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Laboratory accidents and biocontainment breaches

Policy options for improved safety and security

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CHATHAM HOUSE

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Summary

- Laboratory accidents involving high-consequence pathogens can have serious and potentially catastrophic consequences, affecting people, animals and the wider environment. Despite stricter controls over past decades, they still occur regularly – and most are caused by avoidable human error.

- This is a concern for a wide range of stakeholders, from laboratory workers and managers to those in the wider scientific research community and industry, development partners, policymakers, political leaders, law enforcement agencies and the general public.

- This paper discusses a new mapping of all reports of laboratory accidents worldwide, published between 2000 and 2021, which finds that documentation and reporting of accidents are generally poor. Many countries have no reporting requirements at all, and when incidents are reported, the information provided is often not good enough. This makes adequate assessment and tracking of the threat impossible. The review also indicates that more comprehensive and systematic reporting of biocontainment breaches is critical to improving safety and security. Many biosafety measures used today are not based on evidence. To minimize the likelihood of laboratory accidents and biocontainment breaches, it is important to continue to move towards an integrated and sustainable risk-based approach that takes into account the type of activity and local context, rather than the dominant inflexible approach where there is a one-size-fits-all classification of laboratories based solely on the hazard category of the organisms they handle.

- The biosafety profession is still in its infancy in many parts of the world, and there is a marked shortage of personnel with the skills and demonstrable competencies to advise on the implementation of a risk-based approach. So, although there is recent guidance from the World Organisation for Animal Health (WOAH) and the World Health Organization (WHO), there is no critical mass of professionals to make the system more effective and to improve resilience. Properly designed and accessible training programmes are essential to shift the mindsets and behaviour of future generations of laboratory workers.

- While the probability of laboratory accidents occurring cannot be reduced to zero, there is considerable scope to improve the current situation and minimize the prospect of catastrophic outcomes. As with any shift, a combination of political will and the right long-term investments will be essential determinants of progress.

- Consideration also needs to be given to the wider context of the 'pathogen value chain', including pathogen-related activities outside the laboratory itself, from collection of samples to waste disposal. There is currently very little oversight of these activities on a global basis, and, where it does exist, there is large variation in approach and capacity both at the national and regional levels. A conversation is urgently required to help address this gap.

Introduction

Laboratory accidents can have serious and potentially catastrophic consequences, whether they involve occupationally acquired infections among laboratory workers or biocontainment breaches that result in dangerous pathogens escaping into the community. They pose a threat not only to the human population, but also to animals and plants, endangering life and livelihoods, economies, food security, biodiversity and the ecosystem generally. As evidence and concerns have grown, laws, regulations, and biosafety and biosecurity guidance to control pathogens and their use have increased and been strengthened. However, laboratory accidents still occur regularly – and while there are intrinsic risks associated with pathogens and certain laboratory activities, many of these accidents are avoidable. Meanwhile, the number of laboratories and pathogen research projects is expanding.

The situation is a concern for laboratory workers and managers, the wider scientific research community, industry, development partners, policymakers, political leaders, law enforcement agencies and the general public alike. While accountability for day-to-day biosafety and biosecurity lies generally with those directly in charge of laboratories, the biosafety and biosecurity frameworks are set at a higher, policymaking, level.

Concern over the possibility and implications of such accidents has been brought into sharp focus in recent years, with speculation regarding the origins of SARS-CoV-2, the causative agent of the COVID-19 pandemic. The source of the pandemic remains undetermined, but fears persist around the possibility of it having originated from a laboratory accident. These fears, as well as the pace at which new technologies are becoming available and their increasing ease of access, have reinvigorated discussion around the need for regulation and governance to keep pace with advances in pathogen research.

Much more can be done to minimize the risk of laboratory accidents worldwide. Taking a ‘One Health’ approach, where the risks to people, animals and ecosystems are considered together, is important. Neither the documentation nor the reporting of accidental breaches is mandatory in most countries, and it is recognized that what is reported constitutes a significant understatement of the problem. Improving understanding of the true scale of the problem and the causes of accidents, and identifying and filling gaps in the evidence base, are vital for successful and sustainable biocontainment as well as improved biosecurity. It is important that this work uses existing evidence of what really works and is locally appropriate to reduce the likelihood and consequences of accidents.

Background

Early review studies of laboratory accidents, the first of which was published in 1915, examined accidents involving specific diseases or pathogens, either in particular countries or worldwide in higher-containment laboratories handling a variety of pathogen types.[1]

To update the understanding of the scale and implications of the problem of suboptimal practices in laboratory biological risk management today, and to inform policy to reduce the likelihood and consequences of accidents, new research by the World Organisation for Animal Health (WOAH), the World Health Organization (WHO) and a host of institutes, including Chatham House, has for the first time reviewed all publicly available information on human and animal laboratory accidents and their causes as reported worldwide between 2000 and 2021.[2]

The study, the most comprehensive scoping review to date, is part of a wider effort to improve the sustainable implementation of laboratory biological risk management, particularly in low-resource settings, by assessing the evidence base for biosafety measures and providing sound options for biosafety and biosecurity in such countries. The work also aims to inform strategic decisions on global health security and investments in laboratory system capacity-building.

Scientific papers arising from the review have been recently published in scientific journals.[3] This paper puts the findings of that research into the wider policy context, given that the review highlighted some important policy-relevant insights. The themes covered in this paper were developed through a one-day workshop hosted at Chatham House in collaboration with WOAH in March 2023, convening experts involved in the research.

The scale of the problem today

In the updated study, the experts reviewed the peer-reviewed scientific literature and official reports, and identified laboratory-acquired infections in 309 individuals, documented in 94 incident reports covering 51 pathogens of varying degrees of hazard. Some of these infections were fatal, and some resulted in the spread of laboratory workers' infections to others in the community. In addition, the researchers identified 16 incidents of pathogen escape from biocontainment facilities during the period. Most of these occurred in research or university laboratories,

1 Pike, R. M. (1979), 'Laboratory-Associated Infections: Incidence, Fatalities, Causes, and Prevention', *Annual Review of Microbiology*, vol. 33, pp. 41–66, https://doi.org/10.1146/annurev.mi.33.100179.000353; Wurtz, N. et al. (2016), 'Survey of laboratory-acquired infections around the world in biosafety level 3 and 4 laboratories', *European Journal of Clinical Microbiology & Infectious Diseases*, 35(8), pp. 1247–58, https://doi.org/10.1007/s10096-016-2657-1.
2 Blacksell, S. D. et al. (2023), 'Laboratory-acquired infections and pathogen escapes Q1 worldwide between 2000 and 2021: a scoping review', *The Lancet Microbe*, https://doi.org/10.1016/S2666-5247(23)00319-1.
3 Ibid. See also Blacksell, S. D. et al. (2023), 'The Biosafety Research Road Map: The Search for Evidence to Support Practices in the Laboratory – Mpox/Monkeypox Virus', *Applied Biosafety*, 28(3), pp. 152–61, https://doi.org/10.1089/apb.2022.0045; Blacksell, S. D. et al. (2023), 'The Biosafety Research Road Map: The Search for Evidence to Support Practices in the Laboratory – Zoonotic Avian Influenza and *Mycobacterium tuberculosis*', *Applied Biosafety*, 28(3), pp. 135–51, https://doi.org/10.1089/apb.2022.0038; Blacksell, S. D. et al. (2023), 'The Biosafety Research Road Map: The Search for Evidence to Support Practices in Human and Veterinary Laboratories', *Applied Biosafety*, 28(2), pp. 64–71, https://doi.org/10.1089/apb.2022.0040.

and some resulted in considerable community spread. The researchers concluded that the reports captured in the study are certainly an underestimate of the true scale of the problem.

The results were compared with previous surveys. This allowed researchers to observe any trends, such as changes in the frequency of reporting and in the types of pathogens reported during the past two decades. The number of infections reported among laboratory workers was substantially lower (as reported by studies conducted between 2000 and 2021) than those found in studies conducted 50 years previously. Nearly 4,000 occupational infections were reported worldwide in the period to 1976, compared to the 309 reported over the 21-year period considered in the latest study.

However, trend analysis proved not to be possible, as the figures captured in the latest review were not comparable with those reported in the earlier studies. In part, this was because the methods used differed, with key studies during the earlier period using both published reports and direct surveys of laboratory staff to capture unreported accidents, rather than relying solely on reported accidents.[4] The researchers concluded that while reported occupational infections may have decreased recently due to better laboratory practices, advances in technology and increased awareness of biological hazards, it remains likely that the published cases represent only a tiny fraction of infections that are actually occurring.

Causes of laboratory accidents

Among those accidents captured in the research, the leading reported known cause was inappropriate procedures, such as selection of incorrect, or incorrect use of, personal protective equipment (PPE) or containment equipment, inadequate training, improper techniques or mishandling of specimens. Other significant causes included needle-stick injuries; contact with animals that resulted in accidents such as bites, scratches or contact with body fluids; suspected aerosol exposure; and engineering failures due to inadequate facility maintenance, equipment malfunction or other faults.

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Nearly 70 per cent of the known causes were due to procedural errors that can be addressed. The second most frequently cited cause was ‘unknown’ (9.1 per cent), but it was not clear to what extent this lack of attribution simply reflected a failure to record the cause or an inability to trace it. Regardless of the explanation, this failure to identify the precise cause of an accident leaves a gap in terms of the general understanding of the causes of such accidents. In turn, this presents a challenge

4 Sulkin, S. E. and Pike, R. M. (1951), ‘Survey of Laboratory-Acquired Infections’, *American Journal of Public Health and The Nation’s Health*, 41(7), www.ncbi.nlm.nih.gov/pmc/articles/PMC1525598/pdf/amjphnation00425-0004.pdf.

for informed policymaking: to improve systems in a way that minimizes both the occurrence of accidents and their consequences. (Please see Appendix for examples of high-profile laboratory accidents and their causes.)

Issues that need to be addressed

Documenting and reporting laboratory safety and security breaches

A major conclusion of the research is the need for earlier detection and for more systematic documenting and reporting of these breaches at the national level, to improve the quality of information on which efforts to strengthen safety and security are based. To a large extent, both the amount and the quality of available information remain insufficient, even in well-resourced countries. In many situations, there may be a requirement to record accidents in a laboratory ledger or computer system, but the information is not passed up to the national level, nor is it published or shared with the wider biosafety community seeking to learn lessons from such breaches. It is important to note that reporting of accidents may be included as a requirement in a laboratory's biosafety and biosecurity strategy: however, that specific part of the strategy may not be adequately funded.

Where laboratory reporting systems are in place, they often need to be improved, and where there are no reporting systems, they should be established. Reporting should include not only the occurrence of breaches but also analysis of the root causes. This would help greatly in achieving a more accurate understanding of the scale of the problem, identifying lessons to be learned and therefore directly informing improvements in laboratory safety and security.

Relevant to root-cause analysis is the role played in avoidable human error by senior decision-makers, for example by failing to listen to concerns from workers about working practices, by not allowing the work to be done properly, or by creating a culture of fear such that workers will not report incidents for fear of reprisals.

Thought needs to be given to a range of issues related to reporting, such as: raising awareness of how reporting can improve risk management and lead to safer and more secure laboratories; considering how best to provide incentives to encourage the behaviour changes that are needed; deciding what should constitute an incident that requires reporting; and determining what type of reporting system is appropriate and achievable. The latter should include consideration of whether efforts should be made to establish a global norm and whether enforcement or verification mechanisms are needed – or, where they are already in existence, whether they are functioning properly. Consideration also needs to be given to how best to support the development and implementation of robust reporting systems at a national level.

Globally, it has to be recognized that reporting requirements – such as those that exist for outbreaks of infectious diseases of international concern under the International Health Regulations and for animal diseases and zoonoses under WOAH international standards – can constitute a sensitive political issue and thus a further challenge for policymakers to consider. There can be concerns over geopolitical implications, further intrusive scrutiny, embarrassment and reputational damage, at both the laboratory management level and at the political level. For instance, no country would want to be included in a list of disease emergence 'hotspots' linked to laboratory biocontainment breaches.

To inform decision-making, it is important to understand the extent and circumstances not only of accidents, but also of near misses.

A shift towards a risk-based approach

To minimize the likelihood and consequence of pathogen leaks, the research emphasizes the importance of continuing towards the adoption of an integrated and sustainable risk-based approach. This approach must consider the pathogens, the type of activity and the personnel performing it, as well as the local context, including the resources context, and stands in contrast to the more traditional approach, which applies a one-size-fits-all classification of laboratories based solely on the hazard category of the organisms they handle. Risk analysis – particularly risk assessment and risk management, including decision-making as to which risk management option to choose – needs to be informed by an evidence base. This, in turn, should be informed by reporting, by lessons learned from laboratory accidents and near misses, and by ongoing systematic review of the available evidence.

Such a shift would mark an important evolution in the understanding of biosafety. A wide range of laboratories – including government diagnostic and research laboratories, and other public, academic or private laboratories – with different biosafety level classifications work with high-consequence pathogens. Many different activities take place in laboratories within the same biosafety classification. For instance, Biosafety Level 3-classified laboratories include considerable numbers of clinical diagnostic laboratories around the world, as well as large research laboratories conducting potentially high-consequence experiments with wild animals. Routine diagnostic activities in a small hospital laboratory would likely have a very different risk profile from the activities of a large research laboratory that might be developing medical countermeasures or investigating novel animal or human pathogens.

It is also important to consider the environment outside the laboratory itself. For example, if a pathogen is widely detected in nature – as in the case of the anthrax bacillus, which is found in infected animal carcasses – in any one country, the biosafety and biosecurity measures adopted might reasonably be different from those employed in a country where anthrax is rarely seen. Laboratory biocontainment policies therefore need to be consistent with the relevant national infectious disease control policies.

The risk-based approach is relevant to all aspects of the laboratory system, including not only research and waste disposal, but also facility and engineering controls and administrative controls.

The global biosafety community – in the human, animal and environmental health sectors – is moving in this direction, and it is a key part of making laboratories across the world more sustainable. But progress has been slow to date. If laboratories are not sustainable, lapses in laboratory biosafety and biosecurity, giving rise to laboratory infections and leaks, will be more likely.

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Increases in regulation are not necessarily indicated, particularly where tighter regulation is likely to remain unenforced or, worse, fails to address the core problems. Agencies such as WOAH and WHO have issued updated best-practice guidance on biosafety, including on minimizing the likelihood and consequences of laboratory accidents.[5] However, regulations remain in place which do not allow for a risk-based approach, and many practices that are currently being followed either do not have an evidence base or are disproportionate or otherwise inappropriate to the risk involved in the procedures. Furthermore, what works in one region may not be appropriate in another. For instance, an outbreak of foot and mouth disease in the United States or the United Kingdom would require a more aggressive approach to biocontainment (in laboratories) and biosecurity (on farms) to stop it becoming widespread, with severe consequences for national and international trade, in comparison with a similar-sized outbreak (in terms of the number of cases) in a country where the disease is already endemic.

These examples illustrate that much more can – and must – be done to move away from traditional thinking around one-size-fits-all global biosafety and biosecurity standards, and to build the risk-based approach into laboratory culture around the world.

Training and education

The biosafety profession is still very much in its infancy in many parts of the world, and there is a severe shortage of personnel with the skills to make risk-based assessments or develop a risk-based approach. Therefore, although WOAH, WHO and other organizations have issued guidance, there are currently too few competent professionals to make the laboratory system resilient and sustainable. The gap in risk analysis capacity needs to be addressed. A lack of standardization of professional qualifications across the biosafety industry further complicates the issue.

Meanwhile, many countries face capacity and capability shortfalls more widely, making the fundamental biosafety and biosecurity challenges difficult or impossible to manage. These shortfalls need to be addressed without delay. Successfully making the shift to a risk-based approach entails strengthening training and education,

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5 World Organisation for Animal Health (2023), *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals – 12th edition 2023*, Paris: WOAH, https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/A_summry.htm; World Health Organization (2020), *Laboratory biosafety manual*, 4th edn, Geneva: WHO, https://www.who.int/publications-detail-redirect/9789240011311.

not only on how to adopt and implement the approach, but also to build capacity and capability for robust risk assessment and ethics review. In addition, each laboratory should have its own guidance and on-the-job training programme for its staff, supplemented by enhanced specialized training for staff who undertake particular functions. Some international funders are starting to devote resources to filling that gap, but there is a long way to go. The ability to manage laboratory biosafety and wider biosecurity will remain compromised as long as these gaps remain unaddressed.

Furthermore, the necessary shift in mindset needs to be introduced earlier in career development terms, particularly through the higher education system. This, together with a greater awareness of emerging technologies – some of which will make, or have already made, laboratory work safer and some of which will present new risks – will undoubtedly help progress to be made in the future.

The wider context of laboratory activity

In addition to what happens in laboratories, there is a wider chain of activity in pathogen research that is important for biosafety and biosecurity and that remains largely ungoverned, at both the national and international levels.

A conversation is also urgently required on the value of establishing an oversight mechanism for high-consequence research involving dangerous pathogens and activities along the entire chain of activities, from risky practices in wildlife sample collection in the field and the transport of specimens, to laboratory-based activities, to biobanking of samples and waste disposal.

Conclusions

Several key challenges confront the effort to reduce pathogen biocontainment breaches. These concern gaps in the evidence base, the need for increased capacity and capability, and a lack of oversight and governance. All three areas are equally important, and strengthening one in isolation will not solve the overall problem. Specific challenges and recommendations include the following:

- The true scale of laboratory accidents is opaque. There is therefore a need for more systematic documentation, reporting and analysis of laboratory accidents and their root causes. Transparency is vital for learning lessons and informing the evidence base for effective biorisk management.
- Most accidents reported are caused by avoidable human error.
- A continued shift towards a context-appropriate, evidence-based and risk-based approach to biosafety and biosecurity will reduce the likelihood and the consequences of laboratory accidents.
- There is a need to build capacity and capability around the world to conduct robust risk analysis, complemented by the sustainable implementation of a risk-based approach.

- There are gaps in the evidence base needed to inform biological risk management. While improved documenting, reporting and analysis will help in this respect, there is also a need for ongoing research to fill evidence gaps.
- Consideration needs to be given to the wider context of pathogen research in which laboratories exist. Many activities outside the laboratory environment are subject to very little oversight and governance. Attending to the risks presented by the whole chain of activity, from sample collection in the field to disposal of waste, is important.

These issues have considerable implications for policy development to minimize the likelihood and consequences of pathogen leaks that threaten people, animals and ecosystems. The research shows that human behaviour is one of the weakest elements in the system, which presents an obvious opportunity for improving the situation. While the chances of laboratory accidents cannot be reduced to zero, there is much more scope to reduce their occurrence, detect failures earlier to reduce their impact, and generally minimize the risk of potentially catastrophic outcomes. As with any shift in policy or oversight, a combination of political will to engage in improving the system together with the right long-term investments will be critical determinants of progress towards safer, secure and sustainable laboratories.

Appendix

Several examples of biocontainment breaches illustrate the range of scenarios and what is at stake.

- In 1967, a mysterious severe epidemic of haemorrhagic fever occurred simultaneously among workers at laboratories in Marburg and Frankfurt in Germany, as well as in Belgrade, in what was then Yugoslavia. The epidemic caused serious illness in 32 laboratory workers, medics and family members, proving fatal in seven of these cases. It was traced to the extraction of kidney cells from African green monkeys, shipped to all three laboratories from Uganda for polio research. The monkeys were carrying a hitherto unknown virus, which became known as the Marburg virus, one of the deadliest human pathogens. It was the first virus to be discovered from the filovirus family of viruses which also includes the Ebola virus (first discovered later, in 1976). The Marburg virus has since been involved in lethal laboratory accidents and has caused several subsequent sporadic outbreaks, with death rates of up to 90 per cent.[6]
- In 1973, an outbreak of smallpox occurred in London after a laboratory technician working on lung diseases at the London School of Hygiene & Tropical Medicine visited a pox laboratory at the university where equipment needed for the lung research was housed. A frequent visitor to the laboratory, she sometimes watched the harvesting of pox virus strains from eggs, standing close to the technician undertaking the work. Within two weeks of one of her visits to the pox laboratory, she became ill and was admitted to hospital with what would later be diagnosed as smallpox. She survived the infection after being moved to a specialist hospital, but two people visiting a relative in the bed next to hers before she had been diagnosed with smallpox contracted the infection and later died from it.[7]
- One of the most infamous laboratory leaks occurred in 1979, following the accidental release of anthrax spores from a military facility in Sverdlovsk, USSR, that caused 64 human deaths and numerous animal infections (the exact number is unknown). Human procedural and engineering failures led to the leak.[8]
- After the SARS (severe acute respiratory syndrome) epidemic ended in 2003, the virus reappeared several times. Three of those cases were caused by laboratory accidents in Singapore, Taiwan and China.[9] The Singapore case was traced to improper experimental procedures in a university laboratory in 2003, while the Taiwan accident, which occurred the same year in a military institute medical research laboratory (believed to have been supported by international donors), was traced to the improper handling of a leaking bag of virus samples in a transport cabinet. The case involved a series of biosafety

6 Brauburger, K., Hume, A. J., Mühlberger, E. and Olejnik, J. (2012), 'Forty-Five Years of Marburg Virus Research', *Viruses*, 4(10), pp. 1878–1927, https://doi.org/10.3390/v4101878.
7 Great Britain, Department of Health and Social Security (1974), *Report of the Committee of Inquiry into the Smallpox Outbreak in London in March and April 1973*, Cmnd 5626, London: HM Stationery Office.
8 Meselson, M. et al. (1994), 'The Sverdlovsk Anthrax Outbreak of 1979', *Science*, 266(5188), pp. 1202–8, https://doi.org/10.1126/science.7973702.
9 Demaneuf, G. (2020), 'The Good, the Bad and the Ugly: a review of SARS Lab Escapes', Medium (blog), 16 Nov. 2020, https://gillesdemaneuf.medium.com/the-good-the-bad-and-the-ugly-a-review-of-sars-lab-escapes-898d203d175d.

breaches during decontamination, including the failure of a laboratory worker – a SARS researcher – to wear the correct PPE and his decision to put his head inside the transport cabinet to reach the spill.[10] The incident had significant epidemic potential, as the researcher took an international flight to attend a conference shortly after his infection.[11] WHO dispatched an expert team to the laboratory and a total of 95 people who were in contact with the laboratory researcher were quarantined to avert an outbreak. The incident in China involved an outbreak in 2004 sparked by two lab workers, who were not working with the SARS virus; the two workers were infected independently of each other at a national institute laboratory studying the virus.[12] A report by a panel of experts concluded that the source is likely to have been a batch of inadequately inactivated SARS virus brought from a high-containment part of the facility to the diarrhoea research laboratory where the two were working.[13] Nine people were infected, one of whom died.

— In 2007, it was determined that an outbreak of bovine foot and mouth disease in the UK had most likely been caused by contaminated wastewater leaking from a laboratory at the government's Institute for Animal Health in Pirbright, Surrey, where the effluent was discharged through old, damaged drainage pipes, contaminating the surrounding soil. The contamination was traced to an inadequate process to render the material inactive in a bulk holding tank before release. The contaminated soil was then most likely transported to a nearby farm by vehicles that had driven over it. The disease subsequently spread to several other nearby farms. The outbreak resulted in a national livestock movement and trade ban, a European Union ban on UK live animal and meat exports, and the culling of 2,000 animals. The discharge into broken pipes was cited in the conclusion of the official review of the outbreak as occurring in the context of 'creeping degradation of standards' at the site.[14]

— A large-scale outbreak of the zoonotic disease brucellosis in China in 2019, in which more than 10,000 people tested positive for the infection, was traced to the use of expired disinfectant, which resulted in the release of the aerosolized viable pathogen into waste gas vented from the facility. *Brucella* bacteria, which pose a serious public health risk, are a major cause of laboratory-associated infections.[15]

— The anthrax bioterrorism attack that struck postal workers in Washington, DC in 2001 can be classified as a laboratory lapse in biosecurity, due to the high probability that the pathogen used originated from a laboratory source.[16]

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10 Center for Infectious Disease Research and Policy (CIDRAP) (2003), 'Taiwanese SARS researcher infected', 17 December 2003, https://www.cidrap.umn.edu/sars/taiwanese-sars-researcher-infected; Demaneuf (2020), 'The Good, the Bad and the Ugly'.
11 World Health Organization (2003), 'SARS case in laboratory worker in Taiwan, China', 17 December 2003, https://www.who.int/news/item/17-12-2003-sars-case-in-laboratory-worker-in-taiwan-china.
12 Walgate, R. (2004), 'SARS escaped Beijing lab twice', *Genome Biology*, 4 (spotlight-20040427-03), https://doi.org/10.1186/gb-spotlight-20040427-03.
13 Du, L. and Enserink, M. (2004), 'SARS Crisis Topples China Lab Chief', *Science*, 2 July 2004, https://www.science.org/content/article/sars-crisis-topples-china-lab-chief.
14 Anderson, I. (2008), 'Foot and Mouth Disease 2007: a review and lessons learned', London: The Stationery Office, https://www.gov.uk/government/publications/foot-and-mouth-disease-2007-a-review-and-lessons-learned.
15 Pappas, G. (2022), 'The Lanzhou *Brucella* Leak: The Largest Laboratory Accident in the History of Infectious Diseases?', *Clinical Infectious Diseases*, 75(10), pp. 1845–7, https://doi.org/10.1093/cid/ciac463.
16 Blacksell et al. (2023), 'Laboratory-acquired infections and pathogen escapes Q1 worldwide between 2000 and 2021'.

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Cover image: A technician works with samples of the H5N1 bird flu virus in a laboratory at The Pirbright Institute in Woking, UK, on 13 March 2023.

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