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Submission to the Nuffield Council on Bioethics 'Call for Evidence' – Considering future generations, the environment and the interests of non-human species in the analysis of emerging technologies, including solar radiation modification.

SUBMISSION TO THE NUFFIELD COUNCIL ON BIOETHICS 'CALL FOR EVIDENCE' – CONSIDERING FUTURE GENERATIONS, THE ENVIRONMENT AND THE INTERESTS OF NON-HUMAN SPECIES IN THE ANALYSIS OF EMERGING TECHNOLOGIES, INCLUDING SOLAR RADIATION MODIFICATION.

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In addition to Jack Gilbert co-chairing the IUCN MCSG, the group currently receives convening support from Applied Microbiology International.

Microbes underpin all ecosystem services, climate regulation, food security, and host health, yet remain largely absent from conservation and policy frameworks. This invisibility creates both scientific blind spots and ethical gaps when considering non-human species and future generations in emerging technology governance. From the perspective of the IUCN Microbial Conservation Specialist Group (MCSG), integrating microbes into policy would substantially strengthen decision-making in the following ways.

1. Benefits and potential complications of incorporating microbes into policy and decision-making

Benefits - Including non-human biodiversity, particularly microbes, enables more robust environmental risk assessment by capturing early signals of ecosystem stress that often precede visible degradation. Microbial indicators can function as early-warning systems for ecosystem collapse, disease emergence, and biogeochemical disruption. Incorporating microbial processes also improves ecosystem resilience planning and helps prevent unintended cascading effects, such as pathogen proliferation, loss of nutrient cycling capacity, or the disruption of food webs.

Complications - Microbial systems present challenges due to their immense taxonomic and functional diversity, rapid turnover, and context-dependent dynamics. Defining appropriate units of consideration (species, functions, communities, or interactions) and distinguishing natural variability from harmful change requires clear guidance. Baseline data gaps, attribution of causality, and data governance issues (including access and benefit sharing of genetic resources) must be addressed. The MCSG is actively working to resolve these challenges through Red and/or Green List–compatible criteria and Community Integrity Indices that emphasize function and ecosystem relevance rather than taxonomy alone.

2. Methodologies currently used

Existing policy-relevant methodologies already provide entry points for including non-human species, including microbes:

- Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA), where microbial baselines and functional thresholds can be incorporated.
- Ecological risk assessment frameworks that trace exposure-effect pathways for interventions affecting ecosystems.
- Biomonitoring systems using eDNA, metagenomics, and functional gene indicators (already used in the food industry and agriculture, for example).
- Adaptive management approaches using thresholds and trigger points to guide mitigation.
- Life-cycle assessments of emerging technologies that account for downstream microbial and biogeochemical impacts.

These tools are widely accepted in policy contexts but rarely applied explicitly to microbial systems.

3. Proposed frameworks and methodologies for the inclusion of microbes in policy and decision-making.

We advocate for:

- Integrating microbial metrics into the IUCN Red List, Red List of Ecosystems, and Green List processes.
- Embedding microbiome-informed risk assessments into the governance of emerging technologies, including engineered biological interventions.
- Treating microbial community integrity as a measurable environmental performance indicator, analogous to water-quality standards.
- Adopting One Health and planetary health frameworks that explicitly include environmental microbiomes.
- Applying precaution and reversibility principles to interventions that may alter microbiomes at scale.

4. Existing frameworks to build on

While few frameworks explicitly address microbes, several provide strong foundations:

- The Kunming-Montreal Global Biodiversity Framework, particularly its

emphasis on ecosystem integrity and monitoring.
- One Health policy architectures linking environmental, animal, plant, and human health.
- The Nagoya Protocol on Access and Benefit Sharing, relevant to microbial genetic resources.
- Biosafety frameworks such as the Cartagena Protocol, which governs the movement of living modified organisms resulting from biotechnology from country to country.

These frameworks can be strengthened by explicitly recognizing microbial systems as integral components of biodiversity and ecosystem health.

5. Weighing values across species and generations

Microbial functional integrity and intergenerational transmission of ecological capacity (including microbial diversity) should be treated as foundational public goods, essential for safeguarding future human and non-human wellbeing.

6. Making existing frameworks more inclusive

Inclusion can be improved by requiring microbial baselines in EIAs and SEAs, embedding microbial indicators in ecosystem condition accounting, and mandating post-deployment monitoring for emerging technologies with ecosystem-scale impacts.

7. Ensuring ethical considerations are accommodated

Ethical governance should include microbial impact assessments alongside environmental assessments - as early indicators, transparent data sharing, and trigger-based governance systems that link monitoring outcomes to management action.

Excluding microbes' risks protecting only visible biodiversity while neglecting the biological mechanisms that sustain ecosystem function - and are the starting point of biodiversity declines. Integrating microbial considerations is therefore essential for early, responsible, future-oriented policy and technology governance.