

House of Lords Science and Technology Committee inquiry: Forensic Science

Written evidence submitted by the Society for Applied Microbiology

1. The Society for Applied Microbiology (SfAM) is the oldest microbiology society in the UK, representing a global scientific community that is passionate about the application of microbiology for the benefit of the public. Our members work to address issues involving the environment, human and animal health, agriculture and industry.
2. The Society welcomes the opportunity to respond to the Committee's request for information. This response details examples and concerns raised by members in relation to the study of microorganisms (e.g. bacteria, fungi, viruses etc.) as applied to forensic investigations.

What is forensic microbiology?

3. Forensic microbiology (otherwise known as microbial forensics) is a relatively new discipline that can be broadly described as the *application of scientific methods for the analysis of microbial evidence in criminal and civil cases for investigative purposes*.¹ Specifically, forensic microbiology can be applied to analyse evidence from a suspected bioterrorism attack, biocrime, hoax, or inadvertent release of a biological agent or toxin.²
4. This discipline developed following increased global awareness of bioterrorism after the 2001 anthrax letter attacks in the United States. While bioterrorism and biocrime investigations represent obvious direct applications of forensic microbiology, microbial analysis plays an increasingly broad role in forensic analyses (**Box 1**).

Box 1: How is forensic microbiology used?

5. *Bioterrorism:*

- Microbial analysis was necessary in the 2001 Amerithrax investigation, to identify and trace the strain of *Bacillus anthracis* spores used (the bacteria behind anthrax infections).³

6. *Biocrime:*

- Intentional or reckless sexual transmission of infections (e.g. HIV)⁴
- Contamination of food and water supplies. (e.g. a 1996 case of deliberate infection)

¹ Schmedes SE, Sajantila A and Budowle B. [Expansion of Microbial Forensics](#). *J Clin Microbiol.*, 2016, **54**(8), 1964–1974.

² Budowle B et al. [Building microbial forensics as a response to bioterrorism](#). *Science.*, 2003, **301**(5641), 1852–1853.

³ Beecher DJ. [Forensic Application of Microbiological Culture Analysis To Identify Mail Intentionally Contaminated with Bacillus anthracis Spores](#). *Appl. Environ. Microbiol.* 2006, **72**(8), 5304-5310

⁴ <https://www.cps.gov.uk/legal-guidance/intentional-or-reckless-sexual-transmission-infection> (accessed 06/09/2018)

of hospital laboratory staff via food contaminated with *Shigella dysenteriae*)⁵

- Deliberate infection of animals (e.g. introduction of rabbit calicivirus disease (rabbit haemorrhagic disease) into New Zealand in 1997)⁶

7. The application of microbiology has also proved crucial in other criminal investigations, for example:

- In 2004, customs officials in Brussels seized two smuggled eagles from Thailand. The birds were later found to be carrying the highly pathogenic H5N1 influenza (bird flu) virus, necessitating further investigation and quarantine measures to be actioned.⁶
- Microbial analysis was used to investigate a 2009 anthrax outbreak among heroin users in Scotland, England and Germany. Results from this analysis pointed towards accidental contamination of the heroin, rather than the deliberate introduction of anthrax spores.⁷

8. Advances in science and technology are expanding the potential uses of forensic microbiology beyond the investigation of harmful (pathogenic) microorganisms. For example, researchers are revealing the potential for microbiome studies to inform forensic investigations in general (**Box 2**).

Box 2: Microbiome analysis

9. Microbiomes are the complex communities of different microorganisms that are associated with specific ecosystems (e.g. the human gut, soil or waterways). Advances in genome sequencing and bioinformatics have enabled microbiologists to study microbiomes to potentially support forensic investigations.

- *Human identification*: The microorganisms associated with skin, organs and bodily fluids may provide a '*microbial fingerprint*' of an individual. Research in this area is preliminary but has the potential to assist in the identification of individuals and to provide clues on their lifestyle (e.g. diet, travel, pharmaceutical use).⁸
- *Post-mortem interval (time since death)*: Researchers are investigating how the human microbiome changes during decomposition in an attempt to construct a '*microbial clock*' to inform time-of-death estimates.⁹
- *Geolocation*: Detection of microorganisms that are specific to a certain location or environment (e.g. soil or water).

⁵ Kolavic, SA et al. [An Outbreak of Shigella dysenteriae Type 2 Among Laboratory Workers Due to Intentional Food Contamination](#). *JAMA*, 1997, **278**(5), 396-398.

⁶ McEwen, SA et al. [Microbial forensics for natural and intentional incidents of infectious disease involving animals](#). *Rev. sci. tech. Off. int. Epiz.*, 2006, **25**(1), 329-339.

⁷ Price EP et al. [Molecular epidemiologic investigation of an anthrax outbreak among heroin users, Europe](#). *Emerg. Infect. Dis.*, 2012, **18**(8), 1307-1313.

⁸ Hampton-Marcell JT, Lopez JV and Gilbert JA. [The human microbiome: an emerging tool in forensics](#). *Microb. Biotechnol.*, 2017, **10**(2), 228-230.

⁹ <http://www.pnas.org/content/115/1/3> (accessed 07/09/2018)

What is the level of understanding of forensic microbiology within the Criminal Justice System amongst lawyers, judges and juries? How can it be improved?

10. *Biocrime (HIV)*: A recent international expert consensus statement on HIV indicated concerns that criminal justice systems are not sufficiently guided by up-to-date scientific and medical evidence.¹⁰ The report highlights a number of issues:
- 10.1. Prosecutions for non-disclosure, exposure or transmission of HIV have occurred in cases where HIV transmission was extremely unlikely or not possible (e.g. biting or spitting). Furthermore, advances in science and medicine may not be factored into prosecution decisions (e.g. the effect of antiretroviral treatments on HIV transmission risk).
 - 10.2. *Understanding the limits of a technique*: Criminal justice system workers may overestimate the power of a given scientific outcome. For example, phylogenetic analysis (the study of how organisms evolve) cannot conclusively prove that a defendant infected a complainant with HIV, but it can exonerate a defendant. Caution is needed to ensure that judges and lawyers are supported to understand new technological advances, particularly where the interpretation of results differs from commonly used techniques such as conventional DNA analysis.¹¹

Science needs

11. Science priorities for microbial forensics were raised at a 2013 international workshop organised by the Royal Society, the United States National Academy of Sciences, the Croatian Academy of Sciences and Arts, and the International Union of Microbiological Societies.¹² Key unmet needs for forensic microbiology are highlighted below.
12. *Collaboration*:
- 12.1. Need to increase awareness of forensic microbiology among the wider scientific community, especially among disciplines it relies upon (e.g. genetics, bioinformatics, immunology, biochemistry, molecular biology and epidemiology).
 - 12.2. Forensic microbiology (despite being relatively new) utilises many of the same techniques developed for public health investigations (outbreaks of infectious disease and foodborne pathogens). However, microbiologists in veterinary and public health fields have little experience of forensic science and its requirements. The clear synergy between forensic microbiology and public health could be exploited through shared capability and capacity (e.g. coordinating and sharing data systems, training and tools). One clear advantage would be that systems are used for common occurrences (i.e. disease outbreaks) in between rare events (e.g. bioterrorism).

¹⁰ Barré-Sinoussi, F et al. [Expert consensus statement on the science of HIV in the context of criminal law](#). *J. Int. AIDS Soc.*, 2018, **21**(7): e25161.

¹¹ <https://www.nature.com/news/science-in-court-disease-detectives-1.14775> (accessed 07/09/2018)

¹² National Research Council. 2014. [Science Needs for Microbial Forensics: Developing Initial International Research Priorities](#). Washington, DC: The National Academies Press.

13. *Technology*: Microbial analysis can be incredibly complex. Put into context, investigations of human-derived specimens relate to only one species, whereas microbial forensics involves a large number of potential bacterial or viral species and is complicated further by factors such as evolution and (potential) bioengineering.
 - 13.1. This places practical limits on the development of forensic signature assays, specimen archives and databases for use in forensic investigations.
 - 13.2. Microbial forensics cannot yet claim the degree of certainty or specificity as fingerprint or (human) DNA analyses.
 - 13.3. New genomic sequencing technologies are increasing the applicability of certain techniques (e.g. phylogenetic analysis). It is important however that the limits of these technologies for forensic investigations are well communicated to workers in the criminal justice system (paragraph 10).
 - 13.4. In addition to genomics, research should prioritise the advancement of metagenomic approaches (direct analysis of environmental samples) and other techniques that hold promise for forensic microbiology including proteomics (proteins), metabolomics (metabolites), transcriptomics (RNA) and glycomics (sugars).
 - 13.5. Forensic microbiology analyses need to produce reliable answers rapidly, especially in potential bioterrorism or biocrime scenarios. To achieve this, microbiologists must be given the tools to rapidly develop and validate new analytical methods (or adapt existing ones) in response to a 'surprise' event. This could be enacted through the availability of on-the-shelf capabilities that can be adapted to a wide variety of circumstances.
14. *Data*: Several factors require consideration for current and future microbial forensic investigations.
 - 14.1. Current technologies (e.g. next generation sequencing) produce vast amounts of data. Capacity is needed to store these data in line with the high standards required for forensic investigations. Efforts are also needed to ensure data are comparable across different databases, laboratories and equipment. Databases should be able to store appropriate metadata (e.g. information on where and when a genomic sample was taken).
 - 14.2. Existing microbial and phylogenetic databases are not organised with forensics in mind, and so may not satisfy forensic quality standards.
 - 14.3. Data in public health databases should be available for use by forensic microbiologists and should be captured and stored in accordance with the appropriate standards (paragraph 12).
 - 14.4. Scientists require training and guidance to understand the probative value of a small signal (i.e. the microbe of interest) in a large dataset (e.g. all microbes within an environmental sample).
 - 14.5. Understanding microbial diversity (i.e. the various microorganisms in an environment) is vital to distinguish between 'microbial background' and the organism of interest. Building this background picture will require a significant effort

to capture information from different geographic locations, environments and larger organisms (i.e. people, animals etc.).

15. *Skills and capacity.*

- 15.1. As mentioned above (paragraph 12), there is significant crossover between skills needed for forensic microbiology and clinical/medical/veterinary microbiology. However, public health microbiologists are not trained in processing microbial samples for forensic investigations.
- 15.2. Providers of forensic science services in the UK currently make no reference to microbiology.¹³ Furthermore, 'forensic biology' and DNA analysis services refer in general to the identification of humans, plants and animals, and not microorganisms. This clear lack of forensic microbiology capacity must be addressed if the UK is to take full advantage of microbiology expertise as a key component of forensic investigations.

Standards and regulation

16. As with all forensic science, microbiology evidence must be robust, accurate and reproducible. This is particularly relevant to the alleged use of a biological agent, where scientific information and evidence will fall under extensive scrutiny from political, public and media audiences.
17. Reproducibility is a particular concern, due to the complexity of microbial analysis.
18. *Laboratory and data standards:* As discussed above, public health microbiology and forensic microbiology would benefit from shared resources. This however would require standards in laboratory practice and data to be compatible with both public health and legal requirements. Forensic microbiology standards in the UK ought to be developed with the following considerations:
 - 18.1. The United States Federal Bureau of Investigation established a Scientific Working Group on Microbial Genetics and Forensics (SWGMEF) in 2003, which produced quality assurance guidelines for laboratories conducting microbial forensic analyses.¹⁴
 - 18.2. Standards for food microbiology (British Standards Institution)¹⁵ and clinical microbiology (Public Health England Standards for Microbiology Investigations).¹⁶ Environmental microbiology is an important aspect that should not be neglected.

¹³ Based on information from websites accessed on 13/09/2018. Providers checked: Scottish Police Authority; Forensic Science Northern Ireland; Eurofins Forensic Services; AlectoForensics; Cellmark Forensic Services; KeyForensic Services; Socotec UK.

¹⁴ https://archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/oct2003/standards-and-guidelines/2003_10_guide01.htm (accessed 07/09/2018)

¹⁵ <https://standardsdevelopment.bsigroup.com/committees/50001696> (accessed 07/09/2018)

¹⁶ <https://www.gov.uk/government/collections/standards-for-microbiology-investigations-smi> (accessed 07/09/2018)

- 18.3. The UK Accreditation Service Forensic Science Technical Advisory Committee (FSTAC) should ensure that microbiology expertise contributes toward laboratory assessment criteria and decisions.
- 18.4. Veterinary laboratories in particular have been identified as lacking the ability to deal with issues such as chain-of-custody, secure storage of evidence, tracking of individual items of evidence and their derivatives and all the other legal requirements for handling evidence.⁶
19. *International standards.*
- 19.1. Microbial forensics (under the Biological Weapons Convention) lacks the level of international leadership that currently governs nuclear forensics (under the International Atomic Energy Agency).¹² International collaboration and the exchange of information (relevant to biocrime and bioterrorism) could build on the surveillance efforts of international agencies such as the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE) and the World Health Organization (WHO).
- 19.2. It is essential that international data-sharing forums are established, with defined quality and nomenclature standards. Governmental restrictions (not specifically the UK) on the sharing of material across nations has limited the development of global databases.

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