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UPDATED REPORT AND SYNTHESIS OF VIEWS IN RESPONSE TO PARAGRAPH 7(B) OF DECISION XII/24 ON NEW AND EMERGING ISSUES: SYNTHETIC BIOLOGY

Note by the Executive Secretary

I. BACKGROUND

1. In paragraph 4 of decision XII/24,[1] the Conference of the Parties to the Convention on Biological Diversity established an Ad Hoc Technical Expert Group (AHTEG) on Synthetic Biology with terms of reference contained in the annex to the decision.

2. In paragraphs 5 and 6 of the same decision, the Conference of the Parties invited Parties, other Governments, relevant organizations, indigenous and local communities and relevant stakeholders to submit information to the Executive Secretary relevant to the work of the AHTEG, as well as on measures undertaken in accordance with paragraph 3 of decision XII/24, including the identification of needs for guidance, and further information in response to paragraph 3(a) of decision XI/11.

3. Further, in paragraph 7 of the same decision, the Conference of the Parties requested the Executive Secretary:

(a) To make available the information submitted by Parties, other Governments, relevant organizations, indigenous and local communities and relevant stakeholders through the clearing-house mechanism of the Convention and other means;

(b) To convene a moderated open-ended online forum[2] to support the work of the AHTEG in meeting its terms of reference;

(c) To prepare an updated report on the work specified in paragraphs 3(a), 3(b) and 3(c) of decision XI/11, taking into account information submitted in paragraph 2 above and a synthesis of the outcomes of the process mentioned in (b) above, and to submit these for consideration by the AHTEG;

* Previously circulated as UNEP/CBD/SYNBIO/AHTEG/2015/1/2.
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[1] Full text of the decision can be found at http://www.cbd.int/doc/decisions/cop-12/cop-12-dec-24-en.pdf.

[2] The open-ended online forum will be open to all interested participants and continue for a finite period of time.

(d) To submit for consideration by a meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) prior to the thirteenth meeting of the Conference of the Parties, the peer-reviewed reports of the outcomes of the process mentioned in paragraphs (b) and (c) above.

4. In the light of the decision, the Executive Secretary established a continuous process comprising: (a) the submission of information on synthetic biology; (b) an open-ended online forum with online discussions on specific topics of synthetic biology; (c) one face-to-face meeting of the AHTEG; and (d) peer-review of the outcomes of the process.3 The outcomes of this process will be submitted for consideration by the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) at its twentieth meeting to be held in Montreal, Canada from 25 to 29 April 2016.

5. The process was initiated by two notifications that were issued to Parties, other Governments, relevant international organizations, indigenous and local communities and other relevant stakeholders inviting them to (a) submit to the Executive Secretary information on synthetic biology;[4] and (b) nominate experts to participate in the Open-ended Online Forum on Synthetic Biology.[5]

6. In response to the first notification, a total of 27 submissions were received by the Secretariat. Among these were fifteen from Parties, one from a non-Party, and eleven from organizations.[6]

7. In response to the second notification, a total of 235 experts were nominated to participate in the open-ended online forum. Among these, 146 were from Parties, nine from a non-Party, and 80 from organizations.

8. The Open-ended Online Forum on Synthetic Biology was launched through the Biosafety-Clearing House and a total of 402 interventions were made during the virtual discussions that took place between April and July 2015. The topics of discussion were drawn from the terms of reference of the AHTEG, as follows:[7]

(a) How to address the relationship between synthetic biology and biological diversity (moderated by Mr. Ryo Kohsaka from Japan);

(b) Similarities and differences between living modified organisms (as defined in the Cartagena Protocol) and organisms, components and products of synthetic biology techniques (moderated by Ms. María Andrea Orjuela Restrepo from Mexico);

(c) Operational definition of synthetic biology, comprising inclusion and exclusion criteria (moderated by Mr. Mart Loog from Estonia);

(d) Potential benefits and risks of organisms, components and products arising from synthetic biology techniques to the conservation and sustainable use of biodiversity and related human health and socioeconomic impacts relevant to the mandate of the Convention and its Protocols (moderated by Mr. Casper Linnestad from Norway);

(e) Best practices on risk assessment and monitoring regimes currently used by Parties to the Convention and other Governments (moderated by Ms. Jaimie Schnell from Canada);

(f) Adequacy of existing national, regional and/or international instruments to regulate the organisms, components or products derived from synthetic biology techniques (moderated by Mr. Benson Kinyagia from Kenya);

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[3] A tentative calendar of activities for the process is available at https://bch.cbd.int/calendar_synbio.shtml.

[4] Notification SCBD/BS/CG/MPM/DA/84279 (https://www.cbd.int/doc/notifications/2015/ntf-2015-013-synthetic-biology-en.pdf).

[5] Notification SCBD/BS/CG/MPM/DA/84355 (https://www.cbd.int/doc/notifications/2015/ntf-2015-019-synth-en.pdf).

[6] The submissions are available online at http://bch.cbd.int/synbio/notifications/.

[7] The discussions under the Open-ended Online Forum on Synthetic Biology are available at http://bch.cbd.int/synbio/open-ended/discussion.shtml.

(g) Degree to which the existing arrangements constitute a comprehensive framework in order to address impacts of organisms, components and products resulting from synthetic biology, in particular threats of significant reduction or loss of biological diversity (moderated by Ms. Maria de Lourdes Torres from Ecuador).

9. The present note provides an overview of the views contained in the submissions and online interventions. For a full account of all views, it is recommended to refer to the original submissions and online interventions through the Biosafety-Clearing House.[8]

10. For the purpose of this note and in accordance with the online forum, to facilitate a common understanding in the discussions on similarities and differences with LMOs, the term "components" is used to refer to parts used in a process (e.g. a naked DNA molecule), and "products" as the resulting output of a process (e.g. a chemical fragrance).

II. RELATIONSHIP BETWEEN SYNTHETIC BIOLOGY AND BIOLOGICAL DIVERSITY

11. Many submissions and online interventions noted that the relationship between synthetic biology and biological diversity must be addressed in the light of the three objectives of the Convention to ensure the conservation of biological diversity, the sustainable use of its components and the equitable sharing of the benefits arising out of the utilization of genetic resources. This could be done by examining both the potential positive and negative impacts of synthetic biology and their relevance to the CBD objectives, assessing the risks on a case-by-case basis and, where necessary, adopting appropriate risk management strategies.

12. Views on the relationship between synthetic biology and biological diversity converged in suggesting that synthetic biology may affect biodiversity at the genetic, species and ecosystems levels. However, the discussions also indicated the diverse and polarized interpretation of the relationship between the two concepts.

13. According to submissions made by several Parties, synthetic biology techniques could contribute to the sustainable use and conservation of biodiversity, but, at the same time, the components, organisms and products of synthetic biology may lead to situations that compromise the sustainable use of biodiversity and/or ecological balance.

14. In the online forum, it was further noted that the relationship between synthetic biology and biological diversity could focus on areas of concern within the CBD context. It can be described by the potential direct and indirect impacts that these new organisms and components could have on conservation and sustainable use of biological diversity. The risks and potential impacts of the relationship should be assessed prior to any introduction to the environment, taking also into account risks to human health, small scale farming systems and their contribution to biological diversity and ecosystem function, food security, livelihoods and related socioeconomic considerations, indigenous peoples and local communities, including cultural aspects.

15. With regard to the third objective of the CBD, it was noted in the online forum that the fair and equitable sharing of benefits arising out of the utilization of genetic resources must be considered in the light of the development of the many components of synthetic biology, their applications and possible effects on biodiversity. It was noted that the objective of fair and equitable sharing of benefits arising from the use of genetic resources may lose its purpose, as use of components, organisms and products from synthetic biology may replace the need for and use of natural genetic resources. A participant in the online forum also noted that a profit-driven approach to synthetic biology does not necessarily support the fair sharing of costs and benefits between developed and developing countries, and that this situation has

[8] Submissions of views on synthetic biology by Parties, other Governments and organisations are available at: http://bch.cbd.int/synbio/notifications/; Discussions under the Open-ended Online Forum on Synthetic Biology are available at: http://bch.cbd.int/synbio/open-ended/discussion.shtml

been exacerbated by control over the techniques of synthetic biology by a limited number of stakeholders, most of whom are driven primarily by a profit motive rather than by ecological perspective.

16. Views were divergent with regard to which components, organisms and products could pose risks to biodiversity. While some participants of the online forum suggested that the discussion on the relationship between synthetic biology and biodiversity should focus on all components, organisms and products of synthetic biology, others suggested a limited focus on the components, organisms and products of synthetic biology that are capable of replicating or reproducing and could be released into the environment to determine their potential positive or negative impact on biodiversity.

17. It was also noted that a lack of scientific underpinning to ecological and social impacts in the application of synthetic biology processes poses a key issue in the discussion on the relationship between synthetic biology and biodiversity. An increase in the complexity and range of synthetic biology tools and techniques may also lead to an increase in the uncertainty and unpredictability of their outcomes, making it harder to predict their effects on biodiversity, leading to the need for stricter measures to prevent damage to biodiversity.

18. In further discussions on the uncertainty about the safety of the components, organisms and products of the processes and outcomes of synthetic biology, several Parties, organizations and participants of the online forum called for the application of the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development.

19. There were also divergent views in the discussions on whether or not the relationship between synthetic biology and biodiversity should focus on the output from the process (i.e. an organism or product derived from synthetic biology) or on the process itself (i.e. the techniques used). The proponents of the former noted that, if a synthetic biology organism poses a risk to biodiversity, this risk would clearly lie in the characteristics of the organism (e.g. invasiveness, ability for horizontal gene transfer, risk for human beings or the environment), regardless of the techniques used to produce the organism. On the other hand, the proponents of further discussions on the process itself argued that the changes in some of the organisms and products may not be easily detectable and an assessment of the impacts on biodiversity can only be performed if the process is taken as a starting point. In this regard, there was also support to reconcile the two approaches by focusing the future debate on the relationship between synthetic biology and biodiversity on both the outputs and the process in a mutually supportive manner rather than as competing elements of the debate.

20. Some participants in the online forum also noted the challenge in establishing the relationship between synthetic biology and biological diversity in the absence of an operational definition of synthetic biology.

21. There were also participants who noted that it is premature to discuss the relationship between synthetic biology and biodiversity since an agreement has not been reached on whether or not synthetic biology is a new and emerging issue for conservation and sustainable use of biodiversity. Furthermore, some participants also noted that since no one fully understands the risks posed by synthetic organisms to the environment, there are challenges as to what kinds of information is needed to support rigorous risk assessments, or who should collect such data.

22. Finally, in discussing the relationship between synthetic biology and biodiversity, there were suggestions that the potential damage resulting from organisms, components and products of synthetic biology techniques also needs to be addressed through a liability and redress regime.

III. SIMILARITIES AND DIFFERENCES BETWEEN LIVING MODIFIED ORGANISMS (AS DEFINED IN THE CARTAGENA PROTOCOL) AND ORGANISMS, COMPONENTS AND PRODUCTS OF SYNTHETIC BIOLOGY TECHNIQUES

23. There was general agreement in the submissions and online interventions that synthetic biology builds on the advances in molecular biology and biotechnology. However, some elements of synthetic biology which set it apart from other more "conventional" approaches of modern biotechnology initiated intense debate in the discussions.

24. It was noted in a submission that when the terms "components" and "products" of synthetic biology are used to refer to non-living entities, they have more in common with chemical substances. As such, similarities and differences should be drawn between LMOs and the organisms developed through synthetic biology techniques but not between LMOs and the components and products of synthetic biology. In this context, it was noted that some complex living systems resulting from synthetic biology are not always organisms, but rather belong to other structural levels such as organs, tissues, cells or proto-cells.

25. Many submissions and online interventions noted that the techniques that are described as synthetic biology form a continuum of advances in biotechnology tools and techniques, and may equally be described as techniques of modern biotechnology, gene technology or genetic engineering, in particular those applications of synthetic biology that are closest to commercial scale application. Some of the similarities between synthetic biology and modern biotechnology that were noted in the submissions and online interventions include:

(a) Synthetic biology is a "new branch of genetic engineering" and "every organism, component and product of synthetic biology techniques is a result of genetic engineering, but not every LMO is a result of synthetic biology";

(b) Synthetic biology can be considered as "an extension of conventional molecular biology", "an accelerated and intensified form of classical genetic engineering", and that "the underlying technology makes synthetic biology and classical genetic engineering […] basically the same";

(c) Current development of living organisms through techniques of synthetic biology relies on the use of techniques of modern biotechnology, which are combined with other tools such as bioinformatics, nanotechnology, robotics, etc. Therefore, living organisms that are currently being developed through synthetic biology can also be considered as LMOs as per the definition of the Cartagena Protocol, since they result from the application of techniques of modern biotechnology. This would also include living organisms derived from existing ones through the incorporation of xeno-genetic materials;

(d) The Cartagena Protocol broadly defines "living organism" as one that is "capable of transferring or replicating genetic material", while the Convention defines "genetic material" as including nucleic acids from "plant, animal, microbial or other origin", consequently, neither organisms created "de novo" nor xeno-systems may be excluded from the Protocol's scope.

26. On the other hand, there were also submissions and online interventions that were of the view that synthetic biology is qualitatively different from modern biotechnology. The following paragraphs highlight some of the noted differences between LMOs and organisms developed through synthetic biology:

(a) The differences between an LMO and an organism developed through synthetic biology lie mainly on the higher level of complexity of the latter. Such complexity may result from the combination of several techniques of genetic engineering to produce an organism combined with other techniques that rely on the standardization and abstraction of modular biological components. Furthermore, LMOs are organisms developed by incorporating a single or a few gene(s) of interest,

whereas organisms constructed by means of synthetic biology techniques are likely to have larger segments of modified DNA or even complete novel genomes;

(b) As opposed to modern biotechnology, synthetic biology leads to the development of new biological systems that do not exist in nature. Therefore, "modification" and "re-engineering" are distinguishing factors between LMOs and the organisms developed through synthetic biology;

(c) The production of living organisms through modern biotechnology and synthetic biology is similar but the genes and nucleic acid molecules transferred into the recipient organisms differ in that nucleic acids transferred through modern biotechnology exist in nature but not those transferred through synthetic biology. Therefore, some techniques of synthetic biology may or may not be readily classified as "*in vitro* nucleic acid techniques";

(d) In the future, with further technological advances, entire new genomes will be generated by designing new genetic codes. These new synthetic organisms may no longer be considered as "genetically modified" and may be completely different from the current LMOs.

27. In summarizing the apparent divergence of views, one submission noted that current techniques of synthetic biology do not develop organisms that are entirely synthetic. Rather, they create artificial genetic material, which is then inserted into bacterial cells from which the original genetic material has been removed. Therefore, it is important to highlight that such organisms are LMOs obtained through modern biotechnology as per the Cartagena Protocol on Biosafety. However, it remains a matter of interpretation whether or not living organisms resulting from certain areas of synthetic biology research, such as the synthesis of entire organisms, xenobiology or manipulations that lead to heritable characteristics without the creation of "novel combinations of nucleic acids", fall within the scope of the Cartagena Protocol on Biosafety.

IV. OPERATIONAL DEFINITION OF SYNTHETIC BIOLOGY, COMPRISING INCLUSION AND EXCLUSION CRITERIA

28. It was widely recognized, from among the submissions, that synthetic biology is a broad term which encompasses and/or is used to refer to a wide range of disciplines, techniques, potential applications and end products.

29. In discussing the steps towards an operational definition of synthetic biology, the majority of submissions and interventions in the online forum recognized the need for a definition that will support Parties' efforts in policy-making and risk assessment, and which is sufficiently broad to include new developments in the field of synthetic biology. As such, it was noted that defining synthetic biology is not merely an academic exercise, but rather a necessary step to determine if synthetic biology is objectively unique from other already-existing areas, and whether or not the outcomes of its research and development require new approaches to regulation.

30. Many of the interventions made in the online forum indicated that without an agreed definition it would not be possible to discuss the potential benefits and hazards of synthetic biology under the Convention's umbrella. However, one Party, in its submission, also noted that although having a definition for synthetic biology could facilitate enabling a rational discussion, the adoption of such a definition must not be seen as a prerequisite for the discussion on the potential regulatory and risk assessment challenges of synthetic biology.

31. There were several submissions and online interventions that were of the view that the definition of LMO under the Cartagena Protocol can be readily applied to living organisms developed through synthetic biology. In this regard it was noted that, as per its definition in the Cartagena Protocol, an LMO must be "living" and contain a "novel combination of genetic material" as a result of the "application of modern biotechnology", and that these three criteria only expressly exclude non-living entities created by synthetic biology approaches while being sufficiently broad to encompass all living organisms developed through synthetic biology. As such, those interventions and submissions noted that, as a starting point in

defining synthetic biology, it would be useful to determine which, if any, aspects or techniques of synthetic biology would fall outside of the broad definition of "modern biotechnology" as per the Cartagena Protocol.

32. There was also ample support among the participants in the online forum to the operational definition recently agreed upon by the Scientific Committee on Emerging and Newly Identified Health Risks of the European Commission, which reads "SynBio is the application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms", as an appropriate basis for further discussion.

33. The following are some additional concrete proposals for definitions as contained in the submissions and online interventions:

(a) "Synthetic biology is a science of constructing biological parts, pathways and organisms towards useful social outcomes";

(b) "Synthetic biology designs non-living and living useful products using newly designed synthetic or naturally derived DNA and non-DNA molecules in novel configurations that are not found in nature";

(c) "Synthetic biology is the planned design and construction of specific biochemical and biological systems, as well as the synthesis of molecules and the development of biological components and organisms, through genetic and biological engineering and bioinformatics, to perform new functions or to improve the design of existing natural biological systems to optimize their useful applications";

(d) "Synthetic biology is a scientific strategy that combines knowledge from various disciplines such as molecular biology, biochemistry, systems engineering, genomics, protein design, directed evolution, genetic engineering, nanotechnology, mathematics, physics, cybernetics, mechatronics, bionics, etc. and the use of modern techniques (including engineering and sciences), which integrates design, build artificial biological systems (organisms, molecules, etc.) and redesign natural biological systems";

(e) "Synthetic biology describes the application of various techniques of modern biotechnology that exercise control in the design, synthesis or redesign of new biological organisms, parts, devices and genetic systems at the organismal, cellular or sub-cellular level for applied purposes. […][9] Synthetic Biology is particularly, but not exclusively, associated with chemical synthesis or alteration of genetic sequences and nucleic acids, genome editing techniques and an engineering-based approach to the construction of living organisms resulting in a range of traits, applications and products, living and non-living, and of differing characteristics";

(f) "Synthetic biology aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems";

(g) "Synthetic biology is an emerging area of research and development involving novel combinations of methods, techniques and practices drawn from a range of disciplines directed to understanding, designing and engineering biological components, organisms and products";

(h) Synthetic biology includes any "experimental attempts to explore new directions with modified organisms or proto-organisms (i.e. protocells)".

34. In discussing a definition of synthetic biology, it was also noted that it is "difficult and presumptuous to attempt to develop a formal definition of synthetic biology, let alone inclusion and exclusion criteria", "scientific advances would quickly render any definition obsolete", and the "application of strict definitions could unduly restrict or stifle cutting-edge research and development".

[9] The author of this proposal suggested that a list containing techniques and approaches commonly used for synthetic biology could be annexed to the definition.

There were also those who cautioned that the establishment of inclusion and exclusion criteria could lead to situations where products are excluded from regulation or oversight in situations where it is legitimately needed.

V. POTENTIAL BENEFITS AND RISKS OF ORGANISMS, COMPONENTS AND PRODUCTS ARISING FROM SYNTHETIC BIOLOGY TECHNIQUES TO THE CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY AND RELATED HUMAN HEALTH AND SOCIOECONOMIC IMPACTS RELEVANT TO THE MANDATE OF THE CONVENTION AND ITS PROTOCOLS

35. According to several submissions and online interventions, the components, organisms and products of synthetic biology are expected to produce similar impacts, both positive and negative, as classical genetic engineering on biological diversity. The impacts of synthetic biology, however, are expected to be broader and more intense due to the ability of synthetic biology to engineer more complex systems for use in a wider range of applications.

36. Some of the identified potential benefits of synthetic biology as a means to promote the conservation of biological diversity in areas such as bioenergy, environment, wildlife, agriculture, chemicals and health include the following:

(a) Producing sustainable sources of fuel and energy;

(b) Engineering organisms to produce useful products such as microorganisms that can produce any naturally occurring molecule (e.g. flavours, scents, dyes and pharmaceuticals) and thereby eliminating the need to cultivate large monocultures of the original source plants or animals and therefore reducing the amount waste produced during extraction and purification from the original source organisms;

(c) Improving human nutrition and health by, for example, making models for understanding and diagnosing human conditions and producing pharmaceuticals to treat and cure diseases;

(d) Reducing the area of land required for commercial cultivation, aiding in the conservation and sustainable use of biodiversity;

(e) Producing novel useful substances that are not found in nature;

(f) Designing products that will generate socially useful outcomes faster, in a more environment friendly and cost-efficient manner;

(g) Reducing environmental hazards by replacing current industrial chemical processes that are not ecologically-friendly with more sustainable and non-toxic production systems based on biological processes;

(h) Reducing pressure on certain wildlife species and restoration of populations and ecosystems through the production of synthetic products that are currently obtained from species at risk of extinction come from copies of species at risk.

37. Risks from the components, organisms and products of synthetic biology were also identified among the submissions and online interventions for their potential to affect (a) the conservation of biodiversity at the genetic and ecosystem level through, for example, direct impacts to the health and integrity of species and ecosystems, and indirect impacts arising from industrial application of synthetic biology techniques and products, (b) the sustainable use of the components of biological diversity through indirect impacts associated with the replacement of natural products, and (c) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources through a shift in the understanding of what constitutes a genetic resource and implications thereof.

38. Applications of synthetic biology which involve gene-drive systems, enhanced photosynthesis, de-extinction, environmental sensors and bioremediation were identified in some online interventions as deserving close attention because of their potential to cause significant negative impacts on biodiversity and ecosystems. The identified risks include the following:

(a) Organisms developed through techniques of synthetic biology with engineered fitness advantages competing against naturally occurring organisms in the ecosystem, either through intentional or accidental introduction into the environment, causing displacement and/or extinction of existing species;

(b) Increase in mutation rates in organisms developed through synthetic biology given that the genetic material is foreign and novel and has not had time to stabilize;

(c) Increase in the occurrence of lateral/horizontal gene flow due to genome instability as compared to the natural transfer of genetic materials which has recently been reported to take place between humans, vertebrates and invertebrates;

(d) Changes in the interaction between humans and nature (i.e. cultural, social, ethical, traditional changes, among others, driven by synthetic biology techniques, could modify or affect the action and the interrelationship between humankind and nature);

(e) Outcrossing, vertical gene flow and the resulting unknown consequences, for example, to agrobiodiversity and food security;

(f) Monopoly of the technology by developed countries affecting the economy of developing countries which are based on the sustainable use of biodiversity, as well as limiting the ability of developing countries to access and perform research using components, organisms or products subject to patents and intellectual property rights;

(g) Accidental exposure to organisms or components of synthetic biology which were intended for contained use causing adverse effects to humans and other species, including risks associated with bioterrorism;

(h) Further and accelerated disruption of the relationship between mankind and ecosystems, as well as changes to biological systems and processes that naturally support mankind thereby affecting the cultural, social and economic aspects of biodiversity;

(i) Reduced confidence in the conclusions of environmental and health assessments due to higher levels of scientific uncertainty regarding the risk of organisms and products resulting from synthetic biology;

(j) Many-fold increases in the demand for biomass crops, wood and the water, nutrients and soils required for the conversion of cellulose if technologies are further advanced by synthetic biology causing serious negative impacts on biodiversity such as the conversion of forests to tree monocultures, displacement of food production, loss of biodiversity, water and soil degradation, speculative investment in land, and displacement of human populations;

(k) Possible toxic or disruptive effects on soils, food webs, pollinators and biodiversity of industrial products or enzymes (e.g. biofuels, chemicals, flavours and fragrance molecules) in the event that the organisms producing these compounds are accidentally introduced into an open environment and succeed in reproducing and establishing themselves;

(l) Spontaneous and unintentional transboundary movements of organisms developed through synthetic biology causing significant economic and ecological consequences in countries that are not prepared to take adequate measures;

(m) Decrease in agricultural genetic diversity due to a reduction in the efforts to maintain gene banks and botanical collections for the purposes of performing classical breeding since it will no

longer be necessary to have individuals and make conventional crosses to introduce desirable characteristics into cultivated varieties.

VI. BEST PRACTICES REGARDING RISK ASSESSMENT AND MONITORING REGIMES CURRENTLY USED BY PARTIES TO THE CONVENTION AND OTHER GOVERNMENTS

39. A number of best practices regarding risk assessment and monitoring regimes were identified among the submissions and online interventions. They included, for example, legislations, policies and guidelines adopted by countries.

40. Several Parties, in their submissions, noted that risk assessment practices are in place that can be adapted to address the risks posed by organisms developed through synthetic biology techniques. Parties shared their experience with LMOs where risk assessments follow a science-based approach in a case-by-case basis, using comparative analysis and taking international principles and guidelines into consideration. Parties also noted that socioeconomic impacts of the commercial release of an LMO are assessed.

41. With regard to best practices regarding monitoring regimes, Parties noted the importance of regulatory schemes undergoing periodic review to ensure that they keep pace with technology developments and scientific knowledge regarding risks. Furthermore, regulators must consult peer-reviewed publications and may reassess an approved organism if new information concerning its safety comes to light.

42. It was also noted in the online interventions that a number of international organizations and initiatives exist through which countries can share, communicate and develop, as needed, international guidelines for regulatory frameworks and risk management recommendations that they may then be implemented as appropriate and in compliance with individual national statutory and governance authorities. For example, the "Environmental Risk Assessment Toolkit" of the Organisation for Economic Co-operation and Development (OECD) offers guidance on risk assessment and provides consensus information useful in a risk assessment.

43. The work done under the Cartagena Protocol for the development of the "Training Manual on Risk Assessment of Living Modified Organisms" and the "Guidance on Risk Assessment of Living Modified Organisms"[10] was also noted as examples for best practices. Other examples for best practices identified in the submissions and online interventions include the "The Principles for the Oversight of Synthetic Biology"[11] developed by the ETC Group, "*Guía para la Evaluación de Riesgo Ambiental de Organismos Genéticamente Modificados*"[12] developed by the International Life Sciences Institute of Brazil.

44. In spite of having robust risk assessment practices in place to evaluate LMOs, some Parties also noted that risk assessment approaches and protocols for organisms of synthetic biology are still in development and, hence, there is a need for specific guidelines and capacity-building opportunities to be made available as new information concerning their safety come to light and new protocols are developed.

[10] Available at http://bch.cbd.int/cpb_art15/training.shtml and https://bch.cbd.int/protocol/guidance_risk_assessment, respectively.

[11] Available at http://www.etcgroup.org/content/principles-oversight-synthetic-biology.

[12] Available at http://www.ilsi.org/Brasil/Pages/ViewItemDetails.aspx?WebId=C34AB3F5-C89B-49B3-9740-31F407A2A6FD&ListId=91D4243D-A11D-4CB9-B694-551373D9E8C5&ItemID=73.

45. The full range of best practices identified in the submissions and online interventions can be accessed through the Biosafety Clearing-House.[13]

VII. ADEQUACY OF EXISTING NATIONAL, REGIONAL AND/OR INTERNATIONAL INSTRUMENTS TO REGULATE THE ORGANISMS, COMPONENTS OR PRODUCTS DERIVED FROM SYNTHETIC BIOLOGY TECHNIQUES

46. Several submissions and online interventions noted that most of the current commercial and near-commercial applications labelled as synthetic biology involve the modification of existing organisms through the addition of genes coding for entire biosynthetic pathways and/or the modification of existing genes and gene pathways to allow for the production of new molecules. Consequently, any organism that is produced by these means would be considered an LMO developed through modern biotechnology.

47. There was general agreement that living organisms generated through synthetic biology fall within the scope of the Convention and its Protocols, as well as under existing national biosafety frameworks. It was noted that, at the national level, Article 8 of the Convention requires all signatories to establish or maintain means to regulate, manage or control the risks associated with the use and release of LMOs resulting from biotechnology. This article is further supplemented by the Cartagena Protocol and Nagoya Protocol dealing with biosafety and the fair and equitable sharing of benefits, respectively, across national boundaries.

48. On the other hand, some research areas of synthetic biology, including gene editing, protocells and orthogonal systems, could raise potential issues with regard to the regulatory status of the resulting living organisms as they may or may not be considered LMOs as per the definitions in the Cartagena Protocol and national legislations. In this context, some submissions pointed to the need to expand the language of the Cartagena Protocol and national legislations with a view to making them fully adequate in addressing a broad range of current and future living organisms developed through synthetic biology, while others were of the view that the development of a dedicated regulatory instrument which focused specifically on synthetic biology is necessary to fully address the three objectives of the Convention.

49. There was a range of views regarding the extent to which existing international regulatory systems are adequate to address environmental, health, and societal concerns posed by the products of synthetic biology, which are themselves not "living organisms". On the one hand, some submissions and interventions noted that the products of synthetic biology, similarly to non-living products of genetic modification or biotechnology, are adequately addressed in a sectorial manner by current international regulatory regimes designed for certain end-uses (e.g. pharmaceuticals) or by regimes designed to regulate chemicals. On the other hand, some submissions and interventions noted that the current international regulatory instruments are not adequate in that they are fragmented and do not comprehensively address all concerns related to the products of synthetic biology including, but not limited to, socioeconomic impacts and the issue of liability and redress.

50. At the national level, it was noted that existing national biosafety frameworks and legislations may be applicable to synthetic biology if they treat the organisms and products of synthetic biology as equivalents to those of modern biotechnology. Likewise, existing national policies governing the exchange, distribution and commercialization of the products of modern biotechnology may also be applied to the non-living components and products of synthetic biology.

51. In summary, the majority of submissions and online interventions noted that current living organisms resulting from synthetic biology are adequately regulated within the scope of the Convention and its Protocols, in particular the Cartagena Protocol, as well as under national biosafety regulations. Nevertheless, this assertion may need to be revisited at regular intervals to account for the rapid

[13] Available at http://bch.cbd.int/synbio/notifications/ and http://bch.cbd.int/synbio/open-ended/discussion.shtml, respectively.

progresses in the approaches and techniques of synthetic biology. There was less agreement with regard to whether or not existing regulations are adequate to regulate non-living components and products of synthetic biology.

VIII. DEGREE TO WHICH THE EXISTING ARRANGEMENTS CONSTITUTE A COMPREHENSIVE FRAMEWORK IN ORDER TO ADDRESS THE IMPACTS OF SYNTHETIC BIOLOGY, IN PARTICULAR THREATS OF SIGNIFICANT REDUCTION OR LOSS OF BIOLOGICAL DIVERSITY

52. In considering the current and short-term developments in the field of synthetic biology, there was a certain level of agreement among the submissions and online interventions that the principles and methodologies of risk assessment, as well as risk management measures, established for LMOs can serve as a basis for addressing potential adverse effects associated with organisms developed through synthetic biology.

53. There was also some agreement among the submissions and online interventions that, in the future, synthetic biology is likely to lead to the development of organisms that will differ fundamentally from naturally occurring ones, which will raise specific challenges and limitations with regard to risk assessment principles and methodologies that are currently applied to evaluate LMOs. As such, risk assessment methodologies that are currently in use by countries will need to be revised and adapted to ensure that the risks of synthetic biology are adequately assessed.

54. In practice, it was noted that the existing approaches of risk assessment, management and communication can be used as a basis for assessing and mitigating the impacts of organisms developed through synthetic biology techniques, provided that guidelines and methodologies are developed and made available to address the additional uncertainties and knowledge gaps. The need for a revised risk assessment framework to address the possible novel risks posed by products of synthetic biology whereby no parent organisms can be used as comparators was also noted.

55. The following further observations were made in the context of addressing the impacts of synthetic biology:

(a) Many of the current synthetic biology applications are destined for contained use and are somewhat removed from having a direct impact on the environment and biodiversity. The discussion on the impacts of synthetic biology would benefit from a focus on the potential impact of organisms that are being developed for intentional introduction into the environment and which are capable of replicating or reproducing;

(b) Risk assessors and regulators have relatively little experience considering the potential hazards posed by the intentional release of microorganisms, be they the result of synthetic biology or otherwise;

(c) In the future, organisms could be developed through synthetic biology that will fundamentally differ from naturally occurring organisms, e.g. by increasing the number of introduced biological parts, by using novel nucleic acid sequences or by using orthogonal systems. In such cases, it will be impossible to conduct risk assessments based on a comparative principle due to the lack of appropriate comparators;

(d) Due to the complexity and novelty of the organisms developed through synthetic biology, the type and depth of information that may be required to assess their risks will differ from the information typically provided by the developers for conducting risk assessments of LMOs;

(e) It will a challenge to assess the potential short- and long-term socioeconomic impacts of synthetic biology, including the impacts on traditional practices and traditional knowledge as these are usually not measurable.

56. In summary, when considering the degree to which the existing arrangements constitute a comprehensive framework in order to address the impacts of synthetic biology, the majority of submissions and online interventions noted that the methodology that is currently in use to assess the risks of LMOs can provide a basis for the risk assessment of living organisms developed through synthetic biology. Nevertheless, there is a need to revise and further develop risk assessment methodologies in order to fully address the potential environmental and societal impacts of synthetic biology.

IX. OUTLOOK AND POSSIBLE ELEMENTS OF A WAY FORWARD

57. In their submissions, a number of Parties proposed elements of a way forward for consideration in the deliberations on synthetic biology under the Convention, including the following:

(a) A system that not only encourages innovation, but also fosters an open legal framework and transparency is needed. This may lead to awareness by the public and oversight by an informed collection of governments worldwide, for environmentally sound uses of synthetic biology techniques. The cost of health and socioeconomic impacts of processes originating from synthetic biology may be assessed and evaluated in relation to its potential to replace hazardous and polluting chemical processes;

(b) Scientific and technological developments in the field of synthetic biology must be reviewed regularly and action taken if voluntary codes or current regulatory procedures appear insufficient. In this regard, exchange between the research community, risk assessors and policymakers will be central to expanding scientific and technical knowledge and filling potential gaps in risk assessment and regulation of evolving developments. Further approaches to reconsider effective risk governance must also be taken in a global perspective, allowing international coordination and dialogue;

(c) In order to maximize potential benefits and avoid risks, and given the high level of uncertainty associated with the technologies involved, the Convention must prudently support the developments of this technology, by carefully assessing ecological and social values and by seeking to avoid unacceptable damage to species, people and ecosystems. Therefore, the use of synthetic biology must be based on a precautionary approach in line with existing decisions of the Convention of the Parties and, in particular, in accordance with paragraph 4 of decision XI/11, as well as by carrying out risk assessments on a case-by-case basis, and considering potential benefits in an evidence-based manner. Furthermore, an environmental and commercial release of organisms resulting from synthetic biology must not be performed until procedures and regulatory processes or international regulatory frameworks are in place to ensure the protection of ecological systems;

(d) Work being undertaken by other national and international bodies, for example the European Commission, to develop a working definition of synthetic biology is relevant to the work of the Convention in this area and collaboration with these fora would avoid contradictions in the definition developed;

(e) A coordinated approach must be pursued between the Convention and its Protocols, in particular, but not limited to, ensuring a strong synergy between the programmes of work on risk assessment and risk management under the Cartagena Protocol and that on synthetic biology under the Convention. It must also be taken into account that the Nagoya Protocol also applies to conducting research and development on the genetic and/or biochemical composition of genetic resources, including the use of biotechnology as defined under Article 2 of the Convention;

(f) The creation of an online platform to facilitate the exchange of information on synthetic biology is noted as an important step towards providing all countries with access to information related to scientific, technical, environmental and legal issues, as well as capacity-building. A possible way forward in this regard is the establishment of a portal under the Biosafety-Clearing House where all Parties to the Convention – not only those that are also Parties to the Cartagena Protocol – could share information on the commercial release of organisms, components and products resulting from synthetic biology, as well as practical experience and guidance to facilitate capacity-building with regard to synthetic biology;

(g) Existing frameworks to assess the risks of LMOs can serve as a basis for the risk assessment of organisms developed through synthetic biology. However, there may be cases where specific guidelines to address the additional complexity and risks posed by synthetic biology organisms will be needed. As such, the current risk assessment framework must be reviewed and/or adapted, as appropriate, to address any gaps that may exist on how to assess organisms produced via synthetic biology, including how to approach the lack of adequate comparators in the risk assessment. When revising or adapting existing methodologies for risk assessment countries may take the following into account:

(i) Ensuring that risk assessment methodologies advance in parallel with progress in synthetic biology;

(ii) Structuring, standardizing and developing more effective mechanisms for the submission of relevant data on genetic modification and genetic elements to risk assessors;

(iii) Supporting the sharing of specific and relevant information on the components, equipment and systems used in the development process with the risk assessors;

(iv) Supporting the characterization of the biological function of the components and the development of computational tools that can predict the properties of the organisms containing such components;

(h) There is a need to develop an international framework to cover the organisms, components or products of synthetic biology techniques which also provides for an assessment of the cultural and socioeconomic impacts, primarily the impacts on small-scale farmers, and also on biodiversity, and in particular wild relatives;

(i) It would be helpful if all of existing regulatory frameworks were openly shared and discussed in relation to synthetic biology with best practise and gaps identified;

(j) More work is needed to understand how the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and the Strategic Approach to Integrated Chemicals Management (SAICM), as well as international best practices, such as good laboratory practices (GLP) and good manufacturing practices (GMP), may apply to non-living components and products derived from synthetic biology techniques.

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