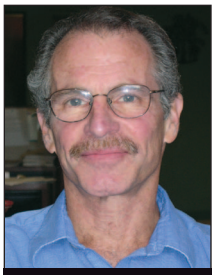
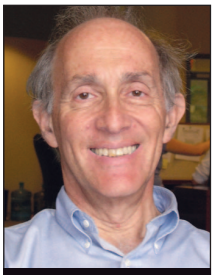
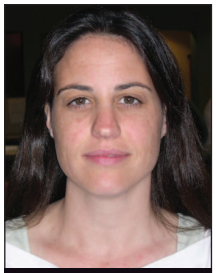
Guest Editorial

Emerging Diseases Threaten Conservation


Paul R. Epstein


Eric Chivian


Kathleen Frith

In April 2003, severe acute respiratory syndrome (SARS) appeared suddenly, sending shockwaves throughout public health systems and economies worldwide. By July 2003, 8,439 cases had been reported worldwide, with 812 deaths; the economic impacts were estimated to be $50–$100 billion (U.S.) (Newcomb 2003). Although public attention was focused on this explosive pandemic, more than 30 such diseases new to medicine have emerged since 1976 [World Health Organization (WHO) 1996].

Historically, waves of infections have often accompanied periods of social and environmental transition (Epstein 1992). Such upsurges include influenza in the aftermath of World War I and the plague during the Middle Ages. Tuberculosis, smallpox, and cholera appeared in concert among the teeming urban centers of Charles Dickens's 19th-century England.

In the past three decades, previously unknown diseases have surfaced at a pace without precedent in the annals of medicine. Indeed, such a renegotiation of evolutionary agreements between microbes and humans and other species may not have occurred since hunters and gatherers became herders—when domestication of animals triggered such a "spillover" of animal microorganisms (Daszak et al. 2000; McMichael 2001).

Today, human practices, widening social inequities, and changes in ecologic systems and climate are compounding and conspiring to unleash a barrage of emerging diseases that afflict humans, livestock, wildlife, marine organisms, and the very habitat we depend upon. As the climate becomes more unstable, its role increases (Epstein et al. 1998). Having underestimated the rate at which climate would change (Houghton et al. 2001), we are only beginning to understand the responses of biological systems to warming (Walther et al. 2002) and the accompanying intensification of weather extremes (World Meteorological Organization 2003).

The cast of new diseases includes HIV/AIDS, Lyme disease, *Legionella* infection, Ebola, Nipah virus, hantavirus pulmonary syndrome, toxic *Escherichia coli* infection, a new strain of cholera, and infection by a host of antibiotic-resistant organisms [Centers for Disease Control and Prevention (CDC) 1994; Institute of Medicine 1992]. Old diseases such as malaria, cholera, tuberculosis, rabies, and dengue fever are resurging, while others, such as West Nile virus (WNV), have undergone redistribution. SARS, like influenza, probably originated from the genetic reshuffling of animal viruses (Marra et al. 2003) and has now found a reservoir in several species.

Is Nature having her way with us, we might ask, and could the results benefit other species? Unfortunately, the same set of global changes and genetic exchanges are stalking flora and fauna, and diseases themselves now threaten conservation efforts, including those in biological "hot spots" (Myers 2002; Pimm et al. 2001).

Many microorganisms are now jumping from species to species in several directions. For example, in 1998, bats bearing Nipah virus swept onto Malaysian pig farms after fleeing forest fires fueled by intense drought associated with the largest El Niño event of the century (Epstein 1999; Institute on Climate and Planets 2003). As a result of this event, Nipah virus killed more than 100 people and crippled the swine industry (Johnson 2003). In early 2003, Ebola jumped back to primates and killed 600–800 gorillas in the Congo Republic, representing two-thirds of those remaining in the Lossi sanctuary (Morse and Colier 2003).

WNV is playing a particularly sinister role in nature. Following its explosive debut in New York City during the prolonged spring drought and heatwave of 1999 (Epstein and Defilippo 2001), WNV abated and incubated. Then, during the hot, dry summer of 2002, it spread across the nation and was detected in 44 states, Washington, DC, and five Canadian provinces. In 2002, WNV encephalitis afflicted 4,161 people and claimed 284 lives in the largest outbreak of mosquito-borne encephalitis recorded in the Western Hemisphere (CDC 2003). WNV also performed a dazzling array of new tricks, with infection occurring via blood transfusions, organ transplants, pregnancy, and probably breast milk.

Of greatest concern, however, WNV has spread to 230 species of animals, including 138 species of birds. WNV is spreading in the Caribbean and Central America, and is a leading suspect in the recent 10-fold drop of migratory song birds in Costa Rica (Causey D. Personal communication). Raptors have died from WNV, though population-level impacts are unknown. Rodents are consumed by birds of prey, and if unchecked, their legions can become prolific consumers of stored and growing grains and purveyors of pests and pathogens.

Diseases of livestock and crops have been particularly costly. The appearance of bovine spongiform encephalopathy ("mad cow") disease in the United Kingdom in the 1990s and new variant Creutzfeldt-Jakob disease in humans had major health, political, and economic impacts (Newcomb 2003). When followed by foot and mouth disease and large-scale flooding in 2001, the blow to the British economy ($30 billion) and psyche were palpable.

Crops face growing threats from extremes of weather and from pests, pathogens, and weeds (Rosenzweig et al. 2001). Cassava mosaic virus, one of the family of geminiviruses carried by white flies (Anderson and Morales 1993), has caused enormous losses of cassava (manioc, yucca, or tapioca) in sub-Saharan Africa, where it is a staple in the diet of millions.

Presently, 35–42% of growing and stored crops are lost to pests, pathogens, and weeds annually, amounting to losses of $244 billion worldwide annually (Pimental 1997). Increased climate variability could substantially alter future food security and global nutrition (Rosenzweig and Hillel 1998).

Habitat is also being subjected to the dual threats of climate change and emerging infectious diseases. In Alaska, spruce bark beetles have denuded 4 million acres of conifers on the Kenai Peninsula, as warming allows the beetles time for an extra generation each year (Kerlin 2002). Dead stands are then vulnerable to fire. In California, several species of trees are infected with *Phytophthora*, a fungus related to the one responsible for the Irish potato famine (Davidson et al. 2003). Extreme weather weakens the hosts and emboldens the agents.

Oaks in New Orleans, Louisiana, are bristling with termites (CNN 1997), as killing frosts became less frequent in the 1990s. New England hemlock trees are under assault from the woolly adelgid, an aphidlike insect that has migrated northward with warmer winters (Foster D. Personal communication).

In the coastal zone—the intersection of land, sea, and air—emerging diseases and algal toxins are affecting invertebrates, shellfish, finfish, shorebirds, and marine mammals (Harvell et al. 1999; Health, Ecological and Economic Dimensions of Global Change 1998). Of greatest concern are diseases of seagrasses and coral; these ancient habitats are nurseries for mobile marine species and birds, and they protect shorelines from saline intrusion, breaking waves, and storms. Corals are already endangered, as high sea surface temperatures have caused widespread bleaching—the most dramatic biological sign of global warming.

Excessive runoff of nutrients causes eutrophication (Townsend et al. 2003), and opportunistic fungal and bacterial pathogens are taking advantage of stressed coral reefs (Cervino et al. 2001), threatening the integrity and longevity of coral reefs worldwide.

Declines in coral reefs threaten the marine food web and will affect such reef dwellers as cone snails, which produce numerous bioactive peptides (Chivian 2002; West et al. 2002), including a nonaddictive, highly potent, opiate-like conotoxin.

Thus, emerging diseases have themselves become new drivers of global environmental change. Emerging diseases can *a*) cause extinction of endangered species; *b*) alter the ratios of predators, prey, competitors, and recyclers necessary for healthy, well-functioning ecosystems; and *c*) alter habitat already threatened by fragmentation and global climate change.

This story of Earth's ills is not a cheery one, but systems are resilient, and unstable systems can be restabilized. Unearthing root causes raises the urgency of conserving natural systems, and deciphering the pattern of consequences can guide us toward local and global solutions.

The first step is improved disease surveillance and response capability worldwide—for the enemies we know and the surprises yet to come. Greater collaboration among wildlife, insect, human health, and climate specialists can help generate early warning systems and environmentally friendly interventions.

The primary goal in public health is prevention. Clean and abundant water supplies are fundamental, but they depend on healthy forests, coastal and riparian wetlands, and a stable climate (McCally 2002; McMichael 2002). Prevention thus means nourishing the biological diversity that buffers against pathogen spread (Chivian 2001; Daily 1997; Epstein et al. 1997) by cutting far fewer trees, restoring lost wetlands, diversifying farming, and burning much less coal, oil, and natural gas, all of which release globe-warming gases.

Emerging diseases affect our health, and they also threaten trade, travel, tourism, and livelihood. The insurance sector is particularly distressed by the risks projected from weather extremes and emerging diseases.

Simultaneously solving environmental, energy, and economic problems will take significant financial incentives and strong new market signals. The good news is that a large investment in efficiency and renewable energy, ecologic restoration and infrastructure retrofits, "green buildings," "smart growth," and coherent transport systems can become the engine of growth for the 21st century. Such an investment in conserving Earth's resources and generating far fewer wastes would constitute a welcome premium for insuring a cleaner, healthier, and more equitable future.

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