Meeting of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction

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Scientific and Technological Advances in the Life Sciences since 1975: How the Last 50 Years Will Shape the BTWC S&T Advisory Mechanism

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I. Introduction

1. Science and Technology (S&T) is at the core of the BTWC. As a cross cutting and integral theme across the BTWC, S&T review also has implementation and operational impact across all agenda items of the Working Group. This paper outlines significant S&T milestones in the life sciences over the past fifty years and the technological surge that has been experienced since 2020. Some example dual use concerns have also been identified to illustrate the importance for States Parties to take a balanced approach to S&T review relevant to the BTWC.

2. The UK illustrates the pace at which S&T development has increased and highlights the need of regular review for the Convention to leverage opportunities, manage and mitigate against dual-use risks, and foster a culture of responsible innovation.

3. This working paper also outlines recommendations for the BTWC S&T Advisory Mechanism to consider as the first themes to be discussed by the S&T Review Group. The UK believes it is of the utmost importance that the S&T Advisory Mechanism can start its work as soon as feasible. Therefore, early thinking about the critical elements of the S&T Mechanism such as tools and techniques that the S&T Review Group could use, and technical topics could be useful for States Parties to engage in now.

II. S&T Milestones relevant to the BTWC

A. 1970-80s: Molecular biology foundations

4. The 1970s and 80s built tools and techniques that shaped our understanding of molecular biology:

- In 1977, Fred Sanger developed the Sanger sequencing method, enabling the order of nucleotide bases in a DNA molecule to be determined;[1]

* The present document is being issued without formal editing.

[1] https://pmc.ncbi.nlm.nih.gov/articles/PMC431765/

- In 1981, tissue culture developed to a point where mouse embryonic stem cells were isolated and cultured, enabling the study of cell differentiation, a key step in regenerative medicine;[2]
- In 1982, the National Institutes of Health established GenBank, the first central and publicly accessible DNA sequence database. GenBank has provided scientists globally with access to vast experimental datasets, fostered data sharing, and enabled S&T collaboration;[3]
- In 1983, Polymerase Chain Reaction (PCR) was invented, offering DNA amplification and accelerating molecular diagnostics capabilities;[4]
- In 1986, the first monoclonal antibodies were produced and approved by the US FDA, laying the groundwork for targeted therapies and diagnostics.[5]

B. 1990s: Increasing platforms and scale

5. The 1990s saw molecular biology progress further, scaling up studies, increasing accessibility of biotechnology, and sharing biological data and information:

- In 1990, the Human Genome Project began, aiming to sequence the entire human genome;[6]
- In 1994, the first genetically modified food, Flavr Savr tomato was approved by the US FDA. While it was discontinued in 1997, it marked a key moment in agricultural biotechnology;[7]
- In 1996, PubMed launched, enabling widely and freely available journal access;[8]
- In 1997, researchers presented Dolly the sheep; the first mammal cloned from adult somatic cells. Whilst a major scientific breakthrough, it sparked ethical and dual-use concerns;[9]
- In 1999, Tsien's research team engineered Green Fluorescent Protein (GPF) variants that were brighter, more stable and contained new colours, enabling multi-colour imaging and real-time observation of protein trafficking and cell signalling. [10]

C. 2000s: Systems biology

6. During the 2000s, there was a shift from studying isolated parts of biology to understanding dynamic and complex networks within humans, animals, plants and across the environment. This was supported by the development of mature systems-level tools:

- In 2000, the Arabidopsis thaliana genome was synthesised, a crucial model organism to characterise plant processes such as growth and environmental response, and identify significant genes involved in pathogen resistance, yield and stress tolerance;[11]
- In 2002, Horizon Discovery released the first commercially available small interfering RNAs (siRNAs) for mammalian use, vastly increasing accessibility of gene silencing experiments;[12]

[2] https://pubmed.ncbi.nlm.nih.gov/7242681/
[3] https://pmc.ncbi.nlm.nih.gov/articles/PMC11765253/
[4] https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/polymerase-chain-reaction
[5] https://jbiomedsci.biomedcentral.com/articles/10.1186/s12929-019-0592-z
[6] https://pubmed.ncbi.nlm.nih.gov/1991595/
[7] https://pmc.ncbi.nlm.nih.gov/articles/PMC5790416/
[8] https://pubmed.ncbi.nlm.nih.gov/27583303/
[9] https://link.springer.com/article/10.1007/s40656-015-0078-6
[10] https://www.nature.com/articles/nbt1099_956
[11] https://pmc.ncbi.nlm.nih.gov/articles/PMC8226293/
[12] https://pmc.ncbi.nlm.nih.gov/articles/PMC280659/

- In 2004, Illumina announced an expanded line of Sentrix BeadChips products for microarray platforms to measure and observe gene expression profiles;[13]
- In 2005, Next-Generation Sequencing (NGS) was introduced, enabling rapid pathogen genome sequencing, variant detection and outbreak tracking of infectious;[14]
- In 2009, the Epigenomics Project was launched to determine how epigenetic processes such as DNA methylation and histone modifications can control gene expression. [15]

D. 2010s: Precision, integration and *De Novo* synthesis

7. During this decade, integrating data and methods enabled precise outcomes and novel synthesis:

- In 2010, the J. Craig Venter Institute published the first chemically synthesised genome, Mycoplasma mycoides JCVI-syn1.0, more commonly known as Synthia;[16]
- In 2012, researchers demonstrated that CRISPR-Cas9 could be programmed to delete DNA at specific regions, offering unprecedented control over genome editing;[17]
- In 2013, researchers published on the expansion of single $Lgr5^{+}$ liver stem cells into stable organoids, a key step forward in regenerative medicine, disease and toxicity modelling;[18]
- In 2017, the FDA approved the first Chimeric Antigen Receptor (CAR)-T cell therapies, to treat previously untreatable blood cancers. This demonstrated the potential of engineered synthetic receptors to target specific antigens, especially for complex and rare diseases;[19]
- In 2019, Ervebo became the first FDA approved vaccine against Ebola virus, significantly strengthening epidemic preparedness. [20]

E. 2020 – Present: technological surge

8. S&T advances over the last fifty years have resulted in increased precision, accelerated speed, increased accessibility. Advances have also led to reduced costs, portability, reduced need for expertise, decentralisation, intangible transfers and de novo creation. The convergence and co-development of scientific disciplines has also become commonplace, all leading to a current technological surge:

- In 2020, the first COVID-19 vaccine, Pfizer-BioNTech, was approved for use.[21] Whilst highlighting the potential of mRNA technology for peaceful uses such as vaccine delivery, experts also cautioned about the weaponisation potential of such delivery means;
- In 2021, DeepMind published the AlphaFold database, an artificial intelligence (AI) programme for protein folding prediction, accelerating scientific research in fields such as drug discovery.[22] However, it also demonstrated the potential to enhance toxicity and design novel proteins, highlighting the importance of stronger guard rails and AI governance;
- In 2022, researchers used synthetic biology to engineer iron-sulphur oxidising microbes such as *Acidithiobacillus ferroxidan*, demonstrating microbes can be

[13] https://investor.illumina.com/news/press-release-details/2004/Illumina-Extends-BeadArray-Technology-to-Address-Wider-Range-of-SNPGenotyping-Projects/default.aspx
[14] https://www.sciencedirect.com/science/article/pii/S0168952514001127
[15] https://pmc.ncbi.nlm.nih.gov/articles/PMC3607281/
[16] https://pubmed.ncbi.nlm.nih.gov/20488990/
[17] https://pubmed.ncbi.nlm.nih.gov/22745249/
[18] https://pubmed.ncbi.nlm.nih.gov/23354049/
[19] https://www.nature.com/articles/s41408-021-00459-7
[20] https://www.nejm.org/doi/full/10.1056/NEJMoa2200072
[21] https://pmc.ncbi.nlm.nih.gov/articles/PMC8862159/
[22] https://www.frontiersin.org/journals/bioinformatics/articles/10.3389/fbinf.2023.1120370/full

programmed for selective metal extraction.[23] This could be transformative for metal extraction and biodegradation of unsustainable plastics. However, the scientific community must remain cognisant of the dual use potential of research into microbial degradation of materials;

- In 2023, researchers published on the use of DNA origami to build custom viral capsids, with control over shape, size and topology, showcasing the potential for next generation vaccines, advanced drug carriers and adaptive nanodevices;[24]
- In 2024, Cas12a-based prime editors were developed, offering improved CRISPR versality and RNA targeting.[25]

III. Proposed first themes for the S&T advisory mechanism

9. Considering the technological leaps that biosciences have taken over the last fifty years, it is imperative that the BTWC reviews S&T relevant to the Convention with urgency. A structured and systematic approach to S&T review will enable States Parties to explore how novel and emerging biotechnology can add value to the BTWC, for example by enhancing operational capabilities for responding to infectious disease outbreaks. Timely and expert driven S&T Review will also inform appropriate and proportionate biological risk assessment and management to strengthen global biosecurity.

10. Given the urgent nature of the need for S&T review for the BTWC, the following topics could be possible first themes for the S&T Advisory Mechanism to explore. The UK anticipates that the following themes could underpin S&T review discussions. The UK also recognises that Temporary Working Groups (TWG) will be a critical element of the S&T Advisory Mechanisms to ensure specific and niche subtopics can be assessed by deep technical experts in a timely and thorough manner.

(a) **Tools and Techniques for S&T review**: There are various tools and techniques that aid structured, evidence-based, and timely S&T review. The S&T Review Mechanism could begin review of the following:

(i) SWOT (strengths, weaknesses, opportunities and risks) analysis to assess current S&T capabilities and support decision making in crisis situations;

(ii) Technology watch for continuous monitoring of S&T breakthroughs and adoption patterns, including technologies on the cusp of maturity or potential to be highly disruptive;

(iii) Horizon scanning to identify future risks, opportunities, trends, and detect early signals of change to support future preparedness;

(iv) Qualitative frameworks to help interpret complex environments, as described in the work by the InterAcademy Partnership.[26]

(b) **Artificial Intelligence and Digital Tech**: As an enabling technology, AI and digital tech can act as a foundation for innovation, a catalyst for other technologies such as robotics, bioinformatics, and synthesis, and increase scalability, efficiency, and identify novel solutions. The S&T Review Mechanism could explore the opportunities and risks of AI within the life sciences, and the potential for layering AI into the BTWC to strengthen implementation and operationalisation.

(c) **Microbial Forensics**: This evolving discipline analyses microbes and their genetic signatures to determine origin. The S&T Review Mechanism could review current S&T capabilities, future infrastructure needs to upscale, and the dual-use implications. It will

[23] https://www.frontiersin.org/journals/bioengineering-and-biotechnology/articles/10.3389/fbioe.2022.920639/full
[24] https://www.nature.com/articles/s41565-023-01443-x
[25] https://www.nature.com/articles/s41587-023-02095-x
[26] https://www.interacademies.org/publication/assessing-biosecurity-risks-and-potential-benefits-advances-science-and-technology

be important to evaluate whether microbial forensics can be applied to areas such as attribution, verification, deterrence and preparedness within the context of the BTWC.

(d) **Engineering Biology**: The trajectory of this scientific field is only growing due to market expansion, democratisation of tools, and integration with AI and robotics. Prospective applications offer to transform healthcare, food security, and climate-driven impacts. However, there are clear dual-use risks, governance gaps, and challenges with public trust particularly in light of increasing misinformation and disinformation. This a highly relevant area for the S&T Advisory Mechanism to continuously monitor and report on.

(e) **Anti-Microbial Resistance (AMR)**: In recent years, AMR has surged as a global health and security crisis. The S&T Advisory Mechanism could assess emerging AMR resistance trends, novel therapeutics, the impact on biodefence, and the state of dual-use research concerning AMR genes, resistant strains, and novel antimicrobials. AMR has been a key focus for international research and collaboration among many international partnerships over recent years. This topic will likely be a cross-cutting theme and of key relevance to the International Cooperation and Assistance Mechanism as well as the S&T Advisory Mechanism.

IV. Conclusion

11. The pace and scope of S&T advancements within the life sciences over the last fifty years has been exponential, even exceeding expectations to that originally envisaged during treaty negotiations. As of 2025, a new biotechnological surge is underway which requires a multi-sectoral, multidisciplinary approach to harness bioscience benefits while managing risks and dual use potential. As AI is integrated and layered into the bioscience sector the pace of development will only increase, and the complexity of the biology landscape will deepen. Therefore, it is ever more important that a culture of responsible use is promoted through all aspects of bioscience communities and in all the other disciplines that biology intersects with. Any review should also consider dual-use potential, global health security, responsible innovation, and take a One Health approach.

12. It is imperative that global governance does not fall behind S&T capability development. Utilising foresight techniques to predict potential S&T advancements relevant to the BTWC and global biosecurity can inform and empower BTWC States Parties to get ahead of biorisks and uphold the core provisions of the Convention in all its aspects. Establishment of a BTWC S&T Review Mechanism will provide States Parties with a source of expert, impartial, and independent S&T advice, act as a strategic enabler to strengthen and operationalise other aspects of the Convention, and support efforts to reinforce global norms against biological weapons.

V. Recommendations

13. The UK urges the Working Group to establish the S&T Advisory Mechanism with immediate effect and proposes the aforementioned topics as potential first themes for the S&T Review Group to assess. The UK also encourages other States Parties to consider and propose themes that the S&T Advisory Mechanism could review.