iGEM | Responsibility CONFERENCE 2025 | OECD BETTER POLICIES FOR BETTER LIVES

Responsibility Conference 2025 Report

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Table of Contents

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Foreword

Dear Reader,

Synthetic biology is at an inflection point. The convergence of DNA synthesis, AI-enhanced biodesign and automation is accelerating innovation at unprecedented rates. These advances hold extraordinary promise: from achieving CEPI's 100 Days Mission of rapid vaccine development, to addressing global challenges through meeting the UN's Sustainable Development Goals. Yet, with this growing power comes profound responsibility.

Over two days, we gathered at the heart of iGEM Grand Jamboree to explore one of the most pressing questions facing our field: How do we innovate and advance synthetic biology in ways that are safe, secure, equitable and truly responsible?

During the conference we explored DNA screening challenges, examined AI-biosecurity convergence, centered voices from the Global South in governance discussions, and charted new pathways for public engagement. Covering topics from red-teaming exercises to new initiatives for public engagement, and from mirror biology ethics to next-generation biosecurity leadership, our community demonstrated that responsibility in synthetic biology requires both technical expertise and inclusive, global cooperation.

The iGEM Responsibility Conference is unique. It's the only venue where scientists, policymakers, students, and the public convene as equals to address these challenges together. The insights generated here, the connections we build, and the commitments made, will ripple outward into labs, policy chambers and communities worldwide.

Thank you for your engagement, your expertise, and your commitment to pushing the frontiers of science safely, securely and responsibly. The work to build a culture of responsibility continues- and it continues with you.

Christopher Isaac

Director of Responsibility
iGEM

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From Participation to Impact - How Next Gen Leaders Are Shaping the Future of Safe and Secure Synthetic Biology

Session Supporter

CEPI

Coalition for Epidemic Preparedness Innovations

Moderator and Speakers

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Introduction

The Coalition for Epidemic Preparedness and Innovation's 100 Days Mission (100DM) aims to develop vaccines within 100 days of detecting new biological threats, minimizing pandemic impacts through leveraging emerging technologies like AI, mRNA platforms, genomic sequencing and synthetic biology. While these technologies enable rapid vaccine development, they may also present significant risks including dual-use concerns and biological misuse. Following the momentum from the 2025 Biosecurity Emerging Leaders Declaration launched at the Munich Security Conference, which established an action-oriented roadmap for global biosecurity based on equity, responsibility and innovation, this session convened six early- to mid-career biosecurity leaders to share experiences and provide actionable strategies for integrating safety, security, and equity into synthetic biology development and governance, ensuring the 100DM is achieved in a responsible manner.

The session addressed a central question: How can emerging technologies enable faster, safer science while ensuring that biosecurity frameworks keep pace with innovation? The panelists emphasized that biosecurity is not about restriction but about trust, access and sustainability. The goal is ensuring that systems built to protect human, animal, and environmental health do not inadvertently cause harm, and that scientists worldwide can contribute equally to global preparedness.

Perspectives from the Panelists

Kim Trollope leads the Stellenbosch Biofoundry, the first academic biofoundry in Africa. She described biosecurity as "a framework for the responsible use of biology, both natural and synthetic, to solve challenges in health, manufacturing and food production, and importantly, to do no harm to society and ecosystems." From her perspective in South Africa's bio-manufacturing sector, she emphasized that establishing biofoundries represents a strategic investment in national bioeconomies. The Global South, she noted, has unique strengths: experience working within resource constraints, the integration of indigenous knowledge systems, and growing public-private partnerships that drive local solutions to regional challenges.

Jose Garza-Martinez framed biosecurity through four interconnected pillars: prevention, detection, response and recovery. Drawing on his experience with the UN Office for Disarmament Affairs and biosecurity education, he argued that biosecurity must become embedded in the culture of innovation—rather than as an afterthought. He recounted a troubling anecdote about a researcher developing bacteria for bioremediation, not considering safety features for deployment. A lack of regulation in this area meant that post-deployment safety was not being considered. This interaction, Jose suggested, reveals a fundamental gap in how safety considerations are integrated into scientific training.

Sriram Kumar brought a virologist's perspective on dual-use research and oversight. He argued for expanding biosecurity's traditional focus beyond living organisms to include inanimate objects, reflecting how synthetic biology is enabling microbes to degrade plastics, metals, and other materials. Sriram emphasized the need for dynamic policy frameworks that evolve in real-time rather than static regulations updated every few years. He also highlighted that AI's capacity to process thousands of pathogen sequences rapidly can accelerate outbreak detection and inform whether a pathogen is novel or already classified.

Discussion and Key Findings

The 100 Days Mission and Emerging Technologies

The panelists explored how synthetic biology and AI can accelerate vaccine development and early pathogen detection. Sriram explained that AI enables rapid processing of genetic sequences to determine whether an outbreak is caused by a novel pathogen or an existing classified agent, a distinction with direct implications for vaccine design strategies. Kim noted that once sequences are known, AI can help design and select optimal targets for testing, while lab automation dramatically speeds development timelines. Jose added that synthetic biology enables faster testing through cell-free systems (laboratory methods that use biological components outside living cells), potentially reducing the time and cost of clinical trials by screening candidates before human testing begins.

Global South Innovations and Challenges

The discussion highlighted distinctive contributions from Global South contexts. Kim described her work with the WHO mRNA Technology Transfer Hub in Cape Town, developing local raw materials for vaccine manufacturing. In India, Sriram noted a shift from PCR-based diagnostics to chip-based systems that enable faster outbreak detection. Jose observed that Latin America's synthetic biology research tends to concentrate on agricultural applications, reflecting regional priorities around food security.

Panelists revealed several Global South strengths: regional training programs in synthetic biology and biosecurity are growing; public-private partnerships are creating practical applications; and Global South innovations emphasize low-cost approaches, standardization of protocols and decentralization of production. As Sriram observed, these developments reduce dependence on centralized manufacturing which proves critical for

equitable pandemic response as demonstrated during the early stages of the COVID-19 pandemic. However, the panelists acknowledged persistent challenges: limited domestic funding for basic science and overreliance on international data storage.

Biosecurity by Design: Embedding Safety in Innovation

A central theme was the concept of "biosecurity by design": proactively integrating safety, ethics, and oversight into every stage of research and innovation. The panelists agreed that waiting for policy to catch up with technology is insufficient. Instead, responsibility must be cultivated from the laboratory level through education, institutional biosafety committees, and cultural norms that treat biosecurity as integral to good science.

Sriram argued for dynamic oversight that includes interim reviews during projects rather than just approval at the outset. Projects may develop biosecurity implications as they progress, and static evaluation frameworks miss these emerging risks. Jose emphasized the need for biosecurity assessments to be incorporated into ethics committee evaluations alongside existing requirements for animal welfare and human subjects protections.

Kim offered a practical approach: addressing ignorance through education and building traceability of research materials. She observed that biosecurity should be discussed at the bench level with new students from day one, creating cultural norms where safety considerations are automatic rather than imposed externally.

The Role of Next-Generation Leaders

The panel addressed barriers preventing young professionals from meaningfully contributing to biosecurity governance. Sriram noted that lack of awareness about biosecurity in educational curricula creates a foundational barrier because young researchers may not recognize the significance of their role in shaping policy. Jose cited data showing that under 12% of participants in Biological Weapons Convention working groups are under 35, reflecting systematic underrepresentation of youth perspectives.

The panelists offered strategies for emerging leaders: pursue fellowships and training programs (including the Emerging Leaders in Biosecurity Initiative from Johns Hopkins, UN fellowships, and iGEM's biosecurity delegate program); seek mentorship opportunities; and, engage at institutional levels before attempting national or international advocacy. Kim suggested that Global South fellows should be "more aggressively marketed." She emphasized that fellowship programs should actively reach out to universities in under-represented regions rather than relying on candidates to discover opportunities.

A key insight emerged around communication strategy. When engaging policymakers, framing biosecurity through the lens of bioeconomy and economic development often opens doors more effectively than emphasizing threats. Kim noted that referencing the bioeconomy, especially given the focus in G20 meetings, could help overcome people not necessarily taking you seriously because you're a younger leader.

Equity, Trust and Public Engagement

The discussion touched on equitable biosecurity and the challenge of building public trust. Jose articulated a vision of equity centered on universal access to technology, meaningful participation in governance, fair benefit sharing and the capacity for self-reliance. He expressed opportunity areas about near-term progress on the Pathogen Access and Benefit Sharing provisions of the Pandemic Accord, noting the need to find a balance between Global North positions treating genetic data as freely shareable and Global South concerns about fair compensation for biological resources.

On public communication, Sriram suggested that scientific innovation should carry mandates to communicate findings, not just to peer communities but also to end-users. Jose noted that social acceptance requires understanding that technology adoption depends on trust, not just scientific validity.

Conclusion

The session revealed a fundamental reframing: biosecurity enables rather than constrains rapid response. The panelists demonstrated that the 100 Days Mission depends not on loosening safeguards, but on having them already in place—allowing diverse partners to act swiftly and on equal footing when emergencies arise.

Three interconnected priorities emerged for achieving this vision:

First, biosecurity must shift from regulatory afterthought to design principle, embedded at the laboratory bench from day one of a researcher's training.

Second, governance frameworks require dynamism—interim reviews during projects rather than static approval at the outset—to catch risks that emerge as research evolves.

Third, the Global South's distinctive contributions (experience with resource constraints, indigenous knowledge systems and decentralized manufacturing models) must move from the periphery to the center of biosecurity discourse.

Perhaps most significantly, the panelists modeled a different kind of expertise: Global South leaders engaged as peers rather than apprentices, bringing perspectives that senior policymakers often lack. Their strategic advice to frame biosecurity through economic opportunity rather than threat, to seek mentorship while building institutional influence, and to pursue fellowships actively marketed to underrepresented regions, offers practical steps for the next generation of leaders to follow as they engage with biosecurity. The question now is whether institutions will create genuine pathways for these voices to shape policy, or whether youth engagement will remain purely symbolic. The answer will determine whether global health security is truly global.

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Governance of Synthetic Biology in the Global South

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Introduction

Synthetic biology represents a transformative frontier in science with profound implications for health, agriculture, environmental sustainability and economic development worldwide. However, the governance landscape for this emerging technology remains dominated by institutions, frameworks and ethical perspectives originating from the Global North, creating a critical gap in representation and potentially perpetuating global inequalities.

This session challenged the prevailing governance paradigm by centering Global South perspectives and exploring "Global Solidarity" as both a normative principle and practical framework for inclusive synthetic biology governance. The session examined how current governance structures may inadvertently exclude or marginalize Global South voices, and explored pathways toward more equitable participation in shaping the future of this technology. The diverse stakeholders present at the session, including policymakers, bioethicists, scientists, civil society actors and youth leaders, articulated a context- sensitive vision of solidarity that responds to the specific challenges, ethical paradigms and opportunities encountered across the Global South.

Perspectives from the Panelists

Ruipeng Lei opened the session by outlining her team's work on the ethics and governance of synthetic biology. She introduced the "Trustworthy Synbio Towards Solidarity" framework, which includes principles anchored in trustworthiness, solidarity, justice, respect for persons, species integrity and human dignity. Solidarity, she emphasized, is not charity but shared responsibility and mutual flourishing. Equitable governance must embed perspectives from the Global South at the outset, not as afterthoughts.

Building on the theme of embedded perspectives, Luis Campos pointed out that the 1975 Asilomar Conference—though presented as 'international' at the dawn of genetic engineering—predominantly featured participants from North Atlantic countries (primarily scientists) who debated whether and how to pursue this potentially dangerous yet promising biotechnology. Critics noted that it allowed a narrow subset of scientists to determine the direction of science. Moreover, the conference's purportedly 'responsible' decisions had varying global interpretations: While Asilomar lifted the voluntary moratorium that had been instituted six months earlier, this move was embraced by some nations but perceived by others (particularly those without genetic engineering technology) as a strategic maneuver to consolidate power. Significantly, the conference failed to address the Global North-South divide.

To address this, a summit was launched on the 50th-anniversary of the original meeting (February 23–26, 2025). "The Spirit of Asilomar and the Future of Biotechnology" summit expanded attendance from 150 mostly scientists, to 300 people with broader geography, age variety and disciplines. It aimed for inclusivity by funding attendance, welcoming unheard voices and exploring flexible international governance (e.g., no pre-set agendas/

outcomes). Instead of a single consensus, it encouraged diverse discussions and produced long-developed "entreaties," such as pursuing a sustainable, equitable global bioeconomy and centering indigenous biotechnology.

Marilene Pavan, director at the SENAI Institute for Biodiversity & Circular Economy, spoke about the effort of this fledgling institution and its ties to the local Brazilian context. Being built from the ground up, the institute will house analytics, pilot-scale and process-development platforms dedicated to all six Brazilian biomes, including the Amazon, to create new value chains that advance the bioeconomy and decarbonization. She noted that the center belongs to a nationwide network of 28 industrial-innovation institutes, yet remains little known abroad. Using the 2022 paper "A global forum on synthetic biology: the need for international engagement" as an example, she endorsed its call for international engagement, but pointed out the absence of authors from Latin America, Africa and most of Asia. Governance debates, she argued, must integrate diverse cultural, ethical and developmental perspectives, eschew one-size-fits-all solutions, and leverage South-South cooperation to share biodiversity and ancestral knowledge for truly inclusive global progress.

Sonja Van Wichelen built upon the previous remarks, noting that global standards often assume Northern infrastructure, creating an "infrastructural mismatch" that prevents Southern actors from meeting biosafety rules. This term describes the gap between governance requirements designed in a well-resourced context and the actual capabilities available in many Global South institutions. Northern-led governance presumes universal ethics and capacity, producing asymmetrical flows of expertise, materials and legitimacy, amounting to "science colonialism." The fix is "infrastructural diplomacy": co-designing labs, data systems and regulatory frameworks through long-term exchanges, regional hubs (e.g., ASEAN) and co-owned intellectual property. Solidarity must redistribute authority, not just benefits, by embedding ethical pluralism and contextual expertise into the infrastructure itself.

Concluding the initial round of remarks, Krishna Ravi Srinivas proposed that SynBio governance in the Global South is hampered by uneven innovation, weak STI capacity and national-level rules that never converge into shared frameworks. Technological leap-frogging, nascent AI-SynBio convergence and the green transition heighten the urgency of building shared frameworks for innovation. True global solidarity requires co-defined visions, mutual learning, and joint research and development. Achieving solidarity at this scale may require cultivation though Triangular Cooperation: authentic South-South cooperation and science diplomacy further buttressed by North-South-South support. Closing governance gaps requires moving from fragmented biotechnology precedents to contextual, rights-respecting mechanisms that value local bioeconomies and circular-economy models. Institutional capacity-building should align with national strategies, while cultural and ethical pluralism needs open explanation without eroding core human rights principles.

Lastly, the panel shared agreement on the value of youth empowerment through iGEM, DIY bio, interdisciplinary training, and global networks to supply the next generation of autonomous, vision-driven Southern leaders in synthetic biology innovation and governance.

Discussion and Key Findings

Redefining and Practicing Global Solidarity

Global solidarity must move beyond moral sentiment and become concrete practice that redefines egalitarian partnerships in governance. In the context of biotechnology governance, solidarity should not be treated as a treaty, a principle, or a textual institution, but as a tool for generating new claims under specific constraints. It accepts that actors need not agree on everything, yet can identify connection points for joint action.

Regional cooperation is especially salient when, for example, neighboring states share interests such as biodiversity, they can create knowledge-production structures more equitable than traditional North–South arrangements. Pacific examples show that regional networks mixing different economic levels can re-define "globality" and transcend the North–South binary. The chief output of such solidarity is cognitive justice: mutual recognition of the validity of diverse knowledge systems. Information sharing underpins solidarity, spanning scientist-to-scientist data exchange and public communication of science. Multi-layered knowledge-exchange systems are needed to keep technological development and social values evolving in tandem in order to increase organic acceptance of technological innovations.

Regional Cooperation as a Path to Cognitive Justice

Regional frameworks offer biotechnology governance a route beyond the North–South paradigm. Asia-Pacific collaboration between Australia and its neighbors demonstrates how states at different development levels can form inclusive knowledge-production networks. The ultimate gain is not faster technology transfer, but rather the creation of the enabling conditions for cognitive justice–a state where multiple knowledge systems meet on roughly equal terms.

New metrics of cognitive justice are needed that track substantive parity in ethical deliberation and legal negotiation, rather than counting hardware or advanced degrees. Shared interests (common biodiversity resources, similar environmental challenges) anchor cooperation. Cooperative decision mechanisms should tolerate difference. Partial consensus on selected issues is enough for joint action.

A multilingual, audience-sensitive information-dissemination system is critical to bridge the gap between scientific understanding and social acceptance. If scaled, this regional model could restructure global governance into a polycentric, networked architecture in which every regional hub contributes distinctive ethical perspectives and knowledge traditions.

Challenges in Science Diplomacy and the Reconstruction of Governance Systems

The practice of science diplomacy faces profound challenges in translating technological cooperation into the reconstruction of governance systems. In current international scientific cooperation, investments in "hardware" such as laboratory construction and data system development often take priority over the development of "software" like governance mechanisms. This leads to capacity-building remaining at a superficial level.

True science diplomacy needs to redefine the mutual relationships among cooperating parties. It should shift from a vertical relationship (where one side is the technology provider and the other is the recipient) to a horizontal one, where all parties are co-designers. The intellectual property rights (IPR) mechanism is a core point of contention. Existing

systems seem to be more focused on protecting the innovation interests of the Global North than on promoting knowledge sharing.

Governance gaps manifest in three aspects: the singularity of evaluation criteria, the asymmetry of negotiation platforms, and the concentration of resource allocation. Potential solutions may include the following:

- Establishing regional dialogue mechanisms for technological ethics.
- Developing risk assessment tools that adapt to different cultural contexts.
- Designing flexible regulatory frameworks to accommodate diverse ethical perspectives.
- Creating innovative IPR sharing models.

These changes require science diplomacy to move from infrastructure construction to the cultivation of institutional innovation capabilities. In particular, it is essential to enhance the voice of the Global South in standard-setting and ethical debates. The ultimate goal is to form a distributed governance network that can respond to different knowledge traditions and value systems, rather than establish a one-size-fits-all standard.

Challenges in International Scientific Cooperation and Knowledge Sharing

Information sharing is a sensitive and controversial topic, especially at the governance level. For example, Brazil lacks its own data storage centers and pays companies in other countries to store sequence data, which weakens Brazil's control of this data, while simultaneously creating a financial burden. The Chinese Academy of Sciences offered to provide Brazil with an alternative, offering to store their sequences at no cost, until such time as Brazil can develop its own data infrastructure. At that time the sequences would be transferred back. This offer, Marilene felt, demonstrated the spirit of international solidarity and cooperation. However, while alternative solutions can distribute control over the data resources, they do not necessarily provide the data-generating partner with control over the data they produce until that data is stored locally.

Knowledge sharing should be mutually beneficial, but the current global situation does not reflect this principle. Co-developing structures that ensure sovereignty of the underlying data is a difficult task, but it's an important one as less-developed countries seek to utilize their genetic sequence resources.

When scientists shared biological information during the pandemic, despite intense governance discussions, they established a clear code of etiquette among themselves rather than strict ethical guidelines. This code focuses more on practice than norms, and as a form of self-governance it allows scientists to develop sensitivities based on the principle of sharing, without having to directly confront existing governance frameworks.

In the current context, this practice-oriented governance approach is particularly important. It provides flexibility for information sharing, instead of relying solely on established norms. Through this self-governance method, scientists have achieved efficient and

harmonious information sharing, while also offering new insights for the improvement of governance frameworks and codesign of local infrastructure.

Legal and Governance Frameworks in Scientific Cooperation

Scientists and researchers need to take the initiative in governance, especially on issues of legal and governance frameworks in scientific cooperation, and particularly in the field of synthetic biology. Science communication is key to these efforts, and must not be overlooked.

Science journalists play a crucial role in disseminating scientific information, yet their work lacks sufficient financial support. In order to increase the total amount of scientific communication with the public, science students could receive training in communication skills and be more involved in science communication, rather than limiting this role to established scientists themselves.

The role of law in scientific practice is underestimated, and there is a need to convey legal parameters in more accessible language. The overlap of science and law touches property rights, personal rights and the application of synthetic biology projects to individuals themselves and to the greater environment. Legal democratization through tools and training could enable broader participation in scientific governance.

Practical Issues in International Conferences and Collaboration

The organization of international conferences faces numerous practical challenges, such as time zone differences and insufficient geographical representation. Research institutions in North America and Western Europe usually dominate, while representatives from Eastern Europe, Africa and South America have less representation.

This geographical imbalance complicates conference organization and coordination, especially when scheduling meeting times. Time zone differences make it particularly difficult to find a time that works for everyone. However, these issues can be partially alleviated through regional collaboration and alternating arrangement of conference times.

Practices in international collaboration show that despite time zone and geographical challenges, effective communication and collaboration can still be achieved through

compromise and mutual understanding. Additionally, in-person conferences remain valuable, as they provide participants with direct interaction opportunities that virtual conferences cannot replace.

Conclusion

This session exposed a structural problem in global biotechnology governance: frameworks designed in the Global North assume infrastructure, ethical paradigms and institutional capacities that do not exist uniformly worldwide. This mismatch produces not only inefficiency but also injustice, by excluding the perspectives of those who may bear the greatest consequences of technological change.

The panelists advanced "Global Solidarity" as both a diagnosis and a remedy. Solidarity, in this framing, is not charity extended from wealthy nations to poorer ones. Rather, it requires co-designing laboratories, data systems and regulatory frameworks through genuine partnership. It demands cognitive justice- mutual recognition that diverse knowledge systems hold validity. And it insists that authority, not merely benefits, be redistributed.

Three pathways forward emerged from the discussion. Regional cooperation offers an alternative to the North-South binary, as neighboring states with shared biodiversity interests create knowledge-production structures on more equitable terms. Triangular cooperation—South-South partnerships buttressed by Northern support—can build capacity without replicating dependency. And practice-oriented self-governance among scientists, demonstrated during pandemic data-sharing, provides flexibility that rigid regulatory frameworks cannot. Ultimately, achieving solidarity will require a rethink of how to approach cooperation and collaboration in synthetic biology.

For Further Reading

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Red Flags & Gene Tags: DNA Screening Games

Session Supporter

International Biosecurity and Biosafety Initiative for Science (IBBIS)

Moderators and Speakers

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Introduction

Can you spot a bad actor ordering dangerous DNA? This interactive workshop explored the challenges and complexities of DNA synthesis screening through hands-on games and collaborative exercises. This session gave participants direct experience with the difficult decisions that screening personnel face when evaluating orders for synthetic genetic material. Rather than presenting biosecurity as an abstract policy discussion, the workshop immersed participants in realistic scenarios that revealed the tension between enabling legitimate scientific research and preventing potential misuse.

The session featured Tessa Alexanian and Jake Beal, leading experts in DNA screening technology, and combined two distinct activities: an order screening role-play exercise and a collaborative brainstorming game called 'Red Light, Green Light'. Together, these exercises illuminated both the human judgment required in biosecurity decisions and the technical challenges of identifying threats in an era of AI-designed sequences.

The Workshop

Understanding DNA Order Screening

Before diving into the games, the facilitators provided essential context about nucleic acid order screening. When a customer orders synthetic DNA from a company like IDT, Twist or Genscript, or from a local biofoundry or DNA printer, those sequences are typically analyzed by screening software before synthesis. The software compares the requested sequences against databases of known dangerous pathogens and toxins. When a sequence raises concerns, the synthesis company must decide whether to fulfill the order, deny it, or report it to authorities.

The facilitators illustrated this process with a short story: During regular business, a synthesis company once received an order for smallpox sequences from a high school teacher who wanted a *negative control* for an environmental sampling program. The teacher's reasoning was that since smallpox is extinct, there would be no matches in the environment. The company declined the order, illustrating that even well-intentioned requests for dangerous sequences require careful evaluation. If the order had instead been fulfilled, dangerous smallpox DNA could have been sent through the mail.

Key Challenges in Order Screening

The facilitators identified three fundamental challenges that make DNA screening particularly difficult:

- **The Legitimate Use Problem**: Many people have genuine, beneficial reasons to work with sequences from dangerous pathogens or toxins. Vaccine developers need pathogen samples. Medical researchers use toxins like ricin and scorpion venoms for therapeutic applications. The screening challenge lies in distinguishing authentic,

legitimate use from someone merely claiming to have one. The facilitators identified this as the primary problem participants would confront in the workshop exercises.

- **Staying Current**: The biological landscape continuously evolves through natural mutation and AI-enabled design. Customer circumstances can also change; a researcher who once had legitimate access may have changed jobs or lost their institutional affiliation. Screening systems must thus keep pace with both biological and social changes.
- **Defining Threats**: In the vast space of possible genetic sequences, which ones actually matter from a security perspective? Traditional screening relies on matching sequences to known dangerous organisms, but this approach fails when novel sequences are created. This challenge became the focus of the second game.

The Order Screening Game: Experiencing the Dilemma

In the first exercise, participants paired up and received customer profiles based on real examples from the history of synthetic biology. Some profiles represented legitimate scientists with genuine research needs; others were based on previous bioterror attempts or other concerning cases. The facilitators instructed participants not to reveal their true identities to their partners.

Each pair received a flagged order that screening software had identified as potentially concerning. Many of these orders, the facilitators noted, actually contained BioBricks, the standardized genetic parts used in iGEM competitions, demonstrating how even legitimate educational materials can trigger security alerts.

One participant played the customer attempting to convince the screener to fulfill their order, while the other played the screening officer who had to make a decision: fulfill the order, deny it, or deny it and report to authorities. After five minutes, participants switched roles with new profiles.

This role-play format forced participants to grapple with the fundamental tension in biosecurity screening; namely, the same conversation could come from a legitimate researcher with a genuine need *or* from someone with harmful intentions using a sophisticated cover story. The exercise revealed that even with face-to-face interaction and the ability to ask probing questions, distinguishing between these cases is genuinely difficult. When participants finally revealed their true profiles to their partners, the responses ranged from relief to surprise to concern about the decisions they had made.

The "Hard Mode" Challenge: When BLAST Returns Nothing

The second part of the session addressed what the facilitators called hard mode for DNA screening. The order screening game, while challenging, represented the easier scenario of cases where screening software has some information about what a sequence might do. But increasingly, companies receive orders for sequences that return no significant matches when analyzed using tools like BLAST (Basic Local Alignment Search Tool).

This situation arises because modern biotechnology increasingly involves sequences that have never existed in nature. Jake Beal presented two illustrative examples: DNA origami, where researchers design sequences with specific binding properties that have no biological function, and DNA data storage, where the entire point is to encode digital information using methods that treat the biological properties of DNA as irrelevant.

These novel sequence types create a fundamental screening challenge: if a sequence has no similarity to anything in existing databases, traditional screening cannot determine whether it poses a risk. The same opacity that makes DNA origami and data storage sequences difficult to evaluate also applies to AI-redesigned threat sequences, which might be engineered specifically to evade detection while retaining dangerous properties.

Red Light Green Light: Identifying Features That Matter

The Red Light Green Light game challenged participants to develop heuristics for evaluating mysterious sequences. Working in groups of four to six, participants brainstormed features that might help identify sequences of concern (red lights) or sequences that could be confidently cleared (green lights).

The facilitators posed two key questions. First, what features might help positively identify a sequence as belonging to a particular category, such as DNA origami, data storage, or AI-redesigned threats? Second, how should screeners evaluate the actual risk of a sequence that no one has ever tested in a laboratory? Just because someone attempts to redesign a dangerous protein using AI does not mean their design will actually function.

Participants submitted their ideas through an interactive polling system and voted on each other's proposals. This exercise surfaced creative thinking about sequence features that might serve as security indicators.

Key Insights from Participant Brainstorming

The collaborative brainstorming yielded several notable proposals that received strong support from participants:

- **Winning Red Light Feature**: The most highly-voted red light feature was the level of similarity between the predicted AlphaFold 3D structure of the target protein to protein structures from pathogenic genomes. This suggestion reflects the recognition that even when sequence-level comparisons fail, structural analysis using AI tools might reveal functional similarities to known threats. If a novel sequence is predicted to fold into a shape similar to known dangerous proteins, that structural similarity could serve as a warning sign even in the absence of sequence homology.
- **Winning Green Light Feature**: The most supported green light feature was the amount of repetitive sequence content within an order. This reflects understanding that many legitimate applications, particularly DNA data storage and certain nanotechnology applications, involve highly repetitive sequence patterns that are unlikely to encode functional biological molecules. Repetitive sequences are poor substrates for protein function and are more likely to represent structural or informational applications.

Other proposals submitted by participants included analysis of Shannon Entropy (a measure of sequence complexity), examination of codon usage patterns, and evaluation of whether sequences contained features typical of natural biological systems versus artificial constructs.

Broader Implications for Biosecurity

The workshop surfaced several important themes that extend beyond DNA screening to broader questions of biosecurity governance:

- **Human Judgment Remains Essential**: Despite advances in automated screening, the order screening game demonstrated that many decisions ultimately require human evaluation. The nuanced assessment of whether a customer's stated purpose is credible cannot be fully automated, and the consequences of both false positives (blocking legitimate research) and false negatives (enabling misuse) are significant.
- **The Move Beyond Sequence Matching:** Traditional biosecurity screening has relied heavily on identifying sequences that match known pathogens. The workshop highlighted the inadequacy of this approach in an era of AI-designed molecules and novel biotechnologies. Future screening will need to incorporate functional prediction, structural analysis, and other methods that can evaluate sequences with no natural precedents.

Conclusion

This workshop achieved something rare in biosecurity education, by making abstract policy debates real and tangible. Participants who arrived with an intellectual or abstract understanding of DNA screening left having experienced the central tension and difficulty of distinguishing legitimate researchers from potential bad actors, even with face-to-face conversation and probing questions.

The next generation of synthetic biologists will be essential contributors to solving emerging challenges related to biosecurity and DNA synthesis. They understand both the creative possibilities of AI-enabled design and the cultural norms of responsible research. Building screening systems that work will require their insights and their willingness to treat biosecurity as integral to their professional identity.

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Synthetic Biology × AI Convergence and the Case for Global Governance

Session Supporter

Organization for Economic Cooperation and Development (OECD)

Moderator and Speakers

Daniel Nadal
Policy Analyst (OECD)

Traci Haddock
Director of Community (Asimov)

Jenny Molloy
Group Leader (University of Cambridge & ICGEB)

Justin Taylor
CBRN Safeguards (Anthropic)

Nick Vangheluwe
Policy Officer (European Commission)

Introduction

The convergence of synthetic biology with artificial intelligence and automation is accelerating the pace and complexity of innovation. These technologies hold potential for both benefit and harm, creating opportunities and risks to be anticipated, understood, and either supported or mitigated. For example, lowered barriers to entry into synthetic biology could democratize the field while also creating biosecurity implications. All the while, questions about the future role of humans in automated systems remain. This panel unpacked and explored the opportunities and challenges of the integration of synthetic biology and AI, with concrete examples from the lab, industry and policy from a broad range of sectors. The discussion covered the current global governance ecosystem for this converging space, identified gaps and explored how they could be addressed by international governance efforts.

Discussion and Key Findings

Opportunities and Applications: Distinguishing Hype from Reality

The session began by situating SynBioxAI (the convergence of synthetic biology and artificial intelligence) as a transformative force reshaping research and development. The panel acknowledged that SynBioxAI applications have existed for several years. Therefore the discussion focused not only on what this convergence can deliver in the future, but also on what it has already concretely delivered, and what implications this has had.

Daniel Nadal (OECD) introduced preliminary results from the OECD's recently published *Synthetic biology, AI and automation: a forward-looking technology assessment*, which sets out concrete areas where SynBioxAI is being applied (including AI biodesign tools, biofoundries, education and applications beyond containment), as well as some initial governance and policy implications (including the need for pro-innovation regulation, data supply chains, human oversight, biosecurity and biosafety, and technological sovereignty).

Traci Haddock (Asimov) described how her company integrates AI into genetic design models to accelerate biological engineering. She explained that AI-driven promoter design has enabled breakthroughs such as tissue-specific gene expression, achieved through generative AI that successfully produced cardiac-specific promoters validated in animal models. Traci emphasized that these tools are time-saving, reflecting both their efficiency and reliability in automating complex design tasks. At the same time, she underlined the importance of human validation and rigorous experimental verification before deployment, consistent with Asimov's philosophy of "never skipping validation."

Justin Taylor (Anthropic) discussed broader AI applications across the life sciences, citing examples like the integration of large language models like Claude into existing platforms such as Benchling and BioRender. He emphasized that AI models not only provide answers but, when engaged as tutors, also create opportunities for deeper learning.

Jenny Molloy (University of Cambridge) offered a nuanced perspective on AI's adoption in laboratories, from the point of view of an academic researcher. When asked whether current enthusiasm around SynBioxAI is mere hype, she responded "yes and no," explaining that while many tools are still maturing, others are already used daily (for example, in documentation and experimental record keeping). Looking ahead, she highlighted that by 2027, AI-based tools will likely be fully embedded in students' academic lives, prompting the need for new educational frameworks that teach not only technical use, but also responsible engagement with these systems.

From a policy angle, Nick Vangheluwe (European Commission) acknowledged that SynBioxAI is surrounded by a degree of hype, yet stressed that the mainstreaming of AI and machine learning makes proper adoption essential. He discussed the European Commission's ongoing efforts to ensure that governance frameworks, including research ethics and oversight committees, are equipped to evaluate AI applications in biotechnology responsibly. He emphasized that responsible integration should not only focus on regulation but also on fostering a culture of accountability and collaboration between policymakers, scientists and developers.

Challenges: Disparities, Risks and Regulation

Panelists then addressed emerging challenges. Jenny Molloy pointed to deep inequalities in access to AI-enabled biotechnology, especially across low- and middle-income countries. She referenced UNDP data indicating that only 5% of Africa's AI talent has access to the computational power it needs, underscoring the severe imbalance in global infrastructure. Such disparities in computational access, data availability and technical training risk amplifying existing divides rather than closing them.

Justin Taylor cautioned that as models improve, their misuse potential grows. Drawing on his experience in biosecurity, he emphasized that poorly calibrated regulations can unintentionally hinder beneficial research. At the same time, AI-controlled laboratory automation poses its own risks, making it essential to strike a balance between enabling innovation and ensuring safety through appropriate regulation.

Traci Haddock elaborated on Asimov's internal practices for ensuring responsible use of data and models, including forward-looking risk assessment processes designed to anticipate potential challenges, secure DNA screening, and create team integration between modelers and bench scientists to avoid siloed workflows. She observed that while large, well-funded companies can implement such safeguards, smaller start-ups and academic groups often lack these resources.

From the EU perspective, Nick Vangheluwe emphasized that regulatory frameworks must evolve as rapidly as the technology itself. The European Commission's approach centers on three pillars: transparency, safety and security. This approach maintains space for innovation through research exemptions. However, he acknowledged that global coordination remains limited, with differing national priorities creating fragmentation in governance.

Global Governance and Solutions

In the final segment, the panelists explored potential governance mechanisms for the SynBioxAI ecosystem. Justin Taylor introduced Anthropic's AI Safety Levels (ASL) framework, modeled after biological biosafety levels (BSL), to structure safeguards proportionally to model risk. He explained that Anthropic's models, like Claude, are released with increasing safety controls at higher ASL tiers, including automated refusal mechanisms and pre-deployment risk assessments. He noted that while these measures can frustrate users, they are essential for maintaining public trust.

Traci Haddock detailed Asimov's "secure-by-design" approach, where every designed genetic sequence is screened through SecureDNA before synthesis. The company also maintains SOC2 compliance and integrates human-in-the-loop validation across its workflow, ensuring AI outputs are always checked experimentally. She argued that governance should not rely solely on synthesis companies or regulators, but should be shared across the research and industry ecosystem.

Jenny Molloy raised the issue of workability in terms of how governance measures can realistically be implemented by scientists under pressure to publish and secure funding. She recounted how new AI restrictions had blocked legitimate coding tasks in her lab, illustrating the fine line between safety and usability. Effective governance, she argued, must integrate seamlessly into daily research practice without imposing undue burdens, accounting for the unique incentives and capacities of typical researchers.

Nick Vangheluwe concluded by reaffirming that governance must balance enabling innovation and mitigating risks. The EU's open science policies require data accessibility and reproducibility while embedding biosecurity considerations within research funding. He underscored the need for continuous monitoring of AI-bio tools (citing existing work as good examples of these activities), as the proliferation of open-source models could make containment impossible once risky tools become publically available.

Conclusion

The session surfaced some productive tension at the heart of SynBioxAI governance: that the same tools that accelerate beneficial research also lower barriers to potential misuse, and that no single actor can address this dual-use challenge alone.
Three fault lines emerged that governance frameworks must navigate.

- The first runs between innovation and precaution. Overly restrictive regulation risks stifling beneficial applications or driving research to less regulated jurisdictions while insufficient oversight risks enabling harms that undermine public trust in the entire field. The panelists converged on anticipatory "secure-by-design" approaches—embedding safety features into tools and workflows rather than relying solely on external regulation—as a middle path.
- The second fault line separates well-resourced actors from everyone else. Large companies like Asimov and Anthropic can implement sophisticated safeguards, but academic laboratories and small startups often lack the resources to do so. Meanwhile, the UNDP's finding that only 5% of Africa's AI talent has adequate computational access reveals a global disparity that governance discussions rarely address. Effective frameworks must account for this heterogeneity rather than assuming uniform capacity.
- The third fault line divides policy aspiration from researcher reality. Jenny Molloy's observation that new AI restrictions had blocked legitimate coding tasks in her lab illustrates a persistent challenge: Governance measures designed in conference rooms must work in laboratories where scientists maneuver around publication pressures, funding deadlines and genuine scientific curiosity. Real solutions must be driven by feasibility as well as principle, co-created with those who would be tasked with implementing them.

The path forward requires sustained collaboration among developers, researchers, policymakers and civil society. The OECD's report on SynBioxAI governance implications offers one vehicle for this coordination. Whether the international community can move from fragmented national approaches toward coherent global frameworks remains the defining question for the field.

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Strategies for Community Engagement on Mirror Life

Session Supporter

Mirror Biology Dialogues Fund

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The Public

40 international students and researchers, participants at the iGEM Grand Jamboree

Introduction

Mirror life represents one of the most serious hypothetical developments in synthetic biology: the creation of organisms built from molecules with opposite chirality to those found in nature. While all known life uses L-amino acids and D-sugars, mirror organisms would be constructed from D-amino acids and L-sugars. Researchers have raised the alarm about this nascent technology, voicing concerns about the implications of mirror organisms for public health and ecology. This session brought together experts and community members to explore the risks, governance challenges and communication strategies surrounding this emerging issue.

Based on current research trajectories, panelists estimated that creating functional mirror life could take between 10 and 30 years. The consensus was clear that the potential risks substantially outweigh the potential benefits, particularly since many proposed applications could be achieved through alternative methods. This session examined how the synthetic biology community can engage effectively with diverse stakeholders to develop appropriate governance frameworks before this technology becomes a reality.

Origins of the Mirror Life Conversation

The global scientific conversation about mirror life risks gained significant momentum in December 2024, when 38 scientists from ten countries published a landmark Policy Forum in *Science* titled "Confronting Risks of Mirror Life." The authors (including two Nobel laureates and 16 members of national academies) argued that governments worldwide should prohibit research and funding aimed at creating mirror bacteria. This publication was accompanied by a detailed 300-page technical report analyzing the feasibility and risks of mirror organisms.

What made this intervention remarkable was that several of the authors had previously been working toward creating mirror life themselves. However, as the working group formed over 2023-2024 to systematically analyze the risks, many researchers shifted their positions from enthusiasm to caution, ultimately concluding that there was no safe way to make a mirror cell.

Following the December 2024 publication, organizers convened a series of international meetings to advance the conversation. A summit at Asilomar in February of 2025, resulted in nearly 100 researchers, funders and policymakers signing an entreaty arguing that mirror life should not be created unless future research convincingly demonstrates that it would not pose severe risks. To the best of the scientific community's knowledge, all research with the explicit goal of creating mirror bacteria has been halted. Follow-on meetings organized at the University of Manchester, and Institut Pasteur convened experts in synthetic biology to further discuss the feasibility and risks of mirror life. This iGEM Responsibility Conference session represented an important opportunity to extend these expert deliberations to the broader synthetic biology community, including the next generation of researchers.

The Scientific Case for Concern

Scientists identify several categories of risk that would make mirror bacteria fundamentally different from other biosecurity threats:

- *Immunological Invisibility*. The most immediate concern is that mirror bacteria would be difficult to detect and would be resistant to the immune defenses of organisms from across the tree of life. The proteins on a mirror bacterium's surface would have the wrong handedness to be effectively processed to kickstart antibody production or be recognized by immune receptors that evolved over billions of years to detect left-handed proteins.
- *Ecological Disruption*. In natural ecosystems, bacterial populations are kept in check by viruses (bacteriophages), predatory organisms and competition with other microbes. Mirror bacteria would likely evade these controls substantially, or bacteriophage controls entirely. Bacteriophages would not recognize their mirror-image genomes to co-opt for replication, and amoebae and other predators would fail to identify them as food. Without natural predators, mirror bacteria could potentially grow to such a scale that they would establish a substantial presence in the environment, competing with normal bacteria for achiral nutrients (resources like simple sugars and minerals that have no handedness), and ultimately encountering and infecting multicellular organisms.
- *Therapeutic Resistance*. Most conventional antibiotics work by targeting specific bacterial proteins or processes. Mirror bacteria would have mirror-image versions of these targets, meaning most existing antibiotics would likely be ineffective. Most antibiotics are chiral, meaning they would only bind to the appropriate mirror image molecules. Very few antibiotics are achiral, which limits our tools for fighting infection. Even if new mirror-image antibiotics could be developed, this would require essentially rebuilding the pharmaceutical toolkit from scratch, a process that would take years or decades while infections spread.
- *Irreversibility*. Perhaps most concerning is that unlike other biosecurity threats, a mirror life release could be irreversible. Once mirror organisms established themselves in environments, there would be no natural mechanism to eliminate them.

Discussion and Key Findings

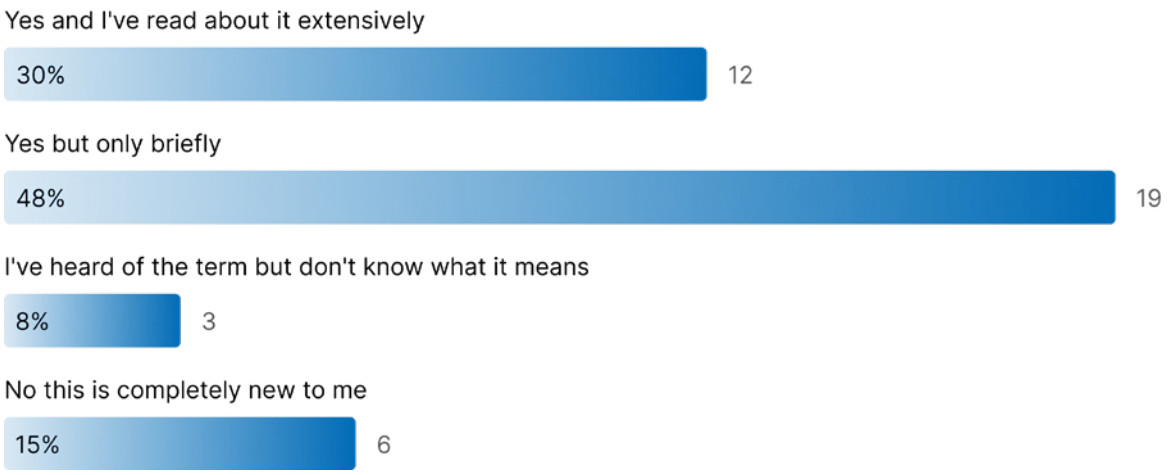
Opening: Assessing Baseline Understanding

The session opened with interactive polling to gauge participants' familiarity with mirror life and their understanding of associated risks. This approach aimed to ensure that discussions could be tailored to the audience's needs while capturing valuable data on community awareness.

Importantly, the audience included a diverse section of early, middle and advanced career iGEM attendees, as well as representatives from a variety of disciples. However, the audience was also self-selected from a population already interested in synthetic biology, and is not necessarily a representative sample of the public.

Prior Awareness of Mirror Life

"Have you heard of mirror life before today?"

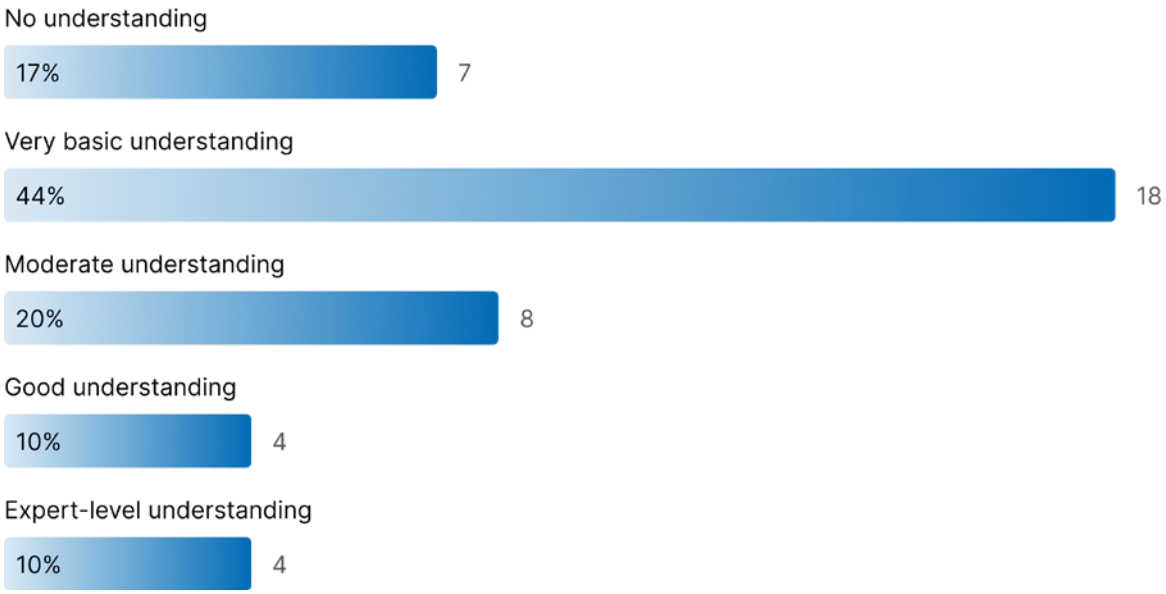


n=40 respondents

The results revealed that while the majority of participants (78%) had at least some familiarity with mirror life, deep expertise remained limited. Nearly half had only brief exposure to the concept, highlighting the need for accessible science communication as the field develops.

Self-Assessed Understanding of Issues (Before Session)

"How would you rate your understanding of the potential issues surrounding the creation of mirror organisms?"



n=41 respondents

Remarks from the Panelists

In order to provide context about Mirror Life, the diverse panel of experts provided an overview of the history of the conversation, technical information about the risks, and perspectives on governance and policy development.

Peter Carr moderated the session and contextualized the broader landscape of mirror life governance. He outlined the intensive international discussions that followed the December 2024 *Science* publication, noting that UNESCO's International Bioethics Committee, the German Biosafety Committee and the UK Government Office for Science had each adopted precautionary stances. He framed the central questions facing the community: identifying appropriate checkpoints along the research pathway, determining which stakeholders should participate in governance conversations, and developing effective communication strategies that balance concern without inducing panic.

Kate Adamala provided the scientific foundation, explaining that mirror organisms would function identically to natural cells but with opposite molecular chirality, rendering them invisible to immune systems, resistant to natural predators and phages, and potentially impervious to standard containment methods. She emphasized her personal trajectory from pursuing mirror life research to advocating against it, after systematic risk analysis convinced her that no safe pathway exists.

Suryesh Namdeo offered a policy framework organized around research, advocacy and action. He called for mapping existing oversight mechanisms, establishing observatories to track foundational technology development and tailoring communication strategies to different national contexts. He suggested that effective engagement would require connecting mirror life concerns to existing regulatory frameworks in each country rather than building entirely new structures.

Daniela Alvarez-Robledo highlighted Global South perspectives, observing that countries facing immediate pressures on health systems and basic research funding struggle to prioritize speculative future risks. She warned that if mirror life required novel countermeasures, the cost would be measured in human lives lost during development and distribution lags, as the COVID-19 pandemic demonstrated.

Chenxiao Wu emphasized philosophical and cultural dimensions, noting that different traditions produce distinct understandings of what counts as life. She advocated for governance frameworks achieving epistemic inclusion, where diverse knowledge systems are recognized as valid contributions rather than merely granting access to deliberative processes.

Ariel Lindner challenged the scientific motivations underlying mirror life research, arguing that creating a mirror cell would not resolve fundamental questions about biological homochirality since outcomes would be entirely predictable. He warned against creating problems requiring resource-intensive solutions and called for centering public engagement on synthetic cells broadly before addressing mirror-specific risks.

Community Perspectives on Risks

When asked to identify risks they foresaw with the creation of mirror organisms, participants used their devices to submit 22 written responses in the first round and 23 in the second. Their concerns clustered around several key themes:

- **Immune evasion and undetectable pathogens:** Multiple participants highlighted concerns about organisms that cannot be recognized by human immune systems, with responses including "failure in immune detection," "pathogens undetectable for the immune system," and simply "immune evasion."
- **Environmental and ecological disruption:** Concerns about ecosystem-level impacts appeared frequently: "ecological risks if released into the environment," "ecological disruption," "outcompetition of natural [organisms]," "resource competition," and "non-degradable waste."
- **Lack of countermeasures:** Participants worried about "antibiotic resistance," "undetected pathogens without ATB/cures for them," "incurable diseases," and "no countermeasures."
- **Bioweapon potential:** Concerns about dual-use applications appeared directly: "bioweapons," "potential bio weapon," and "WMD."
- **Uncontrolled release scenarios:** Worries about "uncontrolled leak," "outbreak that can't be contained," "pandemics that could not be controlled," and "unstoppable growth."
- **Global equity concerns:** Some responses highlighted distributional impacts: "challenging to respond equitably," "unequitable defense from them," and "economic and social inequalities."

Risk Perception: Measuring Seriousness

Participants rated the seriousness of potential mirror life risks on a scale of 1-10. The results demonstrated both high baseline concern and increased awareness through deliberation:

"How serious do you find the potential risks of mirror life?

- Before the session (n=39):
  - Average score: 7.4 out of 10
  - 74% rated risks at 7 or higher
  - Most common rating: 7 (31% of respondents)

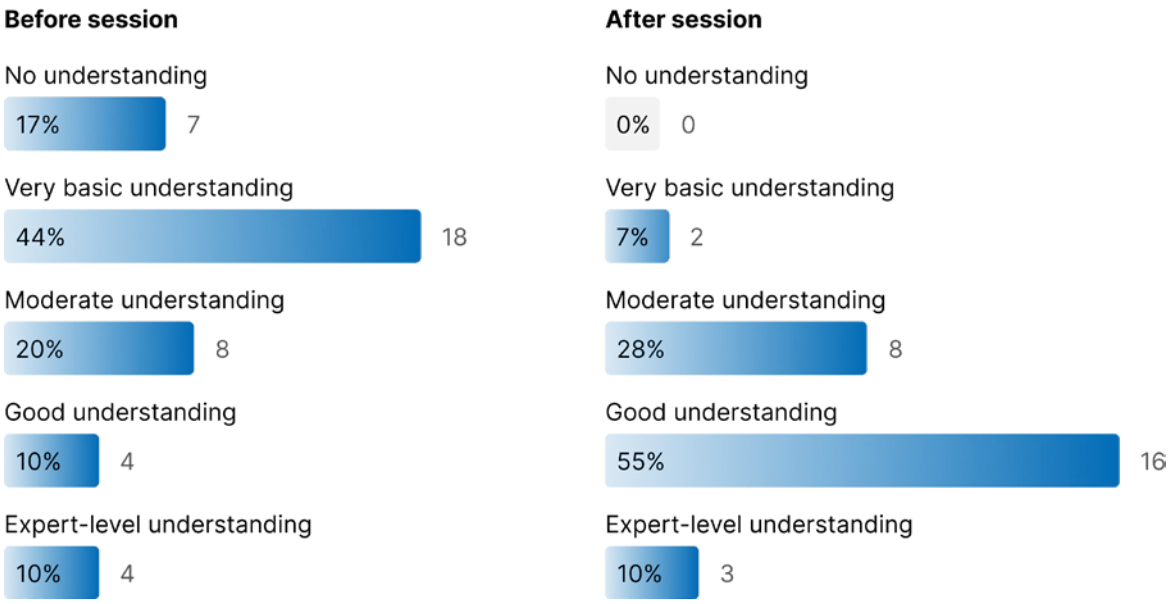
- After the session (n=29):
  - Average score: 8.1 out of 10
  - 90% rated risks at 7 or higher
  - 41% rated risks at 9 or 10
  - Most common rating: 8 (34% of respondents)

The increase in perceived risk severity after the session suggests that informed deliberation leads to greater appreciation of the challenges ahead. The shift in modal response from 7 to 8, and the near-doubling of respondents rating risks at the highest levels (9-10), indicates that the session successfully communicated the gravity of the scientific concerns.

Knowledge Gains Through Engagement

A key measure of effective science communication is whether it enhances understanding. Comparing self-assessed comprehension before and after the session revealed significant improvement:

"How would you rate your understanding of the potential issues surrounding the creation of mirror organisms?"



Before: n=41; After: n=29

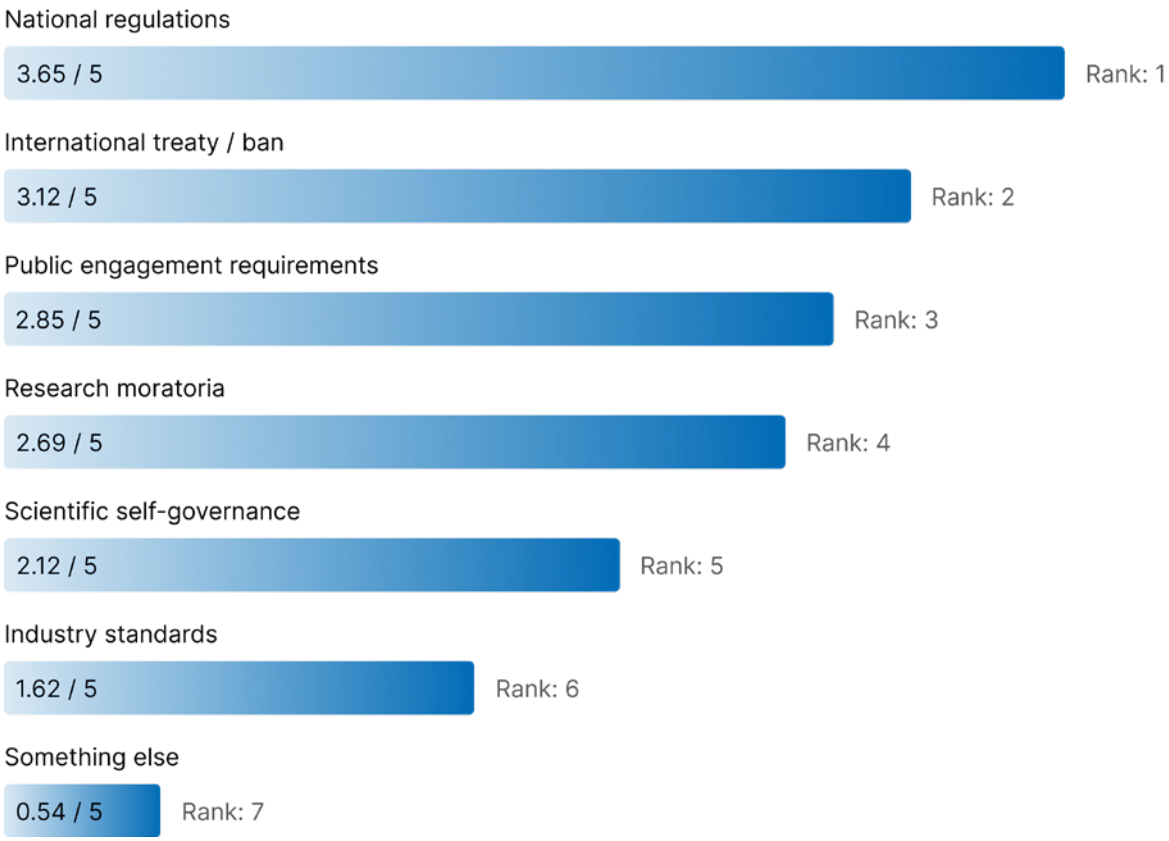
The proportion of participants reporting "good understanding" increased from 10% to 55%, while those with "no understanding" dropped from 17% to 0%. The proportion with only "very basic understanding" fell from 44% to just 7%. This demonstrates that thoughtful, inclusive engagement can meaningfully build scientific literacy, even on complex topics.

It is worth noting that fewer participants completed the post-session polls (29) compared to the pre-session polls (41), which is typical of conference sessions where attendees may leave early or not complete all interactive elements. Despite this attrition, the pattern of increased understanding among those who remained engaged throughout the session is clear.

Governance Approaches: Community Preferences

Participants ranked various governance approaches by appropriateness (n=26). The results reflect a preference for formal regulatory mechanisms while acknowledging the need for multiple complementary approaches:

"Which approaches to governance of mirror life seem most appropriate?"



n=26 respondents. Higher scores indicate greater perceived appropriateness.

The preference for national regulations and international treaties suggests that participants see mirror life as a challenge requiring governmental authority rather than voluntary measures alone. Notably, industry standards ranked second-to-last, indicating skepticism about self-regulation by commercial entities. However, the relatively high ranking of public engagement requirements (3rd place) aligns with the session's emphasis on inclusive deliberation as a foundation for legitimate governance.

Overlooked Stakeholders: Expanding the Conversation

When asked who should be consulted on mirror life governance but has previously been overlooked (n=23, with some respondents mentioning multiple groups), participants identified a remarkably diverse set of stakeholders. The responses reveal a sophisticated understanding that mirror life governance requires truly global and interdisciplinary engagement:

- **The general public:** "Public" was the most frequently mentioned category, along with "general public" and "teachers and students."
- **Policy and governance actors:** "Policymakers", "Global South policymakers," "people who decide what grants are given," and regulators at national and European levels.

- **Scientific communities beyond synthetic biology:** Ecologists and conservationists, marine biologists, environmentalists, xenobiologists and the biodiversity community.
- **Humanities and social sciences:** Bioethicists, STS scholars, sociologists, humanists and, notably, "novelists."
- **Affected communities:** Indigenous peoples, indigenous knowledge holders, the health community, and "The Global South" more broadly.

The breadth of suggested stakeholders reflects both the seriousness with which participants approached the question and recognition that the potential impacts of mirror life extend far beyond the scientific community. The inclusion of "novelists" and "humanists" suggests an appreciation that science fiction and speculative thinking have roles to play in anticipating the implications of landscape-changing technologies.

Strategic Recommendations: What Should We Do Now?

When asked about appropriate next steps (n=22), participants offered 27 distinct recommendations that clustered into several themes:

1. Develop Dynamic Governance Frameworks
Participants called for establishing institutional mechanisms that can evolve with the science:

- "International governance consortium"
- "Establish a framework of real-time risk assessment for the related research"
- "Figure out policy recommendations"
- "Defining the barrier in the research that would limit the complexity level"
- "Define criteria for making research off-limits"

2. Invest in Science Communication
A strong theme emerged around the need for proactive public engagement. Multiple participants emphasized communication as a priority:

- "Vast efforts for science communication"
- "Sensitize journalists"
- "Sci comms!"
- "Communication," "Continue communicating!" and "Talk!"
- "Educate"
- "Transparency around who is initiating this research"

3. Expand Stakeholder Engagement
Recommendations emphasized inclusive, global approaches:

- "Global discussion with all relevant stakeholders"
- "Expert discussions"
- "Research consortiums"
- "Don't block the diffusion of knowledge so that progress is understood globally and there is no race to completion"

4. Consider Precautionary Measures
Some participants advocated for more restrictive approaches:

- "International moratorium on the technology development"
- "Stop and wait"
- "Create cultural norms against development"

5. Invest in Understanding
Others emphasized the need for more research into the risks themselves:

- "Research into the risks of mirror life"
- "Show practical examples"
- "Watch and wait for scientific developments to progress"
- "What evidence would change your mind?"

Conclusion: A Unique Opportunity for Proactive Governance

Mirror life presents a governance opportunity without precedent: a technology that potentially poses severe risks remains 10-30 years from realization, allowing time for deliberation before capabilities outpace oversight. This session demonstrated that this window can be used productively.

The polling data told a story of effective engagement. Participants arrived with varying familiarity (nearly half had only brief exposure to mirror life), yet left with markedly improved comprehension. The proportion reporting "good understanding" rose from 10% to 55%, while perceived risk severity increased from 7.4 to 8.1 on a ten-point scale. Informed publics, it appears, take these concerns seriously when presented with evidence.

The December 2024 call for a moratorium, signed by researchers who had previously pursued mirror life creation, demonstrates that scientific communities can self-correct when evidence warrants. Whether this norm holds as capabilities advance will depend on sustained engagement across borders and disciplines. The work of building that engagement infrastructure has only just begun.

For Further Reading

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iGEM | Responsibility CONFERENCE 2025 | OECD BETTER POLICIES FOR BETTER LIVES

Calling for a New Odyssey of Global Science Dialogue

Session Supporter

Global Science Epistemic Justice

Centre for Global Science and Epistemic Justice

Moderator and Speakers

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Director, Centre for Global Science and Epistemic Justice (University of Kent)

Marta Bertolaso
Full professor (Università Campus Bio-Medico di Roma)

Juliette Mutheu
Founding Director (SciLink Global)

Shambhavi Naik
Chair, Advanced Biology Programme (Takshashila Institution)

Nita Pillai
Director of Partnerships and Governance (Sense about Science)

Introduction

Five chairs for each speaker were arranged on stage, yet, only two were occupied as the session began. The remaining seats stood as quiet symbols not of absence, but of a deliberate choice. Moderator Joy Zhang opened the panel without any hesitation. She explained that the missing speakers had expressed great enthusiasm for participating but were unable to attend due to visa restrictions. Rather than replacing them, the organizers chose to honor their intended presence. This decision reflected a deeper principle that science communication must be inclusive not only in theory, but in practice. Public engagement, as Joy emphasized, is a space where no one should be left behind.

This moment established the tone for a session challenging conventional models of science dialogue, introducing a transformative framework for global engagement in synthetic biology, and beyond.

Discussion and Key Findings

Reimagining Engagement through O.D.E.SS.I.

At the heart of the session lay the O.D.E.SS.I. framework, a new paradigm for public engagement in science. Unlike earlier odyssey models that focused on the "public understanding of science", O.D.E.SS.I. recognizes that public concerns are often grounded in lived experience, cultural values and ethical discomfort. The framework shifts the goal from consensus to encounter, where diverse perspectives are coordinated rather than flattened. By moving away from risk-based discussions, it creates spaces where communities want to engage rather than retreat.

This framework is built on five interlocking principles:

- **Open**: Not simply transparency, but a readiness to revisit questions and priorities in light of new perspectives. Joy emphasized that openness does not always mean open discussion. Sometimes safe spaces are also necessary, but the process should always be open ended.
- **Deliberative**: Engagement should not aim for consensus but for coordination of differences. Transparency is not always the goal; instead, thoughtful negotiation of values is key.
- **Enabling**: Science must empower diverse actors, recognizing that not all participants are uniform. Public engagement should be designed to support both scientific inquiry and community agency.
- **Sensible and Sensitive**: Decisions must be shaped through responsive engagement with difference, not by dominant logic alone. This means seeking compromise, rather than consensus and communicating the "trade-offs."

- **The 'I' in We**: The "I" represents the individual voice within collective deliberation. Rather than simply applying science, it asks how individuals relate to the world and shape possible futures.

The O.D.E.SS.I framework finds practical expression in initiatives like UNESCO's Roundtable Discussion on Empowering the Global Community Through Scientific Literacy, held in 2024. Rather than convening experts to educate the public, the roundtable brought together diverse voices to explore what scientific literacy means across different cultural contexts, thereby embodying the "Deliberative" and "Enabling" principles of the framework.

Joy framed public engagement as a form of internal science diplomacy, by which she means an effort to repair relationships, build trust and co-create futures. The framework will build on additional meetings across the world. Within the next 5 years, there will be focus group meetings and engagement events planned across regions.

From Data to Dialogue

Nita Pillai, Director of Partnership and Governance at Sense about Science, brought a pragmatic lens to the conversation. Drawing on experience in the UK, she explained how some public debates (e.g. on nuclear waste) had been full of misinformation, with no one responsible for or empowered to communicate in the public interest. Sense about Science emerged with the mission of equipping citizens with the right questions to understand science and evidence.

The organization has prepared guides on what the public should ask about scientific research (e.g. whether a study has been peer-reviewed), and has helped people understand why science changes over time (as understanding evolves rather than scientists being wrong). Sense about Science has also worked with researchers to anticipate questions from the public on their work, and equips researchers with tools to connect and respond to questions as fellow citizens, rather than as scientists only.

Nita believes that there are no issues that are too complex or sensitive for the public. Sense about Science's ethos is "public-led, expert-fed": discussions should not be about what experts want to share, but what the public wants to know.

A case involving misinformation around surgery outcomes illustrates the challenge. In the UK, government officials released large amounts of data in a kneejerk bid for transparency. People cherry-picked the data and made decisions on which hospitals to attend based on metrics that were not appropriate for that purpose, creating confusion and potentially harming patient outcomes.

To combat this problem, Sense about Science worked with statisticians to make the data more understandable, advising them to engage patients and hear what they wanted to know. This effort improved engagement, gathered momentum and created appreciation for their work. The work ultimately led to a five-step guide for involving the public in research communication: Scoping, Involving, Planning, Under-Testing and Dissemination.

Nita also provided a perspective on public engagement for scientists that is difficult to achieve, but important to strive for nonetheless:

- **Realistic lessons**: There is no formula for public engagement. People are busy; only some issues are society's issues, and scientists must be open to the outcomes of dialogue. Scientists must clarify what is possible, to manage expectations on all sides.
- **Realistic aims**: Scientists should aim for co-created rationales for research, co-created processes for conducting that research, and for creating "relationships that can hear" – truly listening to the perspectives of the other.
- **Realistic outcomes**: Different purposes require different approaches. Gathering insights, providing early warning, creating collaboration, improving research outcomes and managing differences, each call for distinct engagement strategies.

Turning Risk into Possibility and Curiosity

Juliette Mutheu, Founding Director of SciLink Global, offered pre-recorded insights from Africa's rapidly evolving synthetic biology landscape. For Juliette, public engagement must go beyond information-sharing to building trust, value, and purpose. She feels fear can become curiosity, and risk can become possibility, when scientists communicate with cultural sensitivity and historical awareness.

She offered three key points:

Engage Local Imagination. Conversations on synthetic biology have so far been dominated by Western perspectives. When these discussions take place in Africa, they often focus on controversy rather than opportunities. However, examples of African-led applications of the technology on the continent–including GM crops, bio-based packaging and vaccine manufacture– demonstrate what is possible. Scientists should leverage these successes to capture the public's imagination.

Build transformational trust. Scientific literacy is not just about facts; it is equally about trust. Communities need spaces where everyone can participate and indigenous knowledge has a place in these conversations.

Embed science diplomacy in public engagement. Technology engagement involves exchanging values, not just data. For example, African scientists collaborated on mRNA vaccines not just from the perspective of scientific knowledge, but equally on principles of equity and mutual respect. This collaboration exemplified science diplomacy in action.

She posed two questions to the audience:

- What would global science literacy look like if Southern voices helped shape the global conversation?
- How might public engagement help build cooperation across borders?

Science Must Listen

Shambhavi Naik, Chair of the Advanced Biology Programme at the Takshashila Institution, focused on the ecosystem of public life. In India, as in much of the Global South, government landscapes are complex and public trust is fragile, making genuine listening essential. Public engagement should begin at the research design stage, not after results are published. Her message was clear: Science must be adopted, not imposed. Active, relational engagement built on trust is the only path forward.

Fear of the unknown drives public imagination to worst-case scenarios. Synthetic biology can serve beneficial or harmful purposes, yet in the public imagination it has often been associated with negatives. In India, mRNA vaccines are lauded, while other innovations like genetically modified crops are restricted. This inconsistency reveals how public acceptance depends on context, framing and historical experience, in addition to scientific evidence.

Scientific development intersects with and affects public desires and futures, requiring sensitivity to cultures as much as to facts. She highlighted the importance of empowering local communities as custodians, and not just as subjects of science.

Shambhavi hopes that India's biotechnology development shifts from viewing it only as a tool for public good, but also as a path for responsible economic prosperity. Future engagements should not just be about science *literacy*, but also about science *legitimacy*. When communities see science as serving their interests, genuine partnership becomes possible.

She asked the audience:

- What are the practical avenues for inclusive public deliberation on complex scientific issues?
- How can skeptical publics be shown that benefits are worth pursuing, even when risks are acknowledged?

Conclusion: A Dialogue That Embodied Its Message

The session's opening image of empty chairs honoring speakers unable to attend due to visa restrictions embodied its central argument: Inclusive science communication requires institutional change.

Three tensions emerged that practitioners must navigate:

- The first concerns the meaning of "openness." Open discussion serves many purposes, yet some communities require safe spaces before engaging with dominant institutions. The framework suggests that openness be "open-ended," meaning that it must embody a willingness to revisit questions rather than defend predetermined conclusions.
- The second tension involves the relationship between scientific literacy and scientific legitimacy. In some cases, technologies like mRNA vaccines enjoy public support while

genetically modified crops face restriction, which illustrates that public acceptance depends on more than factual understanding. Trust, cultural resonance and perceived alignment with community values all matter. Science communication that treats literacy as sufficient misses the complexity associated with garnering social legitimacy.

- The third tension concerns scale. Traditional public engagement works well for discrete research projects, but issues like mirror life, AI-enabled biology and other transformative technologies require engagement at enormous scale. How does "public-led, expert-fed" deliberation function when the debate might span continents?

This session offered no complete answers, but instead provided a necessary reframing of science communication as "internal science diplomacy." Work with the public should be focused on repairing relationships and co-creating futures rather than merely transmitting facts. What would global science literacy look like if the voices of neglected communities helped shape the global conversation? The answer depends on whether institutions take seriously the principle that no one should be left behind, including those whose chairs remain empty.

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AI Resilience Lessons from Red Teaming to Risk Indexing

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Introduction

Is our biosecurity keeping pace with AI? This panel presented two major new studies: The first public red-teaming of DNA synthesis screening using AI protein design, and a global index ranking AI-bio tool misuse risks.

While AI-enabled protein and chemical design tools offer remarkable capabilities for beneficial research, they also present new challenges for screening and oversight given their high risk of misuse. This panel explored practical approaches to building resilience through improved screening frameworks and layered security architectures, while acknowledging that even robust systems will sometimes fail- making investment in detection and response capabilities essential, and viewing synthesis screening as one component of the broader biosecurity toolkit.

Discussion and Key Findings

AI Design Tools and the Evolving Threat Landscape

The panelists opened by assessing the current state of AI tools for genomic, protein and chemical design. Specifically, they noted that advances in machine learning techniques combined with increasing data availability have resulted in powerful tools with specific areas of application. However, the panel also emphasized that many tools can also generalize over different domains, and that this will become increasingly true as the data used to train these models becomes more diverse and information-rich.

The panel emphasized that these tools have significantly changed the threat landscape. They cited a concerning example where researchers used an AI tool to design approximately 30,000 novel toxins, then tested whether existing biosecurity screening software could identify them as dangerous. The screening tools failed to flag many of these AI-generated compounds. However, once the gap was identified, developers created a patch within 24 hours that successfully identified 99% of the novel toxins. They also highlighted the generative capability of tools, where current tools are able to predict novel mutant strains of viral families and create novel genomes, as demonstrated in the validated study of functional bacteriophages developed by Evo1 and Evo2.

This example illustrates both the challenge and the opportunity. While AI-based design tools may not be fundamentally different from previous approaches, they have dramatically increased the capability and speed of design, and exposed novel threat surfaces through generative design as well. The panel argued that this shift requires a corresponding evolution

in how we think about risk. Traditional biosecurity screening focuses on identifying known dangerous sequences: the conventional wild-type versions of pathogens that exist in nature. But when AI can generate novel molecules with harmful properties, security measures must evolve to understand why a particular protein or chemical design poses a risk, not merely whether it matches a known threat from maintained lists of biohazardous agents.

From Risk Assessment to Action: The Sequence Biosecurity Risk Consortium

Moving from risk identification to practical action, the panel discussed the Sequence Biosecurity Risk Consortium as a model for collaborative governance. This international collaboration brings together nucleic acid providers, pathogen experts, screening providers, policy makers, cybersecurity specialists, and other stakeholders to create a science-based risk rubric.

The consortium's standards evaluate whether a DNA screening tool can correctly flag if a given genetic sequence is of concern and, if so, whether it should be provided only to certain vetted individuals or groups. This approach represents a middle path between unrestricted access and blanket prohibition, enabling legitimate research while creating appropriate friction for potentially dangerous applications.

The Sequence Biosecurity Risk Consortium (SBRC)

Publicly launched at the 2025 iGEM Responsibility Conference, the Sequence Biosecurity Risk Consortium brings together synthesis providers, screening tool developers, policy makers and scientific experts to develop shared, science-based definitions of "sequences of concern." Responsible DNA and RNA synthesis providers already screen orders to prevent misuse, but translating broad guidance into specific sequence-level decisions has historically involved subjective judgments by individual companies. The SBRC addresses this gap by establishing consensus-based engineering standards, including a standardized risk assessment rubric and validated test sets for benchmarking screening tools. The consortium also provides a trusted forum for disclosing and addressing screening vulnerabilities collaboratively. To learn more or join the consortium, visit sbrc.bio.

SBRC
SEQUENCE BIOSECURITY
RISK CONSORTIUM

Risk Ceilings and Risk Floors

The panel introduced a useful framework for thinking about AI-related biosecurity risks; namely, the distinction between risk ceilings and risk floors.

While AI tools pose new risks, engineering sophisticated biology remains challenging. This difficulty matters when we contextualize risk. The panelists noted that proposed worst-case scenarios are very difficult to execute, and the number of individuals capable of undertaking truly high-risk work remains limited. Understanding this risk ceiling (the upper bound of potential harm) is critical for policy planning.

However, the panel argued that the risk floor is equally important to monitor and guard against. AI models may allow a limited number of sophisticated actors to design novel biological threats, but it is also essential to ensure that non-experts cannot easily access wild-type versions of dangerous pathogens. As AI design capabilities advance and integrate more deeply with laboratory automation, the community needs to think about different time horizons, and the trajectory of these capabilities to guard against both current and future risks.

Building Layered Security: The Swiss Cheese Model

From a security architecture perspective, the panel suggested that the community needs to introduce deliberate friction into the system. They advocated for what they termed the "Swiss cheese model"—an approach in which multiple layers of protection, each with its own gaps, are arranged so that a threat passing through one layer is likely to be caught by another.

Critically, the panel argued that oversight and biosecurity must become features of the engineering and infrastructure used by the community, rather than relying on committee supervision alone. They drew an instructive parallel: "Cybersecurity is everywhere," they observed, and biosecurity must similarly become an aspect of the emerging tools and models that researchers use daily.

The panel noted a concerning dynamic in the current ecosystem: Different players in the community do not want to take responsibility for biosecurity, and many are relying on nucleic acid providers to serve as the main safeguard. This concentration of responsibility on a single chokepoint leaves the system, as a whole, vulnerable. A more robust approach would distribute security functions across multiple actors and embed them throughout the research pipeline.

Planning for Failure: Detection and Response

The panel delivered a sobering but essential message. Even with significant investments in biosecurity, failures may occur. Prevention alone is not sufficient. Therefore, it is critical to invest in detection and response capabilities to rapidly develop, manufacture and deploy countermeasures when incidents arise.

This response infrastructure is an important complement to prevention-focused measures. The same synthetic biology capabilities that create new risks can also accelerate the development of vaccines, therapeutics and diagnostics when threats emerge. However, the rush to develop responses for real or predicted biothreats must be carefully organized to avoid unwanted misperceptions or accidents.

Training the Next Generation

Finally, the panel emphasized the importance of embedding an understanding of biosafety in the next generation of scientists. This includes incorporating biosecurity topics into course curricula and providing experiential learning opportunities through programs such as iGEM.

This educational investment serves a dual purpose. It builds the workforce of experts in science, policy, and regulatory aspects that will be needed as AI capabilities and synthetic biology continue to advance in the coming decades. And it establishes cultural norms in which biosecurity is understood as an integral part of responsible research practice, not an external constraint imposed from outside the scientific community.

Conclusion

A combination of serious vulnerability and rapid response defines the current moment. AI-enabled design tools have fundamentally changed biosecurity's challenge, generating novel molecules that evade screening systems built to identify known threats. Despite this, the biosecurity community possesses genuine capacity to adapt when gaps are identified. The question is whether this ad hoc responsiveness can be institutionalized before a gap is exploited, rather than merely demonstrated.

The session concluded with clear recommendations for the path forward:

- Biosecurity must become embedded in research infrastructure rather than relying on oversight committees alone.
- The community should adopt layered security approaches where multiple safeguards catch what others miss.
- Investment in detection and response capabilities is essential alongside prevention, since even robust systems will sometimes fail.
- Perhaps most importantly, the next generation of scientists must be trained with biosafety and biosecurity as core competencies through educational initiatives like iGEM.

Looking ahead, the challenge is to institutionalize the rapid responsiveness the community has already demonstrated when gaps are identified, transforming ad hoc fixes into systematic, distributed responsibility across the entire research ecosystem.

For Further Reading

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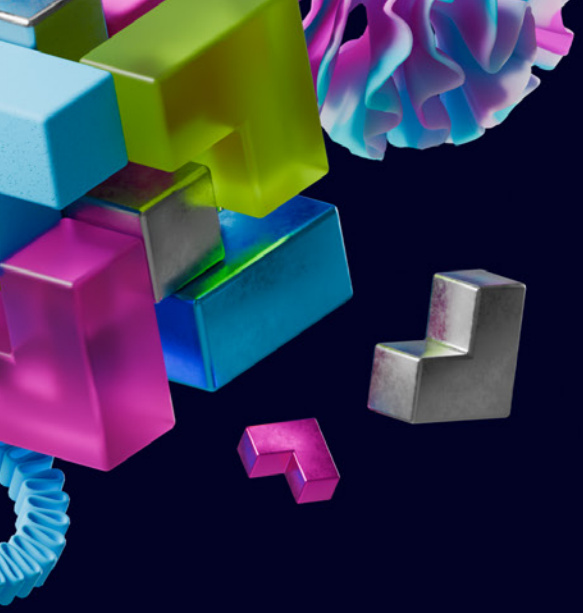

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