Hippocrates Spiral:
Climate Change, Disease and The State – Lessons from History

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The concept of perfect and positive health is a utopian creation of the human mind. It cannot become reality because man will never be so perfectly adapted to his environment that his life will not involve struggles, failures, and sufferings….The less pleasant reality is that in an ever-changing world each period and each type of civilization will continue to have its burden of diseases created by the unavoidable failures of adaptation to the new environment.

-Rene Dubos, Man Adapting (Yale University Press, 1965)

Hippocrates argued that human health was subject to the condition of the 'airs and waters,' and that the poor condition of the elements would dispose human populations to illness and pestilence.[1] The ancient Greeks were not cognizant of pathogens and their vectors of transmission, discoveries that resulted from the 'germ theory' postulates developed in the 19th century by microbiologists such as Robert Koch and Louis Pasteur. Nonetheless, Hippocrates was the first to recognize that poor environmental conditions could result in negative health consequences for human populations.

In the early years of the twenty first century, the human species is increasingly confronted with a world out of balance. The balance of evidence indicates that human-induced changes to the biosphere frequently result in significant non-linear, negative, and frequently unanticipated biological consequences. Examples of such environmental degradation include the degradation of the atmospheric ozone layer, destruction of tropical forests, manifestations of global climate change, and depletion of oceanic fish stocks.

Changes in the macro environment may alter the microbial penumbra that envelops humanity, triggering the emergence of novel pathogens and/or the recrudescence of existing pathogens. Thus, in the microbial realm we have witnessed the emergence of novel pathogens in recent years (e.g. the SARS coronavirus, West Nile virus, and BSE prions) and the proliferation of their vectors of transmission.[2] Specifically, environmental change often facilitates the zoonotic transmission of pathogens from their animal reservoirs in the state of nature, and permits their endogenization within the human ecology.

In this essay I argue that it is time to consider microbial evolution as an additional component of the spectrum of environmental problems that we now face. I illustrate the probable relations and interactions among climate events and the transmission of infectious diseases. Lessons gleaned from the history of public health illustrate how the historical influence of pathogens on society and the state may influence processes of governance under a moderate climate change scenario.

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[1] Hippocrates, *On Airs, Waters, Places*, 400BC, pp. 5-10 in particular.

[2] Joan Aron and Johnathan Patz, *Ecosystem Change and Public Health*, Baltimore, MD: Johns Hopkins University Press, 2001;

Consilience, which one might define as the jumping together of knowledge across disciplinary boundaries, lies at the core of any estimation of risk due to climate change. The idea of consilience begins in the Enlightenment and took hold in the revolutionary ideas of the Marquis de Condorcet, Francis Bacon and William Whewell[3]. In the 20th century consilience enjoyed a resurgence, primarily due to the writing of Edward O. Wilson of Harvard who argued that the modern fragmentation and specialization of knowledge actually created impediments to tackling the complex problems of modernity.[4] Extending Wilson's propositions, one can argue that consilience reveals intellectual blind spots wherein individual disciplines cannot provide salient answers to certain complex problems.

Complex collective action issues such as climate change cannot be solved by one discipline in isolation. Tackling climate change requires the communication of scholars across multiple disciplines, and requires their active cooperation in sharing knowledge, data and formulating strategies to mitigate the phenomena. This is no easy feat, however, as each discipline has developed its own language. Thus, communication across disciplines requires a great deal of intellectual work, often entailing the mastery of several disciplines in order to formulate a cohesive strategy to counter the phenomena. In this sense the analysis of the effects of climate change, and solutions to problem, require two types of thinkers, both the specialists who conduct deep dives into certain domains of the problem, and consilient thinkers who can bring this knowledge together across the disciplines into some greater whole. In this section I attempt the latter, a consilient analysis of the effects of climate change on the microbial world, and the consequences of such for human society.

Despite the body of scientific literature concerning the relationship between global environmental change and the emergence and proliferation of disease agents, there is limited research exploring the effects of environmental change, and the resultant proliferation of pathogenic agents, on the domain of political economy.[5] I argue that pathogens have historically acted as stressors on societies, economies, and institutions of governance. The purpose of this essay is to examine the pathways by which environmental change acts as a disease amplifier, and to articulate the consequences of such contagion upon the political economy of the state. I argue that continuing and accelerating global environmental change will have negative effects on human health (diminishing human capital), which will in turn diminish human productivity and constrain economic development. Further, I contend that a historical lens permits us to analyze the role of emergent and/or recrudescent

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[3] William Whewell, *Philosophy of Inductive Sciences*, London,1847; Francis Bacon, *Novum Organum*, London, 1620; Marquis de Condorcet, Sketch for a Historical Picture of the Progress of the Human Spirit, 1795.
[4] Edward O. Wilson, *Consilience: The Unity of Knowledge*, Knopf 1998.
[5] See, for example Andrew Price-Smith, *The Health of Nations*, MIT Press, 2001; and Andrew Price-Smith, *Contagion and Chaos*, MIT Press, 2009.

pathogens in creating problems of governance, and that such dynamics may be observed in the years to come.

Over the broad span of history, epidemic disease has frequently accompanied human disruptions of the environment. The epidemiologist Anthony McMichael argues that oscillations in the health of human societies over history have frequently reflected the dynamics of local ecological disruption:

> The collapse of the agriculture-based civilization of Mesopotamia 5000 years ago, the drought-assisted epidemics of plague in densely-settled parts of Egypt, Italy and Africa in the second and third centuries A.D., the Black Death of Fourteenth century Europe and the decimation of remote aboriginal populations by infectious diseases from European settlers and invaders – all these testify to the potentially disastrous impact on human health of the disturbance of ecosystems.[6]

The point is that we humans have known for some time that ecological disruption may have significant negative long-term consequences for the health of human populations. What is novel is the absolute magnitude of human-induced environmental degradation occurring on a global scale, and its increasing rapidity.

On Etiology and Emergence

Novel pathogens are currently 'emerging' at the rate of approximately one new agent per annum, with approximately 30 new pathogens having emerged over the past 3 decades. Ecological systems display enormous complexity as they involve the interaction of myriad variables. Emerging diseases often are the result of 'emergent properties' wherein antecedent variables (e.g. population density, speed of transport) combine in unusual and unforeseen ways to facilitate the emergence of a given pathogen, that then becomes endogenized within the human ecology. Much as one would not anticipate the combination of hydrogen and oxygen molecules to produce the quality of wetness, ecological variables often combine to produce benign emergent properties such as ecosystem services.[7] However, such emergent properties may also result in Pareto-negative outcomes such as the emergence of an entirely novel class of pathogens in the form of infectious and lethal proteins, such as the prions that generate bovine spongiform encephalopathy (BSE).

The dynamics of contagion frequently exhibit such emergent properties,[8] wherein the sum total of a phenomenon is both greater than, and qualitatively different from,

[6] A.J. McMichael, *Planetary Overload: Global Environmental Change and the Health of the Human Species*, (Cambridge University Press, 1993), p.73.
[7] ecosystem services cite
[8] For an in-depth discussion see Andrew Price-Smith, Contagion and Chaos, MIT Press, forthcoming 2008.

the sum of its parts. The relations between pathogen, human host, and vectors of transmission (e.g. mosquitoes) are central to both the transmissibility and lethality of any given manifestation of contagion. One modern example of such emergent properties leading to viral proliferation is the SARS coronavirus that appeared in Guangzhou, China in late 2002, and subsequently spread throughout the Pacific Rim nations. In that particular case, this virulent coronavirus spread from its natural reservoir in East Asian bat populations, into palm civets. The variant of the virus that infected civets was transmissible among humans, amplified by elements of the human ecology such as the 'wet markets' of East Asia, the closed environments of modern hospitals which amplified degrees of infection, and modern jet airplane technology that facilitated the rapid spread of the virus throughout the Pacific theatre. Individually these disparate variables would not predict the emergence of epidemic disease, however, when combined together the SARS contagion of 02-03 resulted.

What then is the relationship between climate change, infectious disease, prosperity, and processes of governance? The complexity of such interactions is enormous, and so we begin with the relations between climate and disease.

Global Climate Change

Any serious discussion of anthropogenic climate change requires some discussion of the natural science underpinning the concept. In the early years of the 19th century the French mathematician Jean-Baptiste Fourier investigated the relationship between the energy entering the biosphere from the sun, as compared to the infrared radiation radiating back into space. Fourier's calculations indicated that, in fact, the Earth should be a frozen wasteland. He then concluded that the atmosphere acts as a reservoir of heat, rendering the planet capable of supporting life.[9] The British physicist John Tyndall, of the Royal Institution of London, then determined the elements in the atmosphere that were central to this 'greenhouse effect,' namely CO_2, methane, and water vapor.[10] Thus, the atmosphere acts in a manner akin to a greenhouse, trapping the solar radiation (heat) that enables the existence of life and modern civilization. Without the atmosphere, and the consequent greenhouse effect, Earth would be a dead sphere much like our neighbor, the planet Mars.

The World Health Organization regards global climate change as a significant threat to human health in the 21st century.[11] Variations in atmospheric conditions will have significant effects on the multiplication, dispersal and survival of pathogens, and will also affect the behavior and range of those vectors that transmit the pathogens. The Intergovernmental Panel on Climate Change (IPCC) argues that (in their median warming scenarios) temperatures in the tropics may increase by as much 2 - 3 degrees C by 2100, primarily as a result of anthropocentric greenhouse gas

[9] See J. Cowie, *Climate Change: Biological and Human Aspects*, Cambridge University press, 2007, p. 3
[10] See JR Fleming, *Historical Perspectives on Climate Change*, Oxford University Press, 2005, pp. 69-70.
[11] *Potential Health Effects of Climatic Change* (WHO, 1990).

emissions.[12] One expected result of the warming is a significant change in precipitation levels, including both dramatic increases and decreases contingent upon geographical position (the greatest variation projected to occur in the tropics). According to our current understanding of the phenomena, climate change may also increase the frequency and intensity of weather events (e.g. storms, floods). Climate change may also cause sea level rise as a result of the melting of the cryosphere, and the thermal expansion of the oceans. Further, warming may result in the shift of climatic zones, and their attendant ecosystems and agricultural zones, toward the polar regions by as much as 550 kilometers by 2100.[13]

Haines et al., argue that as global climate change shifts standard isotherms toward the polar regions, vector-borne diseases will shift their ranges accordingly, with yellow fever becoming prevalent at the 10 degree Celsius isotherm, vivax malaria at 16 degrees C, and falciparum malaria at 20 degrees C.[14] Furthermore, when humidity is high, dust particles may serve as harbors for the transmission of pathogens, with the redispersion of the latter being affected by precipitation and wind patterns. Thus, under a scenario of higher relative humidity, one may witness increases in microbial survival rates and in their infectivity.[15] For example the prevalence of poliomyelitis tends to increase during the summer months. Tromp and Armstrong have noted that the incidence of poliomyelitis in the United States increases dramatically when the relative humidity rises above 28 percent. Similarly, in tropical regions the incidence of poliomyelitis is highly correlated with the advent of the rainy season.[16] Furthermore, high levels of humidity may protect microorganisms from the destructive effects of ultraviolet radiation.[17] Scenarios of climate change suggest significant variance in humidity and precipitation. In those areas that witness increasing aridity airborne viral transmission may actually decline, however in those regions that see increased levels of humidity and rainfall, airborne viral transmission may consequently intensify.

Robert Shope articulates the ecological parameters that generally affect pathogen transmission and replication:

> …the infections that will spread with climate change have some commonalities. They are focal, and their distribution is limited by the ecology of their reservoir, be it arthropod, snail, or water. The range of the

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[12] Intergovernmental Panel on Climate Change, 2007, at http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html

[13] See www.who.org/peh/climate/climate_%20change.html.

[14] A. Haines, P. Epstein, and A.J. McMichael, "Global health watch: Monitoring impacts of environmental change," *Lancet* 342 (1993): 1464-1469.

[15] Humidity may in fact exert differential effects on the spectrum of pathogens with various microorganisms thriving at different humidity levels.

[16] S. Tromp, *Biometeorology: The Impact of Weather and Climate on Humans and their Environment* (Heyden and Son, 1980); C. Armstrong, "Poliomyelitis and the weather," *Proceedings of the National Academy of Science* 38 (1952): 613-618.

[17] M. White, Characterization of Information Requirements for Studies of CO2 effects, available at www.ciesin.org/docs/001-235/001-235.html

> reservoir is delineated by temperature and sometimes water. In order to survive global climate change…the agents will need to have reservoirs that will survive; they will probably survive by moving in a polar direction…in order to find a temperature range that is ecologically permissive.[18]

Precipitation:
Data provided by the IPCC regarding changes in precipitation from 1900-2000 indicate enormous variance on a global scale. Certain regions, such as the Arctic and sub-Arctic regions of the northern hemisphere, the northeastern sector of south Asia, and Eastern Australia are clearly enjoying increased levels of precipitation in recent decades. Specific vectors of disease, (such as mosquitoes and snails) thrive in such wet environments. Consequently, increases in precipitation may induce the proliferation of vectors, and thereby increase the transmission rates of certain pathogens such as malaria and schistosomiasis.

Temperature:
Pathogens and their vectors of transmission are often highly sensitive to changes in temperature as well. IPCC data from 1976-2000 clearly indicate increasing temperatures for much of the surface of the planet, with the greatest increases evident in the temperate to polar regions. As isotherms shift toward the polar regions, this will expand the latitudinal range of the vectors in question (i.e. anopheles mosquitoes) and thereby permit the expansion of malaria into previously non-malarious zones. Similarly, increasing surface temperatures permit the movement of malaria in higher *altitudes* than before. For example, Nairobi has historically been non-malarial due to its altitude, but in recent years increases in minimum nighttime temperatures have allowed vector to thrive and the pathogen to take hold in the area. The temperature-induced expansion of malaria is problematic because it results in the exposure of novel populations, who often lack any genetic or acquired immunity to the pathogen. Thus, the mortality and morbidity in such transitional regions may be much higher than in zones where malaria is endemic.

Increasing temperatures also affect the biting rate of vectors. As temperatures rise, the vectors (mosquitoes) feed with greater frequency, and therefore increase the transmission rate of the *plasmodium* (the parasite) into human populations. Furthermore, rising temperatures affect the *extrinsic incubation rate* of the pathogen, such that as the heat rises the parasite replicates within the gut of the mosquito at an ever increasing rate. Thus, under conditions of higher temperatures, there are significantly greater numbers of plasmodium within the vector, and the vector bites with much greater frequency.[19] On a macro level, all of this means that as temperatures rise, the burden of disease (e.g. malaria) on affected populations is likely to increase to a significant degree.[20]

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[18] R. Shope, "Impacts of global climate change on human health: Spread of infectious disease," in *Global Climate Change*, ed. S. Majumdar et al. (Pennsylvania Academy of Science, year).
[19] See Reiter 2001, Kovats et al 2001, Hunter 2003, van Lieshout 2004, Patz et al 2005, McMichael 2006.
[20] M.C. Thompson et al., 2005

In the case of cholera, increasing sea surface temperatures (SST) are highly correlated with the growth of algal blooms. The blooms move across oceans courtesy of dominant currents and winds, and they function as vectors of transmission of the *vibrio* bacteria. Thus, we see a long-term empirical association between SST and the incidence of cholera. In the case of cholera we have also seen that incidence is responsive to the modulation of the El Nino Southern Oscillation (ENSO), with preliminary evidence from case studies carried out in Bangladesh (Rodo, 2002). There is also considerable evidence of thresholds and non-linearities, such that warming temperatures may produce linear increases in vibrio incidence until a threshold point is reached, after which the numbers of the pathogen increase at an exponential scale.[21]

Schistosomiasis is a frequently lethal disease induced by parasitic blood flukes, and it is prevalent in tropical and temperate zones. The vector of the parasite is the snail (*oncomelania*) that thrives under conditions of increased precipitation, and within the temperature range of 15.3 degrees C to an optimal temperature of 30 degrees C. The balance of available evidence suggests that global climate change (GCC) will shift the distribution of the vectors into new regions, and thereby afflict formerly uninfected populations. A caveat however, the IPCC data clearly indicate that certain regions (e.g. West Africa) are becoming increasingly arid, which is inimical to the vector. Consequently, those zones that witness declining precipitation levels will see a decline in the incidence of schistosomiasis in their respective populations. In those regions that exhibit both increasing precipitation, coupled with increasing temperature, we are likely to witness augmented geographic zones of transmission, and increased frequency of transmission within those regions. Thus, GCC will result in winners and losers, dependent upon the particular pathogen in question, and its sensitivity to aridity and temperature.[22]

Economic Outcomes

The economic historian Robert Fogel won the Nobel Prize in economics in 1994 for his analysis of the hypothesis that population health (and human capital) was the central driver of economic productivity (NBER 1994). If health promotes prosperity, then increasing levels of disease consequently erode productivity and wealth. At the microeconomic level disease erodes productivity through mechanisms such as the debilitation of workers, increased absenteeism, increased medical costs, reduced savings and investment, and the premature death of breadwinners. At the sectoral level, disease imposes a particular burden upon those sectors of the economy that are labor-intensive, such as agriculture, and resource-extraction, and thereby imposes a relatively greater effect upon the economies of the developing world.

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[21] See Xavier Rodo et al, 2002, J. Patz, 2002

[22] Nagasaki 1960, Zhou et al, 2002, Yang et al 2005, Steinmann et al 2006, Guo-Jing Yang et al 2007.

The impact of malaria is also profoundly negative at the macroeconomic level. The economists Jeffrey Sachs and Pia Malaney estimate that for those countries where malaria is endemic, the pathogen generates a 1.3 percent drag on their GDP growth rate, per capita/per annum.[23] Further, John Gallup and Sachs estimated that a 10 percent decline in malaria incidence resulted in a 0.3 percent increase in the growth rate of GDP per capita/per annum on a cross-national basis.[24] McCarthy estimated that malaria imposed a drag on the GDP growth rate of affected nations, at the level of 0.25 to 0.55 percent per annum.[25] In case studies of individual nations, malaria control has resulted in greater prosperity for the polity in question. For example, malaria control measures in Zambia resulted in a $7.1 billion increase to that nation's economy.[26]

Assessments of the economic burden of a given illness (e.g. malaria) are complicated by the lack of adequate surveillance infrastructure throughout much of the developing world where the disease is endemic.[27] Moreover, the complexity of measuring the economic impact of GCC-induced infectious diseases is augmented by the interactivity of various pathogens in a given population. For example, the population of country X may be increasingly beset by increased incidence of malaria, dengue fever, and schistosomiasis, and certain individuals may exhibit co-infection with one or more pathogens.

Infectious disease tends to affect the poor to a far greater extent than it does the wealthy. This is because the rich have far better diets and nutrition, better housing and cleaner water, access to medicines and vaccines, and greater access to prophylaxis (e.g. bed nets to prevent vector borne disease). The burden of infectious disease then falls primarily upon the poor and middle classes, and consequently as the burden of disease increases in certain regions it will likely exacerbate both the perceived and real level of economic inequities between socio-economic strata. Historically, such perceptions of inequity have led to periods of social and political destabilization. Thus, the poor and middle classes may face an increasing burden of disease, and therefore diminished economic productivity and wealth, as a result of climate change. Consequently, one should expect to observe the exacerbation of global inequality as a function of climate change, in the not so distal future.

History as a Guide to the Future

Can we then use the historical record of the effects of disease on society and the state, in order to think about the future? In my opinion such a strategy may yield some intriguing insights for political science. Modern political science is

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[23] J Sachs and P. Malaney, "The Economic and Social Burden of Malaria," *Nature*, 7 Feb, 2002, pp. 680-5.
[24] J Gallup and J Sachs, "The Economic Burden of Malaria," *American Journal of Tropical Medicine and Hygiene*, 64 (1), 2001, pp. 85-96.
[25] D. McCarthy et al., NBER paper 7541, 2000
[26] Utzinger et al., 2002
[27] Worral et al., 2004, 2005

impoverished by the lack of historical knowledge on the part of many scholars, particularly in the domain of health and international politics. Yet, knowledge of history is integral to understanding the development of the politics of global health, and to speculating on the future under moderate scenarios of climate change. The political historian John Gaddis argues vociferously against such "Balkanization" of the disciplines: ". . . we have been known, from time to time, to construct the intellectual equivalent of fortified trenches from which we fire artillery back and forth, dodging shrapnel even as we sink ever more deeply into mutual incomprehension." Gaddis posits that political science and history share a common intellectual ancestry, and he fervently objects to the "narcissism of minor differences" that, over the past century, has driven the disciplines apart.[28]

Historical evidence indicates that pathogens have functioned as *stressors* that imposed burdens on both populations (i.e. society), economies (through depletion of human capital) and upon the structures of the state itself. Historical analysis of the stresses generated by epidemic disease demonstrate that pathogens have exacerbated pre-existing conflicts between socio-economic classes, between ethnicities, between those of different religious affiliations, and frequently induced conflicts between state and society.[29]

Despite enormous advances in public health and medicine over the past century, human beings still tend to evince the same psychological reactions to contagion that they did in earlier centuries. It seems that humans are hard-wired for affective responses in the face of emerging disease, with uncertainty generating significant levels of fear. Historically, such levels of fear associated with disease emergence often led to breakdowns in socio-political stability, and the capacity of the state to govern effectively. One of the first recorded observations of this effect was by the Athenian historian Thucydides in his chronicling of The Peloponnesian War between Athens and Sparta. Thucydides argued that the epidemic that swept through Athens resulted in a profound disruption of societal norms, undermined compliance with laws, and consequently had a decidedly negative effect on governance.

> The bodies of the dying were heaped one on top of the other, and half-dead creatures could be seen staggering about in the streets or flocking around the fountains in their desire for water. For the catastrophe was so overwhelming that men, not knowing what would next happen to them, became indifferent to every rule of religion or law. Athens owed to the plague the beginnings of a state of unprecedented lawlessness. Seeing how quick and abrupt were the changes of fortune . . . people now began openly to venture on acts of self-indulgence which before then they used to keep in

[28] J. Gaddis, "History, Theory and Common Ground," *International Security* 22 (1), 1997, p. 75.
[29] See Friedrich Prinzing 1916, David Baldwin 2005, Richard Evans 2005, Alfred Crosby 1986, William McNeill 1976, Charles Rosenberg 1987, Sheldon Watts 1999, Terence Ranger and Paul Slack 1996, and J.N. Hays 1998.

> the dark. As for what is called honor, no one showed himself willing to abide by its laws, so doubtful was it whether one would survive to enjoy the name for it. No fear of god nor law of man had a restraining influence. As for the gods, it seemed to be the same thing whether one worshipped them or not, when one saw the good and the bad dying indiscriminately. As for offences against human law, no one expected to live long enough to be brought to trial and punished.[30]

Despite a continuing debate over the nature of that pathogen (probably typhus), historians have reached a consensus that the epidemic produced intense and destabilizing effects on the social cohesion, governance, and power of Athens during her prolonged conflict with the Peloponnese.

In the centuries that followed, disease-induced fear often drove affected polities to engage in draconian political measures, in an attempt to quell domestic social disruption and restore order. The rise of contagionist tactics to quell societal unrest began in central and northern Italy (Mantua, Milan Firenze) in response to the arrival of the Black Death in Europe in 1347. Niccolo Machiavelli commented on the dislocation that the Black Death visited on Florence in 1521, stating,

> Our pitiful Florence now looks like nothing but a town which has been stormed by the infidels and then forsaken. One part of the inhabitants . . . have retired to the distant country houses; one part is dead, and yet another part is dying. Thus the present is torment, the future menace, so we contend with death and only live in fear and trembling. The clean fine streets which formerly teemed with rich and noble citizens are now stinking and dirty. . . . Shops and inns are closed, at the factories work has ceased, the law courts are empty, the laws are trampled on. The squares, the market places of which the citizens used frequently to assemble, have now been converted into graves and into the resort of a wicked rabble.[31]

The aggregate impact of successive waves of plague generated significant changes in relations between the state and society in Europe. The contagion certainly induced a generalized lawlessness, inter-ethnic violence, and altered accepted norms of behavior. In addition, it often weakened the capacity of governmental institutions to deliver services (public goods) to the people, undermining the legitimacy of the state. These sclerotic effects induced by the plague resulted in declining economic productivity, and consequently diminishing tax revenues available to the state, which in turn eroded the capacity for effective governance. The societal disorder that accompanied visitations of *yersina pestis* often generated correspondingly draconian reactions by the state against the people in order to maintain order, eventually inducing a corrosion of governmental legitimacy, and a shift in power

[30] Thucydides, *History of the Peloponnesian War*, Penguin, 1980, p. 155
[31] Niccolo Machiavelli, Description of the Plague at Florence in 1527, as quoted in pp. 216-217 of Johannes Nohl, *The Black Death: A Chronicle of the Plague*, Westholme, 2006.

toward the state which undermined the social contract between government and governed.

One of the most consequential outcomes of the waves of plague that swept Europe was the construction of an 'ideology of coercion' that focused power in the apparatus of the state in order to maintain dominion over the populace. In this manner, epidemic diseases frequently resulted in a shift of power away from the body politic and towards the apparatus of coercion, frequently entailing the oppression of the citizenry so as to maintain a modicum of order. This ideology, known as *contagionism*, often mandated callous decrees and acts that aggravated tensions between society and the state.

Historically cholera exhibited profoundly negative effects on governance and prosperity in the central states of Europe during the early 1830s. The ambiguity surrounding both the derivations and vectors of dispersal of the pathogen induced profound fear and anxiety, encouraged the perception of elites as adversaries, intensified suspicion between classes, and consequently amplified the potential for clashes between social factions. Such tensions often exploded into overt civil violence. The historian Richard Evans characterized cholera's march across Europe during the 1830s as "marked by a string of riots and disturbances in almost every country it affected. Riots, massacres and the destruction of property took place across Russia, swept through the Hapsburg Empire, broke out in Königsberg, Stettin and Memel in 1831 and spread to Britain the next year."[32]This fear of contagion (coupled with the hypothesis of elites poisoning the poor) led to widespread pathos, to widespread scapegoating, and even to violence at the intra-state level.[33]

The effects of epidemic disease on societies, economies, and polities throughout history may inform our understanding of the effects of contagion on modern peoples. Historical precedents form the basis of our postulates regarding the effects of contagion on modern state-society interactions. Therefore, it is reasonable to assume that the significant work of historians, over the centuries, might provide political scientists with a wealth of qualitative observations from which to derive certain hypotheses regarding the effects of infectious disease on structures of governance.

On Governance

Pathogens may also erode the functionality and efficacy of the state as well. For example, disease-induced economic stagnation (or contraction) of the macro economy will consequently reduce tax-based revenues available to the state. Diminished revenues will in turn limit the state's capacity to provide public goods

[32] R. Evans, "Epidemics and Revolutions: Cholera in Nineteenth Century Europe," in T. Ranger and P. Slack (eds.) *Epidemics and Ideas*, Cambridge University Press, 1992, p. 158.
[33] For an in-depth discussion of the historical influence of pathogens on society and political economy see Andrew Price-Smith, *Contagion and Chaos*, MIT Press, 2009, Chapter 2 in particular.

and services (e.g. education, law enforcement) to its population. This may in turn reduce perceptions of the legitimacy of the state by society. In the domain of human capital, disease may further erode state capacity by debilitating and/or killing trained and skilled personnel, thereby reducing institutional resilience and efficacy.[34] In the modern era, disease emergence continues to create and/or exacerbate existing problems of governance. For example, the SARS epidemic of 2003 generated pronounced problems of governance within China, and the emergence of Cholera in Haiti in 2011 manifested in rioting and violence against the state and UN forces that were blamed for introducing the pathogen.

Will the proliferation of disease result in conflict? Political scientists (Singer 2002, Ostergard 2002) hypothesized that increased levels of infectious disease may lead to conflict between sovereign states. The association between disease, poverty, political destabilization, and outright conflict (intra-state or inter-state) is complex. In particular, there is an endogeneity issue regarding the direction of causality. However, we can make some preliminary observations at this point. First, various iterations of the State Failure Task Force conducted empirical investigations and determined that infant mortality (as a measure) is a strong empirical predictor of state failure.[35]

The political scientist Ted Gurr argued that increasing levels of poverty induced a psychological state of deprivation (perceived injustice) that often led to intra-state conflict.[36] This hypothesis that conditions of deprivation (both real and perceived) led to civil strife was supported by Deininger (2003), and low levels of the Human Development Index are associated with conflict in Indonesia (Malapit et al 2003). Other political scientists have found that poverty combines with ethnic fragmentation to produce intra-state conflict (Easterly and Levine 1997, Wilkinson 2004, Korf 2005). Charles Tilly has argued that inequities are directly associated with intrastate conflict (Tilly 1998).[37] Further, there is empirical evidence that social polarization leads to intra-state conflict (Esteban and Ray 1994, 199, Boix 2004), and that conflict may function as a 'coping strategy' for those populations confronted with extreme levels of economic deprivation (Humphreys and Wienstein 2004, Verwimp, 2005).

Convincing arguments take the form of the state weakness hypothesis wherein deprivation combines with a weakened state to offer both the motive and the opportunity for political violence, with evidence from numerous case studies (see Kahl 2006, and Homer Dixon 1999). Analysis by Letendre et al., [38] provides some empirical confirmation of the hypothesis that infectious disease may in fact be

[34] An expanded analysis of the pernicious effects of disease on the state can be found in Andrew Price-Smith, The Health of Nations, MIT Press, 2002.
[35] D. Esty et al, State Failure Task Force I and II
[36] Gurr 1970.
[37] Also see Stewart 2000, Langer 2004, Mancini 2005
[38] K Letendre et al., "Does infectious disease cause variation in the frequency of intrastate armed conflict and civil war?" Biological Reviews, Vol 85 (3), 2010, pp. 669-683.

a driver of conflict at the intra-state level (Price-Smith 2001). Although there is evidence that contagion leads to political acrimony and trade disputes between nations, there is no evidence (to date) that infectious disease results in war between sovereign states (Price-Smith, 2009).

Conclusions

Humanity confronts a future of two possible pathways, each of them leading to self-reinforcing feedback loops that manifest in a spiral dynamic. The first possibility, the *virtuous spiral*, is one wherein humanity reduces its burdens on the biosphere, and invests in human capital and health care infrastructure. Consequently this should result in much greater long-term returns (in terms of increased labor productivity), and contribute to stable governance. Unfortunately, humanity is currently on the path to a *vicious spiral*, wherein the dynamics of climate change result in the emergence and recrudescence of novel pathogens, and increasing resistance of pathogens to antimicrobials. This path has the potential to forestall the creation of human capital, erode existing reservoirs of human capital, and create challenges for governance at multiple levels of scale (from the local to global).

In short, the further that humanity pushes the biosphere away from a state of natural equilibrium,[39] the more that we may expect the emergence and/or recrudescence of pathogens. Climate change induced proliferation of disease may facilitate socio-political destabilization, particularly in the weak states and impoverished populations of the developing world. Such destabilization is contingent upon several factors, it is pathogen-specific (as different pathogens often produce different modes of destabilization), and it may depend upon existing socio-economic and political cleavages within the polity in question. Areas at risk of such disease-induced destabilization include the sub-tropical to temperate zones, as tropical pathogens and their attendant vectors expand into these contiguous zones to affect immunologically naïve populations.

Human ingenuity, manifest in public health and medicine, has clearly diminished the stresses imposed by pathogens upon the state. However, the emergence of novel pathogens can still trigger socio-economic and political destabilization. Moreover, antibiotic and antiviral resistance is growing, resulting in strains of pathogens that are resistant to our existing arsenal of antimicrobials, such as vancomycin resistant enterococci (VRE). In 2010 the arrival of a novel gene that confers resistance to all antibiotics heralded the arrival of a difficult new era in public health. Specifically, the gene New Delhi metallo-beta-lactamase-1 (NDM-1) confers resistance to all known antibiotics and has been transferred across various types of bacteria, and into both animal and human hosts.[40] As NDM-1 continues to proliferate through the

[39] the past 10,000 years (approximately) have been marked by a considerable degree of equilibrium as the planet has gradually warmed out of the last ice age.
[40] R. Moellering, "NDM-1 A Cause for Worldwide Concern," *New England Journal of Medicine*, 16 December 2010.

bacterial world, many previously treatable diseases may prove to be incurable, resulting in increasing morbidity, mortality, and fear.
In addition, the locus of ingenuity, in the form of nodes of scientific infrastructure, is not equitably distributed on a global scale. It remains primarily concentrated in the most developed nations. Yet, the impacts of climate change on health will be felt most acutely in the poorest nations of the world, those with limited capacity to produce technical ingenuity to counter illness. Moreover, as climate change increasingly imposes social dislocation and significant costs on human societies, there will be less revenue to invest in the creation of ingenuity.

The real question is whether the future will resemble the past. Under conditions of profound (and perhaps non-linear) environmental change, and surging levels of microbial and parasitic[41] resistance, humanity may find itself starting to lag in its race against the pathogens. Under such conditions, the lessons of history, manifesting in inter-ethnic stigmatization, economic destabilization, intra-state frictions, and draconian behavior of the state, may be increasingly salient.
Further research is required to flesh out the complex chains of causation that I have elaborated above. This will require the formation of interdisciplinary teams, which will then model the impacts of climate change upon disease, and the consequent effects upon the economic and political domains.

[41] Recall that the malaria plasmodium is actually a multicellular parasite.