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Who's talking about non-human Genome Editing? Mapping public discussion in the UK.

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Executive Summary

A cluster of new techniques to modify the genomes of organisms has captured the attention of scientists, other experts and the specialised press. The techniques, commonly referred to as Genome Editing, have spread rapidly throughout the life sciences. Many suggest that they offer revolutionary new applications.

Prominent scientists, social scientists and policy organisations have called for public discussion of the ethical, societal and environmental dimensions of Genome Editing. These calls build on historical experience with biotechnologies, which recognises that debate is vital for the development and successful deployment of novel science, technologies and innovations in democratic societies. This debate must be connected to policy, either through direct participation of diverse public groups or through broad-ranging expert representatives.

However, with respect to Genome Editing, it is not clear to what extent calls for debate have been acted upon or how they might interface with existing forms discussion in the life sciences. The Wellcome Trust is currently funding research to map Genome Editing and public discussion in human health contexts. This document is complementary and begins a preliminary mapping of public discussion and engagement of *Genome Editing in non-human contexts*.

The review takes a broad perspective of public discussion to identify both formal and informal spaces. This includes parliamentary inquiries, attitude surveys and Public Dialogues but also news reporting, search frequencies, social media spread and physical public events.

This work's headline finding is that whilst non-human Genome Editing is attracting significant attention from technical and policy experts, there are few indications of any substantial public discussion of the topic. Further, much of the formal public debate (engagement activities, and attitude surveys) has revolved around human Genome Editing as opposed to its applications in non-human animals, plants and microbes. This suggests that non-human Genome Editing is a 'technical category' but not a 'public topic'.

The gap in interest can be explained by considering the ways that topics become matters of public interest. Empirical studies of past controversies and recent data from The Royal Society's Public Dialogue on Genetic Technologies emphasise the important of context. Questions about the purpose (health, the environment, agriculture), people, distribution of costs and benefits, ownership arrangements and geographical locations of use are vital in generating and mediating public discussion. Indeed, it is these questions — in addition to those relating to technical risk — that will be key matters of concern. The answers to these questions will determine whether an application has clear public value.

Whilst non-human Genome Editing is a technical category there are currently very few publicised examples of its use in applications. Thus there remain very few material contexts for discussion to develop around and it is unclear how they will build on, or depart from, past engagement with

biotechnologies. However, our data suggest that interest in the topic is rising and will continue to track prominent public events.

The novelty of Genome Editing techniques presents both challenges and opportunities for governance. To address these, we draw on the results of the Royal Society Dialogue and past social scientific research about emerging technologies to make the following recommendations:

1. Build Capacity for Public Discussion and Debate.

   Instead of trying to predict how the technology will develop and pre-empt public contestation, future initiatives should attempt to build capacity for public discussion about non-human Genome Editing and its related applications. There is time to do this. Research suggests that public trust in science remains high. There is a new diversity of spaces (e.g. science museums, community laboratories) where engagement is taking place. Building a better understanding of what happens in these spaces, what other ones there are, and what outcomes come from them would be a useful first step.

2. Connect discussion to decision-making.

   There are actions to strengthen the governance of non-human Genome Editing that can be taken now. The first is to begin to identify sites at which decision making can be opened-up. This does not necessarily mean making them 'fully public' but may mean broadening the kinds of expertise that inform them. Such mapping work would also act as a form of horizon scanning for future governance of any applications. The second action is to begin to develop new 'rapid methodologies' that are able to open-up such sites in real-time as and when the need arises — while there are numerous examples in the social sciences and humanities, they are often quite resource intensive. Taken together, such an infrastructure would complement developments proposed in other international contexts.

3. Hold-open key moments.

   Finally, public discussion of non-human Genome Editing will evolve around particular key moments, such as regulatory decisions or newly publicised products. It is in such moments that it is especially important, but hard, to discuss and debate new technologies. To date, formal methods of discussion have tried to emulate such moments. This approach is useful but limited because it means that discussion largely remains contained within an artificial environment. An ambitious next step would be to develop the new methodologies necessary to hold-open moments for discussion in real-time, when there are often strong pressures to close them down.

1. Introduction and problem space

This report reviews public discussion about Genome Editing in non-human organisms[1]. Its primary goal is to provide a preliminary baseline regarding the kinds of public discussion about, and interactions with, a development in biotechnology with societal significance.

The term 'Genome Editing' is shorthand for a cluster of new scientific techniques that make it possible to make changes at specific sequences of DNA. The technologies are applicable to a wide range of plants, microbes and animals, including humans. It has been long been possible to deliberately change the genomes of organisms using techniques from molecular biology but Genome Editing techniques such as CRISPR-Cas9 make it much simpler, predictable and cheaper than before.

Thus, Genome Editing has been lauded as revolutionary, attracting a significant amount of attention from scientists, technologists and policy makers. As of March 2018, NCBI PubMed, a search engine for the life sciences, holds 8,563 articles on CRISPR, the main Genome Editing technique[2]. Gateway to Research, the UK public research portfolio analyser, returns 128 distinct projects making use of the techniques representing an investment of roughly £55m[3]. One recent global business forecast suggests that Genome Editing-based technologies will reach a market value of around $6bn by 2022[4]. That most of these articles, grants and valuations have been created in the past two years – 6,000 articles have been published since 2016 – gives an indication of the speed at which Genome Editing has spread throughout the life sciences.

The buzz surrounding Genome Editing is common to other emerging technologies. Emerging technologies are characterised as having the potential to be technically and societally disruptive but also unpredictable in terms of *how* they might be disruptive, that is how they might embed within science and society[5]. It is common for such developments in the contemporary life sciences to be accompanied by pleas for public debate[6]; Genome Editing is no different. Amidst the buzz, calls for public discussion are audible from prominent scientists, company directors, social scientists and science policy organisations such as the National Academy of Sciences and the Nuffield Council on Bioethics. In February 2017, Venki Ramakrishnan, President of the Royal Society, used his speech at the AAAS congress to call for public debate about Genome Editing[7]. To contribute to this debate, the Royal Society ran a public dialogue in the autumn of 2017 to explore public views on genetic technologies and their potential applications[8]

It is important to tease out the motivations driving these calls: each group will have different interests at stake when calling for debate and there are different ideas of what such debate entails[9]. However, the most recent report published by the European Academies Science Advisory Council provides a good indication of the status quo regarding the need for public engagement around Genome Editing and other emerging technologies[10]. It concludes with the following recommendation:

> *"There has to be trust between scientists and the public, and, to build trust there has to be public engagement. As observed in the previous chapters, stakeholders (such as patients, clinicians, farmers, consumers and NGOs) need to be involved in discussions about risk and*

benefit, and scientists need to articulate the objectives of their research, potential benefits and risk management practices adopted. This is not a special responsibility for genome researchers, as all scientists have the responsibility to be open and candid about their work. There is need for additional social science and humanities research to improve public engagement strategies."

Previous research and experience governing emerging technologies has shown that they need to be developed in ways that are ethical, safe and accountable, that deliver meaningful public value and that foster public trust in democratic institutions[11]. Past experience in Britain suggests public deliberation and discourse has a vital role to play in developing effective governance arrangements and the nation has developed significant institutional expertise in developing such arrangements[12].

To date, attention has focused largely on the use of Genome Editing in humans. For instance, in 2015 an international summit produced a consensus statement on human Genome Editing. This was followed by a consensus study by the US National Academies of Sciences, Engineering, and Medicine into the ethics and governance of human Genome Editing, published in 2017. However, Genome Editing techniques span virtually all domains of bioscience and biotechnology that rely on altering genetic sequences. In today's landscape, this means their envisaged uses in both scientific research, as tools, and in developing new technologies or commercially-valuable processes are widespread. It is therefore vital that non-human applications are considered.

In the UK, the Nuffield Council on Bioethics recently concluded an initial study on the ethics of Genome Editing and is undertaking follow up studies on human Genome Editing and Genome Editing in livestock. The Wellcome Trust is currently funding public engagement on Genome Editing as applied to human health and medicine through the *Genome Editing Public Engagement Synergy* with the National Coordinating Centre for Public Engagement[13]. This review complements the above work by providing baseline information about public discussion of, and public engagement with, Genome Editing in non-human contexts.

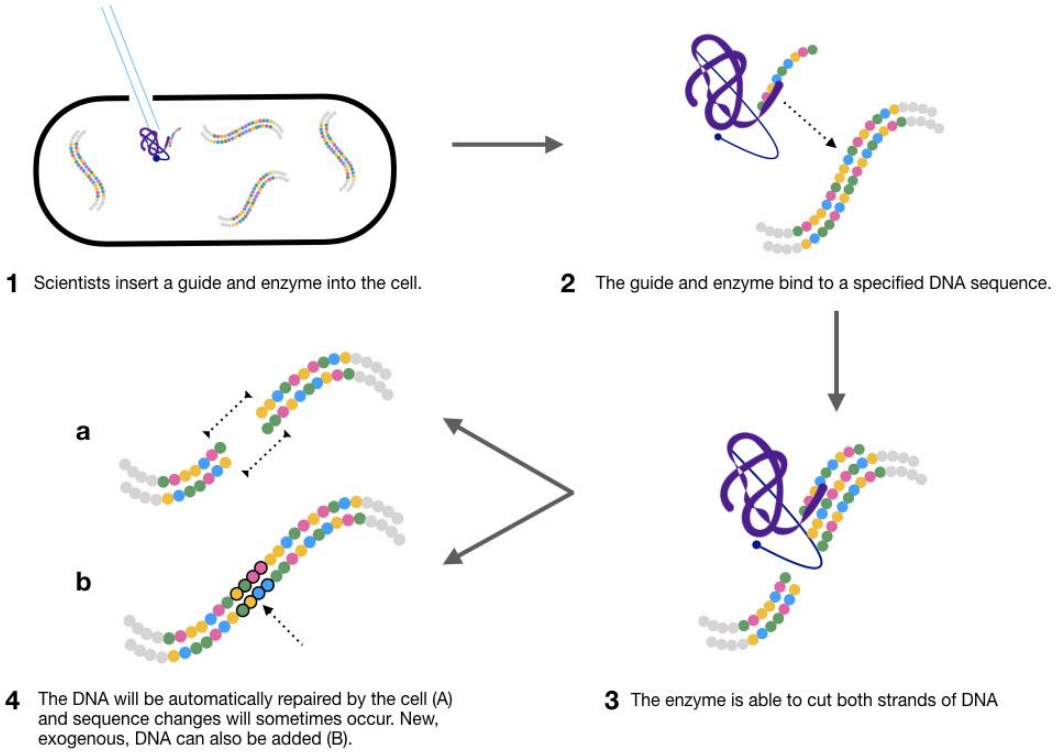
1.1. Questions and review structure

Using a rapid analysis of publicly-available published material, this review asks three questions:

1. What discussion of Genome Editing exists in the public sphere and amongst which groups?
2. What information is there regarding public attitudes to and engagement with Genome Editing techniques and their applications?
3. What challenges and opportunities does this public baseline offer for the governance of Genome Editing?

The remainder of the report is structured to follow these questions: Section Two identifies significant sources of public discussion around Genome Editing; Section Three analyses the content of that discussion; and Section Four considers the results of this analysis for the governance of non-human Genome Editing, particularly regarding the potential role of public engagement therein.

Box: What is Genome Editing?



This report uses the term 'Genome Editing' to refer to a cluster of scientific techniques that are used to make changes to the genetic sequences of organisms. This cluster includes, but is not limited to, techniques such as CRISPR-Cas9, TALENs, and Zinc Fingers. Genome Editing works as follows: First a guide (usually designed by scientists) identifies a particular sequence of DNA. An enzyme (a nuclease) then breaks both strands of the DNA. This break will be automatically repaired by the cell, but it also allows modifications to the DNA sequence to be made[14].

It has long been possible to make deliberate genetic modifications and Genome Editing is part of this lineage[15]. However, Genome Editing is generally cheaper, faster and more predictable than previous methods[16]. These features have captured the attention of scientists – in 2015 CRISPR was awarded 'breakthrough of the year' by the journal *Science* – but also social scientists, companies, policy makers and the media.

Because so many biological applications involve the modification of DNA and because Genome Editing promises to make this easy, hope has built for a wide range of new non-human biotechnologies. Many goals are longstanding, such as the treatment of genetically transmitted disease, modifying crops to increase yield or drought tolerance, or producing biofuels from microbes or algae. However, Genome Editing has allowed other hypothetical ideas to move closer to reality: one is developing 'Gene Drive' technologies to control mosquito populations. These ideas raise fundamental questions for governance as, for example, their development requires large-scale deliberate release of Genetically Modified Organisms into the environment.

2. Public discussion of non-human Genome Editing

The introduction of this review drew attention to the prominence of calls for public discussion and participation surrounding Genome Editing. This section is concerned with two questions: First, what are the main spaces for public discussion of non-human Genome Editing? Second, who is involved in these discussions? To answer these questions the review draws on news reporting, social media, grey literature (e.g. policy reports) and publicly-listed events. These data were identified through systematic review methodologies, detailed in the appendix.

The data indicate that public discussion is largely invited and occurring between technical experts, organisations and governing bodies. Informal discussion – that is not 'invited' – is limited and there is relatively low diffusion of the term 'Genome Editing' into public discourse. This is, however, rising.

Box: Formal and informal discussion

Throughout the report we make a distinction between 'formal' and 'informal' types of public discourse[17]. We do this to begin to capture a broad range of discussion. The former is characterised as spaces where discussion is invited, usually by politicians or science policy organisations. This includes parliamentary inquiries and government-commissioned public dialogues. The latter, 'informal discussion' is closer to 'naturally occurring' or self-organising discussion, which includes media reporting, public lectures and discussion on social media. It is important to recognise that the two categories are not completely discrete. An obvious example of this is that the publication of policy reports can be events in themselves, driving news reporting and upticks in activity on social media.

2.1. Formal spaces

In the UK there have been four major policy reports with relevance to the topic of non-human Genome Editing[18]. Each report has a public consultation period, meaning that they are able act as pockets of public debate. Collectively, the four consultations contain over 240 submissions from a wide range of stakeholders (Figure One). The vast majority of submissions came from experts, policymakers, civil society stakeholders and representing organisations or others' members of society's views.

During the 2000s, Britain institutionalised a mechanism for invited public engagement with science and technology in the form of the 'Public Dialogues'[19]. The term Public Dialogue is formally defined by Sciencewise and the Department for Business, Energy and Industrial Strategy, and Public Dialogues have typically taken the form of discrete large-scale projects[20]. To date, there has been one Public Dialogue on non-human Genome Editing, organised by the Royal Society. This dialogue ran from September to October 2017 and convened 90 members of the British public in Edinburgh, London and Norwich to discuss different applications of genetic technologies, including in livestock, insects, crops and industrially-useful microbes.

Figure One: 172 groups have submitted evidence to policy reports and parliamentary inquiries

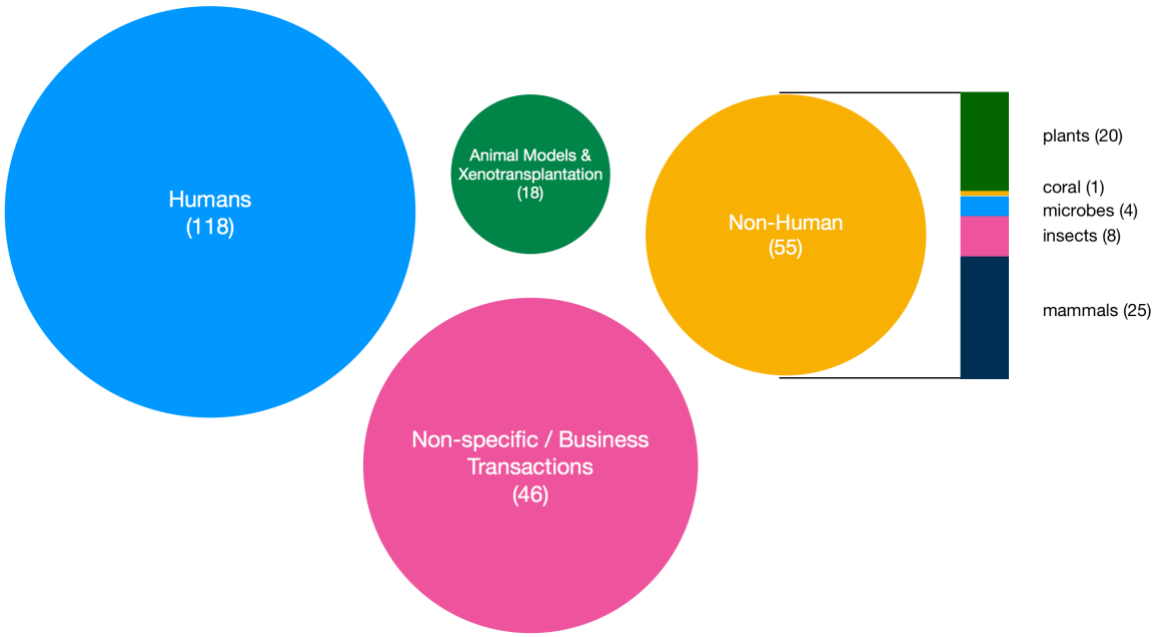


Figure Two: Counts of articles reporting on different aspects of Genome Editing in the UK press (1 March 2016 - 5 May 2018). As is common, the vast majority of these articles follow the publication of scientific articles or policy reports.

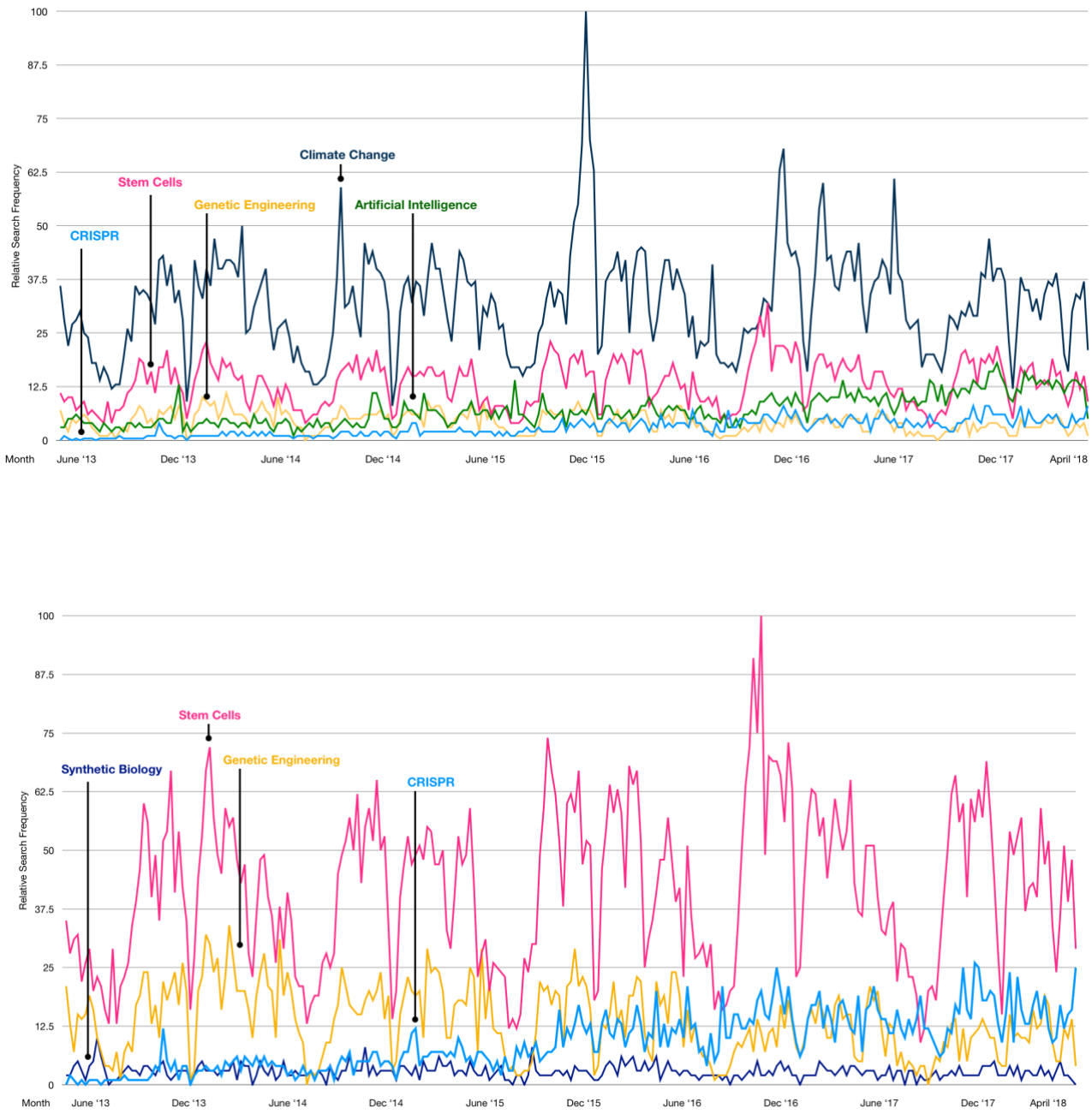


Figure Three: Relative Google Trends frequencies of different search terms in the UK between May 2013 and May 2018. The large peak for climate change relates to the Paris Agreement. CRISPR (Sky Blue in both diagrams) is used as the indicative search term for Genome Editing as the term with the highest relative hits (vs. e.g. Genome Editing, Gene Edit etc.).

A final identifiable invited space is public attitude surveys. Three have been conducted. The first, consulting 2084 people, was commissioned by Bayer Crop Science and run by Populus on the topic of crop science and agriculture. The second was conducted by staff at the website *Whatisbiotechnology,* receiving 570 responses with 126 from the UK. The most recent survey, of 2061 people, was conducted as part of the aforementioned dialogue to validate its findings. While these surveys reach comparatively large proportions of the population, in their own right they provide little opportunity for debate and their methodologies are not transparent, making them difficult to interrogate or replicate. In this respect it is notable that to-date Eurobarometer, which does have consistent methodology and longitudinal power regarding public attitudes to emerging technologies, has not included any questions regarding non-human Genome Editing[21].

2.2. Informal spaces

To supplement these invited instances of public discussion we have conducted pilot analyses of off- and on-line media sources. These analyses indicate that the term 'Genome Editing' has little diffusion into the public domain: as a proportion of total material available, Genome Editing remains low. Further, there is little substantive discussion of non-human Genome Editing. Because of the limited scope of this review this finding is tentative. It does, however, echo findings of the Progress Educational Trust that diffusion of a language of Genome Editing beyond expert communities is low.

In the past two years, UK national newspapers have published 55 articles on the topic of non-human Genome Editing. (To provide a comparison there have been roughly 882 articles relating to Stem Cells in the same period.) The vast majority of these articles report a scientific discovery and contain little in the way of discussion about Genome Editing or its societal context. Without a full analysis, it is difficult to establish a clear sense of how the technology might be framed by such outlets, and in particular how existing debates about genetic modification will influence public trust and attitudes in the future. A cursory analysis indicates differences in language use between human and non-human. There is comparatively more, and deeper, coverage in the specialist online press, such as Wired, and this often contains more discussion around the technology.

Google Trends provides relative search activity for terms and topics and with care is able to supplement public attitude surveys. The service does not provide indications of the constituencies conducting the searches, meaning that without significant effort it is difficult to directly infer which populations of actors are searching. However, as Figure Three indicates, in the UK Genome Editing currently has a low relative interest in relation to other scientific issues, such as Artificial Intelligence and Climate Change. In relation to other biotechnologies, however, topics such as CRISPR have relatively higher, and growing, search activity.

Discussion on Twitter is also limited and largely contained within scientific communities. Tweets related to Genome Editing predominantly originate from business and/or industry sites. Many of these tweets are re-tweets of other scientists or companies. YouTube provides more in-depth information and discussion than twitter or the mainstream news. Searching for "gene editing" on YouTube revealed 278,000 matches and searching for "Genome Editing" revealed 87,000 matches.

Figure Four: Locations and counts of publicly listed events on non-human Genome Editing in the UK

The most-viewed videos are provided by digital media/news companies and online news sites, research institutions and science bodies, and public talks. The most watched YouTube video has 8.6 million views[22], all others having views below 1.3 million.

We have supplemented this information with past and future events listed on the website Eventbrite (Figure Four). Globally, in the English-speaking world, there have been just over 300 events listed on the topic. The vast majority of these are in the United States and are public lectures. In the UK, 38 events have been held or are scheduled. They take the form of debates on the ethics of Genome Editing, outreach lectures, and more technical public events such as DIY biology events. Events are largely clustered around scientific institutions.

The sparse presence non-human Genome Editing in the public domain should not be taken as a lack of interest. In the most recent Royal Society survey, 70% of respondents said they would be interested to know more about the topic. A key finding of its associated Dialogue is that members of the public would welcome increased communication and involvement in the governance of Genome Editing. This finding has been replicated in a wide range of participatory governance processes: while resource intensive, substantive citizen participation is central to robust governance in contested situations[23].

3. Analysis of public discussion

This section provides an interpretative analysis of public discussion on non-human Genome Editing. It focuses on three aspects. First, what lessons regarding public perspectives on non-human Genome Editing can be taken from the formal sites of discussion? Second, what insights can be derived from the informal spaces, especially the high scientific interest and comparatively low media reporting? Finally, we consider the gaps that remain in our knowledge about public discussion of the topic, which may need to be addressed moving forwards.

3.1. Conditional support

Studies on public hopes, aspirations and concerns relating to non-human Genome Editing have been published in five countries (New Zealand, Germany, The Netherlands, Japan and the United States) [24] . There are distinct cultural values between national populations in relation to biotechnology[25], meaning that the specific findings should be compared with caution. However, these studies repeatedly find that the interests of citizens in these studies go beyond questions of technical risk; they are also concerned with questions of the perceived benefits of a technology, trust in actors, equity and questions of bioethics[26].

The Royal Society Dialogue on Genetic Technologies was conducted between July and November 2017. Following advice from the Nuffield Council on Bioethics, it asked participants in three UK locations to generate a series of social challenges facing Britain today and then locate Genome Editing technologies within them. In doing so, the dialogue replicated findings from numerous previous public dialogues on emerging technologies[27]. It demonstrated:

Conditional support for Genome Editing as one method in a portfolio of approaches. In the most general terms, Genome Editing was seen as valuable to pursue and research into it should be supported. There are caveats to this support, most obviously that research into Genome Editing should not 'crowd out' alternative fields of research, forms of innovation and ways of addressing societal challenges.

Prioritise uses of Genome Editing with clear public benefit. Hypothetical scenarios that offered improvements to human health or animal welfare were ranked as more worthwhile than those which offered improvements in food production efficiency. Applications where there was no analogous alternative were ranked over those where there were existing alternative solutions. For instance, despite environmental risk, the use of Genome Editing to remove vector populations was ranked over the use of Genome Editing to increase the production efficiency of fish, but only under not-for-profit business models.

Assessments based on more than just risk. In evaluating the use of different hypothetical Genome Editing applications, participants emphasised that questions of safety should be *a priori* addressed. As important, however, are the following criteria: 1) Prioritising collective wealth over private or corporate wealth; 2) Prioritising more equitable distributions of costs and benefits amongst humans but also animals and the environment; 3) Prioritising applications that can lower cost of existing products or treatment; 4) Valuing cultural and environmental diversity; 5) Ensuring decision making is multidisciplinary, inclusive of citizens and transparent.

Publicly-funded organisations have a vital role to play. When offered a range of potential actors, participants ranked publicly funded scientists, professional societies, and charitable foundations as most the trustworthy bodies to provide information and develop and govern Genome Editing. (Businesses, privately funded scientists and charities were less trusted) This suggests there is no blanket dismissal of expertise and implies an important role for publicly-funded bodies in driving public discussion about Genome Editing.

3.2. Genome Editing is an emerging public topic

This review departures from an observation that a significant amount of attention is focused toward Genome Editing: There is a substantial amount of published scientific literature, a significant amount of funding, and a significant number of calls for public debate. Our data, however, indicate that this attention is largely contained within scientific and policy communities. Discussion amongst lay publics, if it occurs, appears to be predominantly invited and in formal spaces (e.g. Public Dialogues, Attitude Surveys). This suggests that Genome Editing (and non-human Genome Editing therein) may be a defined *technical category* but is not yet a clear *public topic*[28]. The significance of this insight is considered below.

Technical categories matter for science and for the regulation of products because it takes a great deal of specificity, skill and resources (e.g. reagents, equipment, software) to 'do' Genome Editing in a way that can produce viable outcomes. Indeed, there remain technical questions about the specific

conditions under which genome editing works as expected[29]. It is scientifically important to be able to repeat these processes and regulatory processes frequently rely on these stable definitions. In Europe, for instance, early discussions raised the possibility that non-human Genome Editing may challenge or be exempt from existing regulation on the deliberate release of genetically modified organisms (GMOs) when no exogenous DNA is used in the editing process. If a plant is 'edited' using only sequences of DNA found in that organism, it is likely that it will not be regulated as a GMO[30].

Some scientists, policy makers and companies emphasise the need to distinguish between Genome Editing and other genetic engineering techniques[31]. Similarly, the Progress Educational Trust emphasises the importance of clearly communicating the distinctions between different kinds of Genome Editing and their uses when communicating to members of the public. These activities are useful. There is lots of evidence to show that citizens are able to gain appropriate technical expertise — as citizen scientists, patient activists, or public campaigns — when they wish to take part in democratic processes and building clarity through, for instance, common metaphors and shared language is important[32].

The recommendations above are based on the idea of Genome Editing as primarily a technical category. As important for governance is to consider how it may develop as a public topic. Here, past research into science and technology in public suggests three features are important to pay attention to:

The importance of policy moments. Non-human Genome Editing will be given meaning over an extended period of time. However, this will be substantially mediated by particular 'moments' that generate significant media, policy and public attention. Perhaps the best contemporary example of this is climate change. As visible in Figure One, search interest has built over an extended period but spikes appreciably around key events, the most extreme example being the Paris Agreement. Genome Editing follows a similar (but much attenuated) pattern, for example with news reporting tracking key policy reports, regulatory decisions and scientific advances. Some of these moments have already happened or are in motion, such as the European Commissions deliberations about regulation of Gene Edited plants or posited field trials of Gene Edited mosquitoes.

Public topics are more than technical. Second, public topics turn around questions that are more than technical. Debate may be conducted in technical terms (as required by policy processes, which often have tightly definitions of evidence.) but at its heart will be about political, cultural and social issues. Indeed, events such as the Royal Society Dialogue, which give citizens the opportunity to learn and interrogate Genome Editing commonly find that these people tend to prioritise concerns around the wide range of criteria that determine what roles a technology takes in society and how the relative benefits and harms are distributed(fn 31). This means that trying to draw clear and consistent boundaries between different kinds of genetic intervention will be a communication strategy with limited value.

Meaning will build around applications. Non-human Genome Editing will be given public meaning through the uses to which it is put. This is because the applications of non-human Genome Editing

have a material context: constellations of people, organisations, models of ownership, channels of communication spaces of debate, as well as the physical properties of any object and the areas it is used[33]. To labour the point a little, it makes little sense to think about Genome Editing as an isolated technology: the pertinent questions to ask in humans are different to non-humans because societies value these things differently. Similarly, the contexts provided when a purpose is to improve health are different to those if the purpose is improving agriculture. Early examples of this phenomenon are visible in media and scientific reporting of projects, which tightly couple non-human Genome Editing to applications in the world (however speculative they may be). The above discussion of policy moments means that the first applications will be extremely important in guiding the evolution of non-human Genome Editing as a public topic.

3.3. Conclusion

Whilst non-human Genome Editing is a distinct technical category there are currently very few publicised examples of its use in applications. Thus there remain very few material contexts for discussion to develop around and it is unclear how they will build on, or depart from, past engagement with biotechnologies. Our data suggest that interest in the topic is rising, and will continue to track prominent public events.

Findings from the Royal Society Dialogue reinforce the lessons from past Public Dialogues on related topics and provide an initial indication as to the factors that members of the public consider to be important when governing Genome Editing technologies in a range of contexts. However, it is important to remember that such findings are based on discrete, contained settings with hypothetical applications rather than non-human Genome Editing as manifested in an actual precedential moment. It is incredibly difficult to know how such moments will develop, a point compounded by the ubiquity of Genome Editing in the life sciences. In the final section we consider the significance of this review for governance and public engagement.

4. Lessons for the governance of Genome Editing

This final section considers the consequences of the landscape of public discussion for future policy options. It develops recommendations in response to three questions:

1. Why promote public discussion of Genome Editing?
2. When is the right time?
3. How could discussions be supported?

In the past three years, Genome Editing techniques have become ubiquitous in the life sciences. The pace at which this has happened — and at which developments continue — is rare. That the parties developing these techniques are calling for debate about the appropriate ways for them to be used is laudable, emphasising how central the notion of public discussion as vital for technology development has become for democratic societies; this has not always been the case.

Such discussions should happen early, while the directions of technological development can be readily steered, but it is equally important that they are seen not as obligatory passage points that clear the way for applications. Instead, public discussion should be an on-going process to strengthen governance[34]. This is important because there is still significant uncertainty about the social and technical trajectories that non-human Genome Editing will take: There is technical uncertainty regarding the conditions — in what organisms and with what efficiencies — under which Genome Editing will work as expected; There is translational uncertainty regarding the arenas in which Genome Editing will be economically viable; And there is social uncertainty about the kinds of groups and situations that will form as Genome Editing applications move from the laboratory into the world[35].

A 2014 report published by the Government Chief Scientific Advisor convincingly argues that substantive public engagement with – and even contestation of – the different possible development paths that technology development proceeds down is vital to fostering an 'Innovation Democracy'[36]. Rethinking public discussion in the service of such an Innovation Democracy would mean providing support to self-organising sites of discussion, in the process building civic capacity for engagement with non-human Genome Editing. It would also mean experimenting with novel fora and forms of public discussion and finding ways to draw publics into the governance of technology[37]. The suggestions below complement recent recommendations to develop infrastructure for public debate made separately in *Nature* for a 'Global Observatory' and an 'Infrastructure' for public participation[38].

Recommendation 1: Map and support public discussion and engagement.

Our analysis suggests that non-human Genome Editing offers an opportunity to develop such an approach to public engagement. First, there is an apparent demand on the part of scientists,

technologists and science policy experts for public debate and engagement. Second, there is time to build capacity for public discussion.

Perhaps the most important dimension is that there is an inherent diversity to the topic -- the contexts of non-human Genome Editing are diverse and so are the spaces for discussion. We have drawn attention to a range of media and online fora, but the past twenty years have seen a multitude of other spaces for citizens to engage with science and technology. This includes science festivals, community labs and citizen science projects[39]. For instance, focusing on energy, one recent systematic review identified over 300 individual examples of public discussion and engagement[40]. The authors emphasise the diverse forms of citizenship – including but not limited to campaigning publics – within this ecology. Another recent study focusing on citizen science projects has begun to unpack different forms of citizen participation in genetics, offering an alternative typology that pays attention to levels of openness, the groups participation and the outcomes that follow[41].

Emphasising diversity also draws attention to how little is known about such spaces in the non-medical biosciences and, vitally, what resources are needed to support the formation of public groups within them. Thus, we recommend that any attempt to develop an infrastructure for public participation and discussion should be underpinned by a more comprehensive mapping of citizen engagement in the spaces that non-human Genome Editing touches on. While there is significant uncertainty regarding the future of Genome Editing, developing a topic map based on published sources would provide a point of departure to identify any relevant actors. Social scientific methodologies such as issue mapping, sentiment analysis and qualitative interviewing, would be able to systematically address three key remaining questions:

1. What public groups are forming and what kinds of citizenship do they produce?
2. How is Genome Editing being represented in such spaces and by whom? For instance, is framed as an object of hope or concern?
3. To what extent do discussions build on or depart from past experiences with Genetically Modified Organisms and other biotechnologies?

Recommendation 2: Connect public discussion to decision making.

It is important to consider the motivations driving the calls for public discussion. The social sciences frequently distinguish between instrumental, substantive and normative rationales[42]. An instrumental rationale drives public discussion but holds it separate from the power to make, or even inform, decision-making. This is often coupled to an information sharing mode of action: clearly-communicating the logic of / evidence for the decision will encourage people to support it. A substantive rationale pursues discussion on the basis of feeding in different kinds of knowledge to technology development, on the basis of making better decisions about the development of technology in particular contexts of use. A normative rationale drives discussion on the basis that it is the 'right' thing to do in democratic societies[43].

These rationales can have significant consequences for the form that public discussion of science and technology takes and the outcomes that follow[44]. For instance, in practice much decision making power — about, for example, research agendas or product regulation — is separate to the sites of public discussion and debate. While the Public Dialogues aim to connect discussion and decision making, this is extremely difficult to do and in practice they frequently lean towards instrumental rationales that reinforce the separation. That is, they risk viewing public discussion and the groups involved as something to be contained – either in time, space or in terms of valid arguments – or enrolled in support of a policy or technology[45].

There are credible reasons for this separation — for example, based on ideas about expertise needed to discuss scientific proposals — but it is an overly narrow view of the role that public discussion can play in the development of non-human Genome Editing. Focusing too-heavily on the protection of science from public contestation comes at the expense of empowering external stakeholders – with different knowledge, experiences and values – to add value to innovation processes. In a use-case that is directly relevant to non-human Genome Editing, social scientists working at the French National Institute for Agricultural Research (INRA) have demonstrated how drawing in diverse groups can improve the quality of decision-making about the conditions under which technologies are developed and in which direction[46]; that is, the technologies do a better job functioning and the science is more likely to be in the public interest. In doing so, the social scientists emphasise that such discussion is not a recipe to keep everyone happy – there will always be winners and losers. "Rather, it improves the robustness of decisions by taking into account the diversity of world views and interests"[47]. Similar experiences are available in the field of synthetic biology[48].

Thus, we recommend that a clear next step in developing an infrastructure to support discussion of non-human Genome Editing is to find ways to connect discussion to decision-making. There are two obvious points of integration:

1. Strategic decision making relating to research funding agendas, especially in light of mission-oriented public funding[49].
2. Sites of soft law, such as standard setting and certification processes[50],

Recommendation 3: Develop methods to hold-open policy moments.

Some contemporary forms of formal discussion recognise the importance of context and try to build hypothetical scenarios to help reduce the uncertainty around science and technology. The Royal Society Dialogue is both typical and instructive in this regard: In order to contextualise Genome Editing, the organisers hooked discussion to a scaffold of hypothetical scenarios involving a range of organisms and societal challenges. This helped participants to produce context-specific recommendations about the conditions under which Genome Editing applications might be acceptable to them.

However, this is not a case of live policy making and so while useful, the exercise can only partially capture the dynamics of such moments. Take the examples of Gene Drive for Health in the Global

South. Even in the face of potential unknown environmental risks, the participants within the Royal Society Dialogue saw clear value in the application, ranking it higher in priority than applications that might seek to improve food production efficiency. However, this assessment was tightly coupled to a series of criteria that would help to ensure a strong public interest, namely if the benefits were distributed widely, they were deployed for humanitarian purposes and with a not-for-profit economic framework. Given the dominant modes of commercialisation and intellectual property development surrounding biotechnology it is questionable whether such criteria could ever be met. Thus, if this insight from a well-institutionalised mode of public discussion is to be taken seriously, there are questions about the potential models of ownership and intellectual property that Gene Drive technology – an application of non-human Genome Editing – should be subject to[51]. A positive next step, then, is to find ways to connect up public discussion to decision making during moments of live policy making, as and when they emerge.

This is challenging in part because it is extremely difficult to predict how or when such moments will occur naturally: neither technology, governance nor public discussion progress down a clear bright path. As this review has noted, each pass through extended periods of stability interspersed with more dramatic moments of contestation and change[52]. They are increasingly configured by developments in other international contexts[53]. A second challenge is that during these moments of public salience there is often time pressure, reputational risk and differing ideas of what constitutes credible expertise, rational argumentation and acceptable forms of evidence[54]. These dynamics commonly work in concert to provide an intrinsic tendency to close down public discussion and appraisal[55]. And yet, such moments can be important because they set precedents – e.g. when key legal rulings are made – or because they allow the airing of contested values and perspectives that shape positions for extended periods of time afterwards[56].

There are currently few available methodologies that work against these pressures and hold-open moments for discussion and debate in real-time. However, there is expertise within government departments and a range of social scientific methodologies that, whilst currently resource and time intensive, could be suitable candidates to adapt[57].

The first step in this process is to identify historical examples, live sites and future cases. Thus, a systematic mapping of near-term technological pathways, sites of use and sites of governance would significantly reduce the uncertainty around non-human Genome Editing[58] because it will draw attention to the ways in which future applications will interface with existing regulatory regimes, ownership models and stakeholder groups. It would identify near-term policy moments in which to open-up decision making and live cases — such as Gene Drive technologies — that would form productive pilot sites because the coalitions, geographical contexts and envisaged purpose are visible.

Endnotes

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[2] Search terms, (14th March 2018): "clustered regularly interspaced short palindromic repeats"[MeSH Terms] OR ("clustered"[All Fields] AND "regularly"[All Fields] AND "interspaced"[All Fields] AND "short"[All Fields] AND "palindromic"[All Fields] AND "repeats"[All Fields]) OR "clustered regularly interspaced short palindromic repeats"[All Fields] OR "crispr"[All Fields]

[3] "Genome Editing" OR "CRISPR" OR "gene edit" OR "gene edits" OR "ZFN" OR "TALENS" OR "zinc finger" OR "cas9" OR "cas 9". 107 projects are 'doctoral studentships', which have an ascribed funding value of £0, and have been excluded from this total.

[4] https://www.reportlinker.com/p05220258/Genome-Editing-Genome-Engineering-Market-by-Technology- Application-End-User-Global-Forecast.html

[5] Rotolo, Hicks and Martin (2015) What is an emerging technology?

[6] Rose (2012) Democracy in the Contemporary Life Sciences.

[7] The Royal Society (2017) Potential and Risks of Recent Developments in Biotechnology: a Speech by Venki Ramakrishnan, President of the Royal Society.

[8] HVM (2017) Potential uses for genetic technologies: dialogue and engagement research conducted on behalf of the Royal Society. See: https://royalsociety.org/topics-policy/projects/genetic-technologies/

[9] Fiorino (1990) Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms; Wynne (2006) Public Engagement as a Means of Restoring Public Trust in Science - Hitting the Notes, but Missing the Music?

[10] Government Office for Science (2014) Innovation: Managing Risk, Not Avoiding It.

[11] Nuffield Council on Bioethics (2012) Emerging biotechnologies: technology, choice and the public good; Macnaghten & Chilvers (2014) The future of science governance: publics, policies, practices.; Government Office for Science (2014) *Innovation: Managing Risk, Not Avoiding It;* Nuffield Council on Bioethics & Sciencewise ERC (2016) *Public Dialogue on Genome Editing. Why? When? Who?*

[12] See, for instance: Jasanoff, Hurlbut & Saha, K (2015) CRISPR democracy: Gene editing and the need for inclusive deliberation; Sarewitz (2015) CRISPR: Science can't solve it; Kuzma (2016) Policy: Reboot the debate on genetic engineering; National Academy of Sciences & National Academy of Medicine (2017) *Human Genome Editing: Science, Ethics, and Governance.*

[13] https://www.publicengagement.ac.uk/nccpe-projects-and-services/nccpe-projects/genome-editing-public-engagement-synergy; https://www.publicengagement.ac.uk/sites/default/files/overview_of_resources_live_2.pdf

[14] Nuffield Council on Bioethics (2016) Genome Editing: an Ethical Review; POST (2016) "POSTNOTE 541: Genome Editing; Wolt et al (2016) Regulatory Aspects of Genome-Edited Crops.

[15] As we later suggest, Genome Editing is not a stable term and there remains considerable uncertainty as to how the field will develop. For instance, 'base editing' and large scale "Genome Synthesis" Technologies are also being proposed and developed. For this reason, The Royal Society uses the term 'Genetic Technologies'. However for consistency with other policy reports, we use the term Genome Editing. Note also that in specific uses, such as agriculture, the term 'New Breeding Techniques' has been coined. This term includes, but is not limited to, Genome Editing.

[16] It is important not to overstate the predictability of Genome Editing. While high success rates have been reported for some sequences of DNA in some organisms, not all sequences are edited equally. Rates of <1-5% are common, meaning that it can take between 20 and more than 100 attempts to create the desired phenotype. See Feng et al. (2014) Multigeneration Analysis Reveals the Inheritance, Specificity, and Patterns of CRISPR/Cas-Induced Gene Modifications in Arabidopsis; Schumann et al (2015) Generation of Knock-in Primary Human T Cells Using Cas9 Ribonucleoproteins; Roche et al. (2018) Efficient Homology Directed Repair by Cas9: DNA Localization and Cationic Polymeric Transfection in Mammalian Cells.

[17] Stilgoe, Lock and Wilsdon (2014) Why Should We Promote Public Engagement with Science?

[18] There have been many studies and reports conducted globally (see associated endnotes within this review). However, this review focuses on the UK national context for reasons of resources. This is also a methodological decision as there are substantive differences in culture and policy context that must be accounted for in multi-nation comparisons. The most obvious dimension here is linguistic: non-English speaking nations have different phrases for Genome Editing. (See, e.g.: https://blogs.nottingham.ac.uk/makingsciencepublic/2016/11/03/gene-surgerygenchirurgie)

[19] Pallett and Chilvers (2013) A Decade of Learning About Publics, Participation, and Climate Change: Institutionalising Reflexivity?; Pallett (2015) Public Participation Organizations and Open Policy: a Constitutional Moment for British Democracy?

[20] Sciencewise (2018) The Government's Approach to Public Dialogue on Science and Technology

[21] For a related longitudinal analysis, see Gaskell, G. et al. (2010) Europeans and Biotechnology in 2010: Winds of change?

[22] Kurzgesagt – In a nutshell (2016) Genetic Engineering Will Change Everything Forever – CRISPR. Available at, https://www.youtube.com/watch?v=jAhjPd4uNFY (Accessed Wednesday 9 May 2018)

[23] Callon, Lascoumes and Barthe (2009) Acting in an Uncertain World: an Essay on Technical Democracy; Whatmore (2009) Mapping Knowledge Controversies: Science, Democracy and the Redistribution of Expertise; Owen, Stilgoe & Macnaghten (2013) Developing a framework for responsible innovation.

[24] Kokotovich and Kuzma (2014) Conflicting Futures: Environmental Regulation of Plant Targeted Genetic Modification; Araki and Ishii (2015) Towards Social Acceptance of Plant Breeding by Genome Editing; Ishii and Araki (2016) Consumer Acceptance of Food Crops Developed by Genome Editing; Kuzma, Kokotovich and Kuzhabekova (2016) Attitudes Towards Governance of Gene Editing; Bruce (2017) Genome Edited Animals: Learning From GM Crops?; Tanaka (2017) Major Psychological Factors Affecting Acceptance of New Breeding Techniques for Crops.

[25] Felt (2013) Keeping Technologies Out: Sociotechnical Imaginaries and the Formation of a National Technopolitical Identity; Jasanoff (2005) *Designs on Nature.*

[26] A full analysis of naturally occurring debate is beyond the scope of this review but is mirrored in YouTube, where discussions about Genome Editing's associated ethical and social issues featured in nearly half of the top 10 most viewed YouTube clips.

[27] Chilvers and Macnaghten (2011) The Future of Science Governance: a Review of Public Concerns, Governance and Institutional Response; Doubleday and Teubner (2012) Public Dialogue Review: Lessons From Public Dialogues Commissioned by the RCUK.

[28] This is a simplified version of the notion of public reason, see e.g.: Jasanoff (2010) A New Climate for Society; Jasanoff (2012) Science and Public Reason.

[29] For instance, chromatin structure in mammals has recently been shown to modulate CRISPR interventions. Daer et al. (2016) The Impact of Chromatin Dynamics on Cas9-Mediated Genome Editing

in Human Cells; Hinz, Laughery and Wyrick (2016) Nucleosomes Selectively Inhibit Cas9 Off-Target Activity at a Site Located at the Nucleosome Edge.

30 Ricroch et al. (2016) Challenges Facing European Agriculture and Possible Biotechnological Solutions; Ricroch, Amman and Kuntz (2016) Editing EU Legislation to Fit Plant Genome Editing; Nature (2017) Legal Limbo: Europe Is Dragging Its Feet on Gene-Editing Rules and Scientists Should Push the Issue; Abbott (2018) European Court Suggests Relaxed Gene-Editing Rules.

31 See above but also an open letter to Greenpeace, signed by more than 130 Nobel Laureates: http://supportprecisionagriculture.org.

32 There is a long line of research supporting this finding, including, for instance: Wynne (1991) Knowledges in Context; Epstein (1995) The Construction of Lay Expertise: AIDS Activism and the Forging of Credibility in the Reform of Clinical Trials.

33 See, Bijker, Hughes & Pinch (2012). Social Construction of Technological Systems : New Directions in the Sociology and History of Technology

34 Jasanoff, Hurlbut & Saha (2015) CRISPR democracy: Gene editing and the need for inclusive deliberation.

35 Discussion could therefore be best characterised as 'upstream': a state whereby innovation processes are relatively early in their development, the potential connections between public discussion and policy outcomes are vague, and public discussion – and any call for debate – centres primarily around the possible future worlds that may result from genome editing.

36 Government Office for Science (2014) Innovation: Managing Risk, Not Avoiding It.

37 Stilgoe (2015) Experiment Earth

38 Burall (2018) Don't wait for an outcry about gene editing; Jasanoff and Hurlbut (2018) A global observatory for gene editing.

39 Stilgoe, Lock and Wilsdon (2014) Why Should We Promote Public Engagement with Science?

40 Chilvers, Pallett and Hargreave (2017) Public Engagement with Energy: Broadening Evidence, Policy and Practice.

41 Prainsack, B. Understanding Participation: The 'citizen science' of genetics. In: Prainsack, B., Werner-Felmayer, G., Schicktanz, G. (eds). Genetics as Social Practice. Farnham: Ashgate (in press).

42 Fiorino (1990) Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms; Stirling (2012) Opening up the politics of knowledge and power in bioscience.

43 In practice these rationales are not mutually exclusive but appear as messy clusters. For instance, they change over time and different teams within the same organisation can have different motivations. Importantly, the latter substantive and normative modes of action can also produce instrumentally-useful outcomes by building support for decisions.

44 Stirling (2012) "Opening Up" and "Closing Down" Power, Participation, and Pluralism in the Social Appraisal of Technology.

45 This is structural as much as intentional. For instance: there are inherent time-lags in any public dialogue process that can hinder the ability of organisations to respond; there are varying institutionalised ideas of relevant evidence and valid forms of argumentation; and different dialogue processes focus on inviting in particular forms of citizenship from particular public groups. See Wynne (2006) Public Engagement as a Means of Restoring Public Trust in Science; Bickerstaff et al (2010) Locating Scientific Citizenship: the Institutional Contexts and Cultures of Public Engagement; Mohr, Raman & Gibbs (2013) Which Publics? When? Exploring the Policy Potential of Involving Different

Publics in Dialogue Around Science and Technology; Marris (2015) The Construction of Imaginaries of the Public as a Threat to Synthetic Biology; de Saille (2015) Dis-Inviting the Unruly Public; Frow (2018) "From "Experiments of Concern" to "Groups of Concern".

46 Marris, Joly and Ronda (2005) How the French GM Controversy Led to the Reciprocal Emancipation of Scientific Expertise and Policy Making; Callon, Lascoumes and Barthe (2009) *Acting in an Uncertain World: an Essay on Technical Democracy*.

47 Joly and Rip (2007) A Timely Harvest.

48 Smith et al. (2017) Synthetic Biology Biosensors for Global Health: Workshop Report of the Flowers Consortium.

49 Nesta have recently launched such a scheme. See, https://www.nesta.org.uk/project/everyone-makes-innovation-policy

50 For examples, see: Quinlan et al. (2016) Experiences in Engaging the Public on Biotechnology Advances and Regulation; Webster and Eriksson (2008) Governance-by-Standards in the Field of Stem Cells: Managing Uncertainty in the World of 'Basic Innovation'; Timmermans and Epstein (2010) A World of Standards but Not a Standard World: Toward a Sociology of Standards and Standardization; Mackenzie et al. (2013) "Classifying, Constructing, and Identifying Life: Standards as Transformations of 'the Biological'.

51 There are lessons to be learnt from communities that have previously been at the heart of public controversies. For instance, some parts of the UK plant science community have devoted significant time to developing and institutionalising an 'Open Material Transfer Agreement' intended, in part, to provide an alternative form of Intellectual Property for what have been traditionally tightly-controlled plant technologies. See: https://biobricks.org/openmta/. See also: Doubleday and Wynne (2011) Despotism and Democracy in the United Kingdom: Experiments in Reframing Citizenship.

52 Baumgartner and Jones (1991) Agenda Dynamics and Policy Subsystems; Barry (2012) Political Situations: Knowledge Controversies in Transnational Governance.

53 Barry (2012) Political Situations; Jasanoff (2011) Constitutional Moments in Governing Science and Technology.

54 Rothstein (2004) Precautionary Bans or Sacrificial Lambs? Participative Risk Regulation and the Reform of the UK Food Safety Regime; Rothstein (2007) Talking Shops or Talking Turkey? Institutionalizing Consumer Representation in Risk Regulation; Hartley and Kokotovich (2017) Disentangling Risk Assessment: New Roles for Experts and Publics.

55 Stirling (2008) "Opening Up" and "Closing Down".

56 Rip (1986) Controversies as Informal Technology Assessment; Rayner (2004) The Novelty Trap: Why Does Institutional Learning About New Technologies Seem So Difficult?

57 For instance see for suitable methodologies to be adapted: Bellamy et al. (2013) 'Opening Up' Geoengineering Appraisal: Multi-Criteria Mapping of Options for Tackling Climate Change; Whatmore (2009) Mapping Knowledge Controversies. For alternative methods see also Meckin and Balmer (2017) Engaging the Senses, Understanding Publics: Research Methods, Science Engagement, and Synthetic Biology; Ginsberg et al (2014) Synthetic Aesthetics; Selin and Sadowski (2015) Against Blank Slate Futuring: Noticing Obduracy in the City Through Experiential Methods of Public Engagement.

58 In technical terms, it would shift the topic from one of 'novelty' to one of 'continuity'. See Joly (2015) Governing Emerging Technologies? the Need to Think Outside the (Black) Box.

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Annex: Review methodology

This review is based on systematic literature and media searches conducted during March 2018, supplemented in May 2018.

Literature searches

In order to identify publications and media reporting on the topic of Genome Editing, the following set of search strings were used.

It is important to note that the review was commissioned to target public discussion specifically, thus our searches explicitly focused on co-occurrence of synonyms for Genome Editing and the public, potentially excluding articles focusing solely on regulatory or ethical aspects.

Sources	Genome Editing		Public		Discussion
Academic Literature • Web of Knowledge • Scopus • Google Scholar • SSRN preprint archive Grey Literature • Google • DuckDuckGo	"genome edit*" "gene edit*" "CRISPR" "gene drive*" "TALEN" "TALENs" "ZFN" "New Breeding Techn*"	AND	"public*" "stakeholder*" "citizen*" "dialogue*" "forum*" "deliberation*"	(repeat with) AND	"attitude*" "aspiration*" "concern*" "perception*" "hope*" "hype*" "understanding" "debat*" "discussion" "views" "engagement" "dialogue" "participation"

Social listening

In order to rapidly gauge discussion in the public sphere, we monitored high level and prominent social and other media relating to gene technologies.

4.1.2. Mass media

A search in Nexis for the terms "genome editing" OR "gene editing" OR "gene drive" OR "CRISPR" in the headlines or lead paragraphs of UK national newspaper articles over the past 2 years (1 March 2016- 5 May 2018). This revealed 298 articles. Reading the headlines only, and removing duplicate, excessively short or other non-applicable articles (65) left 233 relevant articles. 120 of these articles were specifically related to human gene editing. Searches that cover the whole article text with no limit on timeframe produced 1457 results. Media can provide an indication of public

discussion. Although excluded because of resources, an in-depth analysis of a comprehensive corpus must contain other online sources (e.g., for instance Buzzfeed, Reddit).

4.1.3. Twitter

A brief 30-day (January-February 2018) tweet frequency analysis using the search term "gene editing" revealed limited twitter discussion about gene editing (13,465 tweets). Specific tweets over the months of January and February 2018 containing the terms "gene editing" (on its own, or with the additional search terms "public" or "governance") were explored in more detail to gauge information about the publisher, types and content of tweets being disseminated. A more thorough and rigorous analysis is recommended, if required, for a more accurate description of the data.

4.1.4. YouTube

A YouTube search for "gene editing" AND "public" had 8430 results ("gene editing" had 288,000 hits). The first 50 results were explored to get a sense of the publisher, types and content of the YouTube clips. A more thorough and rigorous analysis is recommended, if required, for a more accurate description of the data.

4.1.5. Hansard

Searches for gene editing, Genome Editing, genome edited, gene edited and GMO were conducted using the UK parliamentary record. Because of the large amount of responses (124 spoken references and 17 written statements) reference to GMOs were later excluded, leaving 8 spoken references to Genome Editing in the House of Lords and House of Commons.

Activity review

Public engagement and science communication activities and events carried out, especially those that fall outside formal literature / reporting, were explored. These were identified from preliminary literature searches described above and specific searches of Eventbrite.

4.1.6. Parliamentary inquiry and Nuffield Council on Bioethics evidence analysis

In order to gauge active parties, written and oral evidence was scraped and collated from four UK policy studies relating to non-human Genome Editing:

1. House of Commons Science and Technology Committee (2015) Inquiry into new plant breeding technologies
2. House of Lords Science and Technology Committee (2016) Genetically Modified Insects Inquiry
3. Nuffield Council on Bioethics (2016) Genome Editing: An Ethical Review
4. House of Commons Science and Technology Committee (2017) Inquiry into Genomics and Genome Editing

Submissions were coded according to a sector. However, it is important to note that this data is messy. E.g. some submissions contained evidence from a range of individuals / organisations in a number of different sectors. Some organisations submitted duplicate or supplementary evidence. Duplicates were removed, and, if more than one author contributed to the evidence, the evidence

was assigned a category relating to the lead author. Because of this, a full mapping is therefore recommended.

4.1.7. Eventbrite

To begin to gauge self-organising public engagement, we conducted searches of past and future events listed on the website Eventbrite. URLs were first extracted from site specific searches of Eventbrite using Google and DuckDuckGo. Any event containing the terms CRISPR, Genome Editing or Gene Edit were returned. Duplicates were removed, and the resulting URLs were fed into a Webscraper to obtain event listing information, organiser, date and location. Data were cleaned (e.g. removing false positives) and mapped geographically using Tableau. Further analysis of the contents of events is possible, recommended. Analysis should be supplemented with data from other publicly listed sites, e.g. Meetup.