U.S. officials are stepping up efforts to keep out foot-and-mouth disease. But in this age of global travel, can they succeed?

Barricading U.S. Borders Against a Devastating Disease

DULLES AIRPORT, VIRGINIA—The question on the customs declaration form, to be checked "Yes" or "No" by every traveler coming into the United States, has a somewhat anachronistic ring to it: "I am (We are) bringing fruits, plants, meats, food, soil, birds, snails, other live animals, wildlife products, farm products; or, have been on a farm or ranch outside the U.S." It seems reminiscent of the days when you had to check whether you were a communist or a homosexual. But in recent weeks, it has become acutely relevant. Question 11 is the first line of defense against foot-and-mouth disease (FMD), which has crippled British agriculture, disrupted the country's way of life, and struck fear across the rest of Europe.

Last week, the U.S. Department of Agriculture (USDA) used the international arrivals hall of this airport near Washington, D.C., to demonstrate that it is increasing vigilance to keep FMD out. As living proof, the agency brought out Quincy, a 7-year-old beagle trained to sniff out meat, cheese, and other contraband after passengers pick up their bags from the luggage carousel. Direct flights from FMD-affected countries will be subject to increased scrutiny by Quincy and his peers, the agency said. For TV crews, USDA also staged the mock arrival of a traveler from Britain who, after confessing she had visited a farm there, was asked by friendly-but-firm agents to surrender her muddy tennis shoes. The footwear was taken to a back room, where an agent scraped off the dirt and disinfected the soles with a stiff brush dipped in a bleach solution. Then she was free to go. "The shoes are clean," sneered one French reporter after witnessing the performance. "The country is safe."

But some experts doubt that it really is. When *Science* went to press this week, no signs of FMD had been seen in the United States, while the epidemic raged on in the U.K. But FMD is one of the most contagious diseases on Earth and is constantly on the rampage: Since early 2000, it has struck Russia, China, South Korea, Taiwan, Japan, Mongolia, and at least seven African and five South American countries. It infects all cloven-hoofed animals, such as cattle, pigs, sheep, and goats. Given that impressive march, there's little doubt that the virus will sooner or later reach the United States, says veterinary epidemiologist Peter Cowen of North Carolina State University, Raleigh. "I just don't see why we would stay immune," says Cowen. "I think the question is when we'll get it, not if."

Without doubt, the economic toll in this agriculture-dependent country would be devastating, say Cowen and others. So why is the nation dependent on bleach and beagles—especially when good vaccines to ward off the disease have been available for decades? Even some scientists are at a loss to fully explain why—but the answer involves the global economics of modern farming, in which the direct and indirect costs of vaccines often make it cheaper to stamp out disease outbreaks than to prevent them.

Funeral pyre. The grim site of burning carcasses here in Longtown, U.K., reflects the fact that it is cheaper to stamp out foot-and-mouth disease than to prevent it.

CREDIT: MURDO MACLEOD/CORBIS SYGMA

Two oceans

Although local foot-and-mouth outbreaks have occurred almost yearly in Europe for most of the 20th century, the United States, where it's often called hoof-and-mouth disease, had its last epidemic in 1929. (Mexico had outbreaks until the 1940s, and Canada had one in 1952.) Similarly, classical swine fever breaks out in Europe regularly; in 1997 it forced Dutch authorities to massacre almost 10 million pigs. The same disease, often called hog cholera here, was eradicated from the United States in 1978. Similarly, no sign of mad cow disease, or bovine spongiform encephalopathy (BSE), has been detected in the United States, although it has spread over the past decade from the British Isles to at least a dozen other countries.

Part of the credit goes to the strict importation rules by the USDA's Animal and Plant Health Inspection Service (APHIS). Beef from the United Kingdom has been banned since 1989 because of the BSE crisis. And after FMD gained a foothold in France last week, the U.S. government temporarily banned the import of all European animals and many animal products. At the borders, Quincy and his human co-workers keep the pressure up on individual travelers who may be tempted to smuggle some bratwurst or salami in their suitcase. But the health of U.S. livestock is also a result of the country's geographic isolation, says Martin Hugh-Jones of Louisiana State University, Baton Rouge. "We have to be very grateful for two things," says Hugh-Jones: "The Atlantic and the Pacific." (How FMD entered the U.K. is still not known, but there are solid clues that an animal transport across the English Channel recently brought the disease into France.)

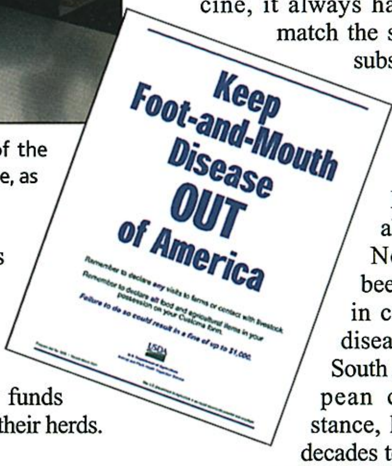
Nonetheless, with a quarter-million people entering the United States daily at 90 entry points, it's impossible to check everybody, and the virus can survive on people's clothes or even in their throats as a passenger. That's why APHIS also has set up a second line of defense, should an outbreak occur. The strategy would be similar to the take-no-prisoners approach that Britain and France are using: Cordon off infected farms and destroy every animal potentially exposed to the virus. And it would work, asserted APHIS administrator Craig Reed at last week's press briefing. "We will contain the virus," Reed promised. "It's our job."

Dead in their tracks. Disinfecting shoes is one of the first lines of defense against foot-and-mouth disease, as USDA officials showed a crowd of reporters.

But even a limited outbreak could have a staggering economic impact. In 1998, Javier Ekboir, then at the School of Veterinary Medicine at the University of California, Davis, built a computer model to simulate an FMD outbreak in Tulare County, California, an area with lots of animals in close proximity and a mild climate that would allow airborne spread of the virus year-round. His simulation showed that the direct cost of destroying animals and disinfecting farms and other facilities would run between $500 million and $1.5 billion; that number would be much higher if the disease spread to other counties. The cost of lost trade in the 2 years after the outbreak would run about $1.9 billion if other countries shunned California animals and meat. If they extended the ban to all U.S. meat, the cost of one small outbreak could run as high as $8.9 billion.

More than anything else, the outcomes of the model depended on how much time elapsed before the disease was detected. With a fast-moving disease like FMD, even a few days can be extremely costly. If, for instance, health authorities started the eradication job in the second week after the first infections, 81% of the county's herds would escape culling; if they started in the third week, only 13% would. But rapid detection may be the Achilles' heel of FMD control in the United States, Ekboir concluded, because farmers don't expect the disease. Hugh-Jones, who was in the trenches during Britain's last battle with the disease, in 1967–68, says a local outbreak often went undetected until at least four or five farms had been hit.

In Texas, too, animal health authorities say an outbreak could be devastating. To be better prepared, the Texas Animal Health Commission played out a mock epidemic last fall, together with Canadian and Mexican officials. The exercise drove home the point that time is of the essence, says state epidemiologist Terry Conger. In this scenario, infected animals were sold at an auction, and then a trucker took them all the way to Canada in a matter of days. Officials also learned that they didn't have enough epidemiologists to deal with a big outbreak, and that red tape would prevent the quick release of indemnity funds needed to make farmers give up their herds.



A costly gamble

The gruesome sight of thousands of carcasses burning atop huge pyres or being dumped in mass graves raises the question of why, even though FMD has been around for centuries, farmers still can't protect their animals. The answer has less to do with science than with the fact that in livestock as opposed to human diseases, economy is all-important. And often, it's cheaper to slaughter hundreds of thousands of animals once in a while than vaccinate all of them all the time.

FMD can be caused by any of seven viruses, or serotypes, called A, O, C, Asia1, SAT-1, SAT-2, and SAT-3, all members of the picornavirus family; each strain also contains many subtypes. The outbreaks now seen in Asia, Africa, and Europe all seem to be caused by one subtype of the O serotype, says Fred Brown, a veteran of FMD at the Plum Island Animal Disease Center, just off the coast of New York state. (The current strain has been dubbed, somewhat confusingly, PanAsian.)

Although highly contagious, FMD does not kill most animals; calves often die, but adults usually recover within a few weeks. But they often remain underweight and exhausted, suffer permanent foot damage, give less milk, or fail to reproduce. Whereas farmers simply had to live with that in centuries past, today the sickened animals are an economic drain and might as well be killed, the argument goes. Given the fast spread of the disease, it is imperative that the culling happens quickly. Because infected animals start churning out new virus particles before they show any symptoms, even those who have potentially been exposed are put down.

Economics also dictate that vaccination should be as limited as possible, despite the fact that current vaccines—which are all made of killed, not attenuated, virus—offer very good protection. Although the vaccines themselves are cheap, delivering them is expensive, especially because periodic booster shots are needed. And there's no such thing as one general FMD vaccine: Like flu vaccine, it always has to be chosen to match the strain, and even the substrain, that's a threat at a given time.

The current vaccines, made by companies such as London-based Merial and Intervet in the Netherlands, have been consistently used in countries where the disease is still endemic. South American and European countries, for instance, have used them for decades to successfully eradicate the disease. Once an area is FMD-free, however, the scales tip, and the vaccines become less attractive. In the past, insufficiently killed vaccines sometimes caused outbreaks; although modern manufacturing methods have greatly reduced this risk, it cannot be totally eliminated. In addition, vaccinated animals can still harbor low levels of the virus that put susceptible animals at risk; that's why disease-free, isolated countries such as the United States, the United Kingdom, and Japan have opted not to vaccinate. And because vaccinated animals produce the same antibodies as infected animals, making it difficult to distinguish between the two, those countries also refuse to import vaccinated animals or their meat. In an effort to expand the market for its meat, the European Union (E.U.) gave in to that demand by banning vaccines in 1992, after FMD had not shown its face for several years. Now, some farmers and politicians,

CREDIT: (LEFT) AP PHOTO/STEPHEN J. BOITANO such as the Dutch agriculture minister Laurens Jan Brinkhorst, argue that it's irresponsible not to start vaccinating anew. But so far, the E.U. has not budged.

A test to distinguish vaccinated from infected animals could end the current impasse. United Biomedical Inc., a company in Hauppauge, New York, has developed one that works well, says company scientist Alan Walfield. As his team described in a 1999 paper in *Vaccine*, the test specifically detects antibodies against proteins involved in viral replication, which the virus produces but the vaccine doesn't. The test, which still needs to be approved and registered, will likely make vaccines more acceptable, Walfield predicts.

Another approach would be to develop a vaccine whose immunologic footprint is distinct from that of an FMD virus; ideally, such a vaccine would also protect against as many strains as possible, instead of just one. But because the different types vary greatly, this is difficult to do. Brown says he's currently testing vaccines that simply consist of a short protein sequence expressed by the virus, as is United Biomedical; another group at Plum Island, led by Marvin Grubman, is trying to develop a vaccine by sticking FMD virus genes into an adenovirus that has been crippled by removing some of its own genes.

Although Walfield says big vaccine makers have recently shown a little more interest in the disease, most FMD researchers expect progress to be slow. After the memories of the devastating 1967–68 outbreak started to fade, Britain decreased its funding for FMD research, says Brown, and currently, the disease is studied by just a handful of labs around the world. "There's a certain degree of complacency," says Brown. "We haven't had foot and mouth for so long, so why should we worry about it?"

–MARTIN ENSERINK

SCIENCE POLICY

Can a King of Catalysis Spur U.K. Science to New Heights?

David King, one of the world's leading physical chemists, is now the U.K.'s chief scientific adviser. He describes the challenges of his new job

LONDON—If politics is supposed to mean catalyzing change for the greater good, David King ought to be a master of the art. After all, few people have a finer grasp on the intricacies of catalysis than the Prime Minister's new chief scientific adviser, a leading expert on the interactions of atoms at surfaces.

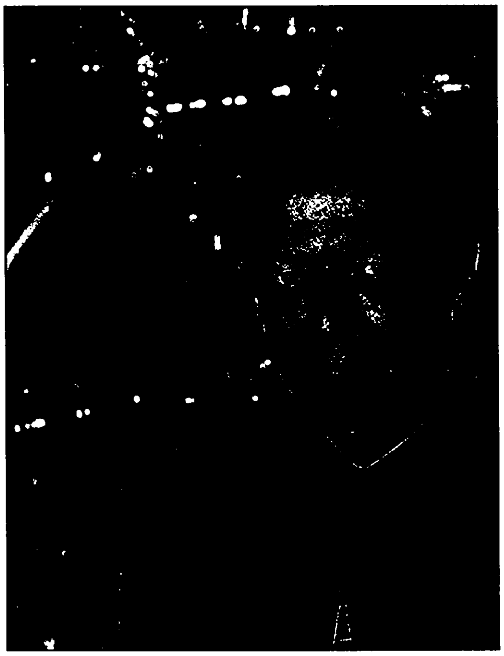
Positioned to exert more political influence than any other scientist in the United Kingdom, King has spent the early days of his 5-year term as chief scientific adviser—he was appointed last October—getting a feel for his new milieu. Earlier this month, King carved out time from a calendar jammed with meetings with key science players in the Parliament, in the government, and among advocacy groups to share his thoughts with *Science* on a range of issues, from low salaries for British scientists to coping with a series of crises culminating in the ongoing outbreak of foot-and-mouth disease.

Although King thus far has refrained from pushing for shifts in science policy, that should change after national elections, which the current Labour government is widely expected to win. (The election could be called as early as 3 May.) "Immediately after the election, he's going to have to swing into action and make sure that science is high on the political agenda," says biologist Ian Gibson, a member of Parliament who serves on the Science and Technology select committee.

Observers predict that King will be an effective advocate for science. The chief scientific adviser should be "somebody who is an excellent scientist" with "a strong and independent voice"—and King fits the bill, says his predecessor, Sir Robert May, who is now president of the Royal Society. But perhaps the biggest asset King brings to the job is his power of persuasion, says Gibson: "He can seduce people into doing things."

Skimming the surface

Born in Durban, South Africa, in 1939, King earned a doctorate in chemistry from the University of Witwatersrand in Johannesburg in 1963, followed by a postdoc at Imperial College London. He spent more than 2 decades at the University of East Anglia in Norwich, U.K., and the University of Liverpool before landing a professorship at his current home, the University of Cambridge, in 1988.



Getting everything done by Friday. David King crams his government job into 4 days a week to make time for research.

CREDIT: JOHN HOLMAN

One of King's early passions was scrutinizing the encounters of gaseous hydrogen and metallic tungsten. He found that as the hydrogen molecules cleave, the individual atoms glom onto the surface, elbowing the tungsten atoms into new configurations. His studies helped show that "metal surfaces are not rigid checkerboards; they are flexible," says physical chemist Richard Lambert, a Cambridge colleague. King also helped improve low-energy electron diffraction, a technique used to build up atomic-scale images of surfaces.

But the innovation that has won King the most plaudits from his peers so far is the single-crystal microcalorimeter. This device measures the heat shed by molecules as they break apart at a surface. Pulses of molecules are fired at a crystal wafer barely two-tenths of a micrometer thick. A thermal camera monitoring this molecular barrage picks up infrared radiation as the wafer heats up by anywhere from 0.1 to 1.0 degrees Celsius per pulse. The device offered a new way to measure the energy liberated when atomic bonds are broken. "It's really a quantum leap above what anybody else has done," says physical chemist John Yates of the University of Pittsburgh.

Such insights are highly prized by industry. "If you understand in detail the mechanisms going on on a surface, then perhaps you can develop better catalysts," says buckyball Nobelist Harry Kroto of the University of Sussex. Indeed, King and his team have recently unraveled how ammonia reacts with oxygen in the presence of platinum—a discovery that, by suggesting a more efficient way to drive the reaction, could save the fertilizer industry millions of dollars on plat-