Design for Biosecurity

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Lecture 10

Anthrax Types and Preventive Measures

Welcome to our tenth lecture! In the last session, we began our exploration of anthrax, focusing specifically on cutaneous anthrax, which we established is not a newly discovered disease. This pathogen has been known for centuries. However, it is only in recent times that anthrax has become one of the hallmark agents of bioterrorism. We concluded the previous class by discussing the symptoms of cutaneous anthrax, where we observed the swelling that forms at the infection site, followed by the appearance of a black spot in the center. Over time, the swelling subsides, leaving behind a small depression with a characteristic black mark. This transition from stage one to stage two is a key identifier of cutaneous anthrax.

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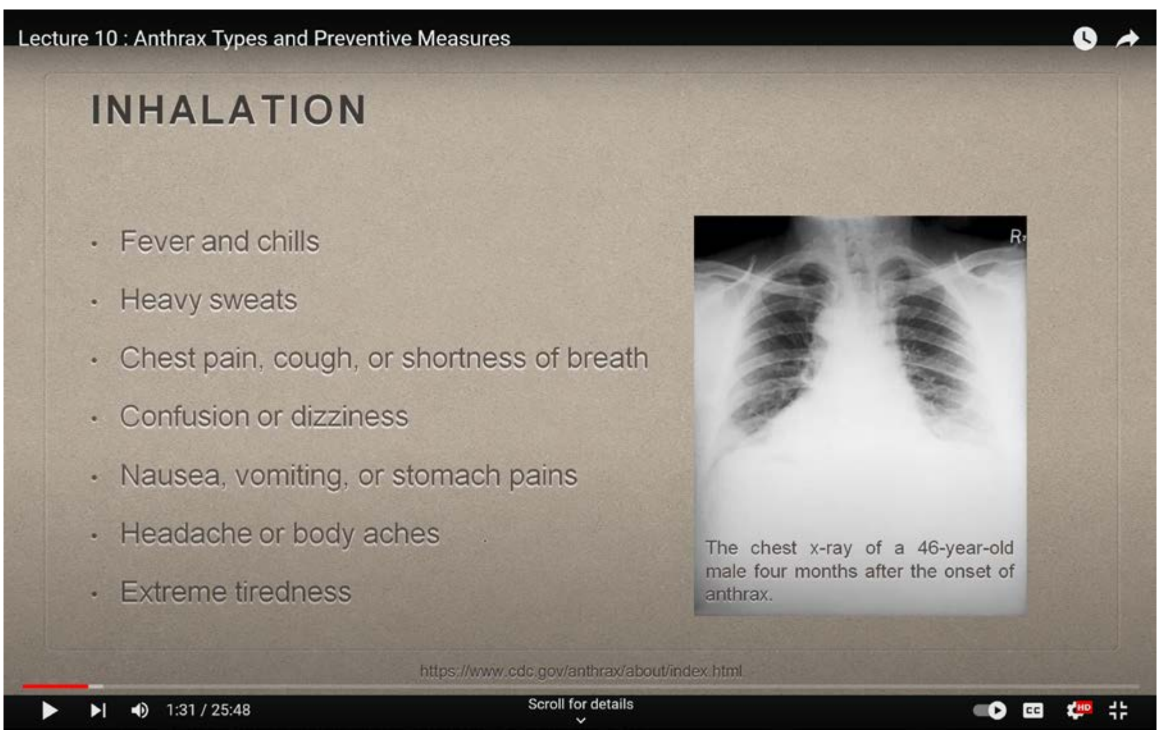

Today, we will shift our focus to inhalation anthrax, which, as I mentioned before, is the most dangerous form of the disease. This is because the spores are inhaled, directly affecting the lungs. Let’s examine the slide before us: it shows a chest x-ray of a 46-year-old male, taken four months after the onset of inhalation anthrax. You can see these infected areas within the lungs, marked by anthrax spores.

The inhalation of anthrax spores severely compromises the alveoli, the small air sacs where the crucial gas exchange occurs, carbon dioxide is expelled and fresh oxygen is absorbed into the blood. When these alveoli are infected, the oxygen intake is drastically reduced, leading to respiratory distress. The body, starved of oxygen, quickly begins to deteriorate. The symptoms include extreme fatigue, headaches, body aches, and nausea. These signs are a direct result of oxygen deprivation.

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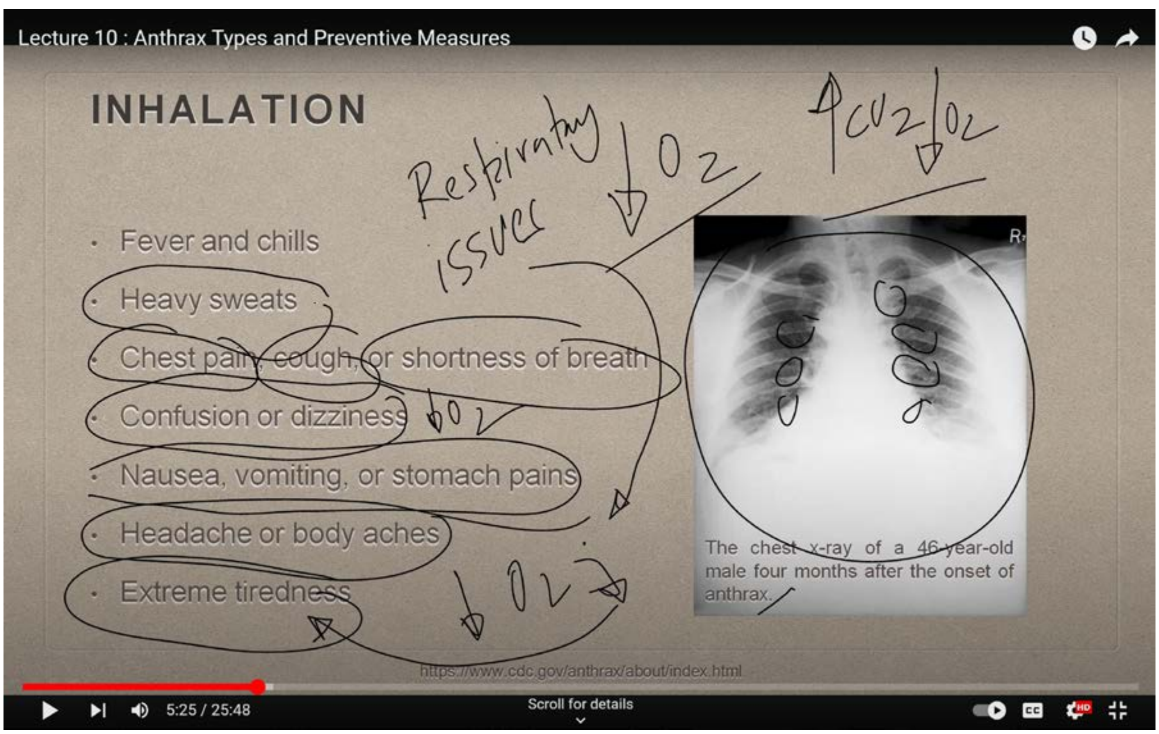

The lack of oxygen in the brain can cause confusion and dizziness, key indicators that the brain isn't receiving the necessary oxygen and nutrients to function properly. This is something crucial to remember. Whenever you experience such symptoms, it’s a clear signal that the brain’s oxygen supply is insufficient. For instance, this is why you're often advised not to eat heavy meals before late-night study sessions. Heavy meals divert your energy towards digestion, reducing the energy available for brain function, which is why you may feel sluggish or unable to focus after eating. Eating lighter and earlier ensures your brain has enough energy to stay alert when you need it most.

Now, the debilitating effects of inhalation anthrax are similar. When infected, your body simply can’t sustain the same level of activity due to the lack of oxygen and energy. Imagine the devastating impact this could have on a military unit. If inhalation anthrax spores were introduced into the environment or food supply of an army base or to soldiers stationed along national borders, it could severely compromise their operational effectiveness. This highlights the dangers posed by anthrax as a biological weapon, an entire unit could be rendered inactive through widespread exposure to this pathogen.

Understanding the mechanisms of inhalation anthrax, particularly its ability to incapacitate individuals by depriving them of oxygen, emphasizes the importance of detection and prevention. It also sheds light on the sinister potential of anthrax as a tool of warfare or terrorism. This awareness should deepen our appreciation for the necessity of developing effective sensors to detect not only active anthrax bacteria but also its dormant spores, ensuring early intervention and the safeguarding of public health and security.

Let’s take a closer look at the progression of anthrax symptoms. The infection often starts with severe chest pain, accompanied by a persistent cough and shortness of breath. These symptoms are indicative of the damage that inhalation anthrax does to the lungs. In addition, there’s heavy sweating, along with fever and chills. Interestingly, the heavy sweating might serve as a potential indicator for early detection through sensors, as it releases numerous volatile compounds. While this is just a speculative idea, it is something worth exploring for the future.

Next, let's talk about gastrointestinal anthrax, which results from consuming poorly cooked or raw meat, or animal products that are contaminated with anthrax spores. This form of anthrax leads to fever and chills, swelling of the neck and glands, sore throat, hoarseness, and pain while swallowing. As the infection worsens, there is nausea, vomiting, often bloody vomiting, and even bloody diarrhea. Be careful not to confuse this with tuberculosis (TB), as the symptoms can seem quite similar. However, the distinguishing feature is the presence of blood in the vomit or stool, which signals that the blood vessels are being damaged by the anthrax toxins.

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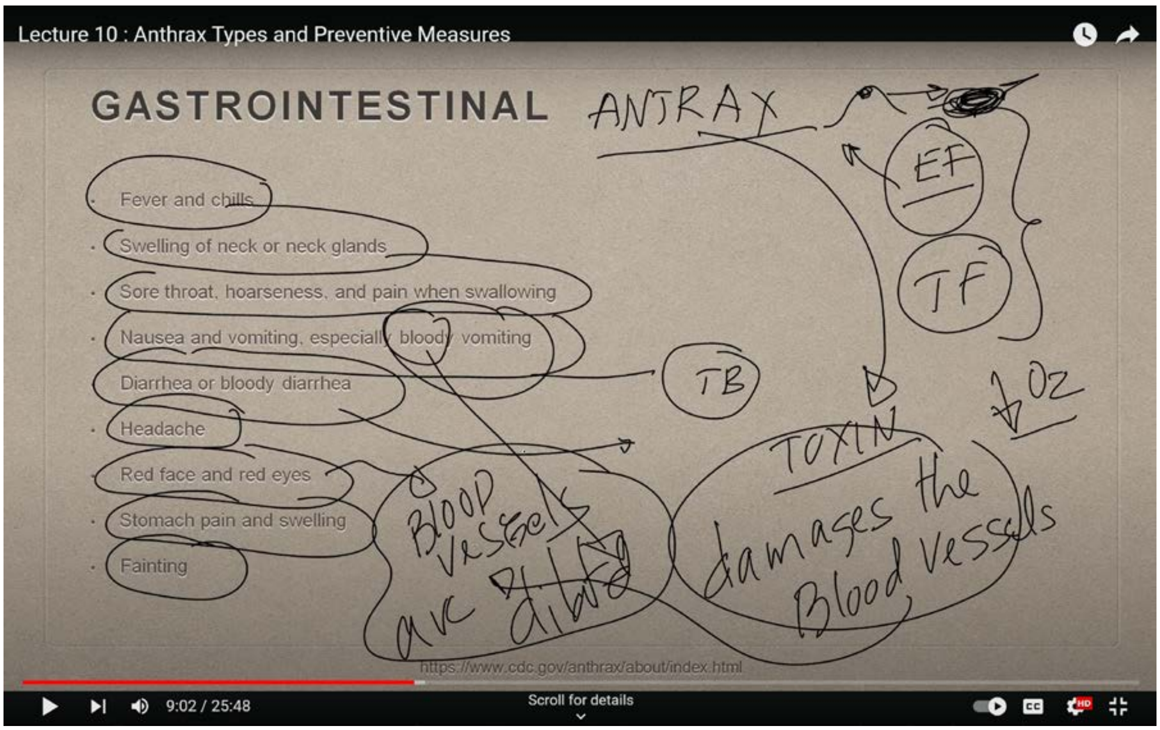

When blood vessels are damaged by the anthrax toxins, blood can leak out through various orifices, from your cough, your stool, and other unexpected places. This is because the toxins disrupt the structural integrity of blood vessels. Referring to the anthrax bacterium's structure, it has an extracellular polyglutamate (PDGA) capsule, as well as two key toxins: the lethal factor (LF) and the edema factor (EF). Both of these are encoded on the bacterium’s plasmids. The edema factor leads to swelling, while the lethal factor disrupts vital bodily functions.

The infection progresses through stages, initially manifesting as swelling, often followed by the appearance of a black spot in the center of the infected area. As the infection advances to stage two, there is significant damage to the blood vessels, which results in reduced oxygen levels. The patient's face may appear red, and their eyes bloodshot due to dilated blood vessels. This dilation occurs because the body is trying to compensate for the lack of oxygen by increasing blood flow to the affected areas.

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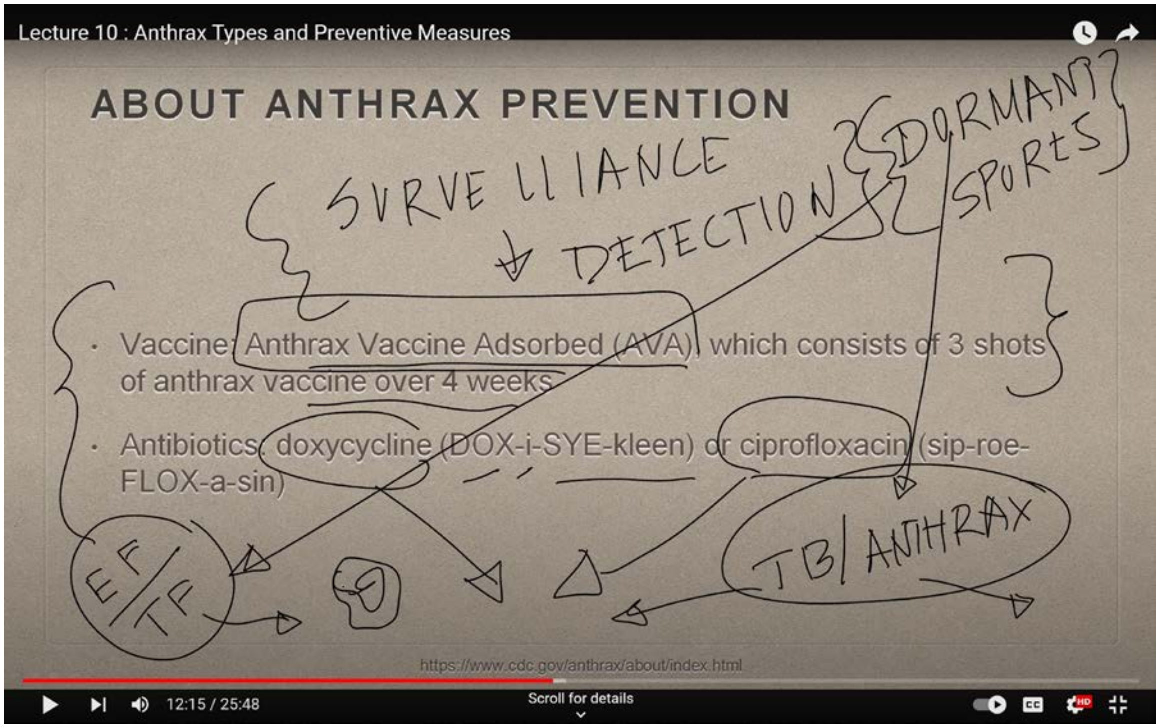

Now, let's shift focus to prevention. One of the key preventive measures is the anthrax vaccine adsorbed (AVA). This vaccine involves three shots administered over four weeks. However, there are challenges in maintaining preparedness for an anthrax outbreak. You can either stockpile the vaccine, but it might lose efficacy over time and incur storage costs, or you could develop rapid production methods. Alternatively, widespread vaccination of the population might be the best strategy, although this would require significant resources and planning.

In any case, the old saying holds true: "Detection is better than cure." Early detection is crucial, and there must be a robust surveillance system in place to catch the infection before it spreads. The antibiotics most commonly used to treat anthrax are doxycycline and ciprofloxacin. These antibiotics are effective but must be administered early. That's why accurate diagnosis is essential, because the symptoms of anthrax and TB overlap significantly. Therefore, it's important to consult a specialized doctor to ensure proper diagnosis and treatment. Misdiagnosis can lead to improper treatment, which is particularly problematic when dealing with dormant spores of either pathogen.

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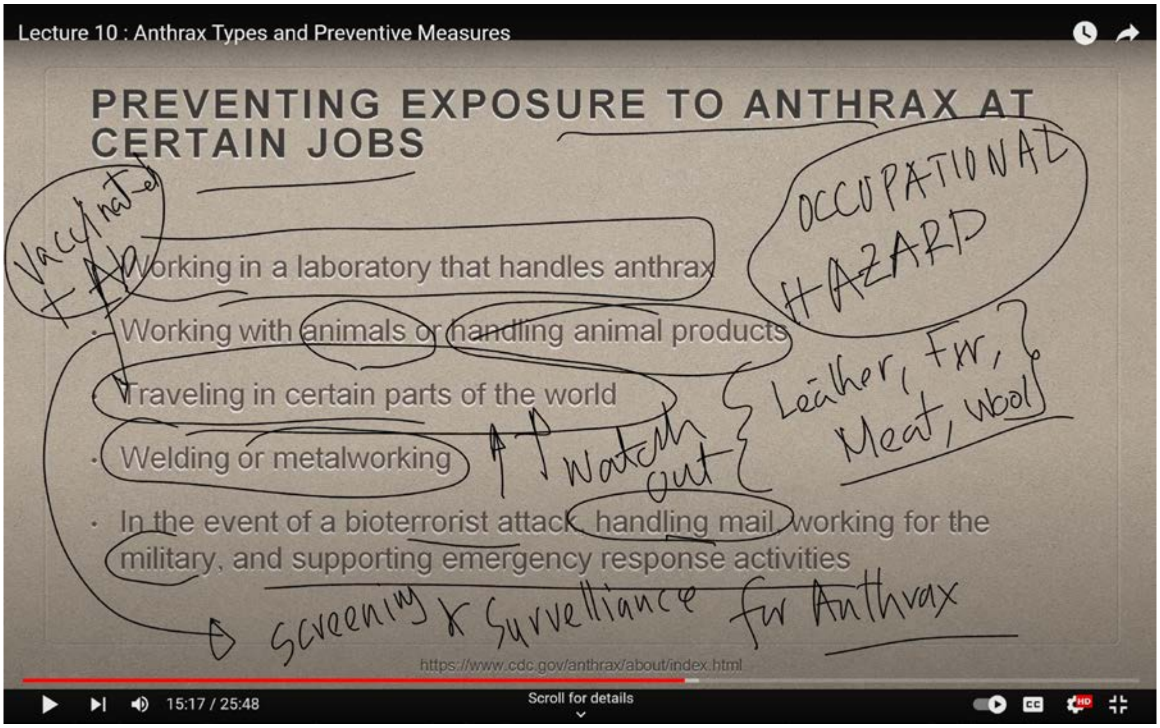

The challenge posed by dormant spores is significant and complex. As we delve deeper into this topic, it will become evident that our primary goal is to detect these dormant spores effectively. This challenge extends beyond anthrax to other diseases, such as tuberculosis (TB), where a dormant phase is present.

Remember those plasmids we discussed, POX1 and POX2? These plasmids encode essential factors: the edema factor and the toxic factor. Understanding the sequence and the products of these biomolecules is crucial. These factors are pivotal in the development of vaccines. By introducing these factors into an animal, the animal's immune system responds by producing antibodies. These antibodies are then used to screen and develop vaccines, marking the initial step toward prevention.

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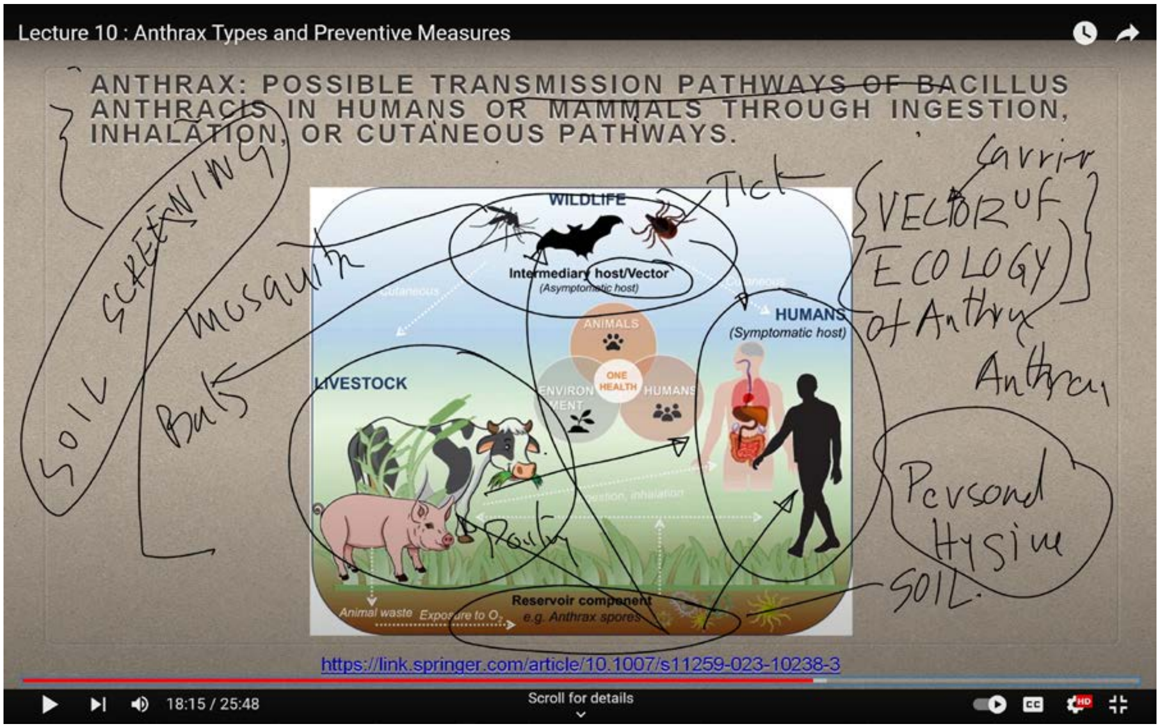

Now, let’s focus on preventive measures, particularly in occupational settings. Anthrax is a known occupational hazard, a technical term used to describe risks associated with specific jobs. If you work in a laboratory handling anthrax, you are in a high-risk environment. Anthrax is classified as a Category A pathogen, meaning extreme caution is required. Working in such laboratories demands stringent safety protocols and high-security measures to prevent exposure.

Additionally, if your job involves working with animals or handling animal products, you must exercise extreme caution. This includes dealing with items like leather, fur, meat, and wool. These materials can be sources of anthrax spores, so proper safety procedures are essential to minimize risk. Always remember, the nature of your work determines the level of risk, and it is crucial to implement appropriate safety measures to protect yourself and others.

Hence, periodic screening and surveillance for anthrax are essential in certain parts of the world. There are specific regions where anthrax is notably prevalent, and I will illustrate these regions on a map shortly. If you are traveling to these high-risk areas, it is crucial to ensure you are vaccinated in advance and carry antibiotics, such as those containing ABA (anthrax vaccine adsorbed).

As previously mentioned, anthrax related to welding and metalworking is an emerging concern. This form of anthrax is particularly alarming because it affects a large number of individuals working in the welding, metal cutting, and related industries. This issue was not widely recognized in textbooks when I studied, highlighting the evolving nature of these risks.

In the event of a bioterrorist attack, handling anthrax samples is critical, especially if you work in military or emergency response roles. Understanding these basic principles is vital for ensuring biosecurity during an anthrax outbreak.

To provide a broader perspective, let's review the transmission pathways of Bacillus anthracis, the bacterium responsible for anthrax. Anthrax can be transmitted through ingestion, inhalation, or cutaneous (skin) contact.

Consider the following flow chart for a comprehensive view. It illustrates the interactions among various elements in the anthrax transmission cycle:

- Livestock (including poultry, though not shown in this diagram) can be infected.
- Wildlife may act as vectors, spreading the disease.
- Humans come into contact with these vectors or infected animals.

The cycle begins with the reservoir, the soil, which can harbor anthrax spores. These spores can then infect livestock, wildlife, and humans, perpetuating the cycle of infection. This overview emphasizes the importance of understanding vector ecology, or the carriers of anthrax, to effectively manage and prevent outbreaks.

In the context of anthrax, vector ecology encompasses all potential carriers of the disease, including various animals and insects such as ticks, mosquitoes, and bats. Understanding these carriers is crucial for effective surveillance, safety, and prevention measures. As we derive food from animals and work in soil or other environments where anthrax could be present, maintaining meticulous personal hygiene is essential.

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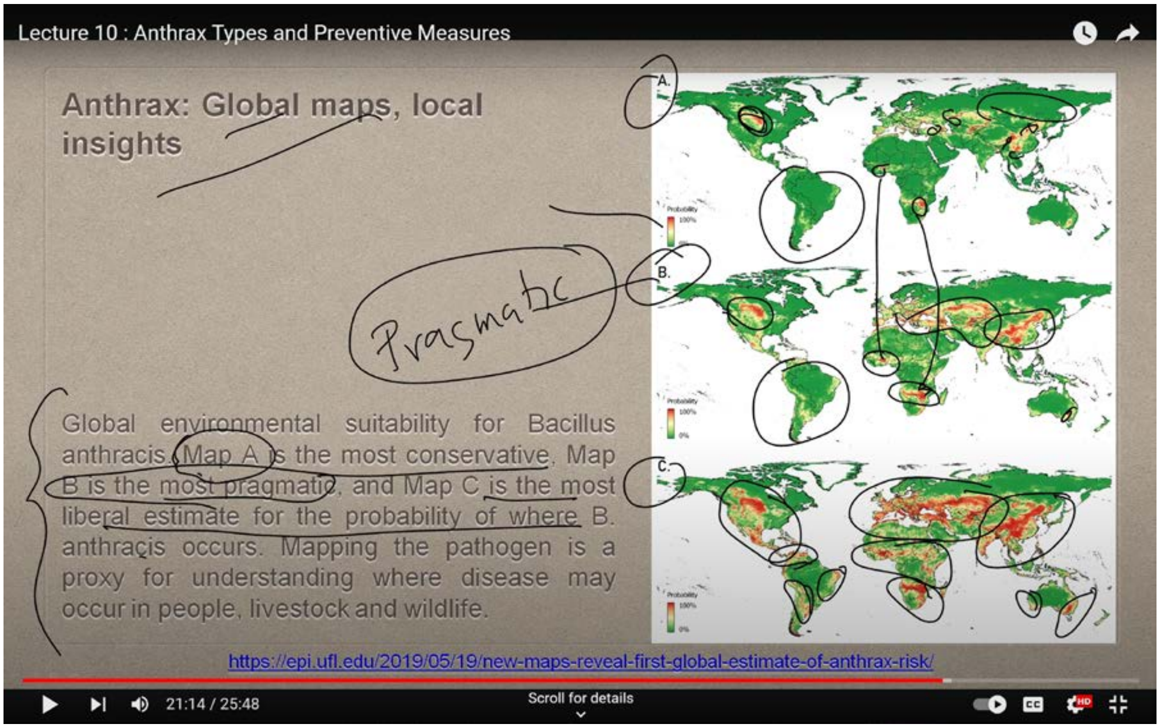

As previously discussed, anthrax can enter the body through three primary routes: cutaneous (through the skin), ingestion, and inhalation. Therefore, periodic soil screenings in areas where anthrax is suspected or might emerge are vital. This is especially important when traveling to regions identified as high-risk for anthrax.

Now, let’s examine the global map of anthrax distribution. This map is divided into three sections: A, B, and C. Each map provides a different perspective on anthrax risk:

- Map A illustrates the global environmental suitability for Bacillus anthracis. This map is considered the most conservative, indicating areas where anthrax is present but not likely to spread extensively. Red areas on this map include parts of China, southern Africa, and certain regions near the U.S. and Canada. Southeast Asia and Russia appear almost free of anthrax according to this map. It is a cautionary guide suggesting carefulness when traveling to these areas.

- Map B presents a more pragmatic view of anthrax risk. This map shows a broader area of concern, with more prominent red regions indicating higher risk. It reflects a practical assessment of anthrax distribution, highlighting the need for preventive measures, potential vaccine stockpiling, and more efficient vaccine production methods in high-risk areas.
- Map C provides the most liberal estimate of anthrax occurrence. This map shows an extensive range, including significant portions of India and the eastern coast of India, as well as Australia, which is relatively unaffected. Although this map might seem overly inclusive at times, it offers a broad perspective on potential risk areas.

Thus, while Map C might be considered overly cautious, Map B is often favored by strategists as it balances practical risk assessment with actionable preventive measures.

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It is not advisable to rely solely on a conservative approach. Instead, I recommend using Map B, which is the most pragmatic and realistic representation of anthrax risk. However, the choice is ultimately up to you based on how you view the world, as these maps are predictions based on possibilities and probabilities for anthrax.

Next, I will present another map focusing on anthrax prevalence across the continents of Asia, Europe, and Africa. This map provides data from 1992 to 2020, covering nearly 28 years. The prevalence rates shown are quite significant: 25% for Asia, 23% for Europe, and 29% for Africa.

These figures reveal a considerable geographical variation. For instance, Europe and Asia have relatively similar prevalence rates of 23% and 25%, respectively. In contrast, Africa exhibits a higher prevalence rate of 29%. Specific zones with higher prevalence are highlighted on the map.

These insights are part of the broader field of health informatics or anthrax informatics, involving predictive algorithms developed over time. Just as we observed predictions for COVID-19, similar algorithms have been used to forecast anthrax prevalence and distribution.

How might a pathogen spread from one part of the world to another? If you recall, we never anticipated the complete shutdown of our entire country, yet the pathogen spread rapidly across the globe. The ease of international travel means that even a single infection, if not promptly isolated, can lead to widespread outbreaks. This rapid dissemination underscores a crucial point: once a pathogen begins spreading, it can be nearly impossible to stop completely.

Over the years, decades, and even centuries, we may never entirely eradicate such pathogens, but we can learn and adapt. By understanding their spread, we can develop better strategies. It's essential for our strategy makers to focus on informatics and intelligence as the keys to managing and countering these threats.

Complete eradication may be an unrealistic goal. There will always be emerging threats, whether it's anthrax today, a virulent form of tuberculosis tomorrow, or even Ebola at another time. However, the lessons learned from the COVID-19 pandemic should make us more informed and prepared for future challenges.

That concludes today's class. In our next session, we will explore why and how certain pathogens, like anthrax, have been used as bioterrorist agents. Thank you.