Microbial Forensics and Biological Terrorism

微生物鑑定和生物恐怖行動

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Introduction

緒言

Most Americans and European adults are familiar with the anthrax letters that were sent through the U.S. Postal System shortly after the attacks of 11 September 2001. The investigation into those letters was code-named Amerithrax. More than 25 full-time investigators from multiple agencies logged hundreds of thousands of hours during Amerithrax. The investigation resulted in the suicide of a person of interest who worked for the U.S. Army and was about to be charged in connection with the incidents.[1] It also led to the development of new techniques that allowed the scientists to determine the strain of anthrax and to pinpoint the exact laboratory from which the anthrax had been cultivated.[2] This arguably represented the birth of microbial forensics and is most definitely the commencement of its use as a tool in biological terrorism investigations.

2001 年 9 月 11 日攻擊事件後不久，經由美國郵政系統發送炭疽信件事件，大多數歐美成年人對此並不陌生。對這些信件的調查專案代號為 Amerithrax。在 Amerithrax 專案期間，超過 25 名來自多個機構的專職調查員，創了數十萬小時調查的記錄。調查的結果導致一位具有涉案嫌疑且將被起訴的美國軍人自殺[1]。這也導致新技術的發展，使科學家們能夠確定炭疽病菌株，並確定炭疽培養的確切實驗室[2]。這可說是微生物鑑定的誕生，而且絕對是開始使用作為調查生物恐怖活動的工具。

Microbial Forensics

微生物鑑定

Humans die with more than 45 times as many genes as they had when they were born. This is due to the accumulation of microscopic organisms over the normal course of human development and life. Most of these microscopic organisms are transmissible, and the makeup of this portion of additional life varies to a degree from

person to person.[3] Given that this microbial community varies from one individual to another, we can assume that the microbial community is able to, or will at some point be able to, be individualized. Additionally, given that most of this microbial community is transmissible, we can assume, based on Locard's exchange principle, that some of this entity will be transferred whenever contact is made with another surface.

人類死亡時擁有的基因數超過出生時擁有基因數的 45 倍之多。這是由於在人類生長和生命的正常過程期間微小生物體的累積。這些微小生物體大多數是可傳播的，並且這部分附加生命的組成，在一定程度上隨人而異[3]。鑑於這種微生物群落隨著個體的不同而不同，我們可以認為微生物群落能夠或在某種程度上能夠具個體特徵化。另外，鑑於大多數這種微生物群落是可傳播的，我們可以基於 Locard 交換法則想當然地認為，當微生物群落與另一個體進行表面接觸時，這個實體中的有些部份將會轉移。

Think about your family tree: Your cousins, many times removed, who live in Europe and whom you have never met, can be definitively identified as your genetic relatives even though your genetic connection dates back dozens of generations. This same principle can be applied to the micro-organisms that are living as a part of you. When a person touches a surface, a portion of that microbial community is transferred to that surface. The microbial sample continues to grow and change because being biological, by definition, means being alive. The "microbial aura" that surrounds each individual is always growing and changing; however, following the same principles that connect you to your European cousins, the transferred microbial sample can be connected to the microbial sample currently living in the individual who transferred it — and it can be matched through genetics as a microbial fingerprint. To illustrate the uniqueness of the microbial aura, one research paper, "Microbial Forensics: The Biggest Thing Since DNA?" notes that "the palm surface of any two individuals share only 13 [percent] of the same bacterial phylotypes."[4]

回想你的家譜：你的親戚們，經歷多次的遷徙，有些親戚住在歐洲，有些親戚你從未見過，皆可以被明確地鑑定為你的遺傳親屬，即使你的遺傳連接追溯到數十代。同樣的原則也可以應用於你身體一部分活著的微生物。當一個人接觸到一個表面時，一部分微生物群落將轉移到該表面。因為根據生物定義是指活著的，微生物樣品會繼續生長和改變。圍繞每個人的“微生物先兆”一直在生長和變化；然而，依照相同原則將你連接到你歐洲親戚，轉移的微生物樣品可以連接到目前活在轉移個體中的微生物樣品—並且可以通過遺傳學作為微生物指紋進行匹配。為了說明微生物先兆的獨特性，一篇研究論文“微生物鑑定：自 DNA 以來最大的事物？”提到“任何兩個人的手掌表面只有 13％相同的細菌系統”[4]。

During the Amerithrax investigation, it became clear that simply knowing which biological substance was used was not going to be enough to discover the source of

the material or the perpetrators of the attacks. Therefore, forensic analysis was applied in such a way that the needed information could be gleaned. The BioSciences Division, Research and Technology Directorate, Edgewood Chemical Biological Center, Edgewood, Maryland, determined that "In the emerging subfield of microbial forensics, these principles [acquisition, analysis, and interpretation of evidence] are now being applied to the analysis of microbial materials, including potential and actual biocrime agents."[5] The identification of the biological agent required a deeper examination into the exact strain that was used; more specificity was required. As stated by the codirector, Center for the Deterrence of Biowarfare and Bioterrorism, microbial forensics provides "much greater detail to determine the precise strain and substrain."[6] Using a greater level of detail, the source of the anthrax was eventually traced to a vat at the U.S. Army Medical Research Institute for Infectious Diseases laboratory and a person of interest was identified.[7] This biological terrorism event is probably the most well-known to Americans today, but was far from the first or only biological terrorism event.

在 Amerithrax 專案調查期間，很明顯地，僅瞭解使用那種生物物質，並不足以發現物質的來源或攻擊的肇事者。因此，採用鑑定分析方式，可以收集所需的資訊。位於馬里蘭州邊木的邊木化學生化中心的研究與技術部門的生物科學分部確定—“在新興的微生物鑑定子系統中，[獲取、分析和解釋證據]這些原則，現在正在應用於微生物材料分析，包括潛在和實際的生物犯罪毒劑“[5]。生物毒劑的確認，需要對使用的確切菌株進行更深入的檢查；需要更多的特異性。正如生物戰與生物恐怖行動制止中心副主管所述，微生物鑑定提供了“更大的詳情來確定確切的菌株和子菌株” [6]。使用更多的詳情，炭疽的來源最終追溯為位於美國陸軍傳染病醫學研究所實驗室的儲缸，並確認一位涉案嫌疑人[7]。這個生物恐怖行動事件可能是現今美國人眾所週知的，但這絕不是第一次或唯一一次生物恐怖行動事件。

Biological Terrorism

生物恐怖行動

The Centers for Disease Control defines a bioterrorism attack as “the deliberate release of viruses, bacteria, or other germs (agents) used to cause illness or death in people, animals, or plants."[8] However, different agencies use different definitions and for the purpose of this article, that definition is augmented by specifying that the goal of the deliberate release is to push an agenda by instilling fear or terror into the population. Biological "weaponry" has been in use (though not widely accepted) in one form or another since the 14th century.

疾病管制中心將生物恐怖行動攻擊定義為“故意釋放病毒、細菌或其他病菌(毒劑)造成人、動物或植物疾病或死亡“[8]。然而，不同的機構使用不同的定義，為了本文的目的，以明確說明故意釋放的目的是藉由逐漸灌輸恐懼或恐怖給居民以推動議程來加強這一定義。自 14 世紀以來，生物“武器”已以一種或其他型

式使用(雖然未被廣泛接受)。

Aum Shinrikyo, a terrorist organization most commonly known for its sarin nerve agent attack in Japan, had an anthrax program and was very interested in more thoroughly pursuing biological weapons.[9] Terrorist organizations around the world would like to develop a biological weapon capability. Biological attacks can go undetected until symptoms start to manifest in multiple individuals, likely causing panic and fear throughout the population and affecting everything from the amount of time the average person spends outside their home to national commerce.

奧姆真理教是眾所周知在日本沙林神經毒劑攻擊事件的一個恐怖組織，也擁有一個炭疽計畫，且非常感興趣的更完整地追求生物武器[9]。世界各地的恐怖組織皆想要發展生物武器的能力。生物攻擊可能不被發現，直到許多人身上開始出現症狀，其可能導致整個居民的恐慌和恐懼，並影響到一般人離家出外到全國性商業花費的所有時間。

In responding to a biological terrorism event, the level of preparedness depends on where the event occurs and how far it spreads. Different regions and different countries have different capabilities, funding, resources, and interest in preparing for a biological terrorism event. A 2015 study that took place in Colorado, published by Homeland Security and Emergency Management, cited many difficulties that local assets may face in a biological terrorism event; two of these difficulties seemed to be due to lack of familiarity. The study stated that local and government officials and incident responders did not know much about hazards or mitigation capabilities of biological terrorism and that lack of knowledge led to a diminished ability to make appropriate choices in a biological terrorism attack situation.[10] The results of this study can be seen throughout the world.

在應對生物恐怖行動事件時，備災程度取決於事件的發生地點和傳播距離。不同地區和不同國家在準備應對生物恐怖行動事件，具有不同的能力、資金、資源和影響。國土安全和應變管理局發行的 2015 年在科羅拉多舉行的研究報告指出，地方資產在生物恐怖行動中可能面臨許多困難；其中有兩個困難似乎是由於缺乏熟悉度。研究報告指出，地方政府官員和事件應變者對生物恐怖行動的危害或緩解能力不太了解，缺乏知識導致在生物恐怖行動攻擊情況下，作出適當選擇的能力下降[10]。全世界皆可看到這項研究的結果。

A great deal of money is spent on nuclear weapons and defense; and chemical defense receives a great deal of attention, given the widespread use of chemical weapons during World War II, events such as the sarin attacks on the Tokyo subway, and industrial accidents that occur more frequently than anyone would like. However, according to a paper published by the Military Institute of Preventive Medicine in Belgrade, Serbia, "Biological weapons are nearly as easy to develop, far more lethal, and easier to deliver than chemical weapons; and unlike nuclear weapons, they are inexpensive to produce and the risk of detection is low. Progress in molecular biology

has made fast and easy biotoxin production possible."[11] Unfortunately, the information is too easily available through the Internet; all that is needed is a little source material cultivation. Many developed nations initiated biological weapons programs in the late 1920s and continued until the creation of the Biological and Toxin Weapons Convention in 1972. Some even continued beyond that.[12] This means that many developed nations had the source material needed to create biological weapons. Although those programs should have been dismantled and the source material safety destroyed or transferred to less nefarious programs, they may not have. With the know-how and the availability of the material, it is only a matter of time before another biological terrorism event occurs.

大量的資金用於核武器和防禦；以及第二次世界大戰期間廣泛使用化學武器，東京地鐵的沙林攻擊事件，與發生比任何人期望的更多工業事故，化學防禦受到了極大的關注。然而，根據塞爾維亞貝爾格萊德軍事預防醫學研究所發表的一篇文章，“生物武器幾乎比化學武器更容易發展，致死性更強，更容易遞送；且與核武器不同，它們生產便宜和被檢測的風險低，分子生物學的進步使生物毒素生產快速且方便“[11]。更遺憾的是，這些資訊透過網路十分容易獲得；所需要的只是些許源材料培養。在 1920 年代後期，許多先進國家啟動了生物武器計畫，並持續到 1972 年制定“生物和毒素武器公約”，甚至在此之後有些國家仍持續生物武器計畫[12]。這意味著許多先進國家擁有製造生物武器所需的源材料。儘管這些計畫應該被解散，源材料安全銷毀或轉移到較少惡意的計畫，他們可能沒有製造生物武器。隨著源材料的專門技能和可用性，另一次生物恐怖行動事件發生，只是時間的問題。

Microbial Forensics in Bioterrorism Investigations

微生物鑑定在生物恐怖行動調查

When another biological terrorism event occurs, microbial forensics will play a much more important role than it has in the past. With the lessons from the Amerithrax investigation, we now know how important microbial forensics will be in identifying the source of material and a suspect. Simply identifying the type of biological material will do little to narrow the suspected source of the material. The identification of a particular strain or substrain will be vital in discovering the origins of the biological material. The goal of the investigation will be to identify the biological material at a level of scrutiny that will allow for this type of characterization. Earlier identification of the source material narrows the scope of the investigation sooner, which will hopefully result in the earlier identification of a perpetrator or perpetrators. This chain of events can counter the proliferation of the know-how and material required to carry out a successful biological terrorism attack.

當另一生物恐怖行動事件發生時，微生物鑑定將比以往發揮更為重要的作用。隨著 Amerithrax 專案調查的教訓，我們現在知道微生物鑑定在確定材料來源和嫌疑人有多重要。簡單地識別生物材料的類型，對縮小材料來源察覺範圍

功能有限。特定菌株或子菌株的鑑定對於發現生物材料的起源至關重要。調查研究的目的是考慮到這類特性描述的細察水準以鑑定生物材料。及早的源材料鑑定，快速縮小了調查範圍，這有助於早日確定犯罪者或犯罪集團。微生物鑑定的另一個連鎖效應，可以反制執行成功的生物恐怖行動攻擊所需專門技能和材料的擴散。

Conclusion

結論

This article discusses microbial forensics as a tool for use in the investigation of biological terrorism. There may be a plethora of uses for microbial forensics in the future; but for now, it fills a niche in biological attack incidents that no other technique is capable of filling.

本文討論微生物鑑定是供生物恐怖行動調查所使用的工具。未來微生物鑑定可能有很多用途；但是現在，它填補了生物攻擊事件的縫隙，且沒有其他技術能夠填補。

Endnotes:

註釋

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