Relational Map of Plant Synthetic Biology in the UK

FIRST EDITION – MARCH 2026

Futuring Biological Commons

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FUTURING BIOLOGICAL COMMONS

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Executive Summary

This Relational Map is part of the Advanced Research + Invention Agency (ARIA)-funded *Futuring Biological Commons* project. It is designed to support the systematic tracking and analysis of emerging social, economic, and political relationships among actors, institutions, and materials within the plant-focused subfield of synthetic biology (here used interchangeably with engineering biology).
The map serves as:

- a central point of reference for researchers within and beyond academia, farming communities, the commercial sector, policymakers, and interested publics;
- a provocation for broader, constructive reflection, enabling the UK's ethical, social, funding, and policy discourses to co-evolve alongside developments in science and its organisation.

The Relational Map will be updated annually. **In this first edition,** we organise the discussion and its visualisation around the following key themes:

- **Historical trajectories**: Through two figures showing the historical development of synthetic biology and policy discussions about it. We draw attention to the fact that plant synthetic biology in the UK reflects not only advances in precision tools (e.g. CRISPR) and shifting regulatory frameworks (post-Brexit), but also enduring societal legacies, particularly from GMO controversies. We highlight that **current trajectories are neither inevitable nor purely technical, but contingent on how scientific shifts and societal responses are jointly interpreted, governed, and carried forward.**
- **Stakeholders:** The stakeholder landscape of plant synthetic biology is expanding and evolving, with **relationships between actors varying in 'thickness',** shaped by factors such as historical connections, resources, shared knowledge, and perceived authority. These entangled relationships are simultaneously shaping their roles and influence ('relationality'). More broadly, civil society engagement is shifting in both focus and approach, while policymakers, academia, and industry are **moving towards more coordinated, 'joined-up' approaches to realise scientific and economic opportunities.**
- **Concerns:** Concerns about plant synthetic biology are not uniform but span ethical, environmental, economic, regulatory, and scientific domains, often overlapping across stakeholders with different motivations, **importantly, these concerns are dynamic, varying in intensity and shifting in form and emphasis, so their value lies not only in capturing them at a given moment, but in tracing how they evolve over time.**
- **Invitation for collective reflections:** A final Resources flowchart situates key resources—Funding & Infrastructure, Skills & Knowledge, and Responsible Research & Innovation—within their historical development, linking past approaches to current examples. This report is intended to be both informative and provocative. **We particularly invite critique and collaboration to explore key questions on (a) reconciling past and future genetic technologies, (b) identifying new and overlooked stakeholders, (c) cultivating necessary new alliances, and (d) developing mutually enriching forms of public, scientific, and policy engagement.**

Preface: Why a Relational Map

Joy Y. Zhang
Principal Investigator, Futuring Biological Commons

The title of the preface is ‘why a relational map’, not ‘what is a relational map’. This is partly because, what a relational map should and could look like is part of what the Futuring Biological Commons project hopes to explore. But, from the beginning, we’ve been very sure that the ‘why’, of tracking social relations in the emerging field of plant synthetic biology and making them visible, is needed.

The full name of our project is ‘Promoting Response-ability among Stakeholders of Scientifically Enhanced Plants’. Prior to embarking on this project, and informed by a comprehensive literature review and our team’s active engagement across public and industry sectors, we identified four interrelated challenges to advancing synthetic plants in the UK. Each stems from misperceptions and/or misalignments in stakeholder relations:

(1) a public–technology misalignment that reduces nuanced, context-dependent views to misleading ‘for or against’ positions;

(2) a stakeholder role misalignment that undermines trust and the effective practice of Responsible Research and Innovation;

(3) an expectation–action misalignment that constrains the critical and robust translation of science into socio-ecological wellbeing; and

(4) an ethics–innovation misalignment, in which socio-ethical discourse on plants lags behind scientific developments in both depth and currency.

For these reasons, we argue that reconfiguring, repairing, and reimagining relationships between stakeholders—both human and non-human—in light of new scientific evidence, technical possibilities, and social and policy resources is key to addressing regulatory impasses, as well as socio-economic concerns and ethical dilemmas.

Accordingly, we propose a map that not only makes visible the positionality of stakeholders (e.g. their layered identities, perspectives, and resources) but also highlights the relationality of those positions. That is, it recognises how relationships between actors shape their views, capacities, and roles in influencing plant synthetic biology and its applications.

In other words, beyond scientific possibilities, the social and structural conditions of relating—how and to what extent stakeholders find plant synthetic biology relatable, whether they are included in discussions and when, and their ability to build and mobilise connections (the ‘thickness’ of relationships)—are as formative and consequential as their social and economic identities and capacities.

This is why we consider a *Relational Map* to be both necessary and informative. At the same time, we see the process of developing the map itself as a means of building relationships. This operates at multiple levels:

First, we aim to cultivate a shared attentiveness, not only to our own perspectives and aspirations, but also to how our relationships with others shape, and are shaped by, those aspirations. We recognise that there can be multiple forms of mapping that help diagnose and repair relationships, and that these may differ in form and approach. Not all maps need to be visual; some may be acoustic, spatial, or otherwise embodied. In this sense, we remain—and hope you will also remain—open-minded about what a 'relational map' can be.

Second, the annual updating of this map is not only intended for tracking or refinement. The iterative process itself expands our collective understanding and imagination of what kinds of relationships are possible, with whom and with what. It can also make visible what may have previously been taken for granted, or reveal patterns that emerge as more constant over time. However, this can only be achieved—and achieved more effectively—through wider critique and participation. We therefore see this Relational Map as a means of reaching out to you: to invite your reflections, your critiques, and your experiences, and to ask how your own position and relationships might be seen, challenged, or reimagined through this work.

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Guide to this report

The graphics in this report are designed to be informative while offering a visual representation of relations between a diverse group of stakeholders and related concerns and resources.

Colours, fonts, other shape sizes, layout, listing and placing of content within the maps have been designed for clarity and accessibility within the boundaries of available space. No interpretations should be drawn from the size or colour of any of the content. These were design decisions chosen to visualise knowledge sourced from academic and grey literature (information produced outside of traditional peer-reviewed channels) by the authors and from supporting colleagues. There are 12 graphics in total, excluding the cover photo, as listed in the table below.

Figures 1, 2, 3, 10 and 11 have complementary commentary sections. Figure 12 has a brief explanation, and Figures 4 to 9 have their own sections of commentary dedicated to supporting the graphics for the reader. The aim of these graphics, maps and flowchart is not to provide detailed analytical interpretations but to unravel for the reader the relationality of the plant synthetic biology landscape in the UK.

The report has been written with accessibility in mind, however, some language specific to the social sciences is used due to its value in meaning. For example, rather than refer to the 'general public', we use the word 'publics.' This usage acknowledges publics as a disparate collective of individuals with interests in public and civic matters and rights as citizens, but without formal decision-making roles (Ossewaarde, 2007; Habermas, 2001; Wright-Mills, 1956).

Introduction

Contemporary agriculture is increasingly recognised as a multi-functional system, contributing not only to food production but also to energy generation, biomaterials, climate mitigation, and wider environmental stewardship. UK agriculture is at a critical crossroads: existing challenges have been compounded by insufficient post-Brexit planning, the COVID-19 pandemic, labour shortages, disruptions to global supply, new tax burdens, rising costs for inputs, increasing regulations and expanding requirements to farm sustainably and for farmers to care for all of nature (Manning, OFC Report, 2026; Batters, Farming Profitability Review, 2025). The year 2026 opened with speakers at multiple agricultural conferences in the UK calling on the industry to be ‘resilient’ and to ‘grow’ in order to take on the challenges that society and agriculture face. These are all issues the UK agricultural sector is aware of, and ones that affect the valued asset of land and the principles of protecting land, nature and restoring environments.

The Green Revolution of the 20th century succeeded in increasing production without significantly increasing land use but nonetheless compounded environmental issues such as biodiversity and hedgerow loss, soil erosion and nitrification of water (Firbank et al, 2008; Mortimer, 2019; Roell & Zurbriggen, 2020; Scheper et al. 2023; Balmford et al, 2025). Farmers face further challenges from abiotic and biotic factors which are exacerbated by climate change and its effects, including changing seasonal weather patterns, flooding and droughts (Sargent et al, 2022). These challenges are further intensified by escalating global trends including the cost-of-living crisis, volatility in international trade, and an atmosphere of political division.

Plant synthetic biology has the potential to play a role in responding to many of these challenges. Synthetic biology (also referred to as engineering biology) is as Hanson et al (2019) state “a transformative combination of DNA technology, engineering principles, and computational tools that makes it possible to design new life processes and to repurpose existing natural ones for useful purposes”. In other words, synthetic biology can purposefully introduce new characteristics in organisms (Davies, 2018), such as creating sustainable and resilient crops. These crops could also deliver benefits such as increased nutrition, carbon sequestration, biopesticides and pest and disease resistance (Sargent et al, 2022), or plant derived therapeutics, biofuels or bioremediation (Davies, 2018; Mortimer, 2019; Rylott & Bruce, 2022).

Technologies do not emerge from, or become deployed in, a vacuum. Beyond the hurdles of funding, regulation, technical expertise and developing a market for their products, developers of plant synthetic biology must also navigate questions of whether its applications and products will be to the benefit of all society and accessible to marginalised communities, locally and globally. It is therefore vitally important to understand the differing positions of all the stakeholders concerned. This mapping exercise tracks and examines the evolving social, economic and political landscape of plant synthetic biology in the UK, positioning it as a science, an industry, a platform technology with the potential to address critical vulnerabilities in manufacturing, food security and agriculture in general.

As the key output from the Futuring Biological Commons project, this report lays the foundation for a central aim of our project research: to bring together diverse social interests, concerns, and resources into a ‘commons’ - a space in which actors (human and non-human), can establish new norms of coordination, enabling differentiated yet aligned uptake of scientific possibilities for the common good. Plant synthetic biology has huge and wide-ranging potential, but the field is most likely to succeed in contributing to our social and ecological wellbeing if it has been developed through open dialogue and meaningful participation of a diverse range of stakeholders.

The report is split into six sections.

- Methodology: This section outlines our methodological approaches, helping readers to contextualise the strengths and limitations of the report.
- Historical Trajectories: This section provides two graphics and an overview of the historical development of synthetic biology and its policy discussions.
- Stakeholders: This identifies six stakeholder groups and visualises how they are constituted. A final graphic highlights the connections between each group.
- Concerns: This section visualises six broad areas of concern in a mind map, with illustrative examples that have emerged from our research and their relationality with specific stakeholders are discussed.
- Resources: A flowchart identifies three areas of resources relevant to plant synthetic biology and how they are related to the concerns discussed in the previous section.
- Questions and Invitations: This section proposes questions to consider regarding the application(s) of plant synthetic biology and how stakeholders can be brought closer together in an open dialogue on this topic.

As plant synthetic biology remain a relatively emerging and specialised are, we have written this report with informed publics in mind, such as interested public, academics (both social and natural scientists), funders, farmers, relevant commercial actors and regulators. However, as synthetic biology is an evolving field that will disrupt and transform how we think about, cultivate, consume, use and relate to plants and the wider ecological system, we believe it is both accurate and prudent to leave the definition of 'stakeholders' open.

Importantly, this is a working document that will be updated periodically. It should not be read as conclusive, but as an invitation, indeed a provocation, for critique, inquiry and active involvement from all interested parties. Conceptualised by the Futuring Biological Commons team, the format of the Relational Map seeks to move beyond the binary and antagonistic divisions that have historically beset debates on technologies and which so often dog contemporary political and bioethical debates. By focusing on the connections, or relations, between the different stakeholders involved in plant synthetic biology in the UK, we aim to illuminate the areas of common ground upon which we can build understanding, respect and trust. As researchers, we aim to inform debates through evidence. We are also seeking to create spaces in which a range of views can be meaningfully integrated into discussions and decisions about whether and how plant synthetic biology can play a part in tackling current and future challenges.

Methodology

The report is primarily based on extensive literature review, guided and complemented by the expertise of the authors, the research team, reviewers, and project participants. For this very first edition, we present an interpretative analysis from policy, academic literature, grey literature (reports, media coverage, etc.) and data from ongoing qualitative research into experiences and expectations of novel scientific and technological innovations and informal discussions with experts within the plant sciences, agriculture and policy. The authors have also been involved in a number of key farming and science conferences in 2026 to gauge current topics of interest within the sector.

Academic literature was sourced via keyword searches (e.g. plant synthetic biology, agriculture, crop production, policy, genetic engineering, gene editing, genetically modified organisms) within databases. Grey literature was sourced from Google searches for keywords and following references from lobbying publications, news articles and from the background knowledge and experience of the authors and supporting team members.

The identification of stakeholder groups and sub-groups was carried out through coding of the academic and grey literature and team members' knowledge of the topic and was informed by the authors' experience and expertise within agriculture, plant sciences, biotechnological research, social sciences and policy areas.

The method of collating secondary sources enables us to picture the landscape of plant synthetic biology within the UK and its broader global interconnections. It is not intended to provide an in-depth analysis of specific relationships between stakeholders, as a full understanding of each relationship (e.g. power dynamics, knowledge curations, benefit sharing) requires dedicated and contextualised discussion. Instead, as stated in the Introduction, we aim to lay a foundation by bringing visibility to the scope and entanglement of these relationships. As such, the gaps and imbalances revealed in this report are equally informative.

Historical Trajectories

Plant synthetic biology is often presented as a recent technological development, yet it builds on a longer trajectory of efforts to understand and engineer biological systems. For some, the modern history of scientific endeavours to get better understanding and control of the biological system can be traced back to recombinant DNA (rDNA) research in the 1970s (Katz et al, 2018). While plant synthetic biology was established as a new field at the beginning of the 21st century, for the purposes of this report it can be considered plant synthetic biology emerged around 2010 (Joshi & Hanson, 2024). Most scholars situate the arrival of synthetic biology through two seminal publications in *Nature* (2000), Gardner et al's paper 'Construction of a genetic toggle switch in *Escherichia coli'* and Elowitz and Leibler's paper 'A synthetic oscillatory network of transcriptional regulators that proposed the engineering of biology via predictable and reusable methods, in conjunction with the Synthetic Biology 1.0 (SB1.0) conference held at the Massachusetts Institute of Technology (MIT) in 2004 (Wachter et al, 2022).

This section shows two parallel historical trajectories: one tracing key scientific milestones, and the other mapping major policy debates and interventions.

The development of synthetic biology and its relationship with society is shown in Figure 1. We include the discovery of the structure of DNA and the 1975 Asilomar Conference on recombinant DNA not only because they are key moments in the intellectual lineage shaping modern synthetic biology, but also because many policy and engagement norms are grounded in ongoing reflections on the legacy of these early periods (Hurlbut, 2015). Other key moments note the creation of the Gibson Assembly in 2009, one of the key tools for synthetic biologists; the identification of synthetic biology as one of the 'great technologies' in the UK in 2013; anti-biotechnology movements from 1998 to 2015 on genetically modified organisms; and a new era of anti-GM lobbying from 2014 including the 'letter from America.' This was an open letter to the UK and EU signed by citizens of America warning them of GMOs, which at the time were grown extensively in North America. Finally, in keeping with the project, potential future biotechnology applications are visually represented with biofuels, genetically edited crops and biomanufacturing.

Figure 2, at the end of this section, presents a timeline mapping the policy journey of biotechnologies from the mid-1980s to the present, showing how technological developments have been taken up by institutions and how synthetic biology has gained significance in the UK and globally. The Timeline map also highlights the significance of the post-2010 political and technological environments. During this period, as plant synthetic biology was established, advanced techniques such as CRISPR-Cas9, a gene editing technology, became widely adopted for its efficiency and specificity in editing the plant genome (Sandhya et al, 2020). This technology (also used in biomedical research) has enabled scientists to develop biotechnology applications at a greater speed, precision, and lower cost than previous methods (Redman et al, 2016).

The Synthetic Biology Roadmap for the UK was launched in 2012, recommended the establishment of the Synthetic Biology Leadership Council. The then Science Minister David Willetts identified synthetic biology as one of the UK's '*Eight Great Technologies'* in 2013. The government of the time positioned synthetic biology as both a tool to improve the health and environment of the UK and a key economic driver (Marris & Calvert, 2020). The vote for the UK to leave the EU in 2016 then provided a path for the UK to bring in new regulations and policy to support this in the absence of consensus in the EU.

Prior to this point, UK policy on biotechnologies had followed the regulations and policies agreed by the EU which rest on the precautionary principle, an approach that prioritises protection of environmental and human health when the scientific evidence about a technology's impact is uncertain (Bourguignon, 2015). For some, this was a key underlying principle to safeguard human health and the environment. For others, the precautionary principle was seen as blocking scientific progress. For example, the 2021 policy document, 'UK innovation Strategy: Leading the future by creating it' made the argument that the precautionary principle is prone to disproportionate application; it can effectively 'become a policy of blocking all potential harms, even a possibility of harm, without a balanced analysis of likely benefits.' (UK Innovation Strategy, 2021, 34).

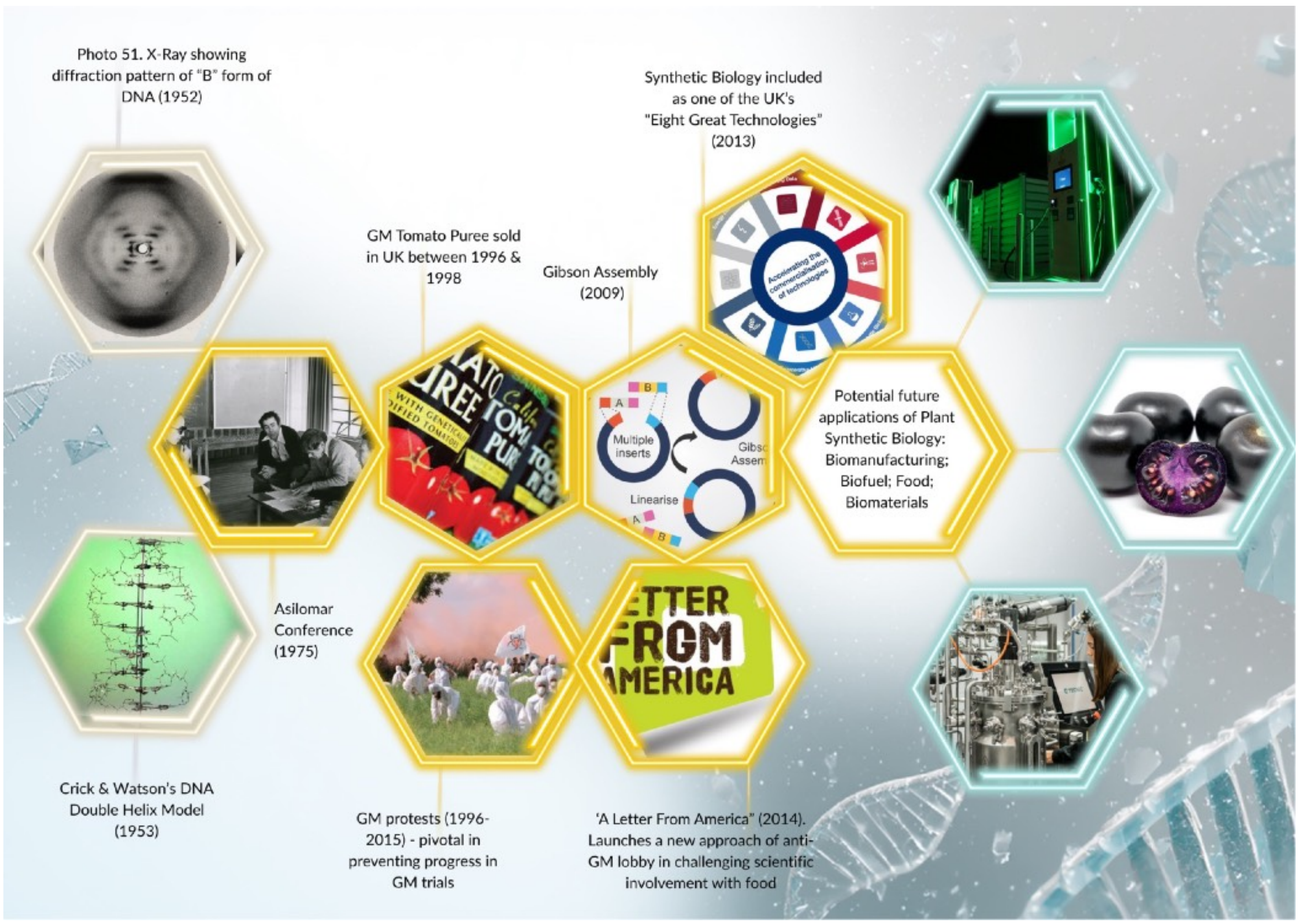

Figure 1: Key historical and future applications of biotechnologies

However, the legislation and regulations that were implemented post-Brexit are still underpinned by historic policies on genetically modified organisms (GMOs) from the early 2000s. For example, the most recent policy in the UK, the Genetic Technology (Precision Breeding Act) 2023 (henceforth PBA), which regulates genetically edited plants through engineering biology techniques, retains references and language from policies of the late 1990s and early 2000s regarding GMOs. While this new political era may have represented a technologically advanced and progressive future by some, this impression is not shared by all stakeholders. The PBA was only passed in England, with the devolved nations of the UK choosing not to enact the policy (BBC, 2022). Publics remain less comfortable about plant synthetic biology in comparison to other biotechnologies. As highlighted in the Department of Science, Innovation and Technology's (DSIT) national report on awareness of engineering biology that surveyed 3,000 UK adults (DSIT, Engineering biology public trust survey, Nov. 2024). Critical voices from groups connected to previous GMO debates who are intermingled and associated with (some) regenerative/ organic farming proponents continue to play an active role in shaping policy discussions and public perceptions.

However, shifting social and policy debates, alongside the gradual uptake of plant synthetic biology, do not constitute a simple 'slippery slope', nor do they indicate technological inevitability. Rather, we argue that these developments reflect changes in the material conditions of research – particularly in terms of feasibility, precision, and efficiency – as well as an expanded scope in how technologies interact with plant systems. A key technical shift shaping both scientific trajectories and their socio-policy reception is the move from earlier forms of genetic modification towards more precise forms of genetic editing.

From Genetically Modified to Gene/Genome Edited

While the terms genetically modified (GM) and genetically edited (GE) are often used interchangeably in everyday conversations, and even in some media reporting, they carry distinct scientific meanings, with different ecological and societal implications. *Genetically modified* is a broad category referring to any alteration of an organism's DNA. This can include traditional methods such as selective breeding, as well as earlier genetic technologies that typically involved inserting genes from one species into another, often in relatively imprecise ways. *Genetically edited*, by contrast, generally refers to more precise, laboratory-based interventions in which DNA is directly edited using new genetic technologies (NGTs), such as CRISPR, enabling targeted changes to specific genes within a plant's genome [Ahmad et al, 2023].

Policy decisions have been shaped by technological developments but also changing political landscapes (notably Brexit) and progress within other nations, such as the commercial success of GMOs in North America and South America, the establishment of Singapore as a synthetic biology hub (House of Lords Science and Technology Committee, 2009) and legislation in Australia allowing gene-edited foods to be sold (Stock, *The Guardian,* 2026). These global dynamics have encouraged the move to establish and support the development of biotechnologies in the UK; but this has not been without dissent. The devolved nations of the UK have not embraced these changes, with concern about recent biotechnology legislation related to experiences of the GMO debates from the 1990s and early 2000s and believing that aligning with the European Union would safeguard exports. For example, at the 2026 Oxford Farming Conference, ministers for agriculture for the devolved nations were asked whether farmers in their nations were being put at a competitive disadvantage by the devolved governments not enacting the PBA. Jim Fairlie, Member of the Scottish Parliament (MSP) and Minister of Agriculture and Connectivity for Scotland, responded that he remembered the BSE (Bovine Spongiform Encephalopathy disease) crisis and the GM protest, stating that "[we] *can't do anything the public doesn't like*". Note that this view does not represent all Scottish politicians with many arguing that the Scottish Government's position risks Scotland being "increasingly isolated in research terms, and less attractive to prospective inward R&D investment" (Carson, *Science for Sustainable Agriculture,* 2025*)*

The legacy of the GMO debate is central to the concerns of civil society (pro and anti) and the potential easing of regulation on biotechnologies such as plant synthetic biology. The UK has historically been seen as a country with a more permissive attitude towards novel life science technologies. Such attitude was reflected in the 2023 PBA and the Genetic Technology (Precision Breeding) Regulations (2025). This legislation was welcomed by pro-biotech lobbyists like the NFU and Science for Sustainable Agriculture. However, for anti-GM lobbyists, such as BeyondGM, the UK's PBA is merely a route to allow hidden GMOs into the food system and ran contrary to the EU more precautionary position (BeyondGM, 2025) . However, with the provisional agreement reached by the EU on NGTs at the end of 2025, anti-GM lobbyists' concern now extends to Europe.

For anti-GM lobbyists within civil society, the resistance to plant synthetic biology or similar biotechnologies is centred on the fact that the new regulations implemented in England (and being proposed in the EU) are that they are removing "new" GMOs from existing regulations that they see having protected food systems in Europe from the inclusion of GMOs over the last 25 to 30 years. They state that GMOs have failed in countries where they have been allowed (USA and Brazil) and have led to lower food and environmental standards and negative impacts on farmers (Soil Association, undated). Additionally, they argue that the new regulations do not account for systemic usage of pesticides, or biodiversity loss and fail to acknowledge concerns over soil health (BeyondGM, 2025; Soil Association, undated).

Analysis of global trends in the commercialisation of GM crops shows that adoption rates are above 90% in Central and South America, North America and the Asia-Pacific region for a variety of crops across these regions such as corn, soybean, canola and cotton with insect and/or herbicide resistance (Cheng et al, 2024). For example, successful control of disease in papaya crops in Hawaii during the 1990s (Gonsalves, 1998), increased yields in Bt-eggplant crops in Bangladesh (Rashid et al, 2018) and increased profits and reduced or diversified pesticide use in the US to overcome glyphosate resistance (Fernandez-Cornejo et al 2014).

There are also misperceptions among policymakers and scientists about the public. Previous studies have shown that discussions of the public often identified them as uninterested or unaffected, and instead "*as a homogenous mass that passively accepts or rejects a technology, and rejection was assumed to be based on irrational fears*" (emphasis added, Marris & Calvert, 2019). This sentiment situates publics within a 'deficit model' of understanding, which leads to opposition of scientific innovation, as was experienced during the GMO debates of the late 1990s to early 2000s (Macnaghten & Habets, 2026; Marris & Calvert, 2020).

Public engagement activities over the last decade and a half have shown that public views on engineering (synthetic) biology are broadly similar to those on GMOs. However, the 2023 Sciencewise report notes this association depends on the context and application (Sciencewise 2023). Publics' perceptions of synthetic biology were more positive when addressing a specific problem, such as medical or environmental applications, but less so when applied to food. Negative perceptions related to food come from publics' concern about unnaturalness and scientists "creating life" and "playing God" (Sciencewise, 2023). These concerns were successfully leveraged during the GMO debates 30 years ago by anti-GM campaigners and activists.

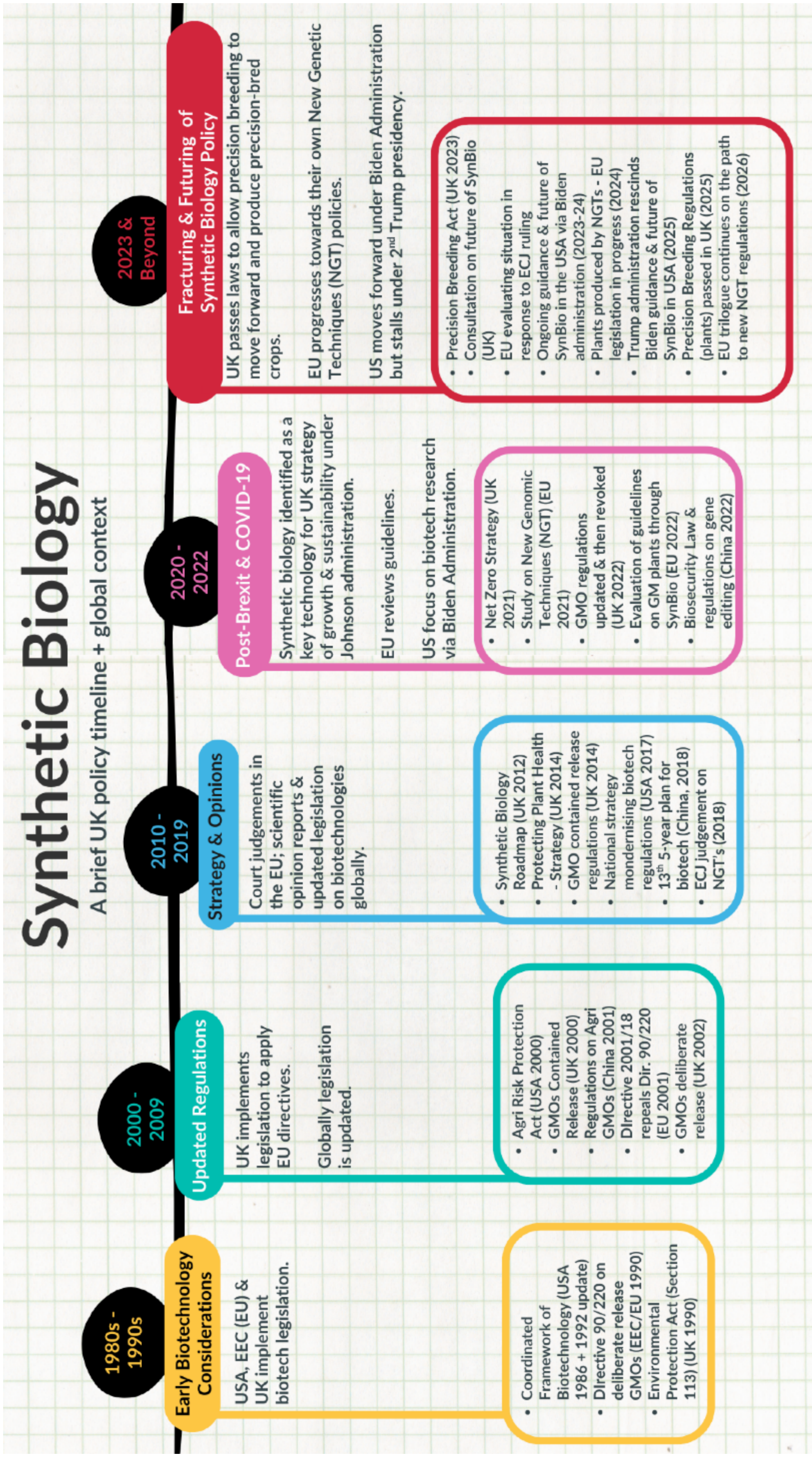

Figure 2: Policy development of Plant Synthetic Biology

However, we invite readers to move back and forth across these trajectories, attending equally to the scientific developments—particularly those shifts that underpin evolving assessments of risk and benefit—and to the human dimensions that shape their reception. This includes inherited social sentiments, as well as the mistrusts, misunderstandings, and norms arising from earlier scientific breakthroughs, all of which contemporary policy and socio-ethical discussions must engage with. A further, humbling reflection is to recognise the legacies current decisions may leave, and the responsibility to ensure they are constructive.

Stakeholders

A logical starting point for understanding a field is to ask who the relevant actors are. However, as with other emerging areas in the life sciences, providing a conclusive and fully inclusive answer is likely impossible. Plant synthetic biology is rapidly developing, and the scope of its impacts, and therefore its stakeholders, continues to expand even as we write. This does not preclude offering a provisional sketch that highlights actors particularly pertinent to this phase of development.

We note this open-endedness to invite reader feedback and to support ongoing refinement of the Relational Map. It also reflects the need for a degree of selectivity in order to maintain clarity and usability. Rather than presenting all stakeholders within a single undifferentiated map, we organise them into six broad groups: policymakers, industry/business, academia, publics, civil society and funders. These categories are further differentiated into sub-groups, showing the diversity of roles and relationships within each.

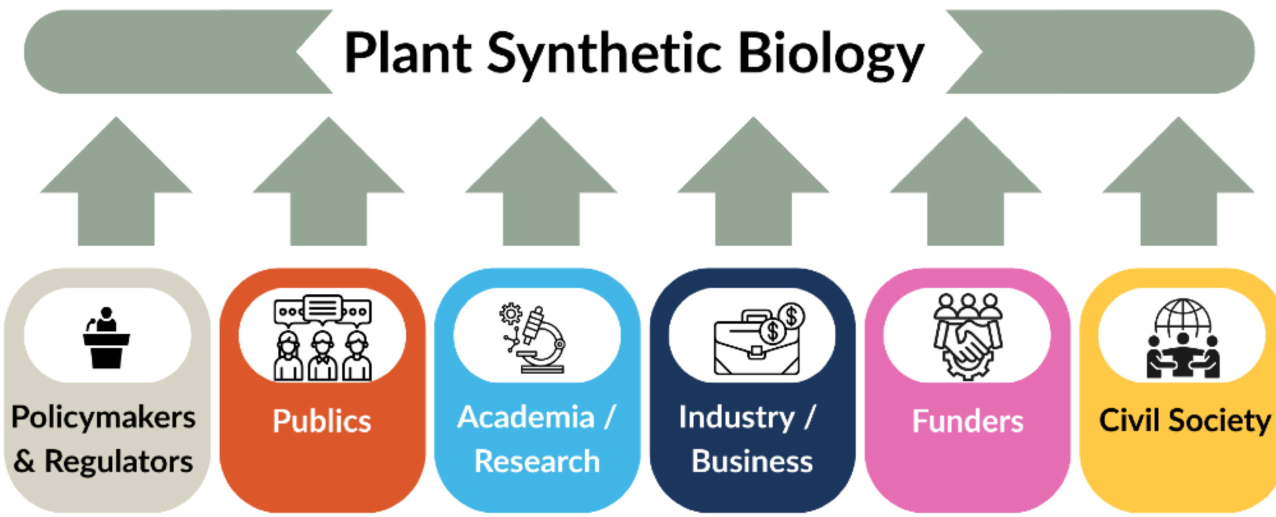

Figure 3: Six Stakeholder Group

Figure 3, above, shows the six stakeholder groups and the arrows pointing upwards indicate that each group has an influence on the development of plant synthetic biology. Figures 4 to 9 show these stakeholder groups with further detail and the subgroups that constitute them. Finally at the end of this section, Figure 10 visually represents connections between the six stakeholder groups.

Subgroups were selected based on their presence within literature (peer-reviewed or grey) and the research expertise of the authors and members of the Futuring Biological Commons project. Civil Society groups were categorised mostly by their position on biotechnology.

Policymakers & Regulators

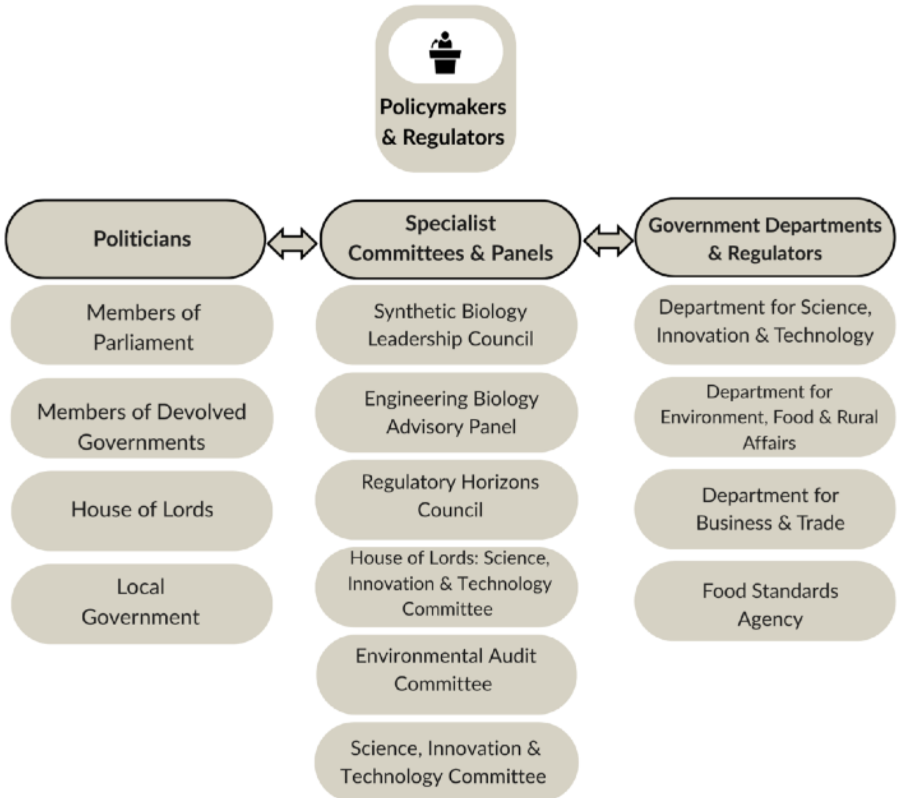

Figure 4: Key actors in Policymakers & Regulators stakeholder group

Key takeaways:

- **Central actors in policymaking, regulation and funding of plant synthetic biology.**
- **Must navigate lack of consensus within and external to themselves via multi-layered interactions.**
- **Engagement with other stakeholders can be limited, transactional and top-down.**

The government is the gatekeepers of the stakeholder landscape related to plant synthetic biology, as policymaker and regulator, the source of the majority of public funding and by incentivising private funding. Policymakers, whether they are ministers, MPs, Lords, devolved parliament or assembly members, local government officials or similar decide how policy will be debated, written and passed. Connected to these actors are special advisors and civil servants acting on their behalf.

While all stakeholders may wish to influence or have the ear of government there is not a level playing field for access and thus relationality. For example, the Food Foundation in its 2025 'State of the Nation Food Industry Report' found that representatives of industry were ten times more likely to meet with government than representatives of non-governmental organisations (civil society) were. They also note that the government department DEFRA held three quarters of their external meetings with trade associations. However, the actors do have differences in remit and numbers of stakeholders competing for policymaker time and attention. There are many more industries, businesses, academic institutions and trade associations compared to civil society groups – particularly the anti-GM lobbyists. Additionally, anti-GM lobbyists generally have single-issue objectives, whereas organisations such as the NFU or agri-chemical companies will have far larger number of reasons for engaging with policymakers.

Additionally, there is competing and potentially conflicting relations between policymakers of the UK national government and those of the devolved administrations. In respect to plant synthetic biology this is further complicated by the UK Internal Markets Act (2020) which allows that anything made in one place in the UK must be allowed to be sold in another, i.e., the devolved nations. Coalitions between the House of Parliament and the House of Lords, between the civil service and between the government, opposition and minority parties are porous. For example, to ensure the passing of the PBA, the language used was constructed to appeal to policymakers irrespective of party-political affiliation – this was particularly key when the bill went to the House of Lords. Furthermore, it was constructed to future-proof the legislation should scientific or technological techniques develop further and to provide a comparison to the imprecise nature of conventional breeding.

Policymaker and regulator relationalities with other stakeholders outside of Westminster are less clear but some evidence points to the 'thickness' of these relationships, shaped by factors such as historical connectedness, resources, epistemic proximity, and perceived authority or influence. Transparency International UK's open access database of government meetings (https://openaccess.transparency.org.uk/) highlights that for topics such as gene editing, precision breeding, genetically modification or synthetic biology, the majority of meetings were held with industry or business (Bayer, BASF, UK Syngenta) or academic or research institutes such as the John Innes Centre or Rothamsted Research (an issue highlighted by anti-GM lobbyists such as Beyond GM). In a few examples, large multi-stakeholder meetings were attended by a broad range of civil society groups, including the NFU, the Soil Association and BeyondGM.

Whilst civil society broadly has access to policymakers, the nature of this access differs from that of industry and business or academia. As noted above, the base for relationality between policymakers and those in industry and business or academia/research is likely to be much broader than that of single-issue groups that make up the majority of anti-GM lobbyists. Furthermore, many lobbyists do not speak for the majority: for example, in 2009 the organic bodies such as the Soil Association represented 4% of UK agriculture as an industry and by 2024 this had reduced to 3% (House of Lords Science and Technology Committee, 2009; DEFRA, Organic Farming Statistics 2024). Different civil society members have differing levels of access. NFU, for example, is more likely to have access to policymakers than GM Watch. Established large civil society groups, industry and business all seem to also have more access to individual or small group meetings with policymakers.

The relationality between policymakers and publics appears to be more transactional and in one direction. Examples of this are the relationship situated within annual or regular public perception or attitude surveys, such as the Public Attitudes to Science survey, normally commissioned by DSIT or through regulators' reports on consumer attitudes to emerging technologies, such as the 2020 reports from the Food Standards Agency. Other organisations, such as UKRI-funded Sciencewise, have also produced reports on public perceptions on engineering biology and its applications. The relationality between various policymaking mechanisms is something that would require further research. For example, it could consider the engagement and consultation between the national government and the devolved governments, which for the PBA has been noted by Mairi McAllan, MSP, in her letter to the UK government on the devolved governments' disappointment with the lack of consultation (Genetic editing in agriculture statement, Lesley Griffiths MS, 2021; Letter to UK Government, from Mairi McAllan MSP, 2022).

Publics

Figure 5: Key actors in Publics stakeholder group

Key takeaways:

- **The 'public' is not static or monolithic. Various publics play critical and differentiated roles in the translation of science into socio-ecological wellbeing.**
- **The legacy of GM-debates remains influential in publics' perceptions and imaginaries of plant synthetic biology.**
- **Collaborative engagement with publics is required from all stakeholders.**

A primary issue with publics is not just who they are, but to recognise the heterogeneity among and within them, so as to understand how to engage with them. Historically public engagement in relation to innovative science and technology has suffered from an embedded culture that the public just requires 'educating' (Macnaghten & Habet, in-press). This 'deficit model' rests on the idea that, if publics are educated, they will learn to embrace innovative science and technology in the same way as those scientists and policymakers who view it as beneficial do. The deficit model persists despite having been identified as problematic for decades by social scientists and science communicators alike. Macnaghten and Habet highlight this through the work of Brianne Suldovsky (2016) who notes that, as long as science is viewed as producing knowledge outside of society, the deficit model will persist. Arguably the anti-GM lobby also views the public through a similar deficit model lens, but with hopes for different outcomes.

If policymakers and regulators are the gatekeepers of plant synthetic biology activity in the UK, then publics are the heart and minds to win for all other stakeholders. As represented in Figure 10, all stakeholders hold a direct relationality with publics. For example, policymakers, industry/business and natural science academics/researchers desire to avoid publics' resistance to ensure adoption of plant synthetic biology, enabling successful commercialisation. Conversely anti-GM lobbyists within civil society want to recruit publics to their mission and objectives to take a different path, such as increasing support for organic or regenerative agriculture. Likewise, funders and social science academics/ researchers wish to engage with publics to understand their unique perspectives on technological or scientific innovation that will impact them. However, what or who publics remains a moving debate.

Many claim to speak (selectively) on behalf of the public, this is particularly present within civil society groups, especially those in the anti-GM lobby.

While public perception and social acceptance of innovative science and technology are gauged through mechanisms such as the Public Attitudes to Science surveys (DSIT, Public Attitudes to Science, 2000, 2005, 2008, 2011, 2014, 2019, 2025) – these quantitative representative samples of public opinion require deeper investigation and engagement such as through qualitative social science research. Furthermore, stakeholders like academia and industry/business should (and in some cases do) pursue communication and engagement training to engage other stakeholders (civil society, publics) with their innovations through public engagement and consultations to strengthen the connections and relationality between science and society.

The category of publics is by its nature ambiguous and context dependent. Figure 5 suggests three broad groupings which also reflect possible touchpoints where individuals may come into contact with information about or express a view on plant synthetic biology. Issue-specific publics may potentially have an interest in topics that plant synthetic biology intersects with areas such as environment, biodiversity or agriculture. Community groups, whether defined geographically or by shared demographic characteristic, are likely to become more pertinent to plant synthetic biology if and when lab-based research moves to field experiments or commercial growing.

Academia/Research

Figure 6: Key actors in Academia/Research stakeholder group

Key takeaways:

- **Intrinsically linked to funding opportunities and government priorities.**
- **Renewed attention to social science research in this area.**
- **Commercialisation of research increasingly desired.**

Plant synthetic biology is carried out across multiple institutions and disciplines, and often involves collaborations between academic, commercial and farming sectors. Notable research hubs on agri-tech, agricultural science, plant science include the National Institute of Agricultural Botany (NIAB), the Norwich Research Park (which includes the John Innes Centre, the Sainsbury Laboratory, Quadram Institute and other companies using synthetic biology) and Rothamsted Research proactively undertake research on biotechnologies and plant synthetic biology. Many of these research hubs have long connected histories with government and agricultural science and most are still government funded via the UKRI research council BBSRC. Higher education institutes, such as Imperial College, University College London, the University of Edinburgh, University of York, University of Oxford, University of Cambridge, University of Exeter and the University of Kent (to name a few) are involved in both the plant sciences and in some cases, particularly with Edinburgh, Exeter, and Kent, also the social scientific study of synthetic biology. All hold relationships with funders and in some cases senior academics also sit on councils and panels set up by government or funders. In the age of policymakers and funders pushing for commercialisation of research and a view of biotechnologies as a driver to grow the economy, research hubs have begun to be spin-out companies from academic research with the aim of commercialisation of their products. For example, The Sainsbury Laboratory, a research institute, launched TSL Ventures in 2024 to commercialise laboratory innovations, aiming to bridge the gap between research and market applications.

Social scientists within academic and research institutes have been involved in public engagement and on the topic of Responsible Research and Innovation initiatives since their inception as a core objective of EU research policy. This long involvement with public engagement is illustrated by the work of social science academics and their inclusion on the Synthetic Biology Roadmap for the UK. While funding for social science in this area has declined over the past decade, the UK's renewed investment in synthetic biology has brought some renewed attention to it. In addition to the ARIA-funded Synthetic Plants programme's social science stream, under which this project is funded, the BBSRC's six Engineering Biology Mission Hubs launched in February 2024 also incorporated some social science research. More recently, the UK's Department for Science, Innovation and Technology (DSIT) and Sciencewise launched a nationwide public dialogue on engineering biology in 2026 to explore public views, hopes, and concerns regarding the technology in 2026 [Sciencewise, 2026].

Research communities build relations with other stakeholders either through individual activities, such as serving on councils, committees, panels in funding, policy or civic organisations, or through institutional research hubs or networks such as SynbiCITE or OpenPlant.

Agricultural science research hubs such as the John Innes Centre and Rothamsted Research are known to actively engage with immediate stakeholders, policymakers, funders and with farmers. There are also several rural research centres across the UK involved in the social elements and technological uptake within agriculture and broader food systems. Examples of this include the Centre for Rural Policy Research at the University of Exeter, the Countryside and Community Research Institute at Gloucester and the Centre for Rural Economy at Newcastle.

There is also a recent growing trend to increase farmer involvement in academic (and commercial) research. Networks such as BOFIN which was recently awarded £1.8m for precision breeding oilseed rape (DEFRA blog, 2026), actively engage with farmers and researchers to bring agricultural science to the field and to involve farmers at an early stage.

In February 2026, UK Research and Innovation (UKRI) has started a significant restructuring of its funding, with a deliberate shift towards applied, outcome-focused research to meet government strategic priorities, with a particular emphasis on business-focused funding (Williams, 2026). How this will shape plant synthetic biology research remains to be seen.

Industry/Business

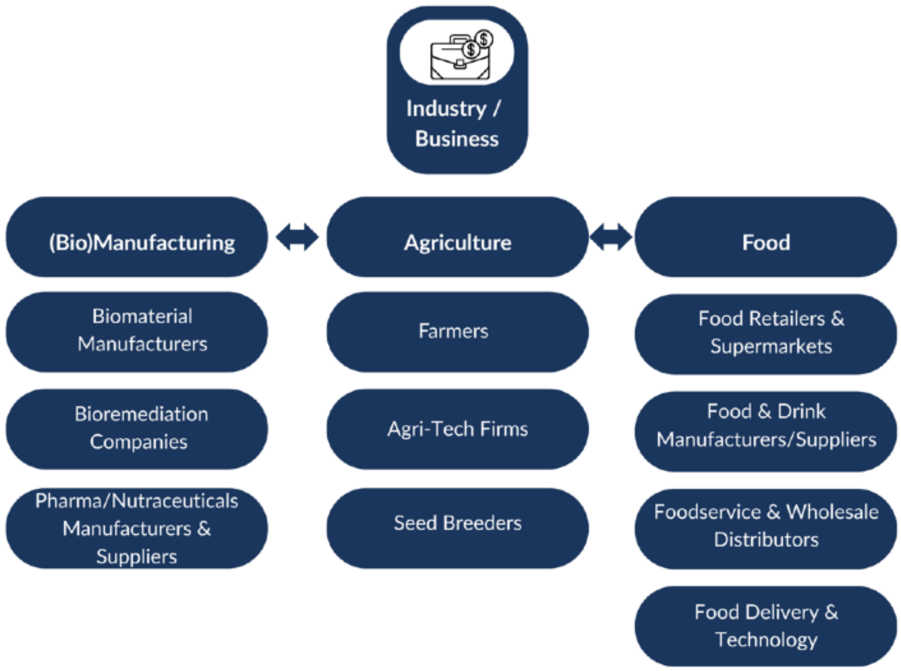

Figure 7: Key actors in Industry/Business stakeholder group

Key takeaways:

- **Shift in turning research into marketable products through spin-out companies and partnerships.**
- **Relationships with other stakeholders are often complex and shaped by historic controversies.**
- **Trust, communication are coordination with other stakeholders are important future challenges.**

The relationality of industry/business with other stakeholders is increasing, as in the case of TSL Ventures launched in 2024 as a spin-out venture from the Sainsbury's Laboratory. In their 5-year restructure plan, Rothamsted Research announced it intended to 'enhance the translational impact of its science' (Rothamsted, 20205). Here 'translational' can be read as commercialisation or bringing products to the market, as evidenced by the creation of the spin-out company, SugarROx, a company focused on crop biostimulants and the licensing of their omega-3 products in Camelina to US-based company Yield10 Bioscience Inc (Rothamsted, June 2024). Likewise, Norfolk Plant Sciences, a spin-out by TSL and John Innes Centre have developed blight resistant potatoes and anthocyanin (antioxidants) enriched tomatoes (purple tomatoes) now commercialised in many parts of the world, including the USA, Canada, Australia and Chinese researchers developing purple tomatoes (Martin & Butelli, 2025; Spencer, *The Times,* 2026; Stock, 2026; Liu, CAS, 2019).

Industry/business holds longstanding relationships with funders, policymakers, and academia/research. Many corporate stakeholders hold complex and complicated relationships with civil society and the wider public. Whilst many have corporate social responsibility (CSR) policies, direct public engagement is rare or facilitated through PR and communication teams. For example, Bayer, which acquired Monsanto (a controversial company with a significant plant biotechnology history) has faced significant criticism by activist groups for the product RoundUp – a widely-used glyphosate herbicide and a significant topic in the organic and regenerative farming sector. For example, John Cherry, the founder of Groundswell – the holy ground of regenerative farming in the UK – recently spoke pragmatically of glyphosate use to combat weed issues in regenerative farming systems (Rootstock, 2026). The use of glyphosate and the controversies surrounding the success or not of GM-crops and the actions of agricultural biotechnology companies like Monsanto and Bayer (and others such as Syngenta, Du Pont and BASF) is a broad and nuanced area which this report does not have space to deeply cover or give justice to. However, it is important to note that civic action opposing corporate approaches to agricultural biotechnologies continues to impact the relationships between industry/business and other stakeholders, such as publics, civil society and policymakers.

While the relative distance between industry and the wider public may not be surprising, and may even been considered as 'prudent' or 'sensible' for some, focus group research conducted along east coast England by the Futuring Biological Commons project, has revealed that public stakeholders also wish to know (and are open to trusting) the voices of independent researchers from academia as well as those who 'are paid to do this for a living'. Such researchers may fit with companies like SugaROx, Phytoform or BioPotatoes, whose innovative profiles may carry fewer reputational burdens than more established commercial monopolies. However, effective engagement still requires researchers to develop appropriate communication skills and training.

What is apparent as the UK moves towards more activity following the PBA and synthetic biology at large, is that there are desires and needs from policymakers, academia and industry to be more joined up in their approach to maximise opportunities, and crucially, realise the potential positive economic outcomes for all.

Funders

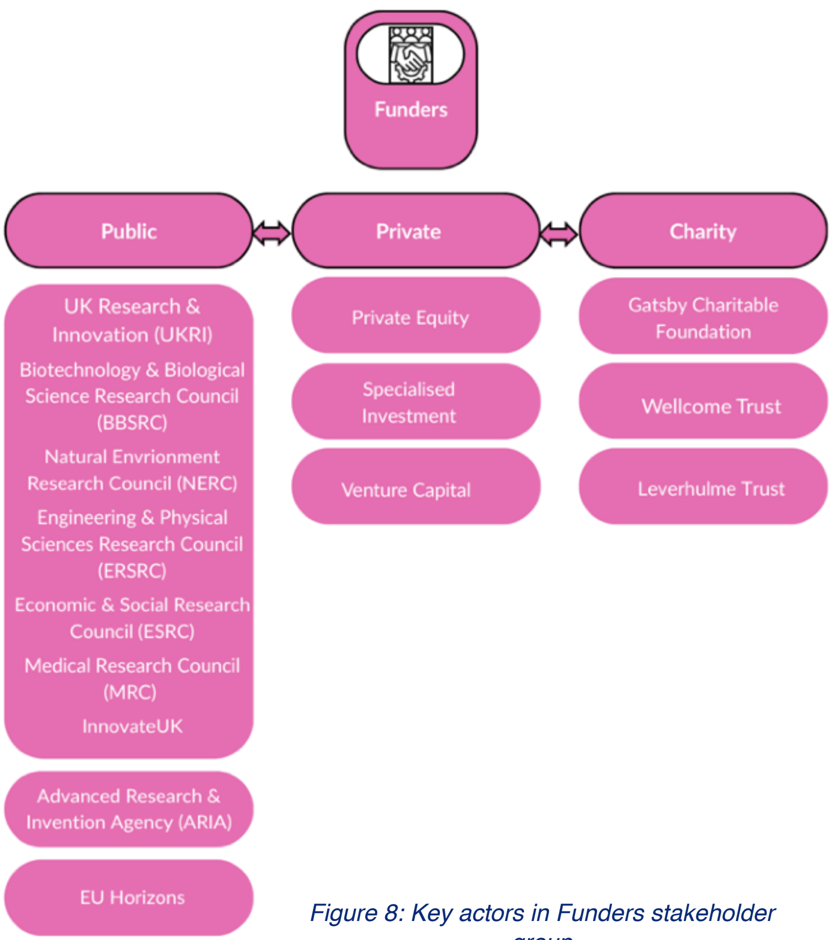

Figure 8: Key actors in Funders stakeholder group

Key takeaways:

- **Funding is diverse, interconnected but heavily shaped by government strategic priorities.**
- **Gap remains between early-stage funding and next stage funding to translate research into market-ready products.**
- **Public perception/acceptance is important to funding structures.**

The landscape of (existing and potential) funding for plant synthetic biology is complex and interrelated as shown on Figure 8. The greatest funding for plant synthetic biology has so far come from governmental funding agencies. UKRI, especially via BBSRC, is a large funder of synthetic (engineering) biology research, releasing position statements on new genetic techniques for genetic crop research in 2014 and on GM research in crops and other plants in 2018. UKRI additionally released a position statement on genome editing techniques for clinical purposes (i.e., continued use of CRISPR-Cas9) in 2015, supported by other funders, both public and philanthropic/charitable, such as the MRC and the Wellcome Trust. Most funders have called for widespread dialogue with ethicists, social scientists, experts and wider publics on these emerging technologies. Public perception and acceptance surveys have been regularly conducted by or on behalf of funders on public involvement/relationship with science since 2000 (PAS surveys, 2000, 2005, 2008, 2011, 2014, 2019, 2025) and frequently in the last decade, surveys on synthetic biology and its applications across health, medicine, and in food/agriculture have been frequently conducted (DEFRA, 2021; FSA, 2020, 2021; Sciencewise 2023, 2024). They continue to feature as part of funder commitments, such as through the Public Acceptance of Science survey undertaken by Sciencewise and more recently by UKRI and the British Science Association. Social scientists are not always, but sometimes included in synthetic biology funding programmes, for example, ARIA's Synthetic Plants programme has a dedicated social science stream, and EPSRC has funded CARMA: Cellular Agriculture Manufacturing Hub, which brings together social scientists, bioengineers and chemical engineers to research on lab grown meat (carmahub.co.uk).

In the last decade, a push to increase public return on funding (Cook et al, 2014) and to drive biotechnologies as a stimulant for the UK economy has resulted in the establishment of a new era of funding via ARIA - established in order to chart a course of high-risk research inspired by the model of the American funder, Defense Advanced Research Projects Agency (DARPA).

Funders within the charitable/philanthropic space are less focused on plant synthetic biology, however, organisations such as the Wellcome Trust and the Gatsby Charitable Foundation are either funding plant synthetic biology projects or are positive towards the use of synthetic/engineering biology more broadly and its application in food and/or agriculture. The Royal Society could also be included in this category of stakeholder, providing smaller research grants, although their remit is broad, including producing policy briefings.

Outside of traditional research funding, public funds and charitable organisations, synthetic biology is and has been attracting significant sums in the UK, including £1.1 billion in equity funding between 2005 and 2018 (Philippidis, 2023). However, compared to funding available in the US, where private funding is believed to reach around $40 billion dollars, with some companies raising upwards of $500 million alone, some like Prof. Paul Freemont, believes that the UK '*should be doing better*' (Philippidis, 2023). Lord Willetts is an example of an individual moving between policymaking and industry/business and funding – now chairing the venture capital fund SynBioVen which has around a £20 million fund. SynBioVen itself is led by a board who are also connected to SynBiCite, the UK's national centre for commercialisation of engineering biology based at Imperial College London with a network of partners from academia and industry. SynBiCite itself was originally funded by BBSRC, EPSRC and Innovate UK – all public funders. The blurred boundaries, connections and relations between funders are broad, reflecting the non-traditional funding model synthetic biology in the UK is moving towards.

The challenge for synthetic biology in the UK is that, while there has previously been strong funding for early-stage research, funding has been lacking in helping translate that research into products suitable for commercialisation. While further research would be needed to draw conclusions, it is likely that leaving the EU and the liberalisation of UK policy towards biotechnologies has and will continue to encourage synthetic biology privately. This is likely to continue to enhance research and commercialisation of plant synthetic biology. One example of this is the Farming Futures R&D Fund: Precision Breeding, which has recently announced funding of £21.5 million to 15 projects across England via DEFRA's Farming Innovation Programme (DEFRA, 2026). Some of the grantees are private companies or networks connected with and supported by academic (higher education and research) institutions, such as BOFIN Farmers Ltd. and a project on light leaf spot resistance in oilseed rape, a British Sugar Plc project on gene editing solutions against Virus Yellows and Precision-Bred Hemp led by Precision Plants Ltd to expand sustainable food, fibre, and biomaterials opportunities and reduce import dependence through gene-editing (DEFRA, 2026).

Civil Society

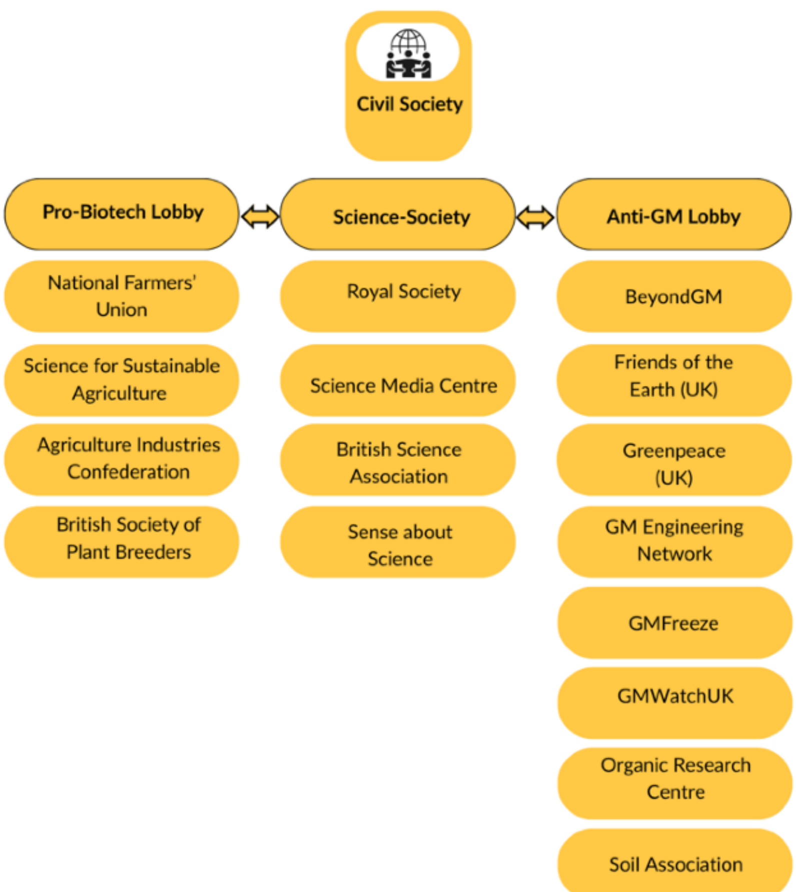

Figure 9: Key actors in Civil Society stakeholder group

Key takeaways:

- **Most diverse and divided stakeholder group.**
- **Different approaches to influencing public discourse, from building trust in science to advocating for precaution.**
- **Polarising history connected to GM.**

Civil Society stakeholders are a broad spectrum of different organisations from trade associations, membership organisations and campaign groups to activist and lobbyist groups. Their position on plant synthetic biology is largely down to the context of their purpose and members. For example, Science-Society Groups, such as Sense about Science, do not have a formal position on plant synthetic biology, but their inclusion is relevant due to their role in encouraging evidenced-based reasoning, transparency and public engagement with innovative science and research connected to policy. Similar organisations would be the Science

Media Centre, established in 2002 with a mission to provide evidence-based information about science and engineering for the public and policymakers, and the British Science Association, established in 1831, to bring people and science together. The Royal Society has also been included as a science-society group for the purposes of this map.

Science for Sustainable Agriculture (SSA) has long argued for the use of biotechnology in agriculture, and the National Farmers Union (NFU), a lobbying group for farmers, has taken a public stance of supporting plant synthetic biology and has welcomed the moves by the UK government to change regulations and policy. Along with the Agricultural Industries Confederation and British Society of Plant Breeders these groups have been classed as pro-biotechnology groups.

However other groups, like the Soil Association, GM Freeze and BeyondGM, hold a more critical position on plant synthetic biology and have a varied relationships with other stakeholders. BeyondGM, for example, has initiated multiple campaigns over the last 10 years - of particular note is ‘A Bigger Conversation’, a platform of ongoing meetings, panel discussions and debates. While these have engaged a broad spectrum of stakeholders, from civil society, industry, business (farmers) and academia, there is a gap in those not obviously involved - policymakers, and funders [REF?]. Furthermore, BeyondGM may run public-facing engagement, film previews and social media campaigns, these have been largely ignored by the mainstream media, compared to the large-scale coverage of the 1990s/early 2000s, and two-way dialogue engagement with the public appears to have been lacking. Certainly, interest in direct action against biotechnologies related to plants and food seems to have dissipated within the UK, with the last attempt at crop-trashing by activist groups against GM or genetically edited crops happening in 2015. This is perhaps a result of greater security and police control, but may also be a reduced interest amongst the British public (Malik, 2012; Mahony & Pallett, 2013).

The organic/regenerative farming movement may also be less concerned by developments in biotechnologies as their focus shifts to issues over glyphosate usage and soil health currently listed as plenaries as seen in the planning of the 2026 Oxford Real Farming Conference, whereas discussions on gene editing and GM products only happened in a panel discussion and not as a plenary. There are also deep associations and relationships between the anti-GM lobby and organic farming lobbyists, especially the Soil Association and the Organic Research Centre.

An additional change to the UK’s activist civil society landscape is the declining role of organisations such as international campaign groups, Friends of the Earth and Greenpeace. These organisations had played pivotal roles in the resistance to GMOs during the 1990s and 2000s (O’Brien, 2021). Friends of the Earth UK also produced no coverage of synthetic biology developments during the development of the Precision Breeding Act framework, and a refocus of resources within Greenpeace UK meant their campaigning against GMOs was focused elsewhere internationally. At an international level, both organisations continued to campaign against synthetic biology and GMOs, but little evidence exists that UK branches are engaged to date in any active campaigns or have paid any attention to UK developments in plant synthetic biology.

Stakeholder Influencers

It is worth noting a few key actors who can influence the stakeholders we have outlined above. These actors are not always necessarily stakeholders with immediate relevance to UK synthetic biology but do have the potential to shape the beliefs held by direct stakeholders. Influential public figures who make claims about the rights and wrongs of agriculture are one such group of actors. For example, George Monbiot, a journalist once critical of genetic technologies has recently embraced precision-fermentation and gene-editing technologies of microbes, whereas King Charles III was a fierce critic of biotechnology in agriculture before ascending to the throne (Monbiot, 2022; Holmes, 2022). Other such influential actors are global governance bodies like the International Union for Conservation of Nature (IUCN) which recently announced their support the use of gene-editing technologies in protecting nature. Public Relations and Communication teams from business and research institutions may also be influential, seeking to shape stakeholder perspectives through campaign materials. One prominent example of this is the Public Affairs Group for the Norwich Research Park, a group active in the lobbying of Parliament in support of the precision-breeding legislation.

Plant Synthetic Biology: Visualised connections

Figure 10 highlights the broad connections between the stakeholder groups that have been discussed above. The aim of the graphic is to visually represent relationships between the six – however, a connection does not always mean these relationships are positive. Three of the six (Policymakers & Regulators, Industry/Business, and Academia/Research) hold connections with all others. Publics shows how connectivity with this group is wanted by all but is largely only returned to three and this is context dependent. The nuances and complexities of stakeholder relationships are not represented in this graphic. For example, the inequalities, power imbalances and differing way each stakeholder is valued by others. These nuances are not represented because largely they come from the subgroups of stakeholders and any visual representation would complicate the broader overview and require further empirical research. However, we hope readers see this limitation as an invitation. We would very much welcome feedback and guidance towards relevant evidence to support a more substantiated and accurate portrayal of these connections in the second edition of the map in 2027, particularly in terms of their intensity, breadth, stability, and adaptability.

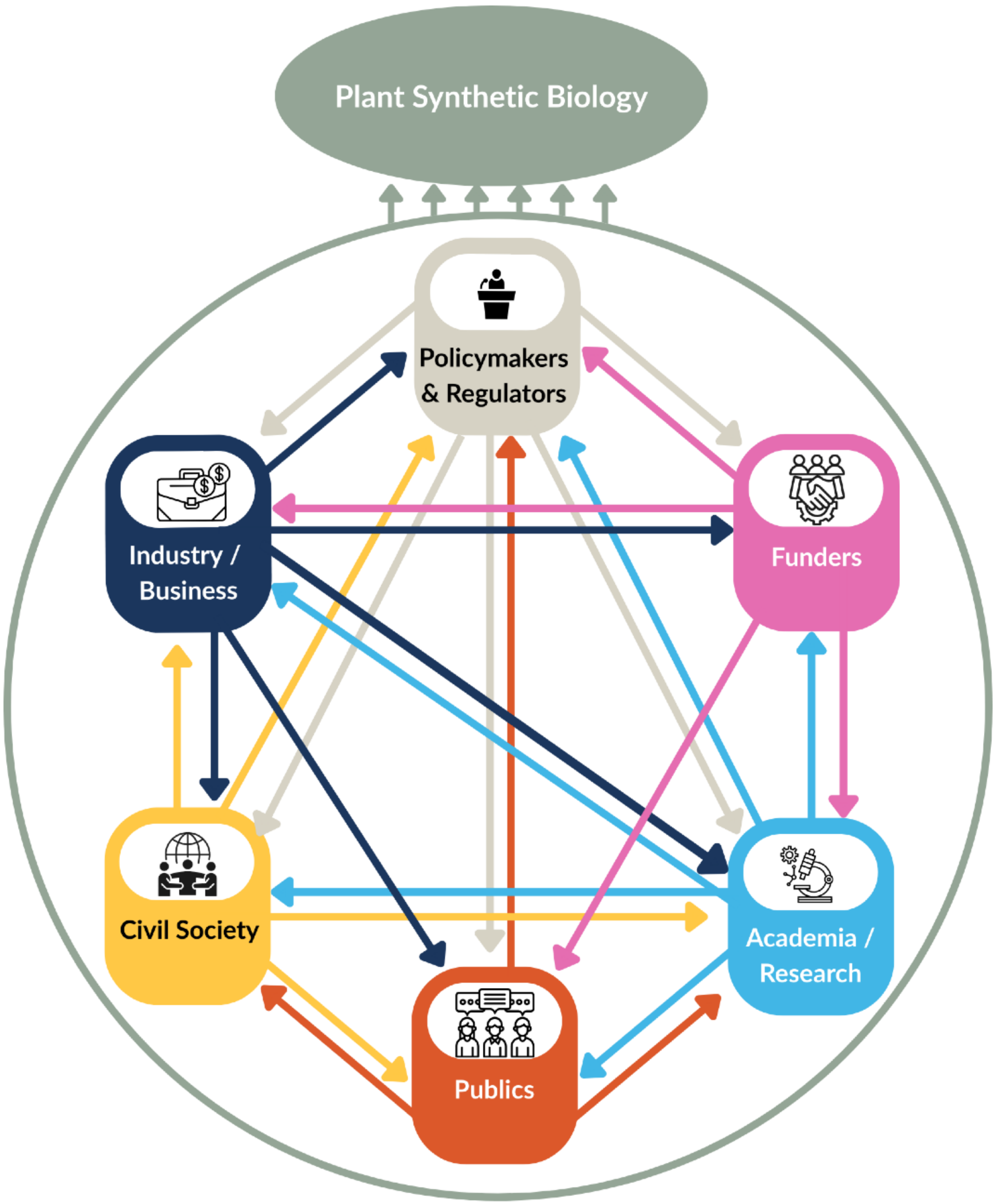

Figure 10: Stakeholder groups relationality and connections

Concerns

The Concerns map highlights broad areas of unease related to plant synthetic biology and stakeholders who hold them. This is not an exhaustive list but focuses on concerns that have been identified in academic and grey literature, policy or position statements of the various stakeholders, engagement surveys and reflected in preliminary research conducted by this project.

What do we mean by concern? It is a worry, an anxiety, an unknown, a perceived or actual opposition. In some contexts, we can view a concern as a call-to-arms, a worry or anxiety so strong that it causes stakeholders to move to action. The cause of concerns could be an absence of knowledge, a loss or lack of confidence in individuals or in institutions (Peyrefitte cited in Bauman, 2000). Sociologist Zygmunt Bauman cites a cause of acute anxiety in society as the unholy trinity of uncertainty, insecurity and unsafety (Bauman, 1999). We have included topics that speak to these issues of loss of confidence, and Bauman's unholy trinity which generates the concern, such as moral and ethical issues, or human health and environmental impact.

The concerns are grouped into six broad areas: moral and ethical, human health, environmental impact, commercialisation, scientific progress, and (de)regulation. Branching off from these broad areas are examples of these concerns which have been found within the literature and/or ongoing research for the Futuring Biological Commons project. Some concerns, for example dual use (technology intended for beneficial purposes but which can be used for harm) have not been included. Many of the concerns are shared, to various extents, by different stakeholders, albeit with different context and objectives related to them. The purpose of the map is to identify key concerns of those stakeholders to show their relationality through the markers applied.

The concerns cover areas that intersect and impact upon each other. Environmental impacts, for example, have the potential to affect commercialisation and human health. Should plant synthetic biology innovations transfer from the laboratory to the field, they are likely to have a positive or negative impacts on the local environment whether they are successful or not. Such results will be key barometers for the potential of businesses to successfully commercialise their research and have the potential to provide a return for funders – a current concern for policymakers and funders. If failure occurs when synthetic plants are transferred to the field this may cause environmental damage. Although no significant environmental damage has been linked to the growing of GM crops and while "superweeds" have emerged with resistance to glyphosate, herbicide-tolerant weeds are common in conventional and regenerative agricultural systems. Furthermore, existing regulations, for example the PBA Regulations 2025 require environmental risk assessments related to the use of Precision Bred Organisms (PBO). Additionally, if policymakers overestimate its potential benefit and adjust food strategies on this potential benefit, the impact on human health could be significant. These may be hypotheticals, but they are concerning for some stakeholders and have related broader concerns that are well documented in policymaker reports (see: House of Lords Science and Technology Committee report 2025; Public perception and acceptance reports and consultations as listed in the references list). Some concerns are more pertinent and immediate, like those that anti-GM lobbyists have over the PBA regulations. The PBA passed in England in 2023 with regulations for plant PBOs passing in 2025. Anti-GM lobbyists see these legislative developments as a process of deregulation of GMO products although regulatory hurdles for PBO remain in place. By contrast, other civil society groups such as the NFU and Science for Sustainable Agriculture are concerned that, without introducing a distinction between PBOs and other GM products to encourage research and development, a new generation of crops will stall and the farming industry, food security and public health will suffer (NFU, 2023; SSA, 2025). Publics hold concerns broadly related to how scientific research and regulations are implemented, but this is dependent on who scientific researchers work for. The 2025 PAS survey showed that the majority of the public believed scientists would follow regulations, unless they worked for industry or business (PAS, 2025).

The Concern map thus provides a cartography of present and future concerns from a variety of stakeholders. Some concerns are shared by stakeholders with opposing views of plant synthetic biology, thus the concern is situated within the context and position of that stakeholder, as noted above in relation to regulations. The concerns cover moral and ethical issues; some relate to the economy and its impact on innovation and how technology can deliver economic growth. Others are related to more specific social worries around environmental impacts or human health and the potential of unintended consequences, traceability and accountability. The important element of this map is the interconnectedness and relationality between concerns and stakeholders. For example, one area not specifically highlighted but present against environmental impact and sustainability claims on the map, is that some stakeholders (funders, policymakers, industry/business), view plant synthetic biology as a route to sustainability and resilience in agriculture. Other stakeholders (civil society, particularly anti-GM lobbyists and organic farming groups like the Soil Association and ORC) view sustainability and resilience in agriculture coming from a more "natural" approach through organic farming and/or regenerative farming practices.

Mapping concerns in an emerging field can be overwhelming, as scientific novelty generates new questions while reactivating older ones. As illustrated in Figure 11, concerns about plant synthetic biology are not uniform but span multiple domains—ethical, environmental, economic, regulatory, and scientific—and often overlap across stakeholders with different motivations. However, as noted in the civil society section above, societal concerns are not static; they vary in intensity and shift in emphasis, form, and the ways they travel across perspectives and domains. The value of mapping concerns lies not only in capturing their contours at a given moment, but in tracing how they evolve over time through iterative analysis. For this reason, we conceive the Relational Map as an ongoing, iterative process, aimed at enabling the accumulation of knowledge across future editions of the report.

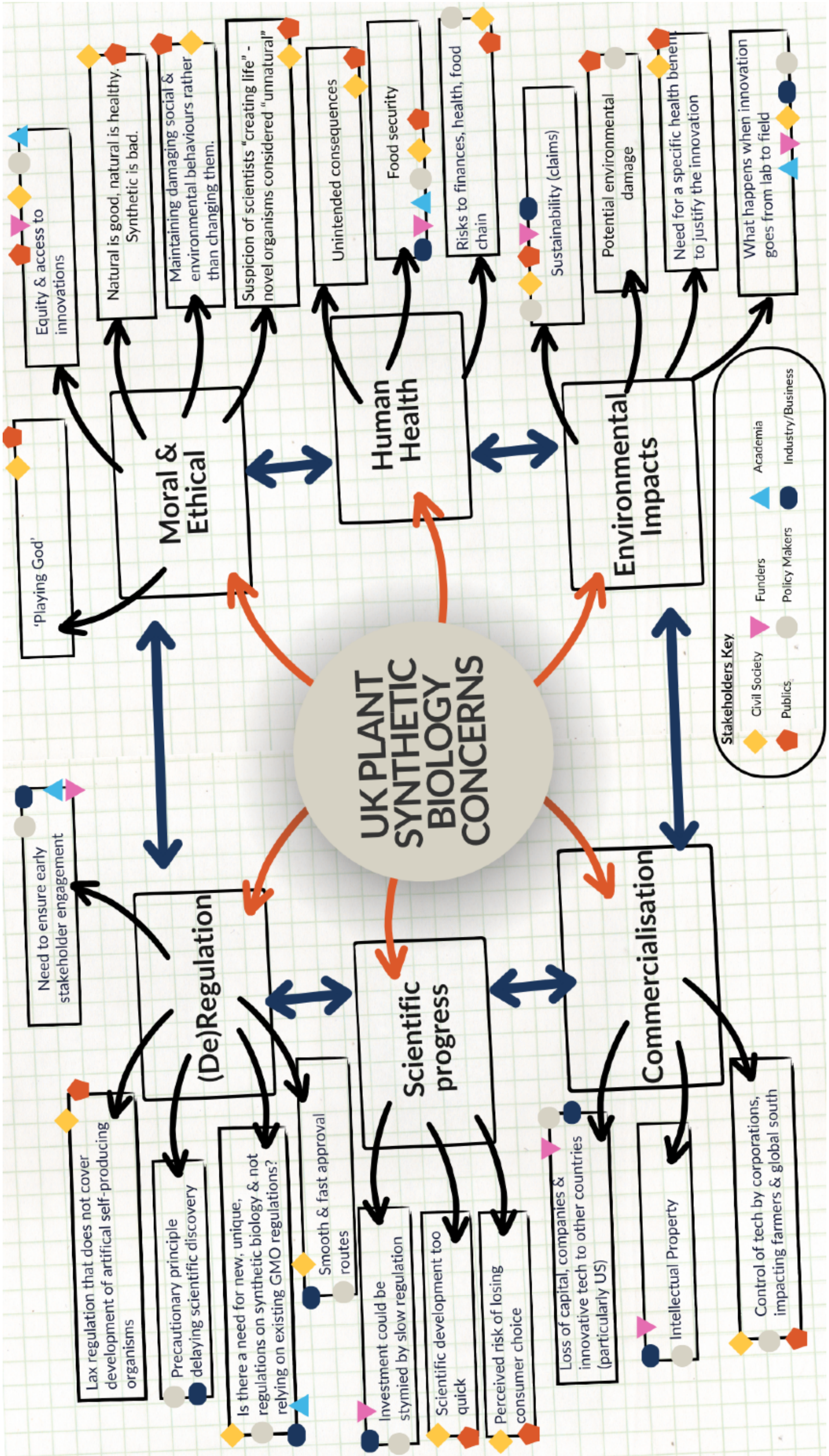

Figure 11: Concerns mind map

Resources

The Resources flowchart situates key resources—Funding & Infrastructure, Skills & Knowledge, and Responsible Research & Innovation—within their historical development, linking past approaches to current examples.

The examples presented identify stakeholders and concerns related to the high-level resource areas. Examples of this include infrastructure improvements required for plant synthetic biology, such as access to laboratories or equipment or the training and retaining of scientific talent, both of significance in an era of increased political and societal debate and restrictive policies on immigration.

The final section of the Resources flowchart provides specific concerns related to the high-level resources. Again, this is not an exhaustive list but an indication of the concerns that exist and whilst the Concern map treats these in isolation, the Resource map links concerns with the resources and also with the stakeholders.

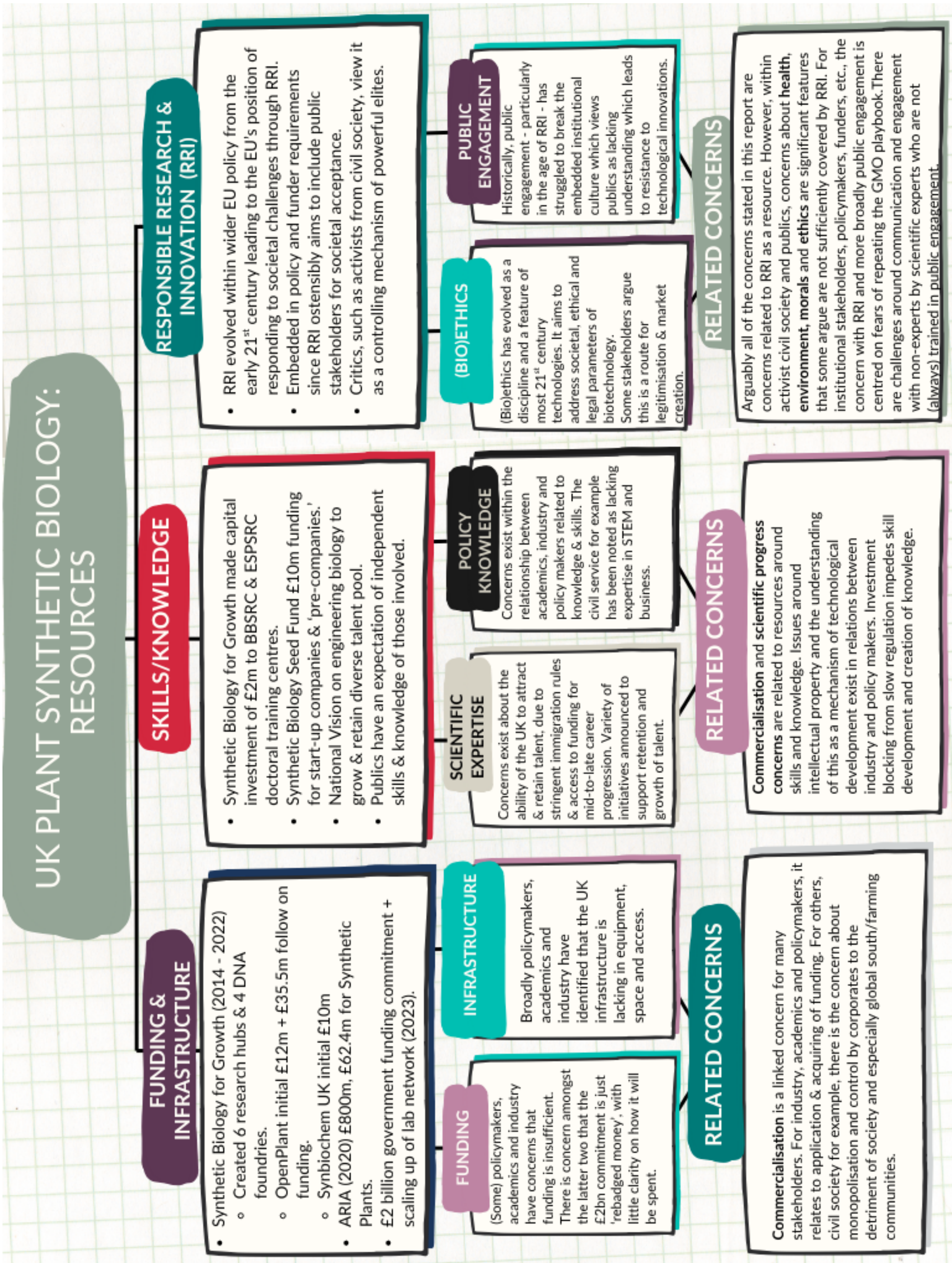

Figure 12: Resources flowchart

Questions & Invitations

A key objective of this report is to engage and consult with a variety of stakeholders and to bring those stakeholders together in an open, deliberative, and enabling discourse (McKenna et al, 2025). The report has illustrated the complexities of stakeholder relationality, connection, and commonality, elucidating on the diversity of plant synthetic biology against the historic binary of for or against of previous GMO debates. By doing so we have highlighted the need for careful, consciousness approaches to public and science engagement. Our recommendations would be for thus involved in the dialogue on plant synthetic biology to adapt engagement and messaging to specific stakeholders as well as ensuring these stakeholders are brought together.

Thus we hope this report is informative but also provocative. We invite critique, addition, inquiries, and support from all stakeholders interested in plant synthetic biology. In particular, we encourage everyone to join us in exploring the following questions:

1) How can we, as a society, reconcile the history of genetic modification of food crops with the present, and future of genetically edited plants to meet societal and planetary needs?
2) Who are the stakeholders yet to be recognised? (Who or what are absent from our maps?) Bear in mind that some may already be influential but are traditionally situated in different fields or play different roles.
3) What new social relations or alliances should be cultivated and supported, particularly in light of the UK's strategic priorities and the shift towards outcome-oriented research?
4) What new practices in public, science and policy engagement need to be developed to enable constructive and mutually enriching dialogue on our shared socio-ecological wellbeing?

In addition to the above questions, we have also highlighted our limitations and extended invitations for discussion throughout this report. Any thoughts or ideas would be greatly appreciated. If you would like to be involved in future research events run by the Futuring Biological Commons team, or hope to collaborate on events, please also feel to contact us.

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