only a small percentage of the countless microbes on Earth are ever thoroughly investigated, and when one merits close attention, it’s typically not for a propitious reason. *Bacillus anthracis* and *Clostridium botulinum*, the bacteria that cause anthrax and botulism, respectively, are among the lucky few. The rest cycle anonymously through Earth’s water, soil, air, animals, and plants.

Within the last decade, and certainly since 9/11, scientists and officials have grown concerned about the threat of disease-causing microbes to both human health and national security. Of particular concern to Jacqueline Fletcher, the director of the National Institute for Microbial Forensics and Food and Agricultural Biosecurity at Oklahoma State University, are the bacteria that infect plants. Plant disease is typically not a prominent security concern, yet Fletcher espouses the many ways plant security figures indirectly in national security and economic planning.

Fletcher became president of the American Phytopathological Society soon after the anthrax attacks of late 2001, which raised public concern about dangerous pathogens and helped to launch a new subfield of pathology. Microbial forensics, as the area of research is known, is concerned with rapidly diagnosing pathogens and tracking the source of outbreaks—a capability that would be particularly helpful in the event of a biological attack on agriculture. The *Bulletin* spoke with Fletcher about how plant forensics differs from other types of investigation and why the public should be concerned about the impact of plant disease.

**BAS:** What is plant microbial forensics?

**FLETCHER:** There are some distinct differences about forensic plant pathology and traditional plant pathology, although they are closely related. In traditional plant pathology, scientists are interested in identifying plant diseases and detecting and identifying the pathogens, with the end goal of treating the disease, minimizing the damage, applying the right kinds of management strategies, and
FLETCHER: Where do plant diseases come from, and how are they transported?

**BAS:** Many people may not think about it, but plants of all kinds are affected by diseases, just like humans and other animals are. These diseases can be caused by a variety of pathogen types, including fungi, viruses, bacteria, nematodes, parasitic plants, and others. And they are disseminated in a number of ways. Some can overwinter in weedy hosts around field borders, in the soil, or in insects that may be acting as vectors. Or they can arrive from other areas on wind currents, which often happens. The recent influx into our country of soybean rust, which is a fungal disease, arrived in Florida from South America on the winds of hurricanes.

It had been carried by wind across the Atlantic Ocean from Africa and Europe and was established in Brazil and other South American countries where a lot of soybeans are grown. In fact, the U.S. Department of Agriculture (USDA) had sent scientists down to South America to assess where it was and to develop epidemiological models about how soon it might get into the United States by natural means. They felt that it would probably get here sooner or later, but they couldn't exactly say when. They didn't expect it to come as soon as it did. By looking at the location of the outbreak in Florida, and by assessing the maturity of the lesions on the soybean plants, they identified that it had come into the United States at the time of certain hurricanes.

**BAS:** How else can you distinguish between a pathogen that appears through a natural process, and one that has been introduced deliberately?

**FLETCHER:** That’s a really critical question, and it’s one that we have been dealing with intensively, because it’s the deciding factor between whether an incident will be handled by normal plant pathology diagnostic laboratories, or whether law enforcement needs to be called in.

Each disease and pathogen has its own set of features that would be considered diagnostic. The pattern of disease in a field can be indicative: If you see multiple entry points of a disease versus one; if the outbreak is occurring in the middle of a field versus the edge; or if the disease is occurring in a place that it’s never been before. If the pathogen strain has never been seen before; if the symptoms are not quite what you think they should be; if the pathogen is transmitted naturally by an insect, but there’s no insect present; or if something else is off—then you begin to think that something’s not normal. That doesn’t necessarily mean that the pathogen was introduced intentionally. It just means that it’s unusual and might warrant some further investigation.

**BAS:** What would the response be like if officials identified a pathogen as intentionally introduced?

**FLETCHER:** Unless there was some sort of tip-off such as a threat letter, law enforcement would not get involved initially. The farmer or an agricultural extension agent would assess the situation and might notice something unusual that would trigger a call to the USDA. Or, the agent might collect samples and send them to the state’s plant diagnostic laboratory, where the diagnostician might recognize that there is a new pathogen or that something else is unusual. If it’s a select pathogen, the USDA must be notified immediately and must confirm the diagnosis. If it is confirmed, then the USDA will notify law enforcement who will send investigators.

**BAS:** What keeps pathologists and law enforcement officials from assuming that every outbreak is a bioterrorist attack?

**FLETCHER:** It’s really the other way around. We’re so focused on plant diseases that occur naturally, because again, there are plant diseases everywhere, all the time. It’s amazing that all plants aren’t sick all of the time. Our normal viewpoint of plant diseases is that they are naturally introduced, and most of them are. It’s very unusual for us to think about them not being naturally introduced—other elements that might suggest that a disease was not naturally introduced could be that infected plants are arrayed only along the edge of a road and not within or on other sides of the field, or that one field has the disease while an adjacent one having plants of the same age doesn’t.
than somebody being disgruntled with a neighbor or something like that.

But the mood and the perspective of all Americans changed after 9/11 and the anthrax attacks. We know that many countries, including our own, had bioweapons programs in the past, and part of those programs included conceptualizing or even moving toward preparation of plant pathogens as agents that could be used as weapons. I don’t know of any clear evidence that they ever were deployed in that way, but they certainly were part of bioweapons development programs.

**BAS:** Has there ever been a verified instance where a plant pathogen was deliberately introduced?

**FLETCHER:** No, with the possible exception of a few cases where biological controls have been tried for situations such as controlling a water weed. But no, I’m not aware of any case where a plant pathogen is known to have been deployed for a harmful purpose.

**BAS:** So what is the justification for investment in the field of plant microbial forensics?

**FLETCHER:** Well, I’m not sure that everyone shares the same opinion on this. My opinion is that it’s very important to be prepared for this sort of thing, for a number of reasons. No one really felt that preparation was a high enough priority for human pathogens such as anthrax, until we had an incident. And then everybody wondered why there had not been prior preparation.

There are a number of factors that make plant pathogens attractive to be used in an adverse manner. I’m not just thinking about terrorism—I’d like to make that point. Other kinds of illegal use or harmful application could be for economic gain, either from a competitor or from a country that is trying to sell the same types of commodities in the world market. It could be that one country is trying to gain an economic advantage over another, because many of our agricultural commodities could be affected by embargoes, or quarantines. This happens with natural diseases.

Also, many plant pathogens are easy to acquire, and handling them requires little training or equipment. Most plant pathogens are also harmless to people, so unlike with human pathogens there is no personal danger to the handler. There is a lower ethical hurdle to their use, as well, since humans are not the immediate target. Other factors include the huge acres covered by crops, forests, and rangelands; if a pathogen is introduced in a remote area there may be a very long lag time until it’s discovered, which may facilitate its establishment and increase its impact.

**BAS:** How big an economic impact could a plant pathogen cause?

**FLETCHER:** One good example of a naturally occurring disease was citrus canker in Florida. Citrus in Florida alone is an $8.5 billion industry. Citrus canker and other disease are threatening the production of citrus in Florida. Hurricanes have been instrumental in this process, spreading these two pathogens significantly farther in one season than had been predicted as possible.

The other citrus pathogen that came into the United States recently was the agent of citrus greening disease. The disease’s official name is Huanglongbing. These two diseases together forced the USDA’s Animal and Plant Health Inspection Service to change their citrus disease management strategy in Florida from eradication—which they had been trying with citrus canker—to a management plan. In other words, they’re trying to develop policies for living with these diseases now, instead of trying to eradicate them.

**BAS:** How would improving basic plant pathologies capabilities strengthen biosecurity?

**FLETCHER:** Before 9/11, many of our nation’s plant diagnostic clinics were understaffed and underfunded. There had generally been one lab in each state that did this work, and they all pretty much worked independently. So each one developed their own methods and became experts in the diseases that were important to that state. They didn’t interact very much.

As a result of the new emphasis in these areas after 9/11, the National Plant Diagnostic Network was created. It’s allowed all of the diagnostic laboratories to work together, and each lab got enough support to purchase two major tools: the capability for real-time polymerase chain reaction, which is the primary method of choice for diagnostics now, and the technology for distance diagnostics and virtual conferences. Now, if pathologists encounter something that they’re not familiar with, they can take a digital picture of it, put it on the network, and other diagnosticians can see it. They work in concert, so that they know more about when a disease is starting somewhere and where it might go.

**BAS:** Prior to 9/11, why were these diagnostic centers left shorthanded and underfunded?

**FLETCHER:** There was little recognition of the need or the role that they could play. Funding for the plant side of agriculture in general has always lagged behind that for livestock and the animal production side. And then, of course, agricultural research has generally been far less well funded than medical research and medical technology. Plants are almost always at the bottom of the list, if they’re on the list at all, for funding.

Funding that came available through the establishment of the national network has resulted in each lab having a full-time staff person, and the labs all have at least a minimum level of technology and communication capability consistent among all the units. That has increased our capacity to respond to naturally occurring diseases that we have all the time. These investments are not for tanks and guns that we hope will sit in a corner and rust; we can put them into our daily practice of plant pathology, making things better for the farmer, the consumer, and the federal government.

**BAS:** Is it inevitable that exotic plant diseases from around the world will make their way to the United States?

**FLETCHER:** Most people who have studied that question feel that there is a reasonable likelihood that just about any pathogen in the world could end up here at some point. The amount of global trade has hugely increased, and people travel more, so we have to accept that it is going to happen. That’s another reason why preparation is good.

**BAS:** Do farmers see it the same way? Have they welcomed the investment in microbial forensics?
**FLETCHER:** There’s a mixed reaction to it, and that’s very normal. One side feels that the deliberate introduction of pathogens is very unlikely, and the money is better spent in other ways.

It’s just so much more likely that farmers’ everyday problems are going to be caused by naturally occurring pathogens, that they feel the money shouldn’t be spent on forensics. On the other hand, there certainly are scares, such as the foot-and-mouth outbreak in Britain, that affect not just the economy but also the psychology. British farmers were personally devastated by the implications of that disease. The farmers who are familiar with what happened in Britain are more aware of the benefits of being prepared.

**BAS:** Are there indications that microbial forensics is gaining traction beyond the pathology community?

**FLETCHER:** We’re doing some training of the law enforcement and security communities, because a large number of people could be called in to investigate an incident like this—the FBI, the police, etc. They know their jobs very well—they know incident command, they know emergency management—but most don’t know plant pathology. We’re preparing to do a field exercise in Oklahoma, where we’ll bring in members of those communities. We’re going to have them go out and sweat in a wheat field, so that they can see what it’s like to be in that kind of environment and how they would go about investigating a potential crime scene in an agricultural setting.

We’re finding a lot of interest in these sessions. We weren’t sure if people were going to be enthusiastic about coming to Oklahoma and going out in a wheat field, but they are!

**BAS:** How does an agricultural crime scene differ from a traditional one?

**FLETCHER:** Most people think about forensic investigations as going to the scene of a murder—you have a body and you question the bystanders—we’ve all seen that on television. When law enforcement personnel come to a wheat field, many may not know where to start. They don’t know what kind of details they should pay attention to, what kinds of features of the landscape would be important to understanding that initial critical question, which is “has a crime occurred?” And they don’t know what kind of samples to collect. Should they collect leaves, or roots, or the whole plant? What should they take pictures of? Do they need to collect soil? Do they need water samples? What kinds of questions should they ask the farmer?

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They don’t know that they should look for the pattern of the outbreak in the field or other signs that could provide relevant clues as to the disease’s origin.

**BAS:** How do the epidemiological and forensic tools differ for plant pathology, as compared to animal or human pathology?

**FLETCHER:** Because the plant pathology community lags behind in terms of funding, research, and knowledge, the best diagnostic methods for many plant diseases are relatively nontechnical. They might also be time-consuming, not very sensitive, or not very reliable. For example, the pathogen causing citrus canker is closely related to other bacteria that don’t cause citrus canker. When canker first became a big issue, the test we had in place didn’t differentiate between those bacteria, which was a serious issue that has since been corrected.

Some plant diseases require pathologists to determine details about the pathogen strain before deciding if it’s a high-threat pathogen or not. And sometimes that strain discrimination can only be done by introducing these pathogens into a series of plants called differentials. The reactions of strains of the pathogen will differ with each cultivar that is part of the differential test. You can imagine how long this takes—you have to grow the plants, inoculate them, put them in the greenhouse, wait for symptoms to develop, and then determine which plants get sick. For forensics you need tools that are more rapid and more reliable than that sort of operation. But we haven’t developed those tools for all plant pathogens.

This is one of the differences between the human situation and any type of agriculture, be it animal or plant. Humans are a single species, and there are probably 10–15 diseases that are really bad for humans. There are hundreds of plant species, and each of them has their 10–15 major diseases. When you think about it, that’s a huge challenge. Pathologists have developed the most modern technologies only for the most threatening plant pathogens. This dearth of research also impacts the effectiveness of DNA databases. Many of the modern methods for identifying pathogens are based on “fingerprints” of DNA banding patterns, on pathogens’ reactions to certain kinds of chemicals, or on their ability to metabolize certain kinds of compounds. A researcher can enter a fingerprint, so to speak, into a database to find matches, but the test is only as good as the information in the database. And most of the databases are composed primarily of human pathogens and some zoonotic pathogens. The amount of plant pathogen information in the databases is relatively small; therefore the results of investigations are not as robust as they might be if there were more pathogens in the databases to which samples could be compared. The system is getting better with each addition of a new plant pathogen into the databases, but significant progress is very slow.