicine. At present, the drug development pipeline for antibiotics is scarce.[77] Of all of the drugs in development by the world's 15 largest pharmaceutical companies in 2004, less than 1.6% were antibiotics.[78] Finally, the organization of food production systems and the treatment of livestock are important; both the density[79] and the health of livestock animals can influence human health and food-borne disease.[80]

Scenarios

Eight scenarios of plausible infectious disease threats facing the European Union by 2020 were ultimately selected for this project (Table 2). These scenarios were based on the aforementioned plausibility criteria and identified through exploring how the various disease drivers discussed here may interact (Figure 1).

We identified 2 broad types of scenarios. The first is the "tipping point" scenario, wherein one or multiple factors change sufficiently to alter the scales of balance and lead to a substantially greater disease burden. Thus, reduced herd immunity, social inequalities, and human travel can combine so that an otherwise preventable disease becomes introduced to a highly vulnerable population, in turn leading to a more general outbreak, such as the recent

TABLE 2—Eight Plausible Infectious Disease Threat Scenarios for the European Union by 2020

Scenario	Interacting Drivers	View for 2020	Priorities for Public Health Action
Extensively drug-resistant bacteria	Awareness and adherence; demographic change; innovation/R&D	Antibiotic resistance was already a significant challenge in the 2000s; in 2007, an estimated 25 000 patients died from multidrug-resistant bacteria in the EU.[77] By 2020, bacteria resistant to almost all available antimicrobials could be widespread,[81] and the prospect of complete drug resistance is not unthinkable. Overuse, poor compliance with antibiotic treatment regimes, population aging, and a scarce drug pipeline could collectively create a serious health threat.	Funding and policies to promote R&D Coordination of antimicrobial resistance at the multicountry level Harmonization and improvement of prescription and adherence practices Enhancement of public awareness (e.g., European Antibiotic Awareness Day[82]) and encouragement of international initiatives (e.g., EU-US transatlantic task force[83])
Introduction of novel vector-borne diseases and shifts in the transmission patterns of existing vector-borne diseases	Global trade, travel and tourism; environmental and climate change; social inequalities	The global spread of disease vectors is facilitated by global trade and travel patterns. Three developments are concerning for 2020: (1) the introduction of new disease vectors, which creates new opportunities for disease transmission, such as occurred with the introduction of *Aedes albopictus* into Europe through global trade followed by an outbreak of chikungunya in Italy in 2007 when the virus was introduced by a traveler[84]; (2) vectors currently existing in Europe will prove to have a previously unknown capacity for disease transmission, such as occurred with the spread of bluetongue as well as with a mutation in the chikungunya virus that made it easier to be transmitted by *A albopictus*; and (3) the shift in the transmission range of diseases, hosts, and vectors, such as tick-borne encephalitis, which had a marked increased in incidence in the Baltic region that was linked to socioeconomic change[85] as well as a northerly expansion of the vector in Nordic countries linked to climate change.[43] Consequently, vector-borne diseases may be an increasing problem across the EU by 2020.	Greater emphasis on mitigating vector-borne diseases wherein disease burdens are highest—a global perspective on national and regional disease control Enhancing global and regional surveillance and control of disease vectors, such as has recently been initiated for Europe in the VBORNET[a] project[86] Expansion of coverage where vaccines already exist, such as for tick-borne encephalitis Enhancing physicians' awareness about a wider range of vector-borne diseases than they are currently accustomed to seeing

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TABLE 2—*Continued*

STIs	Lifestyles and value systems; awareness and adherence; travel and tourism; social inequality; European health care system structures and changes	Some data suggest that younger generations and members of key risk groups for STIs are somewhat complacent regarding safe sex practices. Condom usage appears to be notably low, for example, among younger or lesser educated MSM and injection drug users,[87] and the highest rates of chlamydia occur in people <25 years.[88] This could be exacerbated in the future by widening social inequalities as well as the lack of safe sex education in regions with strained public finances; although 82% of countries in Europe and Central Asia responding to a survey in 2010 indicated that they promote health education for young people, only 43% included HIV education in the primary school curriculum.[89] Meanwhile, sexual networks will become increasingly global as a result of tourism, migration, and human trafficking. Sex tourism in particular is an important but underestimated driver; often, sex tourism occurs in regions of the world where rates of HIV and other STIs are already high, putting further strain on the health care systems and economies of these countries while facilitating the global distribution of HIV.[89] Some categories of migrants, refugees, sex workers, and those of lower socioeconomic status will continue to be more at risk for STIs than the population at large, with evidence suggesting a higher propensity for risk-taking behavior.[90]	Harmonizing reporting across the EU for STIs and for behavioral surveillance Monitoring the implementation of the Dublin Declaration for HIV Rethinking safe sex education (and tailoring messages to a multiethnic population) Continued stimulation of R&D for HIV treatment and vaccine Engaging vulnerable groups, including sex workers, MSM, injection drug users, and migrants, with STI prevention and treatment campaigns
Food-borne infections: *Listeria*	Animal health and food safety; demographic change; global trade (food products); European health care system structures and changes	Although *Salmonella* and *Campylobacter* currently have a much higher incidence in Europe, listeriosis incidence could be much higher in 2020 than it is today. The bacterium is unusual in its ability to replicate in cold temperatures and thus is particularly adept at colonizing food processing plants, where temperatures are kept low to ensure long shelf lives. Processed foods already account for nearly half of global agricultural exports,[91] and EU demand for processed food (such as cold meats and other ready-to-eat foods) is likely to increase through 2020, driven by demographic and lifestyle trends. Those not reached by preventive public health campaigns about food handling and those at lower educational levels would be at greater risk. Likely consumers include the time-pressed and single occupants of households. The elderly will increasingly be a key component of single-occupancy households, and they are particularly vulnerable: in 2008, 55% of reported EU cases occurred among individuals ≥ 65 years.[92]	Evaluation of current regulations surrounding food safety, with zero tolerance for *Listeria* Regulation and monitoring of sanitary procedures at major food processing companies[93] Food handling education particularly targeted to consumers of ready-to-eat foods or where food may be provided to large numbers of vulnerable people (e.g., old-age homes and hospitals)

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TABLE 2—*Continued*

Resurgence of vaccine-preventable diseases	Awareness and adherence; social inequality; lifestyles and value systems; European health care system structures and changes; R&D	A recent outbreak of measles in Bulgaria resulted in more than 23 000 cases and 24 deaths. The outbreak was exacerbated by a high number of patients who did not undergo the full course of MMR vaccination, as well as poor living conditions among a highly vulnerable group, the Roma population. Such situations pose a significant threat to the future health of EU citizens, and they could become more common in 2020, driven in part by public resistance to vaccination programs. Opposition to vaccination is not restricted to MMR vaccines; low vaccine coverage is also a significant potential threat for polio, diphtheria, and other vaccine-preventable diseases. Aside from public resistance, public financing and health system structures play a role in vaccination coverage. As the rollout of the influenza A (H1N1) vaccine in 2009 demonstrated, some countries do not have the finances to acquire the vaccine, and vaccination uptake rates within countries also depend on the efficiency of health systems. In the wake of the recent financial crisis, and in those regions of the EU most vulnerable to globalization, public finances may be especially weak, leading to lower access to care and poor vaccination coverage. With these drivers intersecting, the conditions could exist for a substantial surge in vaccine-preventable diseases by 2020.	Need for public health agencies to become much more adept at understanding and addressing the underlying (and varying) causes of resistance to vaccination[73]; in some cases, this will be the result of deliberate misinformation from anti-vaccine movements Ensuring the provision of transparent and independent information about the risks and benefits of vaccination to health professionals and the public Concerted action to defend the budgets of vaccination programs for which public health gains and cost-efficacy are proven
Health care–associated infections: nursing homes	Demographic change; European health care system structures; social inequality	Population aging in Europe by 2020 will probably lead to many more elderly Europeans living in nursing homes. Nursing homes create opportunities for pathogenic spread among a vulnerable population. Adding to this is the possibility that the quality of care in nursing homes could worsen: European health care systems already face substantial shortages in qualified medical personnel, and this problem is likely to intensify.[75] Together, these factors could lead to a deterioration of the conditions under which health care is provided in nursing homes. Further compounding the threat would be strained public finances and income inequalities among the elderly, leading many to live in crowded, unhygienic conditions.	Solutions for bolstering the future health care workforce, such as enhancing enrollment in the medical sciences and ensuring appropriate incentives for skilled workers to remain in their jobs Safeguarding budgets of public health programs for the elderly
MDR-TB	Social inequality; migration; awareness and adherence; European health care system structures and changes	MDR-TB and XDR-TB could be a substantial public health challenge by 2020. In 2007, 2.6% of cases never previously treated and 23.2% of cases previously treated in the EU were multidrug resistant, leading to an overall EU-wide average of 4%.[94] MDR-TB, like TB, is a disease that particularly affects the vulnerable. Migrants, in particular, tend to have much higher TB rates than that of the population at large.[70] Socioeconomic disparities, which may have been further exacerbated by the recent economic crisis, create social risk factors that drive TB rates: poor housing, overcrowding, indoor air pollution, imprisonment, and smoking.[95] Should MDR-TB or XDR-TB be allowed to persist among these vulnerable groups, there is a significant risk that it will become increasingly difficult to eliminate.	Ensuring strong and internationally coordinated programs for monitoring MDR-TB and XDR-TB and strengthening links between laboratories and clinicians Promoting effective practices for detection and treatment of MDR-TB and XDR-TB and ensuring completion of treatment regimes Improving access to first- and second-line therapies for MDR-TB and XDR-TB

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TABLE 2—Continued

Pandemic influenza	Animal health; global trade and travel; European health care systems and changes; awareness and compliance (vaccines and antivirals); R&D; demographic change	The mutability of human influenza viruses, their ability to exchange genetic material with animal viruses, and ever-increasing global interconnectedness ensure that pandemic influenza will be a perpetual threat to public health. The 2009 influenza A (H1N1) pandemic demonstrated that even a relatively benign pandemic can strain health services as well as cause panic in unprepared societies. EU health care systems by 2020 will need to serve an older and more mobile population. Any pandemic that arises during this time will cause a severe threat among not only the typical risk groups for influenza (including the elderly, children, and pregnant women) but also other users of a health care system under strain.	Ongoing revision and optimization of pandemic plans and preparedness plans, building on lessons learned from the 2009 pandemic Improved international cooperation and better sharing of analyses in real time Seroepidemiology and surveillance for severe disease and mortality Implementation of the global action plan to improve vaccine demand, supply, and use[96] Improved risk communication to the general public and professionals.

Note. EU = European Union; MDR-TB = multidrug-resistant tuberculosis; MMR = measles, mumps, and rubella; R&D = research and development; MSM = men who have sex with men; STI = sexually transmitted infection; TB = tuberculosis; XDR-TB = extremely drug-resistant tuberculosis. Although the scenarios are based on some known facts (for which references are included), they should be read as situations that could hypothetically exist in 2020 and not as concrete descriptions of the present or concrete projections of the future.

[a]VBORNET is a network of medical entomologists and public health experts, funded by the European Centre for Disease Prevention and Control.

outbreak of measles in Bulgaria, to devastating effect.[97] Similarly, the gradual reduction in the efficacy of antimicrobial drugs, alongside slack adherence to treatment regimes (which promotes pathogen evolution) and human population aging (which leads to a larger pool of susceptible victims), may shift the balance so that a pressing issue today becomes a dire one tomorrow. The scenarios on food-borne infections, sexually transmitted infections, health care–associated infections, and multidrug-resistant tuberculosis are also part of this category.

The second type of scenario is the "binary" scenario, wherein all of the preconditions may exist for the detrimental spread of a pathogen, except for the pathogen itself. Should the pathogen arise or be introduced, however, the situation changes. The emergence of a new influenza strain, for example, could harness human mobility to spread quickly around the world and, if virulent enough, inflict harm on vulnerable groups. Likewise, environmental and socioeconomic changes might enable the introduction or spread of a disease vector; should the pathogen also be introduced, likely through trade or travel, a vector-borne disease previously absent could quickly become a public health priority.

DISCUSSION

Because the European Union is a hot spot for the emergence of infectious diseases,[15] it is important to consider future contexts to inform public health planning and policymaking. Intensified human trade, mobility, and agriculture in a warmer, older, and more crowded, multiethnic, and socially uneven Europe could yield myriad opportunities for pathogen spread, some of which have been suggested in the scenarios identified in this project.

The scenarios identified here are overly and intentionally negative. Although it could be argued that they are unnecessarily pessimistic or alarming, it must be stressed that the purpose of this project is to identify threats so as to identify potential vulnerabilities in the future and thereby inform public health planning. We do not suggest that all of these scenarios will manifest, nor do we suggest that there will not be any important public health triumphs over the course of the next decade that could prevent these scenarios from occurring.

Disease spread is the alinear product of myriad factors that both help and hinder transmission. Although most of the scenarios outlined in Table 2 are well-recognized threats today, it needs to be stressed that changes in the social–ecological context could substantially affect the magnitude of these threats. Rapidly changing factors, whether population aging, shrinking public finances, climate or land-use changes, or otherwise, are more clearly linked to infectious disease spread than often recognized and thus need to be better understood with respect to how they might affect public health.

Our study is limited in that we identified only 8 plausible threats. It is further limited by its European focus, given that a central logic of the project is that an EID anywhere can pose a threat everywhere. However, another logical parameter of the project is that social–ecological contexts are strong determinants of health and disease control, and these contexts must necessarily be examined at a scale relevant to the study. Further work to refine the scenarios to a greater level of resolution at national or subnational levels may identify regions that are more and less vulnerable to particular threats and thus inform public health planning and decision-making at a greater level of precision that recognizes regional disparities.

The study is also limited, to some degree, by the assumption that Europe is an EID hot spot. According to all of the available information, this notion certainly seems to be valid, even if it is also the case that reporting biases and comparatively fewer infectious disease data from developing countries could mean that other regions of the world are disease hot spots as well, albeit neglected or unreported ones.

There are opportunities to mitigate each of the threats identified in this study, starting with strengthening and broadening public health capacity and action. Embracing long-term planning and multidisciplinarity will enhance our ability to understand—and address—the key determinants of disease by integrating traditional epidemiology with socioeconomic and ecological perspectives that have too often been neglected.

Environmental scientists and ecologists have much to contribute to discussions about vector-borne disease, for example, whereas health economists, sociologists, and anthropologists can contribute oft-lacking perspectives on the reasons behind vaccine resistance, the health needs of migrants, sexual practices of certain risk groups, or the effects of specific policy changes on health care provision. Meanwhile, if adequately fostered, advances in information technologies and biomedical research will continue to facilitate the development of diagnostics, vaccines, antivirals, communication and e-health, and even remote sensing approaches for disease monitoring.

At a global level, public health agencies, strengthened by the World Health Organization's revised International Health Regulations,[98] can continue to pursue cross-border collaborations to coordinate surveillance and epidemic intelligence and invest in global public health infrastructures; in an increasingly interconnected world, it would be both ethically responsible and in the self-interest of the richer regions of the world, including Europe, to improve health everywhere. Although these would be effective strategies for addressing future infectious disease threats, their successful deployment tomorrow is largely dependent on our willingness to prepare for future threats today: those blind to an undesirable future could be doomed to experience it. ■

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Contributors

Both authors designed the study, conducted the expert consultation, interviewed disease experts, and helped develop the drivers and scenarios. They jointly conducted the literature review and wrote the article.

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No protocol approval was needed for this study because no human participants were involved.

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