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Agroterrorism: Betting Far More than the Farm

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ANIMAL AGRICULTURE IN THE UNITED STATES is perilously vulnerable to deliberate attack with foreign livestock viruses. Traditional government responses to such an event—sweeping quarantines, mass slaughter and burning or burial of millions of carcasses under the ceaseless eye of television—together with staggering financial losses triggered by international trade embargoes are exactly what terrorists want to see and what makes these viruses potential biological weapons in the first place. U.S. policy to counter agroterrorism is fatally flawed, because it mistakenly conflates the threats of inadvertent and purposeful disease introduction. Moreover, this policy was developed without understanding that it is only the ways we have chosen to respond to foreign diseases in the past that allow terrorists to threaten us with them in the future.

As American agribusiness has industrialized, animal health officials have stubbornly clung to 18th century ideas of epidemic disease control, despite abundant recent evidence from overseas that in the American context such medicine would guarantee catastrophe. If we try to counter deliberate assaults the same way, after a successful attack it will be the U.S. government, not a terrorist gang, that is killing, burning, filling mass graves, and wreaking economic havoc nationwide. In 2004 these are the wrong responses to either inadvertent or deliberate disease introduction, and the consequences of this mistake cannot be limited to farmers: there will be lasting damage to the rural economy and public confidence in government and enormous costs for taxpayers. And should the foreign disease infect humans as well as livestock, our families also will be at risk—all of which will greatly embolden and encourage terrorists.

Terrorist attacks on U.S. agriculture are not about imperiling our food supplies: they are about terror, money, mass slaughter, and funeral pyres all day every day on CNN and al Jazeera. Our national policy for inadvertent and deliberate foreign animal disease introductions should be simple: we will minimize direct and indirect economic impacts, and we will not engage in mass slaughter. Fortunately, most of the tools and technologies to permit such a policy already exist. We now have rapid, on-farm tests for these diseases; effective vaccination strategies; Internet-based command, control, and communication systems; and the means to track animal products from farm to table, even internationally. These enable us to respond more effectively than was possible 300 years ago and permit a new national policy. If we choose this way forward, there will be little point in deliberate attacks, because the outcomes terrorists want to see will not be possible and inadvertent introductions will be eliminated with scarcely a footprint. But changing national policy will require input from a much broader group of policymakers than in the past. The purpose of this article is to explain the nature and magnitude of what is at stake and why this is not just a matter for agriculture anymore.

AGROTERRORISM: THE EXAMPLE OF FOOT-AND-MOUTH DISEASE

Agroterrorism implies deliberate attack with a variety of viruses, bacteria, and fungi on commercial crops or livestock populations, either as targets in their own right or as vehicles to attack humans as well when a zoonotic pathogen is involved. It is not possible to describe here the full spectrum of animal and plant threats and vulnerabilities, but the principles are all illustrated by foot-and-mouth disease (FMD) in livestock: FMD has long been considered the most dangerous foreign disease that might be inadvertently introduced into the U.S., and it is also the most likely terrorist threat.

Foot-and-mouth disease is a severe, highly infectious viral disease of cattle, swine, sheep, goats, and other ruminant species. FMD is not a threat to human health. Infection is characterized by large blisters in the mouth, on the teats, and between the toes that burst to cause painful raw sores and even loss of the hooves. Animals cannot eat, drink, or walk, nor can they be milked. FMD virus

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rarely kills animals, but the recovered animal usually loses its productivity of milk or meat.

FMD-infected animals shed enormous amounts of virus, and this easily infects other animals in direct contact—by inhalation of virus-infected aerosols or ingestion of excretions from an infected animal—and at a distance—by virus contamination of water, feed, and bedding or by virus carried for many miles in atmospheric plumes of aerosol droplets. FMD is the most infectious virus known; it is some 20 times more infectious than human smallpox. FMD virus remains viable in the bone marrow of frozen carcasses for months. Cattle that have recovered from disease—and perhaps some vaccinated animals that were subsequently exposed to live virus—may also carry FMD virus in their throats for long periods and be sources of infection for other animals. Left unchecked, FMD virus will spread through all the susceptible animals in a country.

There are seven different types of FMD virus and some 70 subtypes; thus, a vaccine against one virus type does not protect against another type, and even among the members of one type there may be sufficient differences that multiple vaccines are needed. In short, to protect against all FMD viruses, seven vaccines are insufficient and 70 would be too many. In practice, this is not a problem for natural disease control: about 15 different vaccines are manufactured in the world today, and different combinations of vaccine are used in various countries depending on which FMD virus types and subtypes are present. However, the U.S., which has no capability to manufacture FMD vaccines, faces the threat of deliberate introduction of any of up to 70 different viruses.

The last FMD outbreak in the U.S. was in 1929. Today, FMD is not found in North and Central America, the European Union, Australia and New Zealand, or Russia, but it is present on a permanent or irregular basis in most of the rest of the world. Countries that are free of disease, such as the U.S., maintain restrictions on imports of live animals and animal products that might carry the virus: passengers arriving at U.S. ports of entry must fill out a declaration that they are not carrying meat, cheese, or other items. Travelers frequently attempt to bring in favorite sausages or exotic meat products that cannot be obtained here. Most of these contraband importations stem from ignorance of federal regulations and animal health risks, but the scale of the problem is not trivial—some 350,000 items are intercepted each year. Federal officials target the luggage of travelers from certain countries at certain airports where there is an established pattern of contraband imports. There are equivalent inspections of ships carrying thousands of pounds of imported meat and meat products; here inspection relies mostly on scrutiny of documents defining the product's country of origin. Illegal importation of undeclared meat in shipping containers and forged documents providing misleading information about the country of origin (i.e., claiming the origin is a country free of FMD) are very serious problems: the 2001 FMD outbreak in Great Britain was attributed to illegal meat imports.

In countries infected with FMD, there is easy access to the virus: live FMD virus can be found in sick animals, in diagnostic laboratories, and in vaccine plants. FMD vaccine is made by growing astronomical amounts of virus in large vats and then killing the virus with a chemical to make a dead vaccine. Until the chemical is added, the live virus is a potential biological weapon against a country that does not have the disease. No elaborate devices are needed to infect animals with FMD virus: one infected animal can trigger an epidemic. Unfortunately, the list of countries infected with FMD includes all those where terrorists hide—Afghanistan, Pakistan, Iran, Iraq, and Syria—as well as South America and most of Africa, the Middle East, and Central and Southeast Asia.

The significance of FMD for the U.S. in 2004 is that we have some 100 million cattle, 70 million swine, 10 million sheep, 4 million goats, and about 32 million wildlife species at risk (and some 2 billion poultry susceptible to other diseases). All these animals are totally susceptible to FMD: there is no innate resistance, and none have been vaccinated. These flocks and herds are the basis for our highly productive U.S. animal agribusiness—the largest and most integrated in the world and still a significant component of GDP and foreign exports. Our agricultural markets are characterized by enormous capacities, swift flows, and rapid movement: the consumer in Maine can find products on the supermarket shelf from crops or animals that were in fields or feedlots in California or Texas a day or two earlier. And the markets will have taken these identical product batches to Florida, Iowa, and Oregon, and to Canada, Mexico, and Japan, in the same period. Persistence of virus and widespread contamination of animal products and inanimate materials allow FMD to be carried swiftly far and wide once introduced into this production torrent.

FMD is an example of a "transboundary disease"—an infection that if unchecked would spread from one country to another, by way of infected animals and their products or by contamination of animal feed and other products that might come in contact with susceptible animals. The International Office of Epizootics (OIE: now in the process of changing its name to the World Organisation for Animal Health), established in Paris in 1924, has been designated by the World Trade Organization (WTO) as the agency to set global animal health standards to prevent the spread of transboundary and other livestock diseases. Currently, 167 governments are OIE members.[1]

Livestock diseases such as FMD are regulated by the national government in all countries, because these have a direct impact on trade and exports of animals and animal products. In the U.S., farmers cannot vaccinate their stock against FMD, because all aspects of FMD diagnosis, prevention, and control are determined by the federal government, and it has always been U.S. policy to eradicate any FMD incursions by mass slaughter without vaccination.

It is important to appreciate that government policies on how to respond to FMD are not related in any way to the seriousness of the illness in an animal or herd: they do not depend on animal health, welfare, pain, or suffering. They are purely financial and based on estimates of the lowest costs that will ensue for animal agriculture as a whole (not for the whole rural economy). In the past, the U.S. and other FMD-free countries have rightly calculated that their greatest profit could be obtained by not vaccinating their herds against FMD, because this allows producers free access to world markets with their most profitable products and handicaps other countries that use vaccine. Of course, this policy leaves the U.S. and others totally vulnerable to inadvertent introduction of FMD, but the calculation for that situation, which has been assumed to be a rare event, has been that the most profitable option is still not to vaccinate but to eradicate the disease by killing as many animals as it takes. This allows producers to reenter world markets much more quickly than if vaccine had been used.

The British government was working to these exact premises when that country's 2001 FMD outbreak began. Vaccine was not used (there were not sufficient stocks anyway). In the course of the epidemic, however, the government belatedly realized that the critical monetary yardstick was not the animal product export sector but the rural economy as a whole and that protecting animal agricultural interests by not vaccinating was causing huge financial losses in tourism and other sectors that had never been factored into the calculations of outbreak costs.

American farmers are completely dependent on the federal government to prevent inadvertent or deliberate introduction of FMD into the U.S.; individually, they can do very little to prevent its spread to their premises (or to avoid sharing its consequences) when an outbreak occurs. Farmers must rely on actions by federal and state agencies, agribusiness, and their neighbors. Should a farm be within a radius of up to 3 km of an infected farm, its livestock would be slaughtered also, irrespective of whether or not they were infected at the time.

Once an outbreak starts, it is too late to be formulating national policies. Given the total dependence of agriculture, and by extension the entire rural economy, on the actions of the federal government, it is critical that new policies be adopted to deal with the threats posed by inadvertent or deliberate introduction of FMD and other transboundary diseases in the 21st century.

FMD IN GREAT BRITAIN 2001

Most Americans first became aware of FMD in the summer of 2001, when TV news brought them astonishing scenes of mass slaughter and funeral pyres in the Masterpiece Theater scenery of the British countryside. Authorities there spent 6 months struggling to control a disease outbreak that cost some $25 billion and ended only when some 11 million animals had been killed in a country about the size of Oregon. This outbreak is believed to have begun in swine fed garbage from a Chinese restaurant that contained meat scraps carrying FMD virus. The swine farmer did not cook the garbage to kill virus and did not report sick and dead pigs on his farm; there was a history of animal welfare violations at these premises. His infected pigs shed FMD virus that probably spread as an aerosol cloud to sheep on an adjacent farm. Because this strain of FMD virus caused little or no obvious illness in sheep, the sheep on this farm showed few or no signs of disease but were still infectious to other animals. These sheep were sent to market, and the infection thus spread to very large numbers of sheep and other animals in contact: these animals were distributed to many farms in Great Britain and abroad while incubating disease. As a result, by the time FMD infection was first discovered, there were many infected farms throughout the country and in Europe. British veterinary authorities were caught unprepared by these initial widespread outbreaks, but this should not have been a surprise: this is the norm in 21st century agriculture. FMD virus, cattle, swine, sheep, and goats had changed very little since the last major British FMD outbreak in 1967: what had changed were the nature, structure, speed, and movement of British (and European Union) production and marketing practices.

This is not the place to analyze the British experience in detail. Suffice it to note that: (a) FMD virus probably arrived in meat illegally imported into the European Union from a country with FMD. This meat was either smuggled in or labeled with a false certificate of origin, and criminal activities were probably involved at more than one stage in its journey to the first infected farm. (b) Veterinary authorities, which had been greatly diminished by government policies over the previous 30 years, were completely overwhelmed. (c) The vast majority of animals slaughtered were not infected, and the herds they came from were never even tested for FMD. They were just in the wrong place at the wrong time. (d) The outbreak was brought under control only when the Ministry of Defense was put in charge of the logistics.

In 2001, Americans might have been unpleasantly surprised to discover that the U.S. planned to respond in exactly the same ways as the British had if FMD had come accidentally or deliberately to these shores. Today, they should be astounded and dismayed to discover that the planned U.S. response is not only the same as in 2001 but has barely changed over the past half century.

FOOT-AND-MOUTH DISEASE: U.S. DETECTION AND RESPONSE POLICIES

If FMD were suspected on a U.S. farm, a federal official would collect samples from sick animals and send them by express mail to the Department of Agriculture's Foreign Animal Disease Diagnostic Laboratory on Plum Island, NY.[2] The affected herd, and perhaps others in the immediate vicinity or with recent contact, would be strictly quarantined for a few days while the samples were examined for FMD virus. Should virus be found, the affected herd and all cattle, sheep, goats, swine, and susceptible wildlife, infected or not, in a radius of up to 3 km around the infected farm would be killed. Their carcasses would be burned or buried. Authorities would keep on quarantining herds and killing animals nationwide until the disease was "stamped out." FMD vaccines would not be used.

Once FMD was confirmed by the federal government, there would be strict international embargoes on exports of U.S. animals and animal products that might carry the virus, and these trade restrictions would continue for up to 2 years at a cost of tens of billions of dollars. Quarantines and restrictions on animal movement and commerce of all kinds in affected regions would compound the impact of global trade embargoes to produce staggering financial impacts through the whole rural economy. Owners of animals killed to control the outbreak would ultimately receive compensation from the federal government, but other rural enterprises would not be compensated and many would never recover. (In Britain, the tourism industry was hit hardest by FMD.)

The strategy of responding to epidemic animal diseases by quarantine and mass slaughter dates back to 1711, when Dr. Lancisi, physician to Pope Clement XI, laid out these principles to counter Rinderpest, a lethal virus infection brought by oxen from Asia that killed some 200 million cattle in Europe. Despite advances in technology that offer more effective and less costly options, the controls of Lancisi's age remain essentially unchanged.

The potential scale of damage from an FMD outbreak under this policy was seen in a recent Department of Agriculture simulation exercise known as "Crimson Sky," in which some 38 million cattle would have been killed in the course of outbreak control (about 40 million cattle are slaughtered for food in the U.S. each year). There has never been a livestock disease outbreak in the U.S. that demanded anything remotely like this level of slaughter, and the Department of Agriculture is wholly unprepared to respond effectively on such a scale if there were. In 2002–03, federal officials struggled to control even a modest outbreak of Newcastle disease in poultry in California and the Southwest. Fortunately, the infection did not spread to the major poultry production centers in the Southeast. But failure to use modern diagnostic technology, ineffective logistics, and lack of appreciation of changed poultry disease threats along the border in that instance are exactly the weaknesses that would prove catastrophic should FMD be introduced.

ORIGINS OF U.S. FMD CONTROL POLICY

The U.S. did not develop its current FMD control policies in isolation; they were established with other countries decades ago at the OIE. International rules are punitive on the animal export trade of countries that have certain highly infectious livestock diseases, of which FMD and Rinderpest are the most important. Consequently, the rules strongly favor the trade competitiveness of the U.S., Canada, the European Union, Australia, and New Zealand, all of which have strong animal industries and freedom from the most significant infections. On the other hand, FMD-infected competitors, such as Brazil and Argentina, both of which have enormous cattle herds, must export much of their beef in less profitable forms as cooked "corned beef" or with the bones removed to prevent transmission of FMD virus.

Phytosanitary trade rules for animals and plants and their products are an essential component of world commerce, but there is a fine line between a necessary health rule and a trade barrier. In 2004, the trade rules for FMD do not reflect the contemporary science and technology of disease control; they are the lowest common denominator of what is possible internationally. Specifically, the rules penalize vaccination, encourage mass slaughter, and impose antiquated standards to demonstrate freedom from disease. At best, the U.S. has had a laissez-faire attitude to change: there was no apparent need for urgency because the last FMD outbreak took place in California in 1929, and even our limited import and traveler inspections appeared to be keeping FMD far away. Meanwhile, the rules helped our foreign trade.

But the threat of biological terrorism must change U.S attitudes and policies—immediately. The U.S. has the most at risk and the most to lose from deliberate attack. We must use new technologies and policies to counter inadvertent outbreaks now and to deter terrorism in the future. How the U.S. responds domestically to FMD is entirely our business; how our livestock and animal products enter world trade subsequently depends on OIE acceptance of new technologies and policies. Of course, steps must be taken to obtain such acceptance, but our defenses cannot wait.

THE POLICY WE NEED

In 2003, a federal interagency expert group, explaining and assessing U.S. plans for FMD control, mentioned that the country nevertheless remained totally vulnerable to the importation of even one infected sausage.[2] We are not protected so long as this is acceptable. For at least 20 years, it has been obvious that the U.S. cannot use 18th century methods to control naturally occurring outbreaks like FMD in 21st century agribusiness without catastrophic damage and enormous economic costs. But nothing has been done to change our policies or our preparedness. And now the U.S. plans to combat any deliberate introductions by terrorists in the same old ways. This is a grave mistake. We can do much better in both circumstances. U.S. policymakers need to understand that:

- Control of inadvertent or deliberate FMD infections is not an animal health policy issue that can be left to agricultural authorities.
- Traditional inadvertent outbreak controls are based on financial factors, not animal health; the “best” response has been the one that triggered the lowest costs for agriculture, not the whole economy.
- Terrorist attacks on U.S. animal agriculture are not aimed at denying the public food supplies, killing farm animals, or making them sick.
- Attacks are meant to produce terror, staggering financial losses, mass slaughter, and funeral pyres—theater that can be shown all day on television here and in the Middle East.
- The damage from FMD, however introduced, comes from our response, not from the infection itself.
- Our response is conditioned by tradition.
- How we respond is what makes these foreign animal diseases terrorist weapons in the first place.
- Most of the tools and technologies to allow new policy already exist; we have just chosen not to use them.

The policy we need is quite simple and applies to all the potential inadvertent or deliberate foreign disease threats to animals: **The U.S. will minimize direct and indirect economic impacts and will not engage in mass slaughter.** With this policy, there is no theater, nothing to show on television, and no triggering of sweeping, costly trade embargoes. Absent these, there is little point in a deliberate attack, and inadvertent introductions will be eliminated with the smallest possible footprint. The U.S. can implement this new policy tomorrow and work with the OIE and WTO to modernize international regulations on animal health so that all countries that wish can follow the same path.

Such a simple policy direction might seem unlikely to trigger a revolution. But the reality is that 300 years of discouraging market forces and alternatives to mass slaughter has led to the paradox that control of the world’s most dangerous livestock diseases, long an exclusive responsibility of governments everywhere, is the only area of veterinary medicine that still relies on technologies introduced before veterinary schools were established or such a profession even existed.

Fortunately, over the past decade the U.S. has developed the core technologies to implement this new policy, and others will flow once the incentives are there. The key innovations are:

- Rapid, on-farm diagnostic tests that can be read by experts at a distance in real time over the Internet;
- A real time, Internet-based command, control, and communication system to coordinate federal, state, and local responses;
- A differential test that discriminates vaccinated animals from those that have recovered from disease yet might still be infectious for others; and
- Tracking and identification systems to follow animals and products from farm to table through the entire production and processing chain, and even internationally.

Unfortunately, the U.S. has chosen not to use these powerful tools, largely because there is enormous confusion at the policy level stemming from the proximity of the 2001 FMD outbreak in Great Britain, which caused even the most stubborn proponents of mass slaughter to have second thoughts, and the terrorist attacks of September and October 2001, which first brought deliberate attack and biological weapons into sharp focus for most people. As a result, there is muddled thinking about inadvertent introduction and catastrophes abroad, biological warfare, and agroterrorism. To understand how the new policy would work, we need clarity about:

- The nature of the threat;
- The nature of our national vulnerability;
- The technologies that permit new policy;
- Future technologies to prevent disease or cut financial losses; and
- Necessary changes in the relationship between government and industry that will enhance our defenses and minimize the impacts of disease.

THE THREAT

Biological warfare has been planned or employed by many nation states over history as an adjunct to conventional weaponry, but it is not a current threat to U.S. agriculture. In World War II, there were plans (and even limited actions) to use biological weapons that caused disease and death in animals and plants on a large scale as an act of war intended to cause hunger and deny food to the opponent's civilian population and armed forces. Most recently, the former Soviet Union clearly had the weapons, the delivery systems, and the production capacity to threaten U.S. food supplies in time of war. But such a threat does not exist today, and it is highly improbable that a terrorist group has the capability and capacity (or intent) to provoke hunger in the U.S. by waging biological warfare against our animal and plant industries. Specifically, one can discount the idea of kilograms of virus or fungus being dispersed by crop sprayers over vast populations of animals or acres of crops.

Thanks to current policy, however, terrorists need only have capability—not capacity—to successfully attack U.S. agriculture. Terrorists want to see a dramatic public result that attracts media attention. Such results can be triggered *only* by attack on a big target—one or more of the dairy, beef, swine, or poultry industries—with a foreign animal virus that leads to mass slaughter and costly international trade embargoes. Furthermore, to produce an epidemic, the virus must be easily spread by aerosol, direct contact, or a flying insect vector beyond the initial site of attack. Only a handful of pathogens, all viruses, meet these criteria: FMD in cattle and swine; Rinderpest in cattle; classical swine fever and African swine fever in pigs; avian influenza and Newcastle disease viruses in poultry; and Rift valley fever virus. The latter is a mosquito-borne virus of humans, cattle, sheep, and goats; its significance as a terrorist weapon depends less on its impact on agricultural economics and mostly on the ability of infected livestock and insects to serve as reservoirs for human infections. Avian influenza and Newcastle disease viruses also can infect humans; a new strain of avian influenza is emerging in Southeast Asian agriculture that is highly fatal although not highly infectious for humans. Should this virus evolve further to spread easily from person to person, this would pose a very serious global public health threat and the virus would become another potential weapon.

The list of realistic terrorist livestock weapons threats is necessarily much smaller than the list of foreign viruses, bacteria, parasites, and insects that might be inadvertently introduced into the U.S. in the course of normal international travel and trade. Such introductions would, of course, have consequences and would stimulate a federal control response. But their nature is such that this response will be insignificant as compared to FMD and the other six viruses listed above. The Agricultural Bioterrorism Protection Act of 2002 identified some 24 foreign livestock pathogens whose possession and use are restricted in the U.S. because they may be used as terrorist weapons against our flocks and herds; another 14 animal pathogens and 6 microbial and fungal toxins were similarly restricted because they threaten both human and animal health.[3] This laundry list identifies the major foreign livestock pathogens that might inadvertently be introduced to the U.S. in the course of normal commerce and travel, but this does not make them potential terrorist weapons. For example, it is inconceivable that camel pox virus, an infection confined to camels, could in any way be used to terrorize the U.S. by threatening our animal agriculture for the simple reason that camels do not form part of our economy. Nor can the U.S. be threatened by terrorist attacks on our sheep and goat herds—they are simply too small and economically insignificant. The unfortunate consequence of such a lengthy list of spurious threats is that inordinate amounts of money are wasted making them secure.

The Department of Homeland Security currently lists FMD, Rift valley fever, avian influenza, and *Brucella* as priority threats to U.S. agriculture. *Brucella* species cause disease in cattle, swine, and sheep and also infect humans. Terrorists can threaten humans with *Brucella* (by aerosol release), but they cannot threaten U.S. agriculture, because such infections in livestock do not trigger mass slaughter or international trade embargoes—they are economically insignificant. Nor would terrorist infection of livestock with *Brucella* threaten human health; for decades the public has been protected by pasteurization of milk and cheese. This was clearly shown in 1999 when *Brucella melitensis* was found in goats and cattle in Texas, probably after introduction from Mexico. The focus was eliminated without an economic ripple.

FMD virus is a cause of poverty and misery throughout the developing world, where livestock play important economic roles beyond being sources of food. At the same time, these reservoirs of infection threaten the animal industries of disease-free areas like the U.S. and the European Union. The human condition would be greatly improved if FMD were to be eradicated globally by a sustained campaign like that successfully undertaken for Rinderpest. Indeed, an international initiative to eradicate FMD is now stirring. This should be supported for many humanitarian and financial reasons, provided it is clearly understood that eradicating FMD worldwide will not remove the threat of terrorism or (future) biological warfare employing this virus.

Eradicating FMD would certainly make terrorist access to virus more difficult than it is today. But the world's most dangerous biological weapon, once manufactured in large quantities by the former Soviet Union, is smallpox virus, the cause of a human disease eradicated globally almost 30 years ago. The end of smallpox as a public health problem also spelled the end of routine vaccination of the world's population and closure of vaccine production facilities. Today, the entire world population is as vulnerable to smallpox as the peoples of the New World in 1492. Even if all world sources of FMD virus were to be destroyed—an improbable and immeasurable event—new virus could be made synthetically (FMD is a relative of polio virus, which has already been made in the test tube from scratch) and engineered to evade all known vaccines.

THE NATURE OF OUR NATIONAL VULNERABILITY

The U.S. has the largest agricultural market in the world, and this depends on very large populations of domestic livestock and poultry. These flocks and herds are individually very large—just 2% of feedlots produce over 75% of the cattle—and for economic reasons the different industries have become clustered in a handful of states: 75% of swine are in the Midwest, 80% of broiler chickens are in the Southeast, and over 80% of feedlot cattle are in the Midwest and Southwest states. As a result, very large populations of animals are at risk in small areas. These animals and birds have little or no innate resistance to foreign pathogens and, by policy, are not vaccinated against these diseases (which do not occur here under normal circumstances).

The U.S. animal and poultry production, slaughter, processing, and distribution system is highly integrated and characterized by rapid movement of vast amounts of product over broad geographies and through many hands from farm to fork. This system, which is highly efficient economically, could only develop over many decades because the U.S. was free of major animal diseases that might have hindered unrestricted interstate trade. The system now embraces Canada and, to a lesser extent, Mexico and is becoming increasingly global. Of course, producers always realized that the possibility of inadvertent introduction of a foreign disease posed a constant threat, but that seemed remote. As a result, U.S. agribusiness never factored the consequences of introduction of a highly infectious, highly contagious disease into the production and processing system—and government did not do this either. Today, we are so vulnerable to inadvertent or deliberate introduction because we chose to build the system that way.

The U.S. has been extraordinarily fortunate not to have experienced a major foreign disease epidemic in livestock or poultry over the past 20 years. Among the geopolitical changes that have greatly increased the potential for inadvertent disease introduction are: the fall of communism; increased volume and globalization of trade; expansion of the European Union; free trade agreements; containerized shipping; reduction of government investment in disease control, regulation, and inspection of agricultural products; and liberalized international travel with direct flights to the U.S. from formerly distant parts of the world. These factors should have stimulated new policies to reduce vulnerability but didn't.

THE TECHNOLOGIES THAT ALLOW NEW POLICY

The pattern of events in an epidemic of a virulent infectious and contagious disease commonly turns on five characteristics:

- *Complexity*—of nonlinear systems such as the organization of U.S. agribusiness in 2004.
- The three venues of the:
  - *Physical world*—the farms and fixed assets of U.S. agribusiness and the flows between them.
  - *Biological world*—properties of the virus, locations, numbers, and relationships of susceptible herds and flocks.
  - *Virtual world*—everything connected to and available through the Internet, such as true and false information, disease reports.
- *Time*—the temporal world, which permits anticipation and response at home and abroad. Time is the critical dimension. If time is gained, multiple alternate courses of action in space are possible. Generally, the more time, the more options are available, and the more likely it is that one or more of these options will be favorable. Conversely, the less time, the fewer and more unfavorable the options.

Current U.S. policy for FMD control, and the responses this demands, ignores complexity, the virtual world, and, most important, the critical dimension of time.

When FMD strikes, it is likely to have already infected multiple herds over wide geography by the time it is first detected. Nevertheless, there is evidence and experience that indicate that immediate and vigorous action to slaughter all animals on infected and neighboring farms within 24 and 48 hours, respectively (before they can infect others), can nip such an outbreak in the bud, so that an epidemic does not get started in the first place. Slaughter still has a role in FMD control, and this is it. But if it takes several days to slaughter animals on infected and neighboring farms, there is abundant opportunity for virus to be released in enormous quantities to infect other herds at a distance. In this case, there will be an epidemic, and very large-scale slaughter will be required to bring it under control.

It is not our choice as to whether there is an inadvertent or deliberate FMD outbreak in the U.S., and it never will be. The only thing that is our choice is how we respond to such an outbreak, and this in turn depends on our national policy, our preparedness, and how we act in the first week after the outbreak is discovered.

In the long run, over weeks or months, the U.S. can mobilize as many people and resources and spend as much treasure as necessary to halt an FMD epidemic. But to succeed in nipping the outbreak in the bud, even with the right national policy and adequate preparedness, we must be able to go from stand-by to full mobilization, perhaps on a national scale, in about a week after first discovering infection. We cannot act decisively if it takes 3 or 4 of those vital first 7 days to find out if it is FMD virus or not by taking samples to Plum Island. And rapid mobilization requires a federal agency that has the logistical capabilities and capacities to exert "command, control, and communication" in relation to time anywhere in the U.S. Only the U.S. military, and not the Departments of Agriculture or Homeland Security, can do this today. Our most critical technology gap is a full-fledged command, control, and communication system for agricultural epidemic control.

The concept of command, control, and communication is built around four questions that involve all four physical, biological, virtual, and temporal worlds:

1. Is the infection caused by FMD virus, and, if so, what type and subtype?
2. Where has infection likely spread locally around the infected farm?
3. Given the streams of national and international agribusiness:
   a. How did FMD virus get to the index farm (where infection is first discovered)?
   b. Where has the infection been carried already beyond the local area?
4. How can this information be used to mitigate costs and avoid mass slaughter?

Answers to these questions are outlined below; the history of technology development is set out elsewhere.[4]

Rapid on-site detection

USDA policy is to take samples from animals that might be infected with FMD to Plum Island, NY, a process that can delay diagnosis for 3 to 4 days. When Plum Island was built in 1954, it was a dramatic technological advance and the first laboratory in this hemisphere that could diagnose FMD. But the complexity and physical world of U.S. agriculture have made it no longer temporally relevant to wait 3 to 4 days for an answer. So in 2000, USDA scientists developed state-of-the-art PCR (polymerase chain reaction, a process that identifies a piece of the virus' genetic material that is a signature) tests to detect FMD, classical swine fever, African swine fever, Rinderpest, avian influenza, and Newcastle disease (to complement tests for other pathogens, including Rift valley fever, prepared by other federal agencies). These PCR assays were designed to be performed as real-time assays outside specialized laboratories like Plum Island on portable devices taken to the site of the problem. Results are obtained in an hour or less and can be reviewed over the Internet as they take place by technical experts located at distant sites (so the Agriculture Secretary could watch the assay as it proceeded from USDA headquarters in Washington, DC, and start to take effective action immediately). Detection results flow into an Internet-based command, control, and communication system that can translate vast amounts of information from the field into current insight for those federal, state, and local officials charged with responding to the event. To permit this, the detectors are connected by wireless to the Internet and contain a global positioning system (GPS) to allow geographic information systems to be overlaid.

The USDA test is more sensitive than the so-called "gold standard" of cell culture, and it detects all FMD virus serotypes and subtypes, including those that may have unusual properties in livestock. The latter is an important characteristic in advanced biological weapons defense. Most important, it is a preclinical test that detects FMD-infected cattle, swine, and small ruminants before clinical signs of disease are apparent.

Thus far, USDA and agricultural agencies abroad have not deployed rapid detection—or indeed any other modern technologies—to counter foreign animal disease outbreaks. Provided with a portable state-of-the-art device that can detect FMD and other viruses on a farm within minutes, USDA has reluctantly deployed a handful of machines to fixed sites in a dozen state diagnostic laboratories. Given the size of the U.S., this does not add significant new capability.

Regulatory officials have not realized that onsite detection is a transforming technology. Onsite detectors should transform disease surveillance and control, not echo history over smaller geographies. In my view, a federal or state official equipped with an Internet-linked detection device should be on the site of any suspected foreign animal disease outbreak in the U.S. within 4 hours or less of notification so that vigorous informed control measures backed by positive diagnosis can be implemented nationally within 6 hours. Once the presence of FMD is confirmed, as part of an Internet-based command, control, and communication system, continuous real-time surveillance must be employed to define the extent of the problem around the initial detection and to predict and track the progress of infection through the national agricultural commerce streams. This means that neighboring herds would be monitored daily for FMD infection (the test will find virus before there are signs of illness), and only infected herds would be killed. Slaughter would not be based on proximity. This level of timely repetitive testing cannot be achieved by taking samples to a central laboratory.

Currently, the specific type of FMD virus can be identified onsite using real-time PCR, but this information is of only limited value. The key decision is which vaccine would be most effective, and this requires knowledge of the virus type and subtype. To obtain this information speedily, a sample of virus would be flown to Plum Island, where its complete genetic sequence would be determined within 3 hours of arrival. Within the first 24 hours of notification of a suspicious incident, therefore, FMD would be definitively detected; informed control measures would be under way at the federal, state, and local levels; herds in the area would be under regular surveillance using PCR detection; and stockpiles of the best vaccine would be mobilized so that the first animals could be vaccinated starting 3 to 4 days after the initial detection. This timeline can be shortened with known technology that has not yet been applied to FMD.

Local spread

Immediately FMD virus is detected, the question changes from “Does the U.S. have FMD or not?” to “Where are the other infected farms?” and “What can we do to limit the infection while it is still a local problem?” It should be noted that the only federal resources close to the problem are likely to be the federal official on site and his equipment. The most available resources are likely to be those of state and local government, academia, and the private sector, and perhaps the military in some states.

Federal officials in Washington, DC, or elsewhere in the world would use the command, control, and communication system to manage the emergency. Since the location of the infected farm would be known by GPS, the first step would be for the command team to see a map of 50 miles around the farm. Then, knowing the numbers and species of animals infected, the type of FMD virus involved, and the likely number of days of illness, a computer model would be used to predict where virus has most likely been spread by the wind. This requires real information about wind and weather conditions at the index farm in recent days coupled with local landscape and terrain data (all available from databases in various federal and other government agencies). The plume deposition area (Figure 1)—the data-defined quarantine zone—would be superimposed over other data—say the highway system, livestock auction barns, and farms. All this could be done in minutes after the detection of FMD.

Now federal authorities would be in a position to talk factually with state and local officials. The governor, state veterinary and agricultural directors, highway patrol chief, local police chief, and others could be contacted by emergency page. Within minutes, they could be looking via their web browsers at the situation as federal officials knew it. Seeing a confirmed FMD infection at the index herd, state and local officials could immediately take informed steps to halt further spread, such as stopping trucks carrying livestock along local highways; notifying livestock owners in the data-defined zone that they are quarantined and enforcing this with police; closing auction barns; and starting to inspect farms in the data-defined quarantine zone for infection. Within a few minutes, informed actions to define the problem and limit spread could begin according to a coordinated plan, even involving entities and individuals that had not worked together before.

Figure 1 shows that a typical 3-km quarantine zone about the index herd would not necessarily identify the farms most likely to have been infected by wind-blown virus plumes. Sending personnel to check these farms in the first few hours and days and to kill herds (whether infected or not) over the next few days not only wastes precious resources but takes attention away from the real problem—farms in the data-defined quarantine zone. While vital and scarce personnel are wasting their time and efforts in the 3-km zone—and likely killing unaffected herds—truly infected herds elsewhere are releasing virus to infect others.

Samples taken from livestock on farms in the plume zone would be collected and examined locally within hours by PCR; positive samples would identify an infected herd for immediate slaughter. Negative herds would be repeatedly sampled until there was no longer infection locally (ways to do this without sending officials onto the farms can be developed). New computer models would need to be run to plot predicted spread from each infected farm discovered. In any event, very large amounts of changing data of all kinds will flow to and from the location to Washington and local command centers in subsequent days and weeks. The command, control, and communication system would be the means to track events in real time, for command and control at all levels, and for communication between all parties involved, including the public, media, and local community and business leadership of all kinds. The command, control, and communication system will allow responsible authorities to lead a coordinated, cooperative cam-

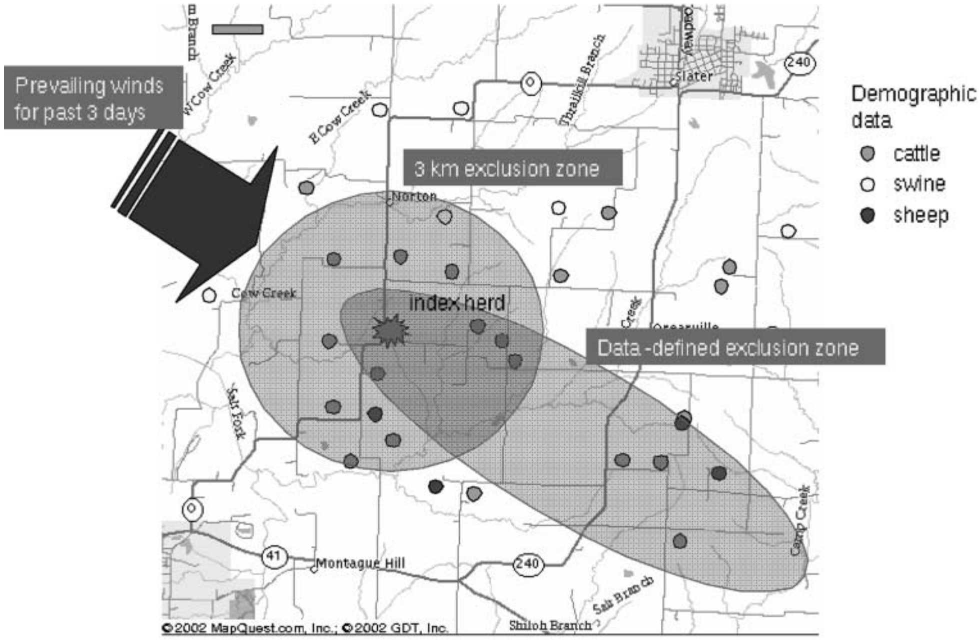

FIGURE 1. A SIMULATION OF A COMMAND, CONTROL, AND COMMUNICATION SYSTEM. The index farm is located by a global positioning device inside a real-time detector that identifies foot-and-mouth virus. A map of the area around the farm is superimposed from a database and then populated with demographic data on farms collected earlier. The traditional 3-km quarantine zone is drawn. Then an area in which farms have most likely been exposed to wind-borne virus is defined based on software incorporating virus properties and real wind, weather, and topographic data for the area over preceding days. This image and data can be shared within minutes of FMD detection over the Internet with federal, state, and local officials.

paign with many other partners beginning immediately the problem is recognized and focusing all available local resources where they are most needed in the first hours and days. The goal is "information to insight in real time."

The command, control, and communication system must be an organization and attendant systems with at least these five characteristics that will allow action agencies to:

- Observe, characterize, and predict activities—both discrete events and patterns—across a minimum of four venues: the physical, biological, virtual, and temporal worlds. Time is the critical dimension.
- Relate information from all these worlds in a temporal way and synthesize the results into a form that can be disseminated to those who need to know in order that action may be taken.
- Catalog historical events and also recognize emerging patterns of hazard, threat, and opportunity in all the venues of human enterprise and natural phenomena to provide foresight and anticipation, the key ingredients of effective action.
- Communicate and present knowledge derived from this information in ways that provide force-multiplying support to the action agency personnel at the center of the system.
- Provide timely, accurate, credible information to the public, media, and local community leaders to promote understanding, allay unnecessary fears, and prevent panic. Cable news channels cannot be the sole source of current information for the public and local leadership.

In the example shown in Figure 1, the physical world would include wind, weather, and location of human, detector, and other physical assets. The biological world would include demographic data on susceptible species and the aerosol characteristics of the exact type of FMD virus causing the problem. The virtual world means anything involving the Internet, including websites of advocacy groups with opinions relevant to the situation and the media. Public opinion in a crisis is not shaped by scientific results appearing after peer review in an academic publication. The Internet has unprecedented potential to drive public perception for good or bad and to shape action agency responses accordingly. The temporal world is time—chronological time and the relationships of events to each other in time. Examples would be the estimated times at which animals had been infected on the index farm and then had become infectious for others and the relationship between these times and times of movements of people, animals, and physical objects from farms in the data-defined quarantine zone.

To be a seamless national system for response to the full spectrum of disease threats, many historical and real-time data resources would also need to be available, including street maps; telephone numbers; topographic, ground cover, and landscape maps; real-time satellite imagery; demographic data on population distribution; economic data by location; locations of specific businesses; water, sewer, and other utility maps; medical resource maps; schools; law enforcement resources; locations of specialist auxiliary personnel and resources appropriate to a particular threat response; and so on. Each responsible agency would best identify the necessary resources in conjunction with all the anticipated partners at the national, state, and local levels. These would have to conform to set standards so the whole is compatible.

FMD virus movement through agribusiness streams

FMD is not present in the U.S., so when it is found on a farm it is important to discover how it got there and where it has been carried to—in other words, to go upstream and downstream from the first detection. This has to be done quickly. Two technologies are vital for this purpose.

The first is the means to track animals and animal products from the production stage on farms, through slaughter and processing, and then along the storage and transit chain to the supermarket and table. Implicit is the ability to track meat products in the home back through the entire system to the whole animal and its farm of origin, recovering data about disease states and microbial testing along the route. In some cases this will be international. This sounds like an impossible task, and federal agencies are only just beginning to express public interest as to whether such capabilities might be conceivable. In fact, private industry has offered exactly these capabilities for some years. Throughout the production and processing system, individual animals, farms, and other premises are identified by bar codes, and as product passes through the chain it preserves its identity and accumulates bar code data that can be tracked and correlated with laboratory analytical information. A demonstration can be seen on the Internet.[5]

The second technology, known as SPIDER (an acronym for System for Prediction and Insight into Decision-making for Earliest possible Response), is under development by William Wilson at Lawrence Livermore National Laboratory. SPIDER is designed to understand and model the normal flows in U.S. agribusiness so that predictions can be made as a result of an observation at some point in the stream. The intent of SPIDER is to be able to follow normal flows through the U.S. agribusiness sector in a time-sensitive way. This is achieved by integrating three classes of algorithms to analyze enormous amounts of data using the most powerful computers.

To give a simple example, there are times of the year when calves are moved from California to feedlots in the Midwest, Oklahoma, and Texas. Discovering FMD in this class of calf at the right time of year in California would raise strong suspicions that the infection was already in one or more of these other states. By anticipating intuitive and nonintuitive situations, SPIDER will give confidence to those who have to implement FMD control restrictions in states that have not yet found clinical infection.

Mitigating costs and avoiding mass slaughter

FMD is a disease that is almost defined economically, yet even the British could not identify the true costs or their impact. Mitigating losses in an American context demands that these costs be identified and attributed so that steps can be taken to minimize them. Much more work needs to be done to understand the potential financial impacts of FMD across the whole economy so that such important policy is not based on anecdotal information. The brevity of these statements is no reflection on their importance.

Costs fall into two categories: those related to the immediate actions taken in the U.S., and those related to international trade regulations set by OIE. In both cases, it is clear that many of the disease control restrictions that are the cause of economic losses are not necessarily supported by good science, and so a parallel effort must take place to ensure that significant costs are not incurred by unsustainable dogma. In contrast, much can be gained from research targeted at mitigating losses—for example, it is possible to recover valuable germplasm, even from infected animals, so that genetic resources are not lost.

The costs imposed by trade embargoes dwarf all others—indeed, the whole rationale for slaughter versus vaccination relies on the calculation that this is the fastest way to return to the export markets. But such calculations are obsolete. Careful attention must be paid to the scientific justification for OIE rules and to modern technologies that can provide the outcomes OIE desires in more efficient ways. Two technologies challenge the dogma of slaughter: The first is product identity preservation and tracking. The other identifies vaccinated animals.

There have long been effective vaccines against FMD, and vaccination was employed over 50 years ago in a heroic battle to beat back an epidemic of FMD in Mexico that threatened the U.S. And it was clear 15 years ago that the U.S. would have to prepare for the day when these vaccines would have to be used here. The main barrier to their use was the fact that with the technology of the 1980s, blood tests could not tell the difference between an animal that had been vaccinated and one that had recovered from a previous infection. Recovered animals sometimes carry virus in their throats for long periods and may be infectious to other animals. This problem was solved by USDA scientists in 1994, and commercial tests are now available.

With these tools, we can confidently vaccinate livestock in the event of an FMD epidemic. When the outbreak is halted (probably no one will want to buy our meat until then), we can immediately resume exports by testing herds (or animals) before slaughter and guaranteeing our customers that the carcass or product comes from an FMD-free animal that can be traced back to a specific herd. OIE embargo rules were established before such technologies were available, but they are not cast in stone. Of course, no country wants to import FMD-infected meat, but they can now rely on science, not a blunt, time-based embargo, for this assurance. The OIE would have to approve this new method to meet its trade goals, and only countries with advanced laboratory and information technologies would be able to carry it out. But this will be a huge step forward in mitigating embargo impacts.

In OIE terms, the U.S. is one country, so a single cow with FMD in Connecticut halts exports from California. There is an alternate concept known as “regionalization,” which allows trade to proceed with defined regions of a country that can provide assurance of freedom from disease. If the U.S. wanted others to recognize “regionalization” here, so that only Connecticut would be embargoed, then we would have to reciprocate overseas, which the U.S. has been reluctant to do. Identity preservation and product tracking is a powerful tool in providing assurance that regionalization is working.

Central to the plan to stop FMD in its tracks is the capability and capacity to vaccinate U.S. livestock against the particular virus type. This depends on having the best vaccine for that type in sufficient quantities. How much vaccine is needed depends on how quickly and intelligently it is used once the outbreak starts. Notionally, the U.S. has a bank of FMD vaccines that is shared with Mexico and Canada; this bank is in the form of frozen concentrated killed virus that has to be reconstituted into vaccine in a bottling plant.

There is an old adage that it is better to have a vaccine and no epidemic than an epidemic and no vaccine. The capability and capacity of the North American FMD Vaccine Bank are sensitive subjects and deservedly so. Suffice it to say that the U.S. must immediately purchase 100 million doses of vaccine that will protect against each FMD type and subtype currently extant in the world: assuming there are some 15 vaccines, that will be 1.5 billion doses. This amount exceeds total world annual production, so it will be a slow process of manufacture to U.S. standards in licensed facilities overseas. The cost will be about $120 million. This range of vaccines will protect against inadvertent FMD virus introductions because these must be currently circulating subtypes. The odds are that it will also protect against most deliberate introductions that also are likely to use the same circulating subtypes.

Rapid detection and command, control, and communication allow the right vaccine to be mobilized within 24 hours of the index case and directed to the areas most at risk; the goal should be to have vaccine administered to animals starting about 3 to 4 days after FMD detection. How widely vaccine should be used may have to be determined at the time, but there should be no hesitation about using vaccine; the trade consequences can be mitigated. Mobilizing and delivering vaccine to farmers requires logistical competence and preplanning so that all animals at risk can be vaccinated in the first 7 days; this is a task for the private sector.

It is possible that science may develop a new type of FMD vaccine that can be manufactured in the U.S. (conventional vaccine that starts by growing live virus cannot be made on the mainland U.S.); this has long been a goal, and every avenue has been or is being tried. But the only vaccine available now is the killed variety, and we cannot wait to start stocking the bank adequately. Conventional FMD vaccines are highly effective, but no vaccine can start to work until it is in the animal. Specifically, the logistics of FMD vaccine manufacture mean that one cannot order vaccine to be produced once an outbreak starts; stocks must be on hand. It takes months to set up a vaccine production capability for a particular type, and then capacity is limited, so there is no substitute for stockpiles.

FUTURE TECHNOLOGIES

The key biological tools to combat FMD are already available: onsite diagnostics, vaccines, and differential tests. Our current deficiencies are not biological: they are in policy and in the tools of command, control, and communication, tracking, and SPIDER. Investment to bring these to fruition has been lacking because they were not needed when the policy was mass slaughter. Once policy is changed, new biological tools will be developed. The most useful would be an anti-protease drug to block replication of all FMD viruses, including any new viruses created as weapons by genetic engineering in the future. Interferons also hold promise as means to quickly stop the progress of an FMD infection without vaccination. It will not be clear how these might best be used until the biology is known—until we know whether interferon treatment delays or clears an FMD infection and whether any virus still remains. Some slaughter will still be necessary, even under the scenarios outlined above. It would be most convenient if this slaughter could take place through normal venues, even if the carcasses were rendered, rather than through on-farm killing and disposal. Antivirals might offer a way to achieve this, even if full recovery were not an option. With all these drugs, there would have to be convenient oral or aerosol means of administration and a limited regimen of doses in order to be practical.

The idea of animals that are naturally resistant to FMD sounds far-fetched but is a possibility. Cell genetic factors have been identified that confer resistance to FMD infection, and it is possible that these can be used to discover animals that are also resistant. It is possible that such animals exist, but in real life they would have to be exposed to FMD in order for anyone to know that they did not catch the disease—and if they were exposed to FMD, they would be killed anyway according to government policy in most countries. Understanding disease resistance mechanisms may also help identify new ways to block FMD infection with antiviral drugs.

Global adoption of rapid FMD detection devices linked to the Internet could minimize the lag between detection of a disease in one country and informed action at ports of entry in another. There are too many travelers arriving in the U.S. to search everyone’s bags. The smarter solution would be to use information technology to identify those travelers arriving from regions (not necessarily countries) with active FMD and to open their luggage. Other technologies can be used at ports of entry to rapidly determine the region of the world from which meat originated, and this can be coupled with Internet-verifiable documentation carrying unalterable seals so that contraband shipments can be interdicted.

INDUSTRY AND GOVERNMENT RELATIONS

When the Department of Agriculture was established in 1862, the only way American business could be threatened by a foreign virus was by accidental importation of FMD, Rinderpest, or some other threat. The relationship between farmers and government on foreign animal disease control was established at that time. In 2004, however, American business is far more likely to be damaged by a computer virus delivered over the Internet from some foreign shore. The costs of such attacks can be considerable and even exceed those often quoted for FMD. Yet government has adopted quite a different approach to the business costs of computer viruses. Government sponsors and encourages research on defenses and supports law enforcement efforts to catch those responsible. But business is entirely responsible for the costs of staff, software, and training to prevent or mitigate attack and for back-up systems to maintain key functions. If a company or individual chooses not to use these protections, they are free to go out of business when crippled by a virus attack.

Lancisi did not propose compensation for farmers whose cattle had Rinderpest: those who did not report the disease were sentenced to the galleys. But in later outbreaks it was found that the promise of compensation increased reporting and helped end epidemics. Compensation has been the general rule ever since. However, in 2004 government compensation is one of the factors that promote complacency about inadvertent and deliberate threats. If all sectors of the industry had to insure against these losses instead of relying on government, there would be immediate changes: private insurance companies would never accept the risky practices that have become engrained.

Government and agribusiness have built a tremendously vulnerable system that could be devastated by inadvertent or deliberate introduction. Yet some business sectors have opposed or blocked some of the tools that would be essential to mitigate losses if disease should strike: animal identification, country of origin labeling, bioterrorism prevention and preparedness steps, and identification and tracking of product. No licenses or tests are required to farm animals, there are no rules on farm or premises biosecurity, and few employees are trained to prevent or detect disease. High-risk practices are common, and the industry structure promotes them. For example, feeding garbage to swine is a very high-risk practice by which FMD and other foreign viruses can get a foothold to start an epidemic. If the garbage is properly cooked, the risks are minimal—but it is everyone’s cooking that must be perfect, not just an individual’s. Even having said this, it is not clear just why it is a societal responsibility to compensate the garbage feeder whose pigs get FMD—this is not different from a computer virus. And it seems unconscionable to compensate the garbage feeder but not the slaughterhouse worker and hotel owner who lose their jobs as a consequence of his actions. The answer is not to extend the scope of government compensation but to curtail it. If farmers had to acquire insurance against the costs of FMD, those that engaged in high-risk practices would probably not be able to purchase insurance and would go out of business. This is not entirely a bad thing, even for other farmers.

But this is not to paint agribusiness as an adversary. The industry is painfully vulnerable, and this will not be solved by government rules and regulations. Industry itself will have to take the initiatives, and government can best assist by using its penalties and inducements to encourage movement in the right direction. Of course, there are already agricultural businesses with very high standards of biosecurity: these are the ones able to exert the necessary degree of process control throughout their operations. They are the benchmarks for others.

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