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INFORMATION FOR DELIBERATIONS ON AGENDA ITEM 3.4

Note by the Executive Secretary

I. INTRODUCTION

1. The terms of reference for the Ad Hoc Technical Expert Group (AHTEG) on Synthetic Biology request it to undertake a review of the current state of knowledge by analysing information, including but not limited to peer-reviewed published literature, on the potential positive and negative environmental impacts, taking into account human health, cultural and socioeconomic impacts, especially with regard to the value of biodiversity to indigenous peoples and local communities, of current and near-future applications of synthetic biology, including those applications that involve organisms containing engineered gene drives, taking into account the traits and species potentially subject to release and the dynamics of their dissemination, as well as the need to avoid duplication with the work on risk assessment under the Cartagena Protocol on Biosafety.

2. The present document has been prepared to assist in this task by summarizing relevant information from the report of the 2015 meeting of the AHTEG and supplementing it with information from the submissions, the online forum and the literature review.

II. INFORMATION ON POTENTIAL POSITIVE AND NEGATIVE IMPACTS FROM CURRENT AND NEAR FUTURE APPLICATIONS OF SYNTHETIC BIOLOGY TO INFORM THE REVIEW OF THE CURRENT STATE OF KNOWLEDGE

3. The online forum and the submissions on synthetic biology raised a number of general considerations related to potential positive and negative impacts from current and near-future applications of synthetic biology. These were similar to the points reflected in section 3.5 of the report of the 2015 meeting of the AHTEG, which are summarized below for easy reference:

(a) Organisms, components and products of synthetic biology are expected to have similar positive and negative impacts on biological diversity as those of classical genetic engineering. However, the potential positive and negative impacts of synthetic biology may be broader and more wide-ranging due to its potential to engineer more complex organisms and biological systems;

(b) In comparison with classical genetic engineering, a distinctive quality of synthetic biology is its rate and depth of intervention, which may lead to decreased familiarity of the organisms developed through synthetic biology in comparison with non-modified organisms;

(c) Potential benefits as well as the potential adverse effects of synthetic biology applications need to be assessed on a case-by-case basis, with an appropriate balance between reasoning based on evidence and forward-looking scenarios;

(d) The potential benefits and potential adverse effects associated with synthetic biology are dependent on the particular circumstances and context in which the application is used: for example, the country in which the technology is being applied, its ecosystem and the relevant production system;

(e) The current and near-future applications of synthetic biology being considered in the assessment of potential benefits and potential adverse effects are at various stages of development, ranging from the theoretical to early or active areas of research to those that are already on the market. Consequently, the timeframe within which the potential benefits and potential adverse effects associated with those applications may be realized would vary considerably.

4. The report on the 2015 meeting of the AHTEG contains illustrative examples of potential benefits and potential adverse effects of synthetic biology. To assist the present meeting of the AHTEG to undertake a review of the current state of knowledge and to build on the work of the 2015 AHTEG, the list of potential benefits and potential adverse effects is presented below. The list is also complemented with information provided through the 2019 process, namely the submissions of information, the online forum and a literature review from which references have been added to the present list whenever possible.

5. The AHTEG may wish to consider the list as a starting point for discussion and identify information gaps in the current state of knowledge on the potential positive and negative impacts from synthetic biology applications, including those applications that involve organisms containing engineered gene drives.

A. Potential benefits identified by the AHTEG in 2015[1]

6. The potential benefits identified by the AHTEG at its meeting in 2015 are as follows:[2]

(a) Medical and nutritional applications may lead to healthier populations, which is a pre-requisite for the conservation of biological diversity;[1–3]

(b) Bioremediation may contribute to the restoration of ecosystems;[4]

(c) Resistance or tolerance to various stresses, such as diseases and abiotic stresses, may contribute to species conservation;[5,6]

(d) Agricultural and agroforestry applications with reduced chemical pesticide/herbicide use may lead to the conservation of pollinators and other non-target organisms;[7–9]

(e) Agricultural and agroforestry applications of synthetic biology, such as abiotic stress tolerance or micro-organisms modified for increased nitrogen fixation, may lead to restoring productivity of depleted agricultural land and to increased crop productivity on existing agricultural land;[10–12]

(f) In the area of bioenergy applications that rely on synthetic biology, some models indicate a potential reduction in greenhouse gas emissions, which would contribute to mitigation of climate change and thereby to the sustainable use of biological diversity;[13]

(g) Application of gene drive systems and other tools of synthetic biology to control agricultural pests and animal and human diseases may improve the sustainable use of biodiversity and human health;[6,14–17]

(h) Using microorganisms produced through synthetic biology to utilize biomass waste from agriculture and/or forestry more efficiently. This may reduce reliance on natural environments or land use for agriculture and forestry;[18,19]

(i) Industrial applications of synthetic biology may lead to alternative methods of manufacture products, such as chemicals and other materials, which are currently produced from natural sources, thereby reducing the impacts associated with the extraction of natural resources;[20–22]

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[1] See UNEP/CBD/SYNBIO/AHTEG/2015/1/3, section 3.5. Bibliographic references have been added as per point “c” of the 2019 AHTEG’s terms of reference, which indicate that the review of the current state of knowledge should be done by analysing information, including but not limited to peer-reviewed published literature.

[2] The superscripted numbers at the end of each subparagraph refer to the list entries of cited literature beginning on page 5.

(j) Provisions on the fair and equitable sharing of the benefits arising from the utilization of genetic resources are covered in Articles 15 and 16 of the Convention and the Nagoya Protocol. The availability of synthetic biology may enable the fair and equitable sharing of benefits with relevant stakeholders in developing countries through greater access to the tools of synthetic biology, thereby facilitating the transfer of knowledge and technology.[23]

B. Additional potential benefits[3]

7. Additional potential benefits are as follows:

(a) Plants can be edited to remove allergens, thus producing safer food sources;[24]

(b) Fast, efficient, and precise creation of new plant varieties and crops;[3,25]

(c) Conservation efforts could be aided by gene drive applications, which could add a beneficial genetic element to a population that could confer disease resistance or increase tolerance to other stresses;[6,26]

(d) Synthetic viruses and virus-like particles could be utilized for highly targeted drug delivery or induce transient, non-inheritable changes to quickly respond to stresses and/or produce valuable products (e.g. vaccines and chemicals);[27–30]

(e) Plants can be edited to overcome natural biological barriers for improved plant production (e.g. self-incompatibility and vernalization);[31,32]

(f) Synthetic photosynthetic pathways could greatly increase yields of crop plants while capturing more carbon dioxide than traditional plants;[33–35]

(g) Non-arable land could be used for bio-reactors and growth ponds to produce nutritional or fine-chemical products;[13]

(h) Use of non-canonical elements could lead to new antimicrobials;[36]

(i) Cells could be redesigned with new or specifically defined functions with enhanced productivity compared to organisms produced through traditional genetic engineering.[37,38]

C. Potential adverse effects identified by the AHTEG in 2015[1]

8. Potential adverse effects identified by the AHTEG at its meeting in 2015 are as follows:

(a) An engineered fitness advantage may lead to invasiveness;[39,40]

(b) Enhanced gene flow that leads to loss of biodiversity;[40,41]

(c) An increased pathogenic potential;[40,42,43]

(d) Increased levels of toxic substances, which may lead to disruptive effects on soil, food-webs and pollinators;[40,44,45]

(e) Negative effects on non-target organisms, such as pollinators;[40,46]

(f) Changes in organisms on the level of basic metabolic pathways, such as altered photosynthesis pathways, carbohydrate metabolism or nitrogen fixation, which, among other effects, may lead to changes in agricultural practice and land use and may challenge risk assessment;[40]

(g) Applications that are aimed at altering and replacing natural populations (for example, gene drive systems) may have adverse effects at the ecosystem level;[6,47]

(h) Increased demand for biomass crops, as well as changes in patterns of extraction of biomass, minerals and other sources of energy, may lead to changes in land use;[48]

[3] Information from 2019 submissions and the online forum on synthetic biology and from a review of peer-reviewed published literature.

(i) Replacement of natural products may lead to changes in the agricultural practices of communities, which may adversely affect traditional crops, practices and livelihoods;[23]

(j) Gene flow may lead to adverse effects on agrobiodiversity;[23]

(k) Loss of market share and income by indigenous and local communities due to the altered exploitation of genetic resources;[23,49,50]

(l) A shift in the understanding of what constitutes a genetic resource and the implications thereof, such as the misappropriation of the original source of the DNA information and, consequently — if benefits are derived from the use of such DNA information without prior informed consent and mutually agreed terms — the fair and equitable sharing of the benefits would not be possible;[51]

(m) Inappropriate access without benefit-sharing due to the use of sequenced data without material transfer agreements under the Nagoya Protocol;[52]

(n) Patent-driven and open-source approaches to synthetic biology may have different implications in the context of access and benefit-sharing;[51,53]

(o) Indigenous peoples and local communities will not necessarily support or benefit from the utilization of genetic resources in synthetic biology.[51,53]

D. Additional potential adverse effects[3]

9. Additional potential adverse effects are as follows:

(a) Misuse of synthetic biology technology to create and develop bio-weapons for use in bio-terrorism;[43,54,55]

(b) The potential integration of cell-free components and circuits into living cells;[56]

(c) Xenobiotic elements could be allergenic and/or toxic on living systems;[57,58]

(d) RNA interference sprays could elicit unexpected affects in off-target species, including disrupting the endogenous micro-RNA pathways or silencing unintended genes;[44,46,59]

(e) Once synthetic or engineered microorganisms are released, dissemination cannot be control and the organisms not retrieved;[41,45]

(f) Gene drive applications could be highly invasive at small release numbers and could result in unintentional transboundary movements;[60–62]

(g) The removal of a specie from the environment using a gene drive could facilitate the introduction of a new disease vector though environmental niche filling;[42]

(h) Unexpected outcomes of gene drives could detrimentally affect biodiversity (e.g. recombination to produce more invasive, self-sustaining drive (e.g. daisy-necklace), effects of payload genes);[63,64]

(i) Gene editing could have the potential to produce CRISPR-resistant viruses through evolution;[65]

(j) Gene editing could produce unknown or unexpected results through on- or off-target mutagenesis or through accidental RNA editing by a DNA editor.[66–69]

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