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PROGRESS IN BIOTECHNOLOGY AS A FUTURE SECURITY POLICY CHALLENGE

Biological weapons do not figure prominently in current threat analyses. However, this might change with advances in biotechnology, and synthetic biology in particular. If the synthetic construction and modification of bacteria and viruses should become a reality, a broad range of useful applications in medicine, environmental protection, and other fields would be facilitated. At the same time, however, constructing biological weapons could become easier, and the necessary skills would be available to a larger spectrum of actors. It seems advisable to explore preventive countermeasures at an early stage.

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In recent years, attention has shifted away from biological weapons and bioterrorism in security policy discussions. While the biological threat briefly topped the security-policy agenda in the immediate aftermath of 11 September 2001 due to the anthrax letter scare, it has since become clear that the acquisition of the necessary expertise and resources as well as the successful execution of a biological attack are far more complex than previously believed.

Non-state actors have so far failed to develop a capability for using pathogens as weapons. The overwhelming majority of states, on the other hand, have consciously relinquished offensive bioweapons programs not only due to ethical considerations, but also because of serious, persistent doubts as to the usefulness of such weapons (cf. CSS Analysis no. 5). Accordingly, current debates and controversies over mass casualty weapons deal mainly with nuclear weapons and their proliferation.

The advances expected in the field of biotechnology over the coming decades might, however, bring a marked increase in the threat of biological weapons. Even though the possible features and potential of the coming biological revolution heralded by many observers is today still a matter of intense controversy, it seems advisable to investigate the security policy challenges of advances in biotechnology at an early stage.

Biotechnology as an engineering discipline

Biotechnology is currently the vanguard of promising technological trends. It is seen as having the potential to bring about a transformation of society in terms of a "biological century", including through the convergence with advances in nanotechnology, information technology, the cognitive sciences, and neurosciences. Nowhere is this development more visible than in the field of synthetic biology. The declared goal of this discipline is as ambitious as it is controversial: the transformation of biology from a natural science into an applied engineering discipline.

The term "synthetic biology" refers to a scientific field of research that aims at the targeted development of molecules, cells, and organisms by applying engineering principles in order to create biological systems that exhibit new properties. In a way, it is a further development of traditional genetic engineering. However, unlike genetic engineering, it involves more than just a transfer of individual genes from one organism to another. Instead, genes, genetic modules, or the entire DNA are artificially created – or synthesised – based on chemical precursor substances. In recent years, this has given rise to a full-blown DNA synthesis industry. Many scientists today order DNA fragments for research purposes via the internet from such commercial providers.

Within synthetic biology, a number of approaches can be distinguished. One basic possibility is to synthesise the entire genome of a known microorganism. Scientists have already successfully reconstructed the poliovirus, for example, mainly for purposes of fundamental research. In another approach that more closely approximates the engineering sciences, attempts are underway to construct a minimal genome reduced to the essential genes required for life, which is to serve as the chassis for mounting genetic modules. At the same time, there is intense research into the development of such standardised genetic modules or "biological circuits" that can be added to the minimal genome in order to carry out predefined tasks – along the lines of modular construction in many industries, such as the car or computer industries. That would, for instance, allow the chassis organism to generate specific metabolic pathways or other desired characteristics.

Promising applications

Synthetic biology promises to make the pursuit of biotechnology and especially the modification of biological systems easier, faster, cheaper, and more accessible to "non-experts" through recourse to the engineering principles of standardisation and modularisation. The number of possible users of biological techniques might increase markedly – while at the same time, the resources required to modify biological systems would be pared down. The reliability of biology-based technology is likely to increase considerably and the time needed to translate scientific insights into practical applications could thus be significantly reduced.

If the advances made hitherto should continue unabated, the consequence would be a significant change in how, and to which extent, modern-day biotechnology is conducted. Already today, a number of potentially beneficial applications are in the offing. For example, there is the justified expectation that the technology could pave the way for the production of biofuels or certain medicinal substances in bacteria – as final products of their metabolism – or for breaking down environmental pollutants through a specially constructed bacterial metabolism. Researchers have already succeeded in producing an antidote to malaria within bacteria. It is also conceivable that bacteria could be constructed to indicate the presence of certain substances such as explosives or radioactive material, which would make it easier to implement certain protection measures.

A double-edged sword

Much as in the case of the nuclear revolution, however, progress in biotechnology brings not only social benefits, but also risks. The core challenge of biotechnology in terms of security policy involves the dual-use problem. Many if not most biotechnological approaches can be used not only for beneficial, but also for malicious applications. Virtually all security-relevant developments in biotechnology can be derived from completely legitimate research efforts and adapting them for nefarious purposes does often not involve any significant detours.

Important documents and initiatives

- **US Presidential Commission for the Study of Bioethical Issues:** The Ethics of Synthetic Biology and Emerging Technologies
- **US National Science Advisory Board for Biosecurity:** Addressing Biosecurity Concerns Related to Synthetic Biology
- **OECD:** Symposium on Opportunities and Challenges in the Emerging Field of Synthetic Biology
- **EU Research Framework Programmes:**
  - Synbiosafe (Synthetic Biology Safety and Ethical Aspects)
  - SYBHEL (Synthetic Biology for Human Health: Ethical and Legal Issues)
  - Synth-Ethics (Ethical and Regulatory Issues Raised by Synthetic Biology)
- **United Nations Interregional Crime and Justice Research Institute (UNICRI):** Synthetic Biology and Nanobiotechnology Risk and Response Assessment

As far as DNA synthesis is concerned, there is an obvious risk of the technology being misused for recreating dangerous pathogenic agents. The necessary genetic sequences are publicly available in internet databases. While the procurement of such agents from nature is still the easier and cheaper method today, that may change. In addition, certain pathogens such as Ebola or Marburg are difficult to isolate in nature. Others, in turn, no longer exist, but could be synthetically reconstructed. Among the extinct viruses that could be used as potent bioweapons are the Variola virus (smallpox) or the pandemic influenza virus of 1918, both of which killed millions of people.

Synthetic biology could also make it easier in the long term to modify the properties of pathogenic agents by making them more suitable for weaponisation through "insertion" of suitable genetic modules. Apart from imparting resistance to medicine, however, the modification of biological attributes in viruses or bacteria is not yet sufficiently controllable. Our understanding of the functions of individual genes and their interaction is still rudimentary. However, in the long run, properties such as virulence, infectiousness, and environmental stability may also become subject to modification.

The ability to modify biological systems as desired – currently still a hypothetical scenario – would make the development of biological weapons more attractive for military or terrorist purposes. Current tactical obstacles to their deployment could be partially removed, for instance by making biological weapons more controllable, i.e., suitable for selective and targeted use. Also, some operational difficulties with their use, such as the degradation of a pathogen through various environmental factors, could be diminished. Furthermore, the development of bacterial metabolic pathways could in the future permit the production not only of beneficial substances, but also of toxins, drugs, counterfeit medicines, or precursor substances for chemical weapons.

Such misuse of applications does not inherently depend on specific developments in synthetic biology and could theoretically also be achieved by way of alternative biotechnology options. Advances in synthetic biology might however make them available sooner, and facilitate acquisition of the necessary capabilities over the longer term.

Inadequacy of current instruments

In the short and medium term, the threat of nefarious use of synthetic biotechnology is small, and it is largely limited to states that can invest the resources necessary for further development of this discipline and wish to do so. Nevertheless, should biotechnology applications indeed become easier and more affordable to use in the future, the risk of misuse through other states and especially non-state actors can be expected to grow considerably. As biotechnology becomes easier to perform and more widespread, the problem of proliferation of offensive bioweapons capabilities will come to the fore. The international norm against the use and proliferation of bioweapons is in danger of being eroded by these developments.

Modern societies are largely unprepared for the security policy challenges of advances in biotechnology. The increasing penetration of society with biotechnological capabilities requires a more comprehensive political response than is currently the case. Already today, the effectiveness of traditional arms control mechanisms such as international treaties or national export control regimes in the field of biological weapons is limited. Due to the problem of dual use, it is nearly impossible even to identify, let alone to control bioweapons-related activities. This is one of the reasons

Self-regulation initiatives in synthetic biology

The DNA synthesis industry

Several international DNA synthesis corporations have joined forces in two industrial consortia, each of which has elaborated a "Screening Framework" for reviewing orders and customers.

- **International Association Synthetic Biology (IASB):** Code of Conduct for Best Practices in Synthetic Biology
- **International Gene Synthesis Consortium (IGSC):** Harmonized Screening Protocol to Promote Biosecurity
- **The US government has also formulated non-binding recommendations for screening in support of these initiatives:** Screening Framework Guidance for Providers of Synthetic Double-Stranded DNA

International Genetically Engineered Machine (iGEM) competition

iGEM is an annual student competition in synthetic biology. The participating international teams are obliged to document any safety-relevant aspects related to their project. There are also plans to develop a code of conduct.

- **Biosafety (unintended release)**
- **Biosecurity (intentional release)**

Amateur biology

In the context of modern-day biology, there is a growing community of amateur biologists or "biohackers" who conduct biological work outside of conventional research institutions similar to the beginnings of the IT industry. Members of this community are also actively engaged in the security discourse and in elaborating a Code of Conduct.

why the international community has so far been unable to agree on a verification mechanism in the framework of the Biological Weapons Convention (BWC) such as those that exist for chemical and nuclear weapons. Research that is of relevance to biological weapons can easily be hidden under the guise of legitimate activities and conducted in the type of small civilian laboratories of which there are hundreds of thousands worldwide. The sheer number of installations that would need to be monitored would preclude even the semblance of a credible inspections regime.

The limitations of arms control mechanisms such as the BWC will become even more apparent once the bioweapons threat from non-state actors increases. Such a scenario seems plausible, since the proliferation of biotechnological capabilities throughout society is inexorable. Imposing limits on advances in biotechnology would hardly seem appropriate in view of the huge potential benefits of this discipline, and would also not be feasible in practice. The expertise, material, and equipment are used across many life science disciplines and are – to varying degrees – already widely available around the world. In this sense, the proliferation of biotechnological knowledge and material, though not specifically weapons-related, is already underway. The geographic and societal-sectoral proliferation of biotechnological expertise is therefore hardly reversible at this stage.

Innovative approaches required

Against this background, it is becoming apparent that the security-policy challenges of biotechnological developments can only be tackled with a comprehensive response and innovative approaches. Instead of the traditional focus on attempting to deny access to knowledge and technologies, a broader approach should be pursued that also engages relevant social groups and actors and enables them to discover and report misuse.

What is required is the installation of an integral network of top-down political steering and regulating mechanisms on the one hand and bottom-up initiatives for self-regulation of interest groups on the other. Such a "Web of Prevention" would consist of national and international efforts, initiatives, and activities at various levels of intervention involving all relevant actors. That would shift the focus towards sharing responsibility among politics, science, business, and society at large.

In analogy to the Hippocratic oath, which is taken as a matter of course in the medical disciplines, the field of biotechnology must also create a culture of responsibility and awareness of risks. However, such a comprehensive approach, which would probably be unique in the history of arms control, would require a shared vision and flexible strategy as to how the various actors and initiatives could be systematically integrated. Clearly, such a consensus can only take root if all relevant stakeholders are sensitised to the security-relevant dual-use aspects of research in biotechnology.

In this context, it is encouraging to see that those dealing with synthetic biology have adapted a highly proactive approach to ethical and security-relevant issues. Not least in response to widespread scepticism towards genetic engineering, many protagonists in the field are unabashed about tackling such issues and actively engaged in public discourse. Students, who are increasingly becoming involved in this discipline, are confronted with these issues at an early stage.

So far, the most concrete efforts have been made by the DNA synthesis industry. As a self-regulating effort, these companies voluntarily – and so far, without significant government assistance – perform checks as to whether DNA orders are congruent with the genetic sequence of pathogens. If this is the case, the customer will be screened and the order refused unless there are legitimate reasons for procuring such a sequence.

All these efforts are laudable, but much more needs to be done to secure the future of biotechnology – not only with regard to synthetic biology, but also concerning the bioscience and technology field as a whole. The goal of such preventive measures should be to maximise the unfettered development of the many beneficial applications of biotechnology while simultaneously minimising the danger of harmful developments. It is important to remember that the net effect of developments in biotechnology could certainly prove to be advantageous – also in terms of countering the bioweapons threat – and that beneficial applications thus should be considered an important variable in the overall risk assessment.

- Author: Sergio Bonin
  bonin@unicri.it
- Responsible editor: Daniel Möckli
  sta@sipo.gess.ethz.ch
- Translated from German:
  Christopher Findlay

- Other CSS Analyses / Mailinglist:
  www.sta.ethz.ch
- German and French versions:
  www.ssn.ethz.ch