The Future Gazers: Will Scientists Ever be Able to Reliably Avert Infectious Disease Outbreaks?

by Leslie Bienen

The Mary Valley Cattle Station, a ramshackle collection of buildings and trailers on the Cape York Peninsula about 100 miles inland from the Queensland coast, is home to one of Australia's largest colonies of bats. The bats are little red flying foxes, a type of fruit bat, and there, in this remote sliver of the Outback, one can sometimes see five million of them, clustered upside down and on top of each other, hanging in the trees.

Flying foxes are nomadic, which means they move unpredictably in accordance with food availability, but the Mary Valley colony was said, even by bat researchers, to be permanent. Our crew – consisting of myself, my husband, our ten-month old son, an Australian veterinarian, and ecologist and two field technicians had made the seven-hour drive from Cairns over potholed, dusty, dirt tracks because we were hoping to eliminate the risk of a long journey with no bats at the end of it, and because the enormous size of the colony would make it easier to catch large numbers of research subjects. After a quick stop at a spot marked on the map as the nearest town (a general store), we entered the station's property, passing several herds of poor-looking cows, and pulled up to the trailers where we'd be staying.

When we had divested the vehicles of food and bat-handling equipment, we made our first foray into the bush. It didn't take long to figure out that, contrary to our information, all five million bats were gone. Mary Valley is experiencing a multi-year drought, and apparently it had finally driven the little reds elsewhere in search of food. Nonetheless, we spent the next three days wandering over reddish earth that was riven with tiny cracks from hundred-degree heat, occasionally stopping to rest under trees too spindly to afford shade and sniffing the parched air in case the bats had relocated somewhere out of sight but still in reach of our noses.

Eventually, we packed up and made another long drive, ten hours south to the tiny town of Chillagoe, which felt positively bustling with its two restaurants, a store, and a post office. A park ranger in the area assured us that the smallish (20,000 animals) colony of little reds was still around as of the day we set out.

Sure enough, at dusk on the evening we arrived, we stood on a causeway that crossed a small stream and watched the air slowly fill with dark shapes until the whole sky was black with bats. We had a perfect view of them dipping into the water for a drink on the wing, then soaring up again, having tanked up for their nightly foraging. There was just enough light to see the flying foxes' faces when they swooped low overhead, and although I had seen photographs, I wasn't prepared for how eerily these animals resemble a hybrid of human, dog, and gargoyle. My husband stood right beside me holding our apprehensive-looking son but we could hardly communicate over the chatter of vocalizations and the whoosh of wings. We didn't mind, though, because the din created a perfect excuse to admire in silence the half-ugly, half-fantastically beautiful elegance of bats.

Just before dawn, when the flying foxes had returned to their roosts and were hanging upside down with their sharp little faces entirely cloaked in their wings, it was easy to see how the myth of Count Dracula, his cape draped across his face in imitation of this bat gesture, had come into being. In contrast to western associations of bats as harbingers of evil, many indigenous Australasian cultures honor, as well as hunt and eat, them.

In November 2003 I traveled to Australia to observe and participate in a research project whose goal is to understand the relationships between flying foxes, humans, landscape-scale ecological changes, and the myriad of viruses to which flying foxes play host. Of these viruses, four that are grouped in their own genus, Henipavirus, are of particular interest.

Flying foxes belong to the order *Chiroptera*, which means "hand-winged," a description that succinctly describes the bizarre body structure of the world's only flying mammals. There are about 65 species of flying foxes, the largest bats in the world, scattered throughout Australasia, South and Southeast Asia, the Pacific islands, and the islands off East Africa. Many species of flying fox are in decline, and several are already extinct.

The flying fox work, known to those involved with it as the Henipa Project, is one of very few organized emerging disease investigations that aims not only to elucidate the molecular biology and virology of host/pathogen relationships, but to understand these elements as factors driving disease spillovers. The ultimate goal of this research, undertaken by scientists working with the Consortium for Conservation Medicine and funded by the National Institutes of Health, is a lofty one: to prevent future disease outbreaks through environmental conservation.

As a veterinarian specializing in diseases that cycle among wildlife, humans, and livestock, I was fascinated by the scientific details of this endeavor. But I was equally compelled by the way in which the project's vision of itself had expanded as the researchers began uncovering layers of a problem that was infinitely more complex than the one they initially hoped to tackle. It is this latter situation that forges the most exciting and creative science, though the solutions are often slow in coming, because it takes time to muster the resources and institutional frameworks necessary to grapple with questions you did not set out to answer. Ten years ago, the first henipavirus outbreak occurred in Brisbane, Australia, and was investigated by a few people who quickly discovered that their lack of knowledge about these pathogens was the tip of an iceberg of ignorance concerning new infectious diseases and their hosts. Today, those same scientists, and tens of others who have since joined them, have come to believe that a now-radical proposition will be accepted in the foreseeable future as common sense: that it is possible to predict where and why certain infectious diseases are likely to emerge into humans. If this comes to pass, their work should change the way governments, medical institutions, conservationists, and even people simply going through their day, think about the way infectious diseases get from one species to another and what this means for the fate of the planet. Whether it will is another matter.

The first inkling that flying foxes might be at the center of some very interesting issues came ten years ago and was sparked by a series of events outside of Brisbane, the largest urban area on the 2,600-kilometer stretch of Australia's east coast between Sydney and Cairns. Here, a densely settled suburb named Hendra became instantly famous, at least in Australia, as the spot where a mysterious lethal virus made its debut in humans.

On September 9, 1994, a pregnant thoroughbred mare, aptly named Drama Series, died after a two-day respiratory illness. Her trainer, Vic Rail, died ten days later, having suffered a course of similar symptoms before succumbing to kidney failure. Because he was well-known in Australia, holding two Australian Cup titles, and the circumstances of his illness were odd, Rail's death generated a good deal of local and national press, but scant international coverage.

A stablehand and sixteen more horses were stricken over the next several days, but health authorities publicly disavowed that Rail's and the horses' deaths were connected. Nevertheless, all racing and transportation of horses in Queensland was halted while the Australian animal and public health authorities, in consultation with the Centers for Disease Control (CDC), in Atlanta, Georgia, launched a search for an agent to explain Rail's demise. Ten days later, a causative virus was isolated, first from horse tissue and then from the deceased trainer, and the notion was put to rest that the human and equine deaths were unrelated. The stablehand also tested positive for the virus, though he eventually recovered.

The virus, logically enough, was named Hendra virus.

Diseases named after places are called toponyms, and many town and city councils have pressured international taxonomy bodies to rename diseases so that their municipality won't be forever associated with an illness. The deadly virus known as Hanta (not its official name) used to be called Four Corners virus, after the part of the Southwestern U.S. where it sprung up in the 1980s. Locals objected to this appellation, and eventually the pathogen was reregistered as *Sin Nombre* virus, which means "no name" in Spanish, because no one could agree on a new name. Hanta itself is a corruption of Hantaan, the region of Korea where the virus originated. The citizens of Hendra, however, like the denizens of Ebola, Marburg, and Lyme, filed no appeal to rid their hometown of the taint of association with an infectious disease, and as a result the name of their suburb is now permanently affixed to a pathogen famous to epidemiologists and virologists around the world, if not to the American public.

At the time of Rail's death, Hume Field, an employee of the Queensland Department of Primary Industries, was drafted to look into the outbreak. Field, a tall, exceedingly calm-looking man with a wide face and spiky grey hair, is a veterinarian with training in environmental science and epidemiology, who also had experience surveying wild and feral animals. His cross-disciplinary education proved to be invaluable in the search for Hendra's origin.

At the time of Hendra's emergence, there were no zoonotic (meaning transmitted from animals to people) pathogens known to be harbored by horses, so the veterinary pathologists did not wear masks or gowns during the equine autopsies. An average-sized horse weighs about a thousand pounds, and its circulatory system holds approximately twelve gallons of blood, so the dissection of several horses generates a substantial volume of possibly contaminated tissue and effluents. After Hendra virus was isolated, residents of the neighboring farms were angry that the horse cadavers were autopsied outdoors, in the open, and blood and other bodily fluids were allowed to run down street gutters. Local papers ran stories criticizing the government's lack of precaution. Luckily, Hendra virus did not prove highly contagious, either through airborne particles, from human to human, from horse to human, or from horse to horse. Nevertheless, when the farm where Drama Series became infected was converted to a housing development, she and another dead horse were dug up and moved for fear that future residents would object to the presence of virus-ridden cadavers beneath the newly rolled lawns.

Field captured and tested rodents, possums, and blood-feeding insects in the area, but tests for Hendra virus yielded nothing, and the investigation puttered along with few results. Then, fourteen months after Rail's death, Mark Preston, a cane farmer who was married to an equine veterinarian, came down with encephalitis. The couple owned an equine stud farm a thousand kilometers north of Brisbane; a month prior to the Hendra events, two horses on their farm died, and Preston assisted his wife with the autopsies. Neither husband nor wife wore gloves or masks. About ten days later, Preston was hospitalized with meningitis, but he recovered. Despite the pathologist's report concluding that one of the horses had died of a snake bite and the other of avocado poisoning, Dr. Preston alerted the Vic Rail hotline of her husband's illness and the equine deaths. She later said that her information was ignored. Preston's relapse the following year had no apparent source of reinfection, and this time he died. His tissue and archived samples from the dead horses all tested positive for Hendra virus.

Preston's death gave the Hendra investigation new life. Field promptly convened a variety of professionals to brainstorm about possible origins and routes of infection of this frustratingly enigmatic disease. The team assumed – probably incorrectly, it turns out – that the two more-or-less simultaneous outbreaks were epidemiologically linked, and since the most likely cause of any new virus in humans is a nonhuman animal, they decided that only a flying animal could plausibly spread the disease such a long distance. This was a fortuitous mistake, because it formed the basis on which the Hendra team prioritized birds and bats in their search for the disease host.

Field used his extensive network of contacts with wildlife rehabilitators to gain access to captive flying foxes, and the team drew blood from as many as they could get their hands on. When the lab results came back, several of the animals had tested positive for Hendra virus. Field and the other researchers were jubilant; at the time, they had little idea of the length and complexity of the research project in store for them, or that other henipaviruses would soon emerge into humans, thereby both confusing their job and raising its stakes immensely.

Although Hendra virus was identified extremely quickly after Preston's death, no one knew yet where it came from, how it was transmitted, or why more people who had been in contact with sick horses were not felled by it. The work of trying to establish exactly how flying foxes spread virus – to each other, to horses, or to other species – is one of the vital elements of an enormous, multifactorial, and still poorly understood, epidemiological and ecological conundrum. Theories abound: bats shed virus onto horses or grass through urinating or defecating; bats spit fruit pulp onto grass, but no hypothesis has been proven.

After Hendra was identified, testing of more than 5,000 domestic animals in the area – horses, dogs, cats, cattle, and poultry – failed to turn up additional Hendra-positive samples, as did testing of stored equine blood samples. As a result, Hendra was deemed a true "emergent" virus, meaning that there was no previous known instance of the disease in humans. Though other species can circulate and even transmit it, these bats are the only animals that can properly be called a natural host for Hendra virus.

Working out the mechanics of disease transmission is absolutely crucial to identifying and defusing situations where elements predisposing to a pathogen spillover come together to form a "perfect storm" of disease emergence. For example, one hypothesis about Hendra virus' transmission is that it occurs through uterine fluids when bats give birth. This means that time of year may be part of a perfect storm, as bats only give birth during certain months.

Many of the elements driving emergence of a variety of diseases appear to be connected to ecological changes; some ecologists argue that all emerging diseases, directly or indirectly, can be tied to environmental disturbance. Links between environmental disruption and disease are a critical component of why flying foxes and their pathogens may provide an ideal microcosm for studying emergence events. Flying foxes are widespread throughout the Indo-Pacific, a region that is undergoing enormous human-driven ecological changes. They also migrate long distances and live in groups that can number in the millions, both of which make their diseases epidemiologically complicated, and at least three and possibly more, of the multitude of viruses they carry can be fatal to humans.

For all of the above reasons, detailed long-term studies of the relationships among flying foxes, their pathogens, and humans, could yield previously elusive answers to some of the thorniest, most pressing questions facing humanity today, not just in countries that have experienced bat-hosted viral outbreaks, but around the world. How, and to what extent, are anthropogenic climate change and land-clearing driving pathogens into closer contact with humans? How many of the past two decades' infectious disease epidemics are attributable to our insatiable drive to consume other species for food and medicinal products? And, most important, through deconstructing the factors that drive pathogen emergence, can future outbreaks be reduced in frequency, lethality, and cost?

Another important reason to study Hendra, and other henipaviruses, is that, taken all together, the number of new viruses identified in flying foxes in such a short period of time is unprecedented in host/virus research. Bats in general seem to host an inordinate number of viruses: approximately forty have been isolated so far, and there is good serological evidence indicating that at least another forty are waiting to be described.

Nipah virus, another flying fox virus and so far the most deadly in the *Henipavirus* genus, killed 105 pig farmers and slaughterhouse workers in Malaysia in 1998-1999. Closely paralleling the recent pandemic of avian flu, in which more than 100 million domestic birds have already been killed, 1.1 million pigs were slaughtered in Malaysia to contain Nipah virus. In the past several years, both India and Bangladesh have reported deaths due to henipaviruses. Nipah virus has a high fatality rate (around 40%), which places it in Ebola's category in terms of human lethality. In comparison, the much-feared SARS corona virus has a fatality rate of about 14%.

Tioman and Menangle viruses are also newly-discovered henipaviruses. So far, Tioman has been found only in flying foxes in Malaysia. In Australia, Menangle virus has caused respiratory disease in pigs and flu-like symptoms in two humans. Australia Bat Lyssavirus, or ABL, was identified in flying foxes in 1996 and is a close relative of rabies. Two human mortalities from ABL have occurred in Queensland, one of them a woman who was bitten on the finger while removing a bat that had landed on a child's back at a barbecue. Bats around the world are associated with rabies viruses, which have the distinction of being 100% fatal to humans unless treated immediately. In the U.S., 75% of human rabies mortalities occurring between 1990-2000 were due to bat exposures, a huge and unexplained shift in the ecology of human rabies. In July 2004, four Americans died after receiving organ donations from a man who had not died of a stroke, as his doctors thought, but of a bat-variant rabies strain.

Even Ebola virus, perhaps the most baffling of emerging diseases owing to the fact that no one has been able to locate its wildlife reservoir, has been found in laboratory experiments to be excreted by bats. In China, Japanese encephalitis, a disease that kills thousands of people across Asia, has been isolated from two species of fruit bats. Ross River virus causes polyarthritis and its incidence in humans is increasing in Australia; the virus is known to be carried by flying foxes, though their role in transmitting it is unclear.

Emerging and reemerging diseases are on the rise and, in addition to their cost in human morbidity and mortality, are wreaking havoc on ecosystems. From lions in the Serengeti to frogs in Australia, pathogens that enter previously unexposed populations (usually arriving, directly or indirectly, via human activities) are decimating fauna large and small, winged, finned, furred, and scaled. There are now documentations of species becoming extinct due to introduced pathogens. The cost of addressing such diseases just in our own species is astronomical. The direct cost of SARS in one year, in the U.S. alone, was 11 billion dollars; the cumulative costs of HIV by 2002, 500 billion.

Though 70% of new diseases enter humans directly from wildlife species – whether or not there is a root cause of ecological disruption – few public health initiatives and disease investigations are taken on with ecologists, veterinarians, or wildlife biologists as integral parts of the team. Instead, we get hysteria by the popular press, and then exactly the wrong reaction by public health officials operating in a vacuum: more environmental damage in the form of ineffective and misguided mop-up campaigns, such as spraying pesticides to kill mosquitoes in response to West Nile virus, or killing palm civets in China to control SARS.

Even highly respected health practitioners and commentators, such as Lawrence Altman, an M.D. who writes regularly for *The New York Times* and has the ear of many people in the medical professions, are not suggesting alternatives. In an article entitled "New Microbes Could Become the New Norm" (*NYT*, March 9, 2004), Altman described public health officials as being in a "lose-lose situation" because they are trapped between the Scylla of creating needless (if no epidemic emerges) panic, and the Charybdis of having done nothing, should everyone's fear of a spillover event pan out. A third way, that of pursuing research into averting infectious disease spillovers through the allocation of funds into areas that could shed light on mechanisms of zoonotic disease transfer, received no mention.

Neither does the American medical system's nearly exclusive focus on coping with disease events after the fact come in for any serious criticism by those in a position to reform the situation. Nowhere is this more true than in infectious disease control, the backbone of which remains more sophisticated versions of measures instituted fifty years ago: surveillance to identify infections quickly when they happen, an infusion of resources to contain spread of disease, technology transfer to developing countries, and drug and vaccine development. Thus it is no surprise that, with an approach to disease control that is so weak on prevention, combined with worsening environmental destruction, annual infectious disease deaths in the U.S. have doubled since 1980. And still, America's premier governing medical bodies are silent when it comes to recommendations to stem the tide of emerging diseases. The National Intelligence Council 2000 report, "The Global Infectious Disease Threat and its Implications for the United States" states that, "In the opinion of the US Institute of Medicine, the next major infectious disease threat to the United States may be, like HIV, a previously unrecognized pathogen." But not a single strategy to help limit the spread of infectious disease by minimizing human-caused ecological degradation is mentioned. A 2003 report by the Institute of Medicine, entitled "Microbial Threats to Health: Emergence, Detection, and Response," lists thirteen factors driving disease emergence, three of which are climate change, changing ecosystems, and economic development and land use. Again, no strategies to minimize the influence of ecological factors on disease spillovers are discussed. America is still, with all our scientific might and wealth, locking the barn door long after the horse has been stolen.

The Consortium is attempting to address these enormous institutional gaps with endeavors such as the Henipa project, whose goal is to devise effective tools for disrupting disease emergence. First, however, the question "what changed to cause these ancient viruses to suddenly spill over into humans?" must be answered as thoroughly as possible. Because one can never hold an ecosystem still and untangle its individual components, or go back to a time before the disease emerged, this is a daunting question indeed.

In the case of virtually all the diseases that have passed from bats to humans, probably even rabies in the U.S., a major component of the answer is undoubtedly increased contact. (Paradoxically, although humans and bats encounter each other more frequently, bat species worldwide are experiencing large declines, particularly in the Old World tropics.) Certainly, bats and humans in eastern Australia, as well as in the rest of tropical Asia, have recently come to share a sizeable amount of habitat. In major cities up and down Australia's east coast, all you have to do is look up at sunset to see clouds of bats overhead; they have colonized botanical gardens, as well as suburban yards and urban plantings. Australia is cutting down its forests faster than any other developed country, particularly rapidly in Queensland. One of the most important goals of the Henipa research is to sort out which of the many factors altering bats' roosting and foraging behaviors are having the most profound effects. In addition to habitat loss, attractants are clearly playing a part in drawing bats toward humans. Some cleared land is now under fruit cultivation, thus providing a new and readily available source of food for bats; inhabitants of coastal cities such as Sydney and Brisbane have planted flowering eucalypt trees – one of the major food sources for flying foxes – to lure butterflies and birds to their yards, and have inadvertently invited in flying foxes. Knowing how all these elements interact is vital to comprehending how and why bats are ending up in suburban areas, and what can be done about it.

Brisbane's suburbs are perfect examples of living arrangements that have put bats and humans side by side. Thirty minutes from downtown Brisbane by train puts you in Hendra. The neighborhood is unremarkable, filled with large leafy trees, and smallish houses with peeling paint and concrete stoops. However, after strolling for a few minutes, you notice that hanging over many of Hendra's little yard-cum-paddocks are large mango trees – a fruit not native to Australia and now a favorite of flying foxes – and that the houses have tiny horse barns packed in beside them, because two race tracks, Doomben and Ascot, are smack in the middle of Hendra. These factors, in addition to there now being bats in the suburbs of Brisbane at all, may have contributed to the Hendra outbreak. Walking past Vic Rail's former home, with its pretty wrought-iron horse heads on the gate, I thought of how baffling his death must have been to his family and to the community, and of the bitter irony of loving horses enough to spend your whole life among them, then dying of a virus passed on to you by a horse. Nobody knows exactly how the virus spread among the horses in Hendra; but however the thoroughbreds acquired it, a pathogen that jumps from bat to horse, horse to horse, and horse to human, would be in clover here.

Though deforestation in Southeast Asia has been severe, there may be another landscape-scale ecological change with a more direct effect on Nipah emergence: *El Niño*-year forest fires in Indonesia. The theory holds that the fires, which were partially anthropogenic, created smoke haze throughout Southeast Asia, which negatively affected fruiting trees and forced flying foxes to turn up in new places in search of food. Stress from the fires may also have increased prevalence of viruses in the bats, and thus contributed to cross-species transference.

Other factors that could help precipitate a disease outbreak must be understood before a thorough roster of emergence prevention strategies can be arrived at. For example, how the bats themselves maintain the virus, and how the amplifier hosts (horses for Hendra, pigs for Nipah) act to make the virus more pathogenic to humans. New agricultural practices – such as the introduction of pig farms with high densities of animals into the middle of the jungle in Malaysia – are being examined to determine how they may have contributed to the Nipah spillover. Also, Malaysian farmers were in the habit of planting fruit trees around their pig enclosures, to add to the productivity of the land, which virtually guaranteed close contact between bats and pigs. An outbreak of Japanese encephalitis in Malaysian pigs (and humans) and a subsequent vaccination effort against that disease prior to the Nipah events may have helped spread the latter disease through piggeries, via the recycling of needles. In Australia, the high density of horses near the race tracks probably facilitated the ability of Hendra virus to cross species, by giving the pathogen more opportunities to get into horses and thus into humans.

One thing is clear from examining the increased habitat overlap between bats and humans: people are more unhappy about their new shared housing than are flying foxes. The bats are remarkably impervious to harassment by disgruntled human neighbors who don't like the sights, sounds, and smells that emanate from a colony. Mostly because these bats live in densely populated groups, they give off an intensely unpleasant odor. Their acrid feces can take paint off cars, and doesn't do wonders for the clean laundry hanging out to dry; and flying foxes are incredibly noisy animals, constantly arguing with each other about logistical details that arise when thousands of individuals occupy a few trees. People have tried extreme measures to get rid of flying foxes (often using fear of infectious diseases as an excuse), such as firing off rockets or smoking them out, and occasionally electrocuting them with a device called "Fire Fox" that consists of wires strung over fruit crops.

After watching the bats until it was nearly dark and most of them had departed in search of their dinners, we left to eat ours and to gear up for a long night. We arose at two in the morning, and by three a.m. we were at the field site ready to start bat-catching. The moon was tiny, hardly casting any light at all, but the sky was so thick with bats returning from foraging that it wouldn't have mattered anyway. As soon as a bat flew into the fine mesh net we had set up, two people rolled it down and Craig disentangled the flying fox, an extremely tricky proposition. Being bitten, of course, would be the worst type of potential disease exposure. Although there are no documented cases of someone catching a henipavirus from a bat bite or scratch, none of us wanted to be the first. Craig wore leather welding gloves on top of two layers of puncture-resistant gloves, and the rest of us wore only layered puncture-resistant gloves. We also wore safety goggles, face masks, and, despite the heat, long-sleeved, long-legged coveralls and boots. Nevertheless, one of the times I took off my goggles to adjust them, a low-flying bat urinated on my forehead. Craig and Carol told me I shouldn't worry because it was impossible not to get peed on when handling bats, they had suffered this indignity thousands of times and weren't dead yet.

Once a bat was freed from the net, we placed it in a pillowcase, tied the pillowcase shut and hung it on a line until we were ready to process all the individual flying foxes we had caught. The pillowcases, each with an angry bat inside, all bounced up and down next to each other, as though demons had possessed someone's laundry.

By about five-thirty, we were ready to begin processing. Craig took down a jumping pillowcase and untied it. Then, through the material, he pinned the bat by the neck with one hand and rolled the pillowcase down with the other to reveal a head. Someone else then placed a mask delivering anesthetic gas over the bat's face until the animal became unconscious. From just a few inches away, the bats were even more spectacular than at a distance. If you only looked at a face, you might be looking at a Chihuahua; with wings and claws, they looked like supernatural toy dogs. Unspectacularly, they were also crawling with a species of wingless fly that were as happy to jump on us as on the bats. Since whoever was holding the bat was gloved, it was impossible to remove the parasites and you either had to tolerate the horrible crawling sensation of fly legs on scalp and skin, or beg someone who was not wearing gloves to pick through your hair, find the insect, and pull it off.

Next we took turns weighing and measuring the sedated bat, drawing blood from a wing vein, and swabbing the oral cavity and urogenital area to get saliva and urine samples for virus testing. After painting red nail polish on the bat's claws (so we would know if we caught the same one again the next night) we put the animal back in the pillowcase to wake up, tied it on the line, and waited until the linen started hopping again before letting the bat go. Bats are not retiring animals, and when you gingerly open the pillowcase to free one, they look you furiously in the eye and ratchet up the already intense chattering noise, leaving little doubt as to what they think of you and of their temporary captivity. When the samples came back from the lab, we would know if any of the flying foxes we'd handled were henipavirus carriers. Presumably, some of them were, since Field's work indicates that seroprevalence in little reds is about 15%.

The ultimate purpose of the many hypotheses, and the years of data-gathering, will be to produce mathematical models that can predict potential hotspots of disease emergence. But a model is only as good as the information plugged into it, and so the Henipa team has allotted at least five years to collect data. Some strategies to prevent another outbreak of Nipah in Malaysia have already been put into effect, however. Fruit trees are no longer planted around pig farms, and the ones that were there have been cut down. In addition, some farms are now screened in to reduce contact between bats and pigs. There has not been a Nipah outbreak in Malaysia since these measures were put into effect.

Because Hendra virus has caused only two human fatalities, there is less urgency to change human behavior or equine management in Australia, compared with the urgency of altering pig management in Malaysia. Still, recommendations to stable horses at night when bats are feeding and wear gloves and protective clothing around any horse showing symptoms of a respiratory virus may be partially responsible for the fact that there have been no human deaths, and only one equine fatality, due to Hendra virus since Mark Preston's death set the wheels of the Henipa project fully in motion.

An important reason the Consortium is one of so few institutions that have achieved concrete successes in unraveling these extremely complex disease issues is that, on a structural level, all its undertakings are designed as multidisciplinary collaborations. Since the Consortium itself – headed by Peter Daszak, one of the world's foremost experts on emerging diseases from wildlife – is a joint venture of Harvard's Center for Health and the Global Environment, Tufts University's School of Veterinary Medicine, Johns Hopkins' School of Public Health, the United States Geological Survey's National Wildlife Health Center, and the conservation organization Wildlife Trust, all of its investigations are conceived from the beginning as cooperative efforts among professionals from numerous disciplines.

Donald McNeil, one of *The New York Times*' most respected health writers, raised this issue of lack of "cross-talk" in the context of our failure to foresee infectious disease outbreaks. In his editorial, "The Next Generation of Diseases are in Hiding, Somewhere." McNeil wrote, "In 2004, the world will be on the lookout for the re-emergence of SARS, monkey pox, new forms of flu and the unexpected," and blamed the "little cross-talk between environmentalists upset over dying apes and doctors treating dying people," for perpetuating an epidemic of Ebola in the Congo which lasted from January-June of 2003 and killed 120 people. Gorilla and chimpanzee deaths from Ebola (some primatologists think that thousands of lowland gorillas perished) had been documented two months before any humans became ill. The human outbreak almost certainly began with consumption of infected gorilla or chimp meat. Though identifying it as a problem, McNeil seems to accept this paucity of cross-talk as inevitable, and does not speculate on how to remedy it. Thus, when he poses the rhetorical question, "But must epidemics always catch humanity by surprise?" the answer he posits is, clearly, yes. McNeil's lament, and it is offered as an excuse, is that "the world does not put the clues together in time."

The work of Consortium scientists has demonstrated that it doesn't have to be this way. Sadly, while researchers are stretched thin and funding even thinner, spillovers from the *Henipavirus* genus continue to claim human lives in other places, so far unforeseen and unplanned for. From January to April 2004, an outbreak of a Nipah-like virus occurred in Bangladesh. The CDC tested blood, bone marrow, and other tissues sent from Bangladeshi patients, and determined that 35 deaths and many more illnesses were conclusively caused by this virus. The fatality rate in some areas of the outbreak was as high as 70%. Troublingly, none of the surviving Bangladeshi patients reported contact with a pig host. In one cluster of cases, a majority were boys who had been eating fruit directly from trees early in the morning, presumably not long after bats had fed there. In a different district, several people seemed to have caught the virus directly from other sick people. Initial sampling of flying foxes in the infected areas indicates, as expected, that some of the animals are carrying the Nipah-like virus. However, both of these mechanisms of disease transfer are new to Nipah ecology, and probably mean that the virus has mutated and is now more readily transferable to humans. This is scary news on many fronts: obviously, more routes of acquiring a fatal virus is bad for people. But it also does not bode well for flying foxes, which may become targets of eradication campaigns if Nipah virus infections become widespread. Under such conditions, the Henipa team must work harder than ever, both to provide alternative methods of preventing pathogen spillovers, and to convince people, as has been proven time and time again, that eradicating wildlife reservoirs is an expensive, ecologically damaging, and ineffective way to control infectious disease.

Conservationists want to spread the word that environmental encroachment has negative consequences for humans. Physicians and epidemiologists think that understanding human health on a broader, ecosystem scale will help clarify the opacities of human diseases and their origins. The rest of the world can only hope that together, these scientists, motivated as they are by different yet complementary interests, can keep the heart of such a long-term, complicated effort pumping long enough to get some answers. When or if they do, the reply to the question, "must epidemics always catch humanity by surprise?" may change from *yes* to *no*. Or, at the very least, to *not every single time.*