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"SCENARIOS TO DESCRIBE VARIOUS BIOTECHNOLOGY INNOVATION DIRECTIONS FOR THE FUTURE WORLD"

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ABSTRACT

The possibility for tomorrow's innovation to be based on today's biotechnology research advancements may vary depending on how the future plays out. It will be easier to focus, accentuate, or de-emphasis discovery research quickly and to increase the likelihood of successful innovation if progress is monitored against indicators for many future scenarios. In this study, we demonstrate how learning scenarios with a time horizon of 2050 aid in recognizing the consequences of social and political changes on the innovation potential of ongoing biotechnological research. We also put forth a strategy to enable basic research investigate finding areas that are more likely to be useful for applied research, increasing open innovation between academia and the biotechnology value chain.

***Keyword**: earning scenarios, biotechnology, research and innovation, bioeconomy, microbiome, open innovation*

I. CREATING SCENARIOS FOR BIOTECHNOLOGY IN COMPLEX SOCIAL SYSTEMS

The boundaries of biological science's understanding are always growing. As our understanding of biological processes advances, we have a wider range of alternatives for creating incremental and unique improvements in the fields of medical, agricultural, and industrial biotechnology.

A key question for today's biotechnology discovery research is "innovation for what future world? " given that it can take between 10 and 25 years from understanding fundamental biological processes to the conceptualization of an invention and the production of a commercial product.

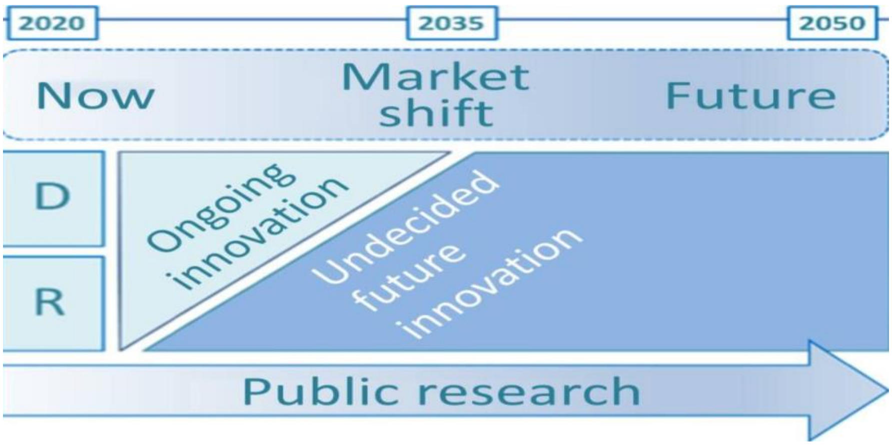

Figure 1.

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Innovation Flow

In the coming 15 years, the market will be served by R&D that is performed today. Different biotechnology sectors address changes in demand by repositioning and emphasizing what is in today's pipeline. New R&D and public research ideally address the demand of the future market. Scenario analysis is well suited to narrow down the most promising fields of investigation and to address the unmet needs of future markets. Abbreviations: R, research; D, development.

In order to comprehend the range of options for agricultural biotechnology, we conducted a first-of-its-kind scenario study with a 2050 time horizon in 2019. The complete agricultural socioeconomic system's 45 trends and 22 uncertainties were examined in order to map the potential futures and determine how agricultural biotechnology may best ensure the future security of food, nutrition, and health. Trends included consumer and demography, agricultural and technology, as well as political, economic, and sociological trends. Identified uncertainties were grouped into three categories: Priorities in the value chain and the need for adaptability.

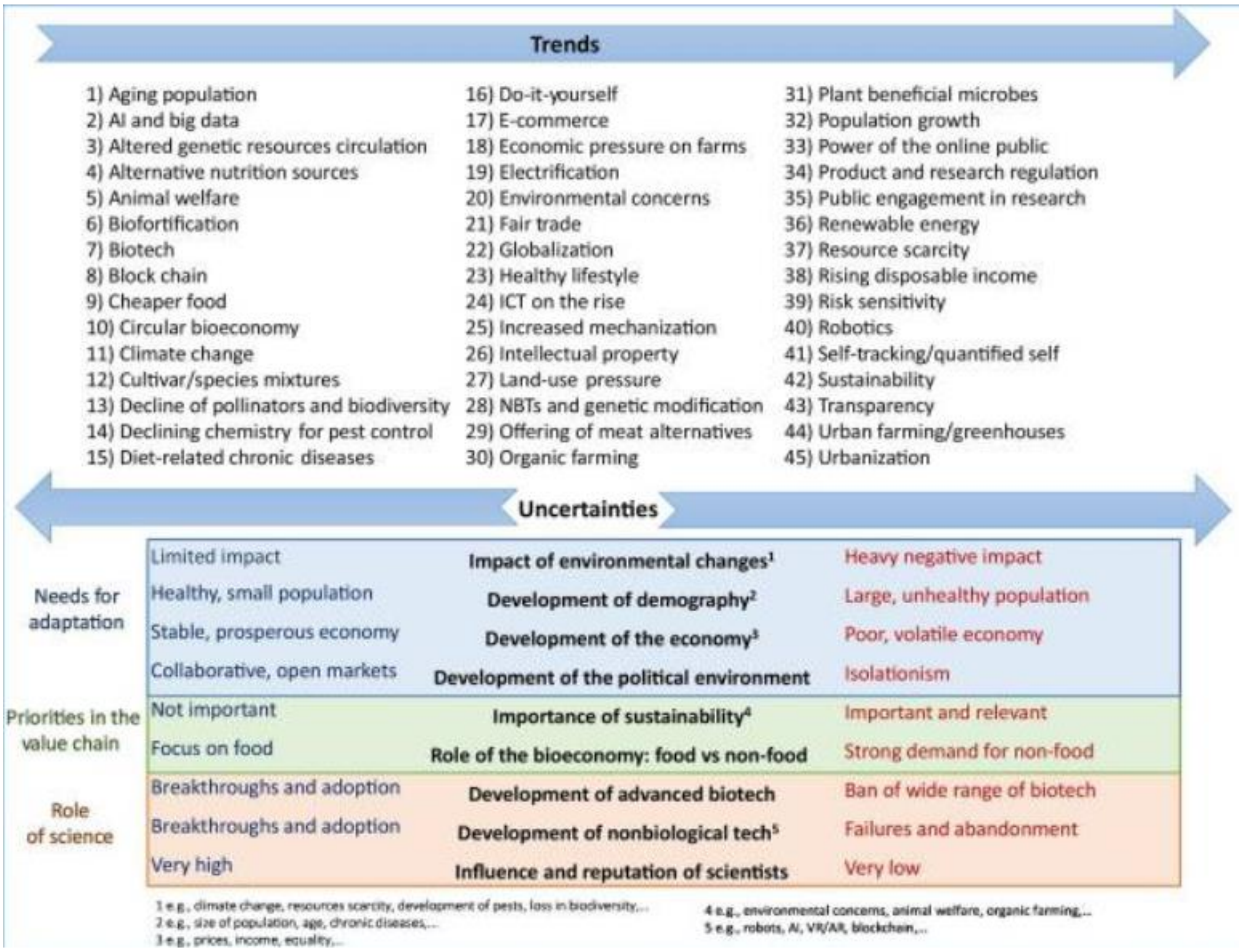

Figure 2

Trends and Uncertainties

Trends are considered developments going in a certain direction, while uncertainties can determine distinct outcomes with very different implications. Here the two most extreme ways that the uncertainties could play out are presented. Examples of specific uncertainties clustered around three more general themes are provided in the footnote. The exercise delivered four contrasting learning scenarios by detailing out specific aspects of possible future worlds and making them as concrete and vivid as possible (Figure 3). As the selected trends and uncertainties deal with society, environment, innovation, and policy, the learning scenarios helped to characterize implications not only for the future

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of agriculture in Europe, which was the initial scope of the scenario building, but they can also serve to aid decisions on future research and innovation (R&I) investments in other fields of biotechnology globally. Abbreviations: AI, artificial intelligence; AR, augmented reality; NBT, new breeding technique; VR, virtual reality.

The development of pertinent indicators is necessary to determine which scenario the world of today is moving towards [1, 2]. To do this, it is required to identify, chronologically organise through narratives, and assess the in formativeness of the key developments or events that must occur in order for a scenario to occur (Figure 3). Learning scenarios may be used again, and the diversity of knowledge on the team that is using them will determine the extent of the indicators that are detected. Indicators for the scenarios Bio-innovation and REJECTech and My Choice include changes in data privacy laws or gene editing legislation, whereas indicators for the scenario Food Emergency can include changes in water availability in a given region.

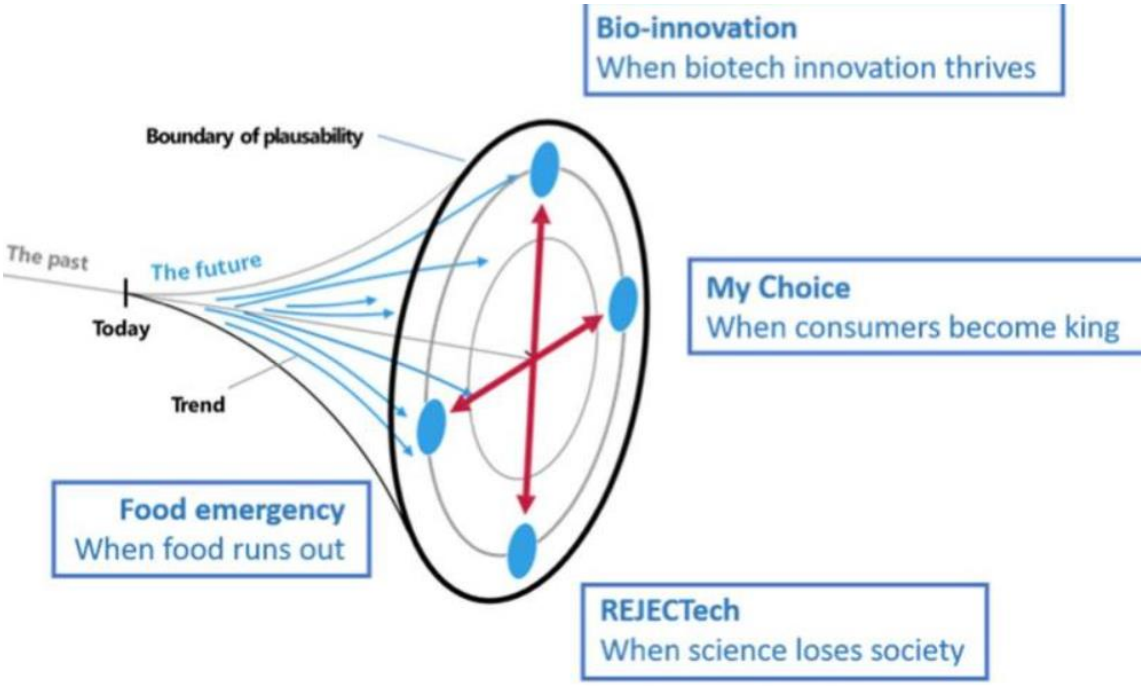

Figure 3

Learning Scenarios

Four contrasting learning scenarios enable us to delineate the option space for the direction and context of future biotechnology. **Bio-innovation**: Biotechnology solutions are intensively used and sustainably provide sufficient high-quality food and large-volume feedstock for a thriving bioeconomy; **My Choice**: Health and sustainability concerns drive all sectors to be diverse and transparent; meeting the needs and preferences of individuals, personalized medicine, and nutrition are the norm; **REJECTech**: Consumers have little trust in politicians, scientists, and big industry. Society is highly polarized and rejects biotechnology-derived products and services, despite dissatisfaction about missed opportunities, such as a broad adoption of the bioeconomy due to limited agricultural production; **Food Emergency**: Due to severe environmental degradation, the world is struggling to fulfill basic food demand. In response to the crisis, global adoption of innovation, including biotechnology, occurs to mitigate impacts.

II. Using Scenarios to Direct the Focus of Biotechnology Discovery Research

Many new innovations will determine how the world will change. Examples include the switch to renewable energy and decentralised storage, the adoption of new genomic technologies by patients, the acceptance of preventive medicine by society and the demand for information about food properties, dietary changes, the creation of new high-tech materials, lifestyle changes, and advancements in robotics and artificial intelligence. Observing such changes and

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extrapolating their long-term effects on how we live may motivate researchers to make a translational step and create biotechnology discovery research routes that would serve as the foundation for research and innovation (R&I) addressing future demands.

By 2050, many new technologies that will benefit humanity will certainly be based on biotechnology discovery research. The possibility for tomorrow's innovations to be based on today's biotechnology research advancements will, however, vary depending on how the future plays out. Also, the lack of an open innovation culture in academia and business raises the chance of losing out on innovations that, trend-wise, are likely to satisfy market or consumer demand.

For example,It is certain that there will be a large demand for biotechnology innovations connected to climate change, and that this demand will be backed by decision-makers. [3, 4] Uncertainty persists over the unfulfilled demands for the various stakeholder groups. We still don't completely understand the effects that changing and unpredictable weather patterns and the new environmental conditions that arise, such as new pests and illnesses, will have on cities, gardens, parks, lakes, and agriculture fields. Hence, a translational step from an innovation opportunity to necessary new knowledge is not straightforward. The same goes for how to bring innovation into products. [5] Gene editing and cutting-edge, yet-to-be-implemented, knowledge-driven processes are just a few examples. There is little chance that the first exercise, learning about climate change, won't be useful. The second, creating biotechnology innovations to combat climate change, depends on how global policy is developed and hence entails a bigger risk.[6] For example, While it is possible that society could transition away from fossil-based synthetic materials in favour of bio-based alternatives in a world of bio-innovation, this development is less likely to take place in a REJECTech environment because, while the know-how would be there, the technical enablement would not be supported.

Using the microbiota is a different illustration. The majority, if not all, complex ecological systems are impacted by microorganisms, therefore exploitation of biological know-how is anticipated to present opportunities for innovation across a wide variety of biotechnology sectors and serve as the foundation of new markets and business models. Medicine, health care, food systems, commercial and domestic manufacturing processes, recycling of resources, and energy capture are a few examples. In order for this to materialise, broad basic biotechnology discovery research on microbiomes must reach a tipping point, making R&I for smaller and larger possibilities across industries possible.[7] A third illustration focuses on dietary changes that favor different protein sources. Food attributes including flavor, texture, palatability, color, convenience, and cost have a significant impact on consumer choice. Would need significant progress in biological understanding to update food sources to order to make alternatives to meat competitive with it.[8] To ensure that expenditures made in biotechnology discoveries have a practical impact, it is challenging to be precise about the carriers, such as algae, insects, crops, fermentation, and so on, as well as the precise features. As it is presently unknown which items and product attributes will best satisfy future market expectations, it is not evident how to achieve this successfully. This highlights once again how crucial it is to compare learning contexts and how crucial it is to recognise scenario-specific indications in order to gain early insights into how certain trends are developing. These signs may be related to yes-or-no decisions made during the formulation of policies, the timely implementation of essential enabling technologies, or the presence of sizable consumer demands. To increase the possibility of successful innovation, it is helpful to keep track of the development of many, scenario-specific indicators. This helps to direct the emphasis of discovery research and to concentrate or de-emphasize urgent matters.

The COVID-19 (coronavirus disease 2019) pandemic, which was not anticipated and for which only comparatively modest and dispersed attempts of study were made before to the pandemic, is a contemporary real-life example. The present race in research and development to create a treatment and vaccine for COVID-19 would have benefited enormously from enhanced knowledge of coronaviruses acquired via biotechnology discovery research.[9,10].

III. CONCLUDING REMARKS

The biotechnology examples listed above highlight the possibility of a low level of innovation output when the underlying know-how from discovery research is not easily accessible and useful in a usable manner. The utilisation of learning scenarios and the monitoring of progress against indicators for these scenarios may considerably enhance the timely availability of founding know-how. In order for such a strategy to be successful, some unresolved concerns must be addressed first.

We feel determined that in order to increase the production of innovation, the conversation must include more than just financial tools and artistic expression. Instead, we advise considering the operation of the innovation ecosystem. [11] It would be beneficial to thoroughly analyse the present operating procedures between academics, value chain participants, and society in order to optimise the utility of technological advancements. For biological science to more effectively transition from discovery to innovation, there must be ongoing cross-stakeholder engagement. A paradigm for open innovation governance that can handle precompetitive and competitive big data activities and information is a requirement sine qua non for effectively managing biotechnological R&I.

As a response, we consider setting up virtual innovation pathways that involve participants from the academic community and the value chain. It is intended to create specialized ecosystem knowledge bases that support, for instance, the medical, agricultural, or industrial biotechnology sectors or a wide innovation topic like the microbiome. These ecosystem knowledge bases ought to contain curated and harmonized data in forms suitable for the needs of stakeholders. In a two-step approach, these needs may be established for each biotechnology sector. The general process at handover points between academic institutions and value chain participants should be specified first, and then the data and format specifications in this generic workflow, which would be essential to begin. Ideally, both directions of these processes should be explained. Also, users extracting data using their own software, if private, should agree to submit results that are made anonymous so that the following round of experimental questions can take into account updated data and the knowledge base grows over time both in scope and productiveness. However, time, not necessarily financing per se, is a constraint because of the ongoing requirement to do major biotechnology discovery research. In a similar vein, creating scenarios now to envision how the COVID-19 pandemic could evolve in the future could aid in anticipating the long-term effects of current activities and enable nations, governments, and communities to respond to the issue more skillfully. The current pandemic appears as a pertinent signal for the Food Emergency scenario in the context of the scenarios shown in Figure 3. Critical agricultural supply lines may be threatened by a global economic crisis, making food security an even bigger problem in some parts of the world.

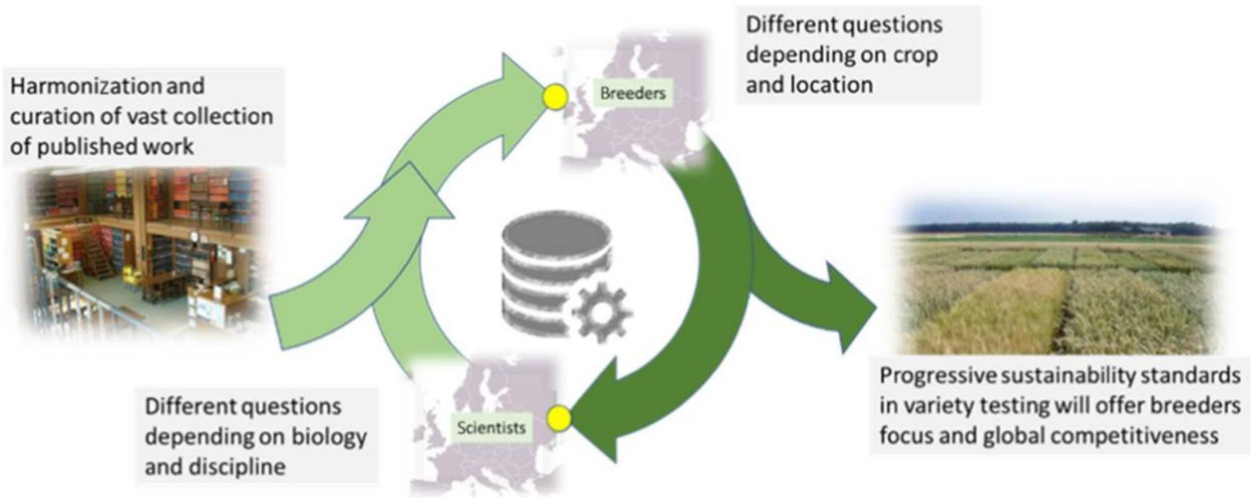

Figure 4

Outline of a Future 'Virtual Innovation Workflow' Driven by Biotechnology Big Data Governance

An example is given for agricultural innovation in Europe. To meaningfully contribute to the EU Green Deal, a rejuvenation of the agricultural ecosystem including academia, breeding and R&D companies, farm supply industry, and farmers is desirable. Required innovations should address environmental sustainability, impacts of increased weather volatility, climate change and associated pest and disease development, the European protein plan, development of more healthy and nutritious food, and an enablement of the bioeconomy. It should offer a lever to improve farm economics structurally through product branding and traceability. The novelty of the proposed 'virtual

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innovation workflow' is the bidirectional handover of outcomes and the holistic integration of data coming from plant, microbial, soil, agronomy, robotization, machine learning, modeling, and weather/climate disciplines. Critical success factors are, among others, the alignment of key performance indicators of stakeholders, incentives to participate, an open innovation attitude, a common benchmark to measure progress, smartly located research field stations, dedicated data centers with a user-oriented data curation, harmonization, storage and display approach, and an agreeable data governance concept. A pipeline of consecutive innovations can be primed by raising, over time, the requirements to successfully pass the formal variety testing and registration process. Customer demand (not shown) is in this example translated to requirements for official variety testing trials that, for example, meet progressively increasing levels of sustainability.

Dedicated data stewardship teams must be created, and suitable economic models and governance ideas must be built to address, among other things, data ownership and intellectual property, in order to make this feasible and sustainable. To achieve the optimal balance between stakeholder interests, this setup will probably require numerous rounds of adjustment. Nonetheless, it is ideally positioned to enhance the total flow of innovation to the market and to provide the needed flexibility to handle emerging trends in a constantly changing environment.

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