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Genetically Modified Insects

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CONTENTS

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Q in footnotes refers to a question in oral evidence.

SUMMARY

The problems caused by infectious disease and agricultural pests are real. Genetically modified (GM) insects have the potential to address both these problems. The UK is a world leader in the development of this technology. The European Union's regulatory process, however, is likely to hold back progress. There is a moral duty to test the potential of the technology. We therefore support further research and call for action to test the efficiency of the EU process via a trial which should also be used to drive public engagement.

The world's fastest growing insect-borne disease is dengue. The global incidence of dengue has grown dramatically in recent decades and about half of the world's population is now at risk. Dengue can be found in tropical and sub-tropical climates across the world. The possibility of an outbreak of dengue, however, now exists in Europe. This mosquito-borne viral infection causes a flu-like illness, and can develop into a potentially lethal complication named severe dengue. Severe dengue is a leading cause of hospitalization and death among children in many Asian and Latin American countries. A recent study estimated there to be 390 million dengue infections per year.

In 2015 there have been approximately 214 million cases of malaria and 438,000 deaths. Sub-Saharan Africa is particularly affected; so far this year, the region has been home to 89% of malaria cases and 91% of malaria deaths. Malaria is both preventable and curable, and increased efforts have seen significant reductions in malaria incidence (the rate of new cases) and deaths. Nevertheless, about 3.2 billion people, nearly half of the world's population, live in countries, territories and areas where malaria is endemic.

By 2050 the world's population will likely increase by more than a third to over 9 billion people. World food production will be required to increase by 70% to feed this larger, more urban and richer population. Insect pests affect all aspects of food production, storage, transport and waste. Agricultural losses due to insect damage are high. For example, insect pests cause an average annual loss of 7.7% in production in Brazil, a reduction of approximately 25 million tons of food, fibre and biofuels, with total annual economic losses reaching around US$ 17.7 billion. Insect-borne diseases also have a heavy impact on livestock. Research conducted at the Pirbright Institute in the UK prevented Bluetongue disease becoming endemic in UK sheep and cattle, an estimated saving to the UK economy of £480 million in 2008 alone.

The development and use of GM insects offers significant potential for both the control of infectious diseases and the management of agricultural pests. It is possible to manipulate an insect's DNA in order to alter its function or reduce its fitness. In this way, insects which transmit diseases or damage crops can be modified. GM insect technologies are a potential form of biological control, in contrast to the use of chemical controls, such as insecticides, which can be harmful to people and the environment.

GM insect technology has already been trialled for dengue transmitting mosquitoes. Developed by the UK company Oxitec Ltd., field evaluations have seen a >90% reduction in numbers of the target species in the Cayman Islands and a 96% reduction in Brazil, which is argued to be sufficient to prevent endemic dengue fever anywhere in the world. From the evidence we heard, it

may be the case that GM insect technology is more suited to tackling dengue than malaria.

In November 2015, scientists announced that they had successfully used GM insect technology so that a modified mosquito passes on genes conferring resistance to a pathogen (an organism that causes disease) to almost all of its offspring, not just half, as would normally be expected. This offers the possibility of a gene resistant to the parasite that causes malaria being able to spread quickly through a wild population of mosquitoes. In early December 2015, scientists, including Professor Austin Burt who gave oral evidence to our inquiry, announced findings that could speed up the development of techniques to suppress mosquito populations to levels that would not support malaria transmission.

The potential of GM insect technologies, however, should not be over-stated; an arsenal of strategies is required to tackle insect-borne diseases and crop pests. GM insect technologies do not represent a panacea. They are one of a number of experimental techniques being investigated in order to control insect-borne diseases and reduce agricultural pests.

Nevertheless, despite inevitable uncertainties, we conclude that GM insect technologies should be afforded an opportunity to play a complementary role in helping to meet the global challenges of disease control and food security. The UK, moreover, is a world leader in this area and hosts the only company in the world producing and distributing GM insects (Oxitec Ltd.).

Unfortunately, we are very concerned that the benefits offered by GM insects may not be realised. The EU regulatory regime for genetically modified organisms (GMOs) is not functioning effectively. Although no EU-level GM insect applications have been received to date, the regime has seen many applications for GM crops. In these cases, the regime is failing lamentably. The prescribed process is not being followed and the system is gridlocked. Strenuous efforts must be made to ensure that the system operates more efficiently and that future GM insect applications are not stymied unnecessarily. To this end, the UK Government must bring pressure to bear on the European Commission to ensure that the current regime works as intended.

However, ensuring that the current system works as intended is not sufficient. The EU regulatory regime does not take into account the benefits of a technology; regulation is entirely on the basis of risk. Any rational approach to deciding whether or not to pursue a given technology should include an assessment of its net benefits. At the moment, moreover, no consideration is given to the risks of alternatives to the GM application. A potential new GM insect technology to reduce an agricultural pest population, for example, would not be compared alongside the insecticide currently used to tackle the pest. As such, GMOs are effectively considered against an idealised, risk-free alternative. For many GM insect technologies, the alternative may present a number of risks and problems, and, in many cases, such risks and problems (the use of insecticides for instance) may be the imperative behind the development of the GM insect technology in the first place. Consideration of the benefits of a technology, and acknowledgment of the control methods currently in use, should be incorporated into the regulatory regime in order to address this illogical situation.

In order to attempt to break the current impasse, we recommend that the Government invests in a GM insect field trial to test fully the science of GM insects, regulatory processes and policies. This stimulus is required in order to move beyond the current stasis induced by the failings of the EU regulatory regime. Moreover, the pursuit of such a trial should be the catalyst for a public engagement exercise. It is imperative that the public is given the opportunity to understand the development of GM insect technologies in a transparent way so that the polarised debate which has enveloped GM crop technologies is avoided.

GM insect strategies for agricultural use are likely to have greater scope for application within the EU, though there may be future uses for public health purposes that could be applicable in Europe. In all likelihood, however, the main uses of GM insect technologies, particularly for public health purposes, will occur outside the EU. In this regard, we are concerned that the application of GM insect technologies in the countries whose need is greatest may be affected by a lack of international guidance and leadership on the governance and regulation of these technologies. We therefore recommend that the Government, in light of its strong commitment to international development, actively considers how these challenges of international guidance and leadership can be fully achieved.

The application of GM insect technology, together with advances in the broad area of biotechnology, has the potential to provide additional tools for the control of insect-borne diseases and crop pests. The conceivable prize is enormous and the opportunity must not be squandered. Our concern is that unless there is change, and an injection of momentum and urgency, it will be.

Genetically Modified Insects

CHAPTER 1: INTRODUCTION

Our inquiry

1. The United Kingdom has eminent academic research groups working in the area of genetically modified (GM) insects, including those guided by Professor Luke Alphey[1] at the Pirbright Institute and Professors Austin Burt and Andrea Crisanti at Imperial College London.[2] Furthermore, Oxitec Ltd. is a biotechnology company based in the UK that has drawn on the UK's scientific excellence to produce and distribute GM insects with the aim of controlling insects that spread disease and damage crops. Spun-out from the University of Oxford, it is the only company in the world, to the best of our knowledge, which is engaged in this activity.

2. Against this background, the presence of a pioneering company based in the UK, and the world class research being conducted in our universities and institutes, we decided to pursue an inquiry into GM insects. Primarily, we set out to:

   - explore the potential of GM insect technologies to control human and livestock diseases and crop pests; and

   - establish whether the regulatory environment was conducive to the development and deployment of GM insect technologies.

3. In the chapters that follow, we discuss the underpinning science, its potential applications and the prospects for commercialisation. We next consider the complex regulatory environment and conclude by addressing concerns about the use of these technologies and the role of public engagement. In this regard, we were well aware during our inquiry that GM technologies remain a contentious area of science, and that debates around GM insect technologies are inevitably held in the shadow of the controversy over GM crops. As such, while this report focuses on GM insects, it has been necessary, from time to time, to enter more generic debates around GM technologies and the biotechnology sector, not least because the regulatory regime for GM crops is also applied to GM insects.

4. Many of the recommendations that we make in our report coalesce around our conviction that there ought to be a GM insect field trial to test fully the science of GM insects, regulatory processes and policies. If the Government is not minded to accept the case for a field trial, however, we would ask that it does not then dismiss all the issues that we think should be considered in the context of the field trial, but responds to them in turn.

5. The science underpinning the development of GM insects is complex and the terminology used is often not straightforward to understand. We have endeavoured to be as clear and accessible as possible without over-simplifying

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1 Prof Luke Alphey established Oxitec Ltd. as a spin-out company from the University of Oxford in 2002.

2 We would also wish to acknowledge the valuable research being undertaken across Europe and the rest of the world.

unduly. Appendix 5 attempts to explain some of the technical terminology referred to in this report.

6. We would like to thank everyone who gave evidence to us, both at oral evidence sessions, which we held across October and November 2015, and in writing. We also wish to thank our Specialist Adviser, Professor Michael Bonsall, who greatly assisted our work.[3]

7. Finally, we note our surprise and regret that individuals and groups who are sceptical of the merits of GM technologies did not engage with our inquiry. No written submissions were received from groups known for their concerns about GM, and there was seemingly little appetite from them to give oral evidence to us. There was, of course, no obligation on this community to engage with our inquiry. Nevertheless, it was puzzling that they did not wish for their voices to be heard.

3 We also wish to acknowledge the role of the Parliamentary Office of Science and Technology (POST). Its POSTnote, *GM insects and disease control,* POSTnote 483, November 2014; together with the subsequent briefing meeting it hosted earlier this year, served to stimulate our interest in this topic.

CHAPTER 2: THE SCIENCE BEHIND GM INSECTS

8. GM insect technology is an emerging field across many disciplines in biology, including molecular genetics, ecology, environmental management and synthetic biology. GM insects are created by inserting genes into an insect's DNA (deoxyribonucleic acid) in order to alter its function or reduce its fitness. In this way, insects which transmit diseases or damage crops can be modified.

9. Many potential genes have been identified that influence the biology of insects. Short sequences of carrier genetic material, usually DNA or RNA (ribonucleic acid), are used to integrate a novel gene into an insect's genome. By injecting this genetic package into insect eggs or embryos, genetically modified strains can be created.

10. Currently, recombinant[4] DNA technology has been used to create transgenic[5] insects with:

- marker genes (fluorescent markers for distinguishing modified from unmodified insects);
- lethal genes (that cause an insect to die, or make it unable to reproduce); and/or
- refractory genes (that confer resistance to a particular pathogen[6], rendering the insect unaffected or unable to transmit a disease).

11. GM insect technologies build on methods developed in the mid-twentieth century (for instance, sterile insect technique—explained below). These technologies represent a form of biological control in contrast to the use of chemical controls, such as insecticides, which have dominated the management of insect disease vectors and pests historically. GM insect technologies can be grouped into population suppression or population replacement strategies. We will explain these strategies in turn.

Population suppression

12. A population suppression strategy seeks to reduce the size of an insect population by introducing a lethal gene whereby offspring cannot survive. A population of so-called sterile[7] insect males is reared in the laboratory and released into the environment to mate with wild females. The resulting offspring are non-viable and as such the insect population is reduced.

13. GM insect population suppression strategies are based on the traditional Sterile Insect Technique (SIT) used in pest management. This approach involves a large-scale (inundative[8]) release of mass-reared sterile male insects

4 Bringing together genetic material from multiple sources, thereby creating sequences that would not otherwise be found in the genome.
5 Modified via insertion of genetic material from another organism.
6 An organism that causes disease. For example, in dengue infection, the pathogen is a virus whereas in malaria infection, the pathogen is a unicellular parasite.
7 The term 'sterile' is commonly used although the male insects are able to reproduce; albeit to yield non-viable offspring. This is by way of analogy with the traditional SIT insect approaches that yield insects that are in fact reproductively sterile as a result of irradiation.
8 Inundative biological control involves the release of massive numbers of the control agent in order to control the pest rapidly.

into wild, native insect populations so that there is a highly skewed sex ratio of sterile males to wild females.

14. Traditional SIT approaches usually achieve sterilisation using radiation or chemicals. SIT has been applied most widely against agricultural pests, particularly screwworm, Mediterranean fruit fly and Mexican fruit fly. There have been some attempts to use this sterile insect technique for the control of insect vectors[9] such as mosquitoes.

15. GM analogues of the traditional SIT technique arguably present a more precise approach to population suppression strategies. Genes can be specifically targeted to be active in particular insect life stages, hence making it more likely that the viability and fitness of the modified insect are not compromised.

Population replacement

16. Population replacement strategies aim to modify an insect with heritable traits in order to affect insect physiology or, in the case of disease vectors, render a pathogen harmless in the insect. This involves introducing a genetic modification into an insect that is designed to be inherited and so, over time, an entire insect population can be altered to include this modification.

17. Population replacement strategies require less mass-rearing than population suppression strategies and it is expected that the heritable constructs will spread through populations by means of gene drive mechanisms. It is anticipated that these modifications will be persistent in an environment.

Gene drive and gene editing

18. The aim of gene drive is to cause a gene to spread through a population at a greater rate than would be the case with natural inheritance. Recent advances in molecular biology provide an array of techniques for editing genes and engineering gene drive mechanisms.[10] These molecular methods cut genes at specific sites and can be used to insert novel genes or disrupt specific gene function. For instance, CRISPR-Cas9 endonucleases[11] cut specific gene sequences, and together with specific RNAs (ribonucleic acid), can be guided to specific sites in a genome. After the cut, gene repair mechanisms replace the original sequence with an altered version of the sequence. Recent developments, based on the CRISPR-Cas9 gene-editing method, have shown that this gene drive can be used to modify insect populations rapidly.

19. One recent piece of research, published in the *Proceedings of the National Academy of Sciences* in November 2015, reported that US based scientists had successfully used the CRISPR gene editing method so that a modified mosquito resistant to a pathogen passed these new resistance genes onto almost all of its offspring, not just half, as would normally be expected.[12] This offers the possibility of a gene resistant to the parasite that causes malaria

9 A vector is any agent (person, animal or microorganism) that carries and transmits an infectious pathogen into another living organism.

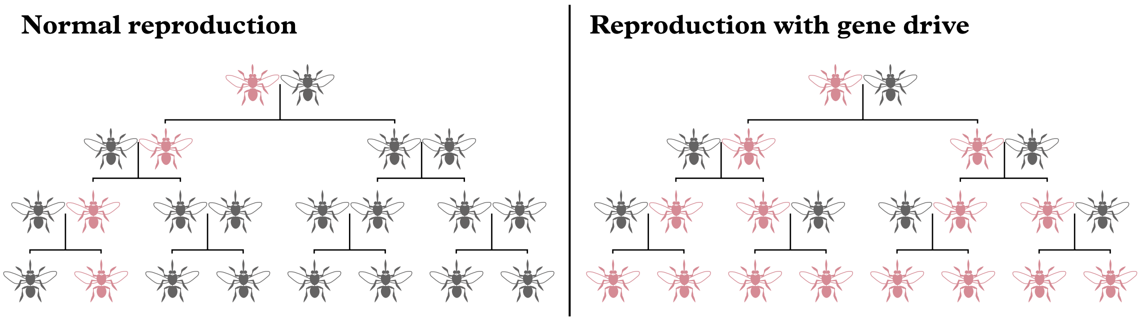
10 These approaches include: zinc finger nucleases, TALENS (transcription activator-like effector nucleases) and new CRISPR (clustered regular interspaced short palindromic repeats) based techniques.

11 An enzyme (biological catalyst) which cuts strands of DNA at specific points.

12 'Gene drive mosquitoes engineered to fight malaria', *Nature* (23 November 2015): http://www.nature.com/news/gene-drive-mosquitoes-engineered-to-fight-malaria-1.18858?WC.mc_id=TWT_NatureNews [accessed 9 December 2015]

being able to spread quickly through a wild population of mosquitoes. The principal investigator behind this research, Professor Anthony James, submitted evidence to our inquiry.[13] Just before we went to press in early December 2015, scientists, including Professor Austin Burt who gave oral evidence to our inquiry, announced findings that could speed up the development of techniques to suppress mosquito populations to levels that would not support malaria transmission.[14]

Figure 1: A simplified depiction of natural inheritance versus inheritance with a gene drive construct



A red fly will leave only a few offspring under normal reproduction. A gene drive that favours 'red' colour can ensure that nearly all offspring inherit the 'red' colour gene causing it to spread rapidly through the population.

Resistance and resistance management

20. The development of resistance to control methods is an inevitable phenomenon; there will always be an evolutionary response to genetic changes resulting in altered characteristics in organisms. This will arise irrespective of the method by which the alterations occurred.

21. Many agricultural insect pests have evolved resistance to widely-used insecticides. Resistance evolution to gene modifications, although currently unreported, is entirely possible. The development of resistance would have economic and environmental effects due to loss of efficacy of the control intervention. Environmental costs would include the potential effects on ecosystems and human health of increased use of alternative control measures (insecticides) and/or the use of additional gene technologies.

22. We were told of the need to monitor resistance and include consideration of it in GM insect strategies. The Advisory Committee on Releases to the Environment (ACRE) said of resistance management:

> "In general, we will need to harness our understanding of the mechanisms involved and apply this knowledge on a case by case basis. Where GM insects are used for biological control, integrating different approaches for controlling pest populations will be essential for a durable and resistant outcome."[15]

13 Written evidence from Prof Anthony James (GMI0004)

14 Andrew Hammond et al, 'A CRISPR-Cas9 gene drive system targeting female reproduction in the malaria mosquito vector *Anopheles gambiae*', *Nature Biotechnology*, (2015): http://www.nature.com/nbt/journal/vaop/ncurrent/full/nbt.3439.html [accessed 9 December 2015]

15 Written evidence from the Advisory Committee on Releases to the Environment (ACRE) (GMI0014)

The Wellcome Trust stated:

> "Resistance would be expected to evolve both to the drive mechanism (e.g., mutations in the genomic region you were targeting making the drive mechanism ineffective) and towards any genetic trait you were modifying (e.g., the ability to resist a particular pathogen). In developing such technologies, it will be important to learn from the development of resistance in other pathogens."[16]

23. Austin Burt, Professor of Evolutionary Genetics, Imperial College London, compared the evolution of resistance to GM insect strategies to the resistance developed to chemicals:

> "Overall, I would say it is too early to say whether resistance is more or less likely to evolve compared to a chemical. What I would say is that when you get resistance to a chemical, often it is a whole class of chemicals that they become resistant to, so that takes them off the table. There is a possibility that the genetic approaches will lead to resistance to a specific construct, and by tweaking the construct it would be able to get around the resistance. However, that is a hunch, not something we have proved."[17]

24. There may be a number of ways to combat resistance to GM insect strategies. The use of so-called multi-hit approaches may be one such means. Paul Eggleston, Professor of Molecular Entomology, Keele University, likened this approach to that used in combination drug therapy.[18] In designing such an approach, a number of modifications can be built in so that the desired affect is achieved via a variety of modifications rather than a single means. Professor Eggleston described such an approach:

> "A single intervention such as that may be something which parasites could work their way around. If you engineered your insect with two or three independent approaches that tackled the parasite or the pathogen from a number of different angles, it would be more difficult for those parasites or pathogens to evolve resistance. It is similar to combination drug therapy."[19]

25. Scientific understanding of the evolution of resistance in GM insect strategies is a developing area. As such, on-going research and monitoring will be required in order to increase understanding and to allow for the design of strategies that can maximise the potential to delay the onset of resistance.

26. Using the techniques described above, GM insects could provide alternative and/or additional tools for the control of insect-borne infectious diseases as well as the control of agricultural pests. The next chapter elaborates on the potential applications of GM insect technologies.

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16 Written evidence from the Wellcome Trust (GMI0025)
17 Q 50 (Prof Austin Burt)
18 Q 50 (Prof Paul Eggleston)
19 *Ibid.*

CHAPTER 3: POTENTIAL APPLICATIONS OF GM INSECT TECHNOLOGIES AND PROSPECTS FOR COMMERCIALISATION

Potential public health applications

27. Insect-borne infectious diseases are a significant source of mortality across the world. Malaria is a disease caused by parasites that are transmitted to people through the bites of infected female mosquitoes. According to the most recent World Health Organisation (WHO) estimates, released in September 2015, there have been 214 million cases of malaria in 2015 and 438,000 deaths.[20] The WHO asserts that about 3.2 billion people, nearly half of the world's population, are at risk from malaria. Sub-Saharan Africa is particularly affected; in 2015, the region was home to 89% of malaria cases and 91% of malaria deaths.

28. Malaria is both preventable and curable, and increased efforts have seen significant reductions in malaria incidence (the rate of new cases) and deaths. Between 2000 and 2015, the WHO reports, malaria incidence fell by 37% globally and malaria death rates fell by 60% among all age groups, and by 65% among children under five.[21] Vector control (in other words, controlling infected mosquitoes) is the principal means of preventing and reducing malaria transmission. Vector control, such as the use of insecticide-treated mosquito nets and indoor residual spraying, can be effective in a range of circumstances.

29. The world's fastest growing insect-borne disease is dengue. The WHO reports that the global incidence of dengue has grown dramatically in recent decades and about half of the world's population is now at risk.[22] Dengue can be found in tropical and sub-tropical climates across the world, mainly in urban and semi-urban areas. The possibility of an outbreak of dengue, however, now exists in Europe and local transmission of dengue was reported for the first time in France and Croatia in 2010.

30. This mosquito-borne viral infection causes a flu-like illness and can develop into a potentially lethal complication named severe dengue. Severe dengue, the WHO reports, affects most Asian and Latin American countries and has become a leading cause of hospitalization and death among children in these countries.[23] The actual numbers of dengue cases are underreported, and cases are often misclassified. A recent study estimated there to be 390 million dengue infections per year.[24] As there are no vaccines for this virus, dengue prevention and control depends on effective vector control measures, such

20 World Health Organisation, *Malaria Factsheet No. 94* (reviewed October 2015): http://www.who.int/mediacentre/factsheets/fs094/en/ [accessed 9 December 2015] All information in this paragraph is derived from this source.

21 *Ibid.*

22 World Health Organisation, *Dengue and severe dengue Factsheet No. 117* (updated May 2015): http://www.who.int/mediacentre/factsheets/fs117/en/ [accessed 9 December 2015] All information in this paragraph is derived from this source.

23 *Ibid.*

24 Samir Bhatt et al, 'The global distribution and burden of dengue', *Nature*, vol. 496 (2013), pp 504–07: http://www.nature.com/nature/journal/v496/n7446/full/nature12060.html. The article states that: "Using cartographic approaches, we estimate there to be 390 million (95% credible interval 284–528) dengue infections per year, of which 96 million (67–136) manifest apparently (any level of disease severity)."

as managing environments so that mosquitoes are prevented from getting to egg-laying habitats.

31. Evidence from Research Councils UK (RCUK), on behalf of the Biotechnology and Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC) and the Natural Environment Research Council (NERC), provided examples (though not an exhaustive list) of human diseases to which GM insect technology could be applied, including, but extending beyond, dengue and malaria (Box 1):

Box 1: Diseases to which GM insect technology could be applied[25]

Chikungunya: Chikungunya has been identified in over 60 countries in Asia, Africa, Europe and the Americas. The two mosquito species transmitting this disease can also transmit other mosquito-borne viruses, including dengue fever. Around 1.8 million cases of this viral disease were reported between 2005 and 2007. There is no specific antiviral drug treatment and no commercial vaccine.

West Nile Fever: Birds are the reservoir hosts of West Nile Fever (WNF) virus. In Europe, Africa, Middle East and Asia, mortality in birds associated with WNF infection is rare, but WNF is highly pathogenic for birds in the Americas. WNF virus is transmitted to people and other mammals mainly through mosquito bites as a zoonosis. The virus can cause severe disease and death in horses, but equine vaccines are available. No vaccine is available currently for humans.

Chagas (American trypanosomiasis): Vector-borne transmission occurs in the Americas. The insect vector is a triatomine bug that carries the parasite *Trypanosoma cruzi* which causes the disease. About 6 million to 7 million people are estimated to be infected worldwide, mostly in Latin America. Vector control is the most useful method to prevent Chagas disease in Latin America.

Source: Written evidence from the Biotechnology and Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC) and the Natural Environment Research Council (NERC) (GMI0017). The Research Councils' submission also noted additional diseases to which GM insect technology could be applied: African trypanosomiasis (sleeping sickness), Japanese encephalitis, Leishmaniasis, Lymphatic filariasis and Yellow fever.

32. The Research Councils provided a commentary on how the range of insect disease vectors has changed over recent decades on account of factors such as climate change and globalisation, and that consequently some non-endemic diseases now pose a threat to Europe. They told us that:

> "there are currently five invasive *Aedes* mosquito species known to be established in Europe, of which two species [were] implicated in the recent outbreaks of chikungunya and dengue fever in Europe; laboratory and field observations indicate that they have the potential to also transmit other pathogens of public health importance."[26]

33. We heard considerable enthusiasm for, and optimism about, the potential of GM insect technologies. The British Ecological Society (BES) stated:

> "The potential benefits that GM insect control could bring are obvious. This is especially significant in the case of malaria, where parasites are becoming resistant to drug treatments and mosquitoes are becoming resistant to pesticides, and for dengue where no licensed vaccine or

25 Dengue and malaria are included in the list provided by the Research Councils, but are not reproduced here. See previous paragraphs.
26 Written evidence from BBSRC, MRC and NERC (GMI0017)

dedicated therapy exists, and prevention and control solely depends on effective vector control measures."[27]

34. The Wellcome Trust told us that: "Genetically Modified Insects (GMIs) potentially offer a more targeted and less environmentally harmful approach to insect-borne disease control than non-GM techniques and insecticides."[28] Importantly, the Wellcome Trust stressed that GM insects would play a complementary role alongside existing practices:

> "It is important to note that the most effective way to control vector-borne diseases is through a combination of approaches (e.g., for malaria, a vaccine when available, plus vector control, bed nets and anti-malarials). We envisage GM insects will play a complementary role alongside existing Integrated Pest Management (IPM) programmes and we encourage this approach."[29]

35. Target Malaria, a not-for-profit research consortium, explained the distinct advantages that GM insects could bring to disease control, whilst acknowledging that the use of modified mosquitoes would not be a 'silver bullet', and would be complementary to existing malaria control methods. They stated that modified mosquito technology could provide: "long-lasting effectiveness without the intensity and frequency of application required by current methods … particularly valuable in remote and difficult to access places", and that it could improve access as "the intervention spreads naturally through wild mosquito populations and benefits all communities and individuals, regardless of wealth, education, or access to services and without direct cost to them."[30]

36. In addition, Target Malaria argued that it should be "cost-effective and easily deployable", not needing "extensive facilities, labour or equipment", and, furthermore, "it would not require investment in human behaviour change because people do not need to change the way they work, live or sleep to obtain the protection provided by modified mosquitoes."[31] Target Malaria catalogued further benefits of the technology: "It limits harm to non-target species in the environment because it directly targets only the species of mosquitoes responsible for transmitting malaria, without affecting other species or the environment."[32]

37. The Pirbright Institute set out conditions under which the use of GM mosquitoes would be most beneficial. The Pirbright Institute suggested that they would be most suitable for use where all the conditions below were met:

- "One species of insect is exclusively or almost exclusively responsible for transmission, because the technique only directly affects the target species.
- The insect vector can be readily reared and mass-reared in captivity.
- Only one sex is responsible for the impact of the insect species."[33]

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27 Written evidence from the British Ecological Society (GMI0024)
28 Written evidence from the Wellcome Trust (GMI0025)
29 *Ibid.*
30 Written evidence from Target Malaria (GMI0013)
31 *Ibid.*
32 *Ibid.*
33 Written evidence from the Pirbright Institute (GMI0019)

38. While the evidence we received was often very positive about the role that GM insect technologies could play, we were also made aware of the complexity involved in tackling insect-borne diseases. The differing epidemiology of diseases means that the application of GM insects may be more appropriate in some circumstances than others. GM insect technologies, for example, may be more applicable for the control of dengue than malaria. While mosquitoes which transmit malaria bite between dusk and dawn, mosquitoes transmitting dengue are day-flying. Insecticide treated mosquito bed nets, which can prevent malaria transmission, are therefore not effective against dengue.

39. Chris Whitty, Professor of Public and International Health, London School of Hygiene & Tropical Medicine, and former Chief Scientific Adviser, Department for International Development, expressed caution about the role that GM insect technologies could perform:

> "For the sterile male technique equivalent technologies, it is possible but at the moment it is looking relatively niche. That may improve. For the replacement technologies, I have to say it is pretty speculative. The question is whether you are starting from a public health impact point of view or from a science point of view. From a public health impact point of view, this is a footnote on a footnote at this point in time. That does not mean it will necessarily remain that way."[34]

40. Professor Whitty argued that GM insect technologies may be of more efficacy in controlling dengue rather than malaria:

> "When we come to dengue and the *Aedes*-transmitting mosquitoes, the opportunities for GM technologies are greater, but for malaria, my own view—and I think this is a pretty middle-of-the-road view—is that, even potentially, the opportunity for these technologies is small."[35]

41. Professor Whitty's notes of caution—he described GM insects as "a relatively niche product" that we "may find uses for in due course"[36]—must be taken seriously. He also told us that GM insects were only one example of a number of new technologies under development in order to combat insect-vectored disease. He added:

> "the possibility that this technology [GM insect] might become useful at some later stage strikes me as entirely plausible. For that reason, I am certainly not against investing in it, but what I would not want to do, to go back to a previous question, is take money away from, let us say, investing in getting new insecticides into this technology on the basis that these are somehow comparable. That does not strike me as realistic."[37]

42. We endorse Professor Whitty's view that investment should not be re-directed from the development of new insecticides to GM insect technologies, and we acknowledge that the complexities of disease control, not least the plethora of local circumstances, are manifold. Moreover, we agree that GM insect technologies are currently in their infancy.

34 Q 66 (Prof Chris Whitty)
35 Q 67 (Prof Chris Whitty)
36 *Ibid.*
37 Q 70 (Prof Chris Whitty)

43. **We are, nevertheless, persuaded of the potential of GM insects as part of a complementary approach to pest and vector control management. The sheer disease burden means that all avenues should be explored, and the positive outcome from Oxitec's dengue fever field trials should be capitalised on. This potential must be explored; it would be a mistake not to pursue GM insect technologies for a range of potential applications.**

Potential agricultural applications

44. The Food and Agriculture Organisation of the United Nations (FAO) estimates that by 2050 the world's population will increase by more than a third to over 9 billion people. If this proves correct, it would raise enormous challenges for global food security; world food production will be required to increase by 70% to feed this larger, more urban and richer population.[38]

45. Agricultural losses due to insect damage are large. For example, insect pests cause an average annual loss of 7.7% in production in Brazil, a reduction of approximately 25 million tons of food, fibre and biofuels, bringing annual economic losses of around US$ 17.7 billion.[39] We were told repeatedly that the range of potential applications of GM insects for crop pest and animal disease control is vast. As Rothamsted Research told us:

> "The possible applications of GM insects across the world is enormous as in theory any insect causing nuisance, damage or vectoring disease to livestock and any insect damaging crops either directly or indirectly (via transmission of plant pathogens) could be controlled this way."[40]

46. George Freeman MP, Parliamentary Under Secretary of State for Life Sciences at the Department for Business, Innovation and Skills and the Department of Health, told us that: "globally we see a huge opportunity."[41]

47. The submission received from RCUK provided a useful list of threats to livestock (Box 2):

Box 2: Some current, global threats to livestock (including aquaculture) and horses

Key threats:

- Bluetongue: a viral disease of cattle and sheep; transmitted by biting midges.
- Equine infectious anaemia: a viral disease; transmitted by large biting flies.
- Infectious salmon anaemia: a viral disease; transmitted by sea lice.

38 Food and Agriculture Organisation of the United Nations, *How to feed the world in 2050* (2009): http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf [accessed 9 December 2015]. We note that population control is clearly an aspect of this debate; it was not, however, the focus of our inquiry, so discussion of it is omitted from the paragraphs that follow.

39 Charles. M. Oliveira et al, 'Crop losses and the economic impact of insect pests on Brazilian agriculture', *Crop Protection*, vol. 56, (2014), pp 50–54: http://www.sciencedirect.com/science/article/pii/S026121941300269X [accessed 11 December 2015]

40 Written evidence from Rothamsted Research (GMI0007)

41 Q 79 (George Freeman MP)

Other potential threats (in no particular priority order)

- African horse sickness: a viral disease; transmitted by biting midges.
- Bovine ephemeral fever: a viral disease of cattle; transmitted by mosquitoes.
- Epizootic haemorrhagic disease: a viral disease of cattle and sheep; transmitted by midges.
- Equine encephalosis: a viral disease; transmitted by midges.
- Lumpy skin disease: a viral disease of horses; biting insects implicated in transmission.
- Rift Valley fever: Caused by a virus; can be transmitted to humans as a zoonosis by blood-feeding insects.
- Schmallenberg disease: a viral disease of cattle and sheep; transmitted by biting midges.
- Sheep pox virus; goat pox virus: viral diseases; indirect transmission by insects.

Source: Written evidence from the Biotechnology and Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC) and the Natural Environment Research Council (NERC) (GMI0017)

48. In terms of which of these diseases might be considered particularly important targets, the Agriculture and Horticulture Development Board (AHDB) told us that:

> "For livestock an important target would be the control of a range of Culicoides species which vector bluetongue and Schmallenberg virus infecting livestock in the UK and throughout Europe. Other potential targets related to livestock would be flies in buildings and also blowflies in sheep where in field trapping has been tried in the past."[42]

49. As for agricultural pests and insect-borne crop diseases which can be found across the world, the Research Councils provided an extensive list, which included three particular pests which were highlighted repeatedly during our inquiry:

> "Diamondback moth: the biggest global pest of brassica crops and one of the world's significant agricultural pests, costing farmers billions of dollars every year.
>
> Mediterranean fruit fly: now spreading worldwide, a pest of fruit crops.
>
> Spotted Wing Drosophila (SWD): this is a major threat to soft fruit, stone fruit, tomatoes, vines and other crops and could cause serious losses if not controlled. SWD originated in Asia and has been identified in the UK since September 2012."[43]

50. The AHDB sought to quantify the potential economic benefit from the use of GM insects:

> "The benefits to the UK accruing from the use of GM insects are potentially very large. To give an example it is estimated that the potential

42 Written evidence from the Agriculture and Horticulture Development Board (GMI0015)

43 Written evidence from the Biotechnology and Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC) and the Natural Environment Research Council (NERC) (GMI0017)

losses from spotted wing drosophila in the fruit industry (strawberries, raspberries, blueberries, blackberries, cherries, blackcurrants etc.) are between £80–120 million pounds per year at current levels of production and given current trends in production could rise to £135–235 million in 5 years. Whilst these losses are not realised because of existing control operations these compromise the use of biological control for other pests in fruit systems and can result in the need for repeat releases of biocontrols resulting in an additional cost of thousands of pounds sterling per hectare."[44]

51. The British Ecological Society (BES) highlighted the advantages of GM insect control in comparison to the use of insecticides:

"GM insect control presents numerous benefits when compared with the use of broad spectrum insecticides; it does not rely on the release of toxic chemicals into the environment, and works well against targets that are difficult to find, and/or difficult to reach by conventional practices. These insects are unlikely to yield direct off-target effects however there may be some indirect impacts on wild populations and communities."[45]

52. In terms of the extent to which the potential highlighted above may be realisable, Oxitec Ltd. asserted that they had:

"demonstrated solutions for a number of these pests including the olive fly … the Mediterranean fruit fly which is considered the world's most damaging fruit pest, and *Drosophila suzukii* (spotted wing drosophila) which is now affecting soft fruit growers in the UK. This pest was inadvertently introduced to Europe in 2009 and now threatens a £1.8 billion UK industry including strawberries and raspberries …

… Multiple agricultural applications for pest suppression approaches using the same core technology are ready for field evaluation, and regulatory approvals for field trials have been secured (USA—Diamondback Moth, Pink Bollworm; Brazil—Medfly)."[46]

In summary, a range of GM technologies for the control of agricultural pests is in development and either in or approaching field trials.

53. GM insects clearly have the potential to provide an alternative tool for the control of insect crop pests and vectors of livestock diseases. Current technological solutions for the control of pink bollworm (a major pest of cotton), Mediterranean fruit fly and diamondback moth are currently under different stages of development and have the potential to be a novel tool to be integrated into the control of many agricultural pests. It is, of course, uncertain whether, and to what extent, this potential may be realised. We are persuaded that as the potential 'prize' is so great, and the challenge of food security so profound, every effort must be made to realise benefits in this area.

Speculative applications

54. GM insects may also play a future role in tackling invasive species. The suppression of such populations could bring conservation benefits. The

44 Written evidence from the Agriculture and Horticulture Development Board (GMI0015)
45 Written evidence form the British Ecological Society (GMI0024)
46 Written evidence from Oxitec Ltd. (GMI0016)

British Ecological Society (BES) told us of the potential of GM insects to play a role in wildlife conservation, for instance, in "the control of avian malaria (*Plasmodium relictum*) which continues to threaten multiple native species in Hawaii after the introduction of mosquitos in the early 19th century."[47]

55. Professor Luke Alphey, Head of Arthropod Genetics Group, The Pirbright Institute, noted the problem of invasive species:

> "Invasive species are a huge problem for conservation and biodiversity in any number of different places and some of those are insects, so what about controlling those? Those might be the same technologies as we are talking about here, but for a conservation biology target rather than a human health target."[48]

56. We envisage that there could be future potential for the application of GM insect technologies beyond infectious disease control and reduction of agricultural pests.

GM insect research in the UK: funding and commercialisation

57. Against the background of the many potential applications highlighted above, we sought information on the research and development underpinning this sector in the UK and the prospects for commercialisation of GM insect technologies. Sources of funding for GM insect research in the UK involve a mixture of public, charitable and private investment: including RCUK studentships and research grants; Innovate UK[49] grants; Wellcome Trust and Gates Foundation funding; and private investment from Oxitec Ltd.

58. RCUK, over a five-year period ending in 2014/15, have invested approximately £50 million in GM insect research.[50] An important distinction, however, must be drawn within this between two different kinds of GM insect research. The first relates to the use of GM insects as a research tool in laboratories in order to increase fundamental scientific understanding of genetics, cellular development and other aspects. Such model organisms would never be deliberately released into the environment; that is not the purpose of the research. The second is GM insect research of the type considered by this inquiry, that is modification of insects that, upon release, could have public health or agricultural pest management applications. A smaller proportion of funding has been invested in the latter, approximately £3.9 million from BBSRC and MRC together.

59. GM insects have not been a targeted funding priority for RCUK. Dr Paul Burrows, Executive Director, BBSRC, explained that funding has come from what is called 'responsive mode' sources whereby researchers apply for money. On the number of such applications received, he stated:

> "The fact is, at the moment, we are not seeing many of those [responsive mode funding applications], and that is why the spend is relatively small."[51]

47 Written evidence form the British Ecological Society (GMI0024)
48 Q 55 (Prof Luke Alphey)
49 Formerly the Technology Strategy Board (TSB); an executive non-departmental public body charged with progressing science and technology innovations in order to grow the UK economy.
50 For a detailed breakdown of BBSRC, MRC and NERC spending on research related to GM insects from 2010/11–2014/15 please see their written evidence (GMI0017).
51 Q 3 (Dr Paul Burrows)

60. Dr Burrows told us that a specific RCUK strategic initiative to drive research into GM insect technologies would be unlikely. He suggested, however, that a broader initiative could be possible:

> "it would be framed in a much broader sense of alternative control mechanisms for agricultural diseases or something, so it would keep the options open. There is no reason why, technically, we should not prioritise this type of research in the future, along with all the other priorities that we have and our future budgets, if it was considered to be a priority."[52]

61. Innovate UK funding in the broad biocontrol area has been approximately £3.2 million to date; approximately £1 million of this relates to the GM insects research of the type considered by this inquiry, which has been received by Oxitec Ltd.[53]

62. Professor Luke Alphey, Head of Arthropod Genetics Group, The Pirbright Institute, highlighted the support of Innovate UK as crucial in the development of fledgling businesses:

> "Although it is very small scale, the support of Innovate UK … for small companies is very valuable, and R&D tax credits are very helpful. For those relatively early stages, there is a good economic environment, albeit perhaps a little at risk at the moment."[54]

63. GM insect research in the private sector in the UK is dominated by Oxitec Ltd., a British biotechnology company, and the only company in the world producing and distributing GM insects.[55] Oxitec was (August 2015) recently acquired by Intrexon Corporation, an NYSE-listed public company with operations in North America and Europe. Oxitec's primary operations, including its research and development facilities, continue to be based in the UK. Ian Meikle, Head of Agriculture and Food, Innovate UK, perceived this as a good example of inward investment rather than a development which should necessarily cause concern.[56]

64. The BioIndustry Association (BIA), reflecting on the acquisition of Oxitec, also saw the acquisition as a positive development:

> "Successful business deals like Oxitec's will send a positive signal: a) to other companies, encouraging them to invest and grow in the UK and potentially to list on the public markets; and b) to the investment community, stimulating additional interest in UK biotechnology from specialist and cross-over investors."[57]

65. The UK is currently a world-leader in the field of GM insects. Professor Tim Dafforn, Chief Scientific Adviser at the Department for Business, Innovation and Skills, told us:

> "scientifically we lead or are close to leading in insect molecular biology, which covers both of these [areas]: the fundamental and what Oxitec

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52 Q 6 (Dr Paul Burrows)
53 Q 2 (Ian Meikle)
54 Q 54 (Prof Luke Alphey)
55 Written evidence from Oxitec Ltd. (GMI0016)
56 Q 8 (Ian Meikle)
57 Written evidence from the BioIndustry Association (GMI0026)

> do. You have to remember that we have one company that leads; it is the only company in the world as well. It leads not just the UK; it leads the world."[58]

66. The National Institutes of Bioscience provided a helpful analysis of the commercial prospects for GM insect deployment (Box 3):

Box 3: Prospects for commercial GM insect deployment

As developer: design and development of GM insects and GM insect based control methods represent an emerging, knowledge-intensive and potentially high-value industry. Total value is hard to estimate, but it could potentially address a number of multi-billion-dollar problems in agriculture and public health around the world. Could the UK become a leader in this industry? What are the potential sources of comparative advantage, if any, for the UK, as a developer of GM insect technology?

Current position: The UK has a clear lead in the commercial development of GM insect technology through Oxitec … The UK also has a number of leading academic research groups active in this area, including those led by Luke Alphey (The Pirbright Institute) and Austin Burt and Andrea Crisanti (both Imperial College), world-leading developers of GM insects, respectively focusing on self-limiting and self-sustaining methods. More generally, the UK has a strong bioscience sector in universities, research institutes and small and large companies. However, there is competition in the US and elsewhere, notably China where there has been considerable recent investment in this area. Furthermore, the current regulatory—and perhaps political—situation makes it hard to test GM insects in the UK. This has a knock-on effect on potential markets as there is an expectation that a developer would first test a product "at home". Developers that can do this will have an advantage over those that cannot.

Market: as noted above, the domestic market for this technology is limited. This precludes a common route for small companies of starting with a local market then expanding. If the government were to encourage the development of GM insect technology for those specific, otherwise intractable problems for which it seems appropriate, this would catalyse and underpin the development of an export industry which would likely otherwise struggle to gain traction.

Source: Written evidence from the National Institutes of Bioscience (GMI0012)

67. In a similar vein, Innovate UK suggested that the UK could benefit economically from new GM insect technologies but warned that a restrictive regulatory environment could have an impact on this:

> "The UK has the capability in the underpinning science and technology to benefit economically whether that deployment is within the UK, EU or elsewhere. However, where deployment is only possible in overseas markets, the UK risks losing its world-leading talent."[59]

68. Ian Meikle, Head of Agriculture and Food, Innovate UK, alluded to opportunities for Innovate UK to invest further in GM insect research:

58 Q 7 (Prof Tim Dafforn)
59 Written evidence from Innovate UK (GMI0008)

> "going from a responsive mode to being targeted, that is something where we would look for the results of this inquiry, certainly in the Innovate UK space, and we always work in partnership with the research councils. If the results of this inquiry are positive, we could certainly do something that was more targeted to draw through more."[60]

69. It will, of course, be vitally important to ensure that the excellence of the science base, and the UK's world-leading research groups and institutes in this field, continue to be supported appropriately.

70. **We conclude that the excellence of the science base, investment in infrastructure and the skills pipeline must at least be preserved, and preferably enhanced, in order to maintain the UK's position as a world-leader in GM insect technology development. In this regard, we welcome the Chancellor's announcement in the recent Spending Review that the resource budget for science will be protected in real terms for this Parliament.**

71. **We also welcome the announcement, as part of the Spending Review, of the new £1 billion Ross Fund[61] which will be used to support the global fight against malaria and other infectious diseases. The Ross Fund will provide an opportunity for further research and development into products for fighting infectious diseases. This will benefit low to middle income countries which bear the greatest burden of infectious diseases.**

72. **On account of the potential that GM insects offer, both economically and in terms of public health, we conclude that there is a strong case for Innovate UK to invest further in this area to promote commercialisation of UK-based GM insect research. We therefore recommend that Innovate UK, in partnership with the Research Councils, considers providing targeted funding in order to develop the commercial deployment of GM insect technologies (see also paragraph 147).**

73. It is important to note that only population suppression strategies, not population replacement strategies, have been taken towards commercialisation so far. Population replacement strategies may not be able to be commercialised as the desired outcome can be achieved by a single or limited number of releases.

74. We were dismayed to be told by Professor Luke Alphey that it was the EU regulatory environment, and European views on GM, which were holding back the development of GM insect technologies:

> "The fact is it is impossible to sell this technology in Europe at the moment. Field trials, perhaps, but there seems to me no possibility of getting commercial registration in a reasonable time, or even having any idea how much time or money it would take. That is probably the biggest negative factor …

60 Q 15 (Ian Meikle)
61 Named after Sir Ronald Ross, the first ever British Nobel Laureate who was recognised for his discovery that mosquitoes transmit malaria.

> … it is the view of GM in Europe which has this chilling effect on the investor community as well, because they think, 'You will never be able to do that', or, 'It will take too long or be too expensive,'"[62]

75. As articulated above by Professor Alphey, and alluded to by others in previous paragraphs, we were told, time and again, that the principal and overwhelming barrier to the fulfilment of commercial potential, at least for population suppression strategies, was the EU regulatory regime, and it is to this issue, which we now turn. As George Freeman MP, Parliamentary Under Secretary of State for Life Sciences at the Department for Business, Innovation and Skills and the Department of Health, put it to us:

> "Unless we are also a good economy for using innovation, putting it to work and testing it in the field, we are in danger of being simply a good place to do research but the commercialisation will go elsewhere. That argument writ large confronts the EU on an even bigger scale."[63]

62 Q 54 (Prof Luke Alphey)
63 Q 80 (George Freeman MP)

CHAPTER 4: REGULATION OF GM INSECT TECHNOLOGIES

The current regulatory regime

76. The current regulatory framework for GM insects in the UK is underpinned by two EU directives: contained use (2009/41/EC)[64], which assesses measures for the contained use of genetically modified organisms (GMOs[65]), for example, in research; and deliberate release (2001/18/EC)[66], which outlines the risk assessment required before any release of GMOs into the environment. These directives have been transposed into UK law to create a set of national regulations. Crucially, this regime covers all transgenic GMOs created using recombinant DNA technology, including both GM crops and GM insects.

77. There is also an EU regulation (1946/2003)[67] on the transboundary movement of GMOs, which provides for implementation of the international Cartagena Protocol on Biosafety. Broadly, this aims to ensure there is prior informed consent before a GMO is exported from one country to another. Companies working in this area, such as Oxitec Ltd., are also regulated under quarantine regulations and the animal feed and animal by-products regulations.[68]

78. These regulatory requirements, with the exception of the implementation of the Cartagena Protocol on Biosafety, only apply to trials and commercial releases within the EU. In all likelihood, the main uses of GM insect technologies, particularly for public health purposes, will occur outside of the EU. There is a dichotomy between the geographic location of the underpinning scientific research and where some of the main applications will likely be.

79. There is no consistent, internationally recognized, regulatory protocol or convention for the testing and release of GM insects. This appears to conflict with the fact that insects, unlike crops or other GMOs, are not contained by national boundaries. Indeed, increasing global import and export trade means that insects can readily be moved across the world.

80. In 2014, the World Health Organisation (WHO) produced guidelines on testing GM mosquitoes.[69] Whilst they did not propose a regulatory framework, it is a clear, practical document that discusses elements that could be part of a regulatory framework i.e. case by case assessments, increasing environmental exposure in incremental steps, risk/benefit, efficacy and stakeholder engagement. The guidelines describe regulatory regimes and discuss risk assessment frameworks.

81. The immediate beneficiaries of GM insect technologies that serve to control insect-borne diseases are most likely to be in low to middle income countries

64 Directive 2009/41/EC of the European Parliament and of the Council of 6 May 2009 on the contained use of genetically modified micro-organisms
65 A GMO is an umbrella term for any organism whose genetic material has been changed.
66 Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC
67 Regulation (EC) No 1946/2003 of 15 July 2003 of the European Parliament and of the Council on transboundary movement of genetically modified organisms
68 Written evidence from Oxitec Ltd. (GMI0016)
69 World Health Organisation, *Guidance framework for testing of genetically modified mosquitoes* (June 2014): http://www.who.int/tdr/publications/year/2014/guide-fmrk-gm-mosquit/en/ [accessed 9 December 2015]

(LMCs). The Institute for Science, Innovation and Society, based at the University of Oxford, highlighted the situation in Latin America where a number of ad-hoc approaches to regulation have developed. They warned:

> "Regulatory jurisdictions without a central authority in charge of assessing new GMO releases have struggled to deal with the complex challenges posed by GM insects."[70]

82. Professor Anthony James, Distinguished Professor of Microbiology & Molecular Genetics at the University of California Irvine, also highlighted this situation and suggested that it may serve to hold back the development of GM insect technology:

> "the circumstances created by the fragmented regulatory jurisdictions of multiple international, national and local agencies, and how this lack of coherency puts at risk the development of new technologies for which specific review and approval pathways do not exist."[71]

83. Professor James cited a specific example he had experienced of selecting collaborators and sites for field trials of a transgenic mosquito strain developed to control the spread of dengue:

> "The issue of how to get regulatory approval for the testing of a new technology when there was no dedicated agency to receive and review our applications was not trivial. Applying our checklist criteria, we identified Mexico as the only country at the time that had a horizontally- and vertically- integrated regulatory structure that could assure complete and ethical approval. Brazil may be there now."[72]

84. George Freeman MP, Parliamentary Under-Secretary of State for Life Sciences, Department for Business, Innovation and Skills and the Department of Health, also highlighted that we must "make sure that we get the international framework right."[73]

85. For resource-poor countries with limited regulatory capacity—the key constituency for vector control applications of the technology—GM insects may represent a problematic area of governance and regulation.

86. **We are concerned that the application of GM insect technologies in the countries whose need is greatest may be affected by a lack of international guidance and leadership on the governance and regulation of these technologies. We recommend that the Government, in light of its strong commitment to international development, works through international organisations to help to address challenges of international guidance and leadership.**

87. GM insect strategies for agricultural use are likely to have greater scope for application within the EU. Furthermore, there may be future uses for public health purposes that could be applicable in Europe. Hence it remains vital that the regulatory environment in the EU is fit for purpose.

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70 Written evidence from The Institute for Science, Innovation and Society (GMI0030)
71 Written evidence from Prof Anthony James (GMI0004)
72 *Ibid.*
73 Q 75 (George Freeman MP)

88. Scientific risk assessment is currently the foundation of the EU regulatory process for GMOs. The European Food Safety Authority (EFSA) performs this assessment at the EU level and serves as the scientific advisory body that informs the European Commission. At the UK level, the Advisory Committee on Releases to the Environment (ACRE) gives statutory advice on the risks to human health and the environment from the release of GMOs. Established under the Environmental Protection Act 1990, ACRE advises the Secretary of State for Environment, Food and Rural Affairs as well as Scottish and Welsh Ministers.

89. Directive 2001/18/EC on deliberate release has arguably the most influence on the regulatory environment for GMOs and, as such, was the main focus of our inquiry. It is implemented through two parts: part B for research trials (assessed nationally—in the UK by ACRE) and part C for commercial release (assessed at the EU level by EFSA). That is to say: the regulation of trials is a national decision. Any larger scale commercial use, however, would require EU approval.

90. No applications have been made to release GM insects in the UK for research purposes, and across all EU Member States (MS) there has only been one national application for a trial release of GM olive flies in Spain in accordance with part B of 2001/18/EC (see Box 4). There have been no applications at an EU level for commercial release (part C of 2001/18/EC). Dr Ladislav Miko, Deputy Director-General in the DG for Health and Food Safety at the European Commission, highlighted this and emphasized that the current regulatory framework remains untested for GM insects: "we have never had any applications, so we do not have practical experience."[74] Why the regime remains untested is a question that we will return to.

Box 4: Oxitec GM olive fly (OX3097D) application[75]

Oxitec Ltd. developed a GM insect approach to tackling olive fly pests based on a genetic-equivalent of the traditional SIT approach. After contained trials, the strain OX3097D of modified flies was deemed ready for a field trial. Oxitec made an application to the Spanish National Authorities under Ley 9/2003 (the implementation of part B of directive 2001/18/EC in Spain) in late 2012.

The Spanish authorities, however, felt that they could not authorise the trial without additional data and significant containment measures in place. Due to the timeframes required to generate the data, Oxitec determined that the appropriate administrative approach would be to withdraw the application and re-submit at a later date.

In 2015, a new regulatory submission was made to the Spanish authorities which included additional data. Despite having addressed the 2012 requirements, concerns remained with the second application regarding the confinement of the trial site. While additional confinement measures were presented, it appeared to Oxitec that only a fully-contained trial would be accepted and the application was subsequently withdrawn once again.

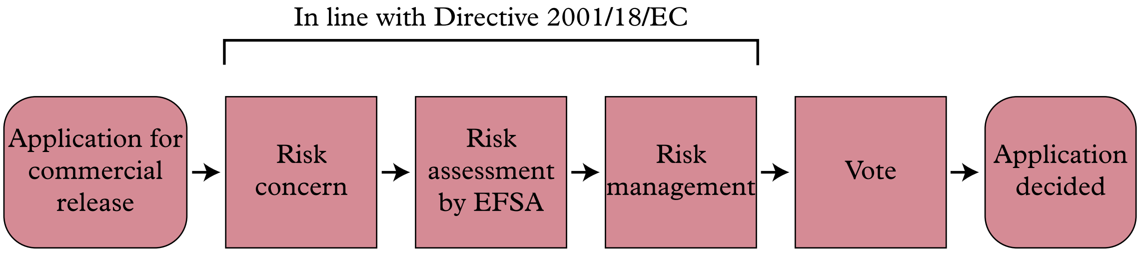
74 Q 88 (Dr Ladislav Miko)
75 Based on further supplementary written evidence from Oxitec Ltd. (GMI0033)

The governments of Brazil and the USA, Oxitec report, have recently allowed environmental release approvals (outside of netted enclosures) for self-limiting GM insect plant pests based on identical technology. While risk assessment is case-by-case, and site specific considerations are unique, Oxitec highlighted to us that they find it difficult to rationalize the decision of the Spanish authorities given the internationally accepted principles of evidence-based risk analysis.

The only application for a GM insect field trial in the EU failed. "We cannot even get to the first hurdle of getting a genetically modified insect in a field cage," Oxitec told us.[76]

91. Figure 2 depicts how the EU regulatory process for GMOs should function in accordance with part C of directive 2001/18/EC.

Figure 2: The EU regulatory process for GMOs



92. While the process depicted in Figure 2 looks plausible, we were repeatedly told that there were profound problems with how the system works in practice. The Minister of State for Farming, Food and the Marine Environment, Department for Environment, Food and Rural Affairs, George Eustice MP, told us that that the principal problem for GM crops was one of implementation, and explained how a situation of deadlock had been reached:

> "we do not think there is anything particularly wrong with the regime as written, but there is certainly a great deal wrong with the way it is implemented, in that if all member states followed the evidence and had a risk-based approach, there are actually lots of checks and balances in the system, but there is no reason why an application, if it were proved to be safe, should not proceed to commercial cultivation in a relatively straightforward way and in a relatively short timeframe. In practice, we have seen, frankly, political deadlock over the last 10 years between member states and an inability to get qualified majority voting to block [GM crop] cultivation, or indeed to allow cultivation, and a feeling generally from the Commission that because this is such a divisive hot potato, there are usually lots of reasons to ask for more evidence and new reviews and for outdated information to be updated. So we tend to have applications that have been stuck in limboland in most cases for many, many years."[77]

93. At the insistence of the UK, an agreement was reached last year on allowing national derogations for commercial cultivation of GM crops. We acknowledge the efforts made by the Government to achieve this. George Eustice MP hoped that this "might unblock that logjam and make other

76 Q 29 (Camilla Beech)
77 Q 75 (George Eustice MP)

member states less inclined to try to block these cultivations so that we can allow member states that want to do the commercial cultivation of crops that are shown to be safe to do so."[78]

94. The Minister told us about how the process became log-jammed:

> "What tends to happen is that member states that have more political objections to these technologies find reasons to question the science, to question the recommendation. Again, that is foreseen in the process, so when that happens the Commission asks the EFSA to carry out its own independent assessment. When that authority concludes, it then makes a recommendation to the Commission, and at that point the matter should go to a vote and either be carried or not under QMV.[79] The difficulty is that whenever these have come back and gone to QMV, there is never a QMV to do either one thing or the other. What should happen at that stage is that the Commission can go ahead and authorise it if that is where the balance of evidence lies. I hope that it will be more inclined to do that now that we have allowed the national derogation."[80]

95. This is a bleak picture. The process for GM crops is clearly failing lamentably. It is not working as intended. The new national derogations for commercial cultivation of GM crops,[81] referred to by the Minister, are to be broadly welcomed as a potential means of breaking the gridlock, but only time will tell if they can have any effect.

96. Concerns expressed about the regulatory regime were voluminous, and extended beyond poor implementation, and the vagaries outlined by the Minister, to fundamental misgivings about the design of the regime. We heard repeatedly, from nearly all parties involved, that the system does not work as intended and is subject to excessive political interference once the scientific risk assessment has been completed by EFSA. Policy-makers should not ignore the scientific evidence base.

97. Further concerns highlighted to us also included:

- regulation was not designed with GM insect technologies in mind, but is rather an extension of the legislation for GM crops;
- regulation is entirely on the basis of risk, and benefits are not considered;
- the process is regulated rather than the product generated; and
- self-limiting population replacement strategies are considered in the same way as self-perpetuating population replacement strategies.

98. In the paragraphs that follow, we briefly catalogue the litany of criticism that was directed towards the regulatory regime. As Dr Jack Stilgoe, Senior

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78 Q 75 (George Eustice MP)

79 Qualified majority voting (QMV) is the most widely used voting method in the EU Council of Ministers. A qualified majority is reached if two conditions are met: 55% of Member States vote in favour—in practice this means 16 out of 28; and the proposal is supported by Member States representing at least 65% of the total EU population.

80 Q 76 (George Eustice MP)

81 As of October 2015, an amendment to directive 2001/18/EC allows Member States to restrict or prohibit the cultivation of genetically modified organisms (GMOs) in their territory. Directive (EU) 2015/412 *of the European Parliament and of the Council of 11 March 2015 amending Directive 2001/18/EC as regards the possibility for the Member States to restrict or prohibit the cultivation of genetically modified organisms (GMOs) in their territory* (March 2015).

Lecturer at the Department of Science and Technology Studies, University College London, put it to us: "I am afraid it is one of those situations where you could say 'you wouldn't start from here'."[82] We agree, but we have, of course, no choice, and if the potential of GM insects is to be realised, then urgent actions are required.

99. As we have noted, the regulatory regime covers all GMOs including both GM crops and GM insects. Although it does remain to be seen if GM insect applications would be subject to regulatory difficulties resulting from part C of directive 2001/18/EC, all the experience of GM crops would seem to point to it. Professor Rosemary Hails, Chair, Advisory Committee on Releases to the Environment (ACRE), stated: "in the EU we do not have a functioning system for GM crops."[83] Camilla Beech, Head of Regulatory Affairs at Oxitec Ltd., gave a clear view from the commercial sector:

> "As an applicant we believe that the European system does not work because it is just not predictable. You put an application in and you can never predict when you are going to receive a response. That is bad for innovation and it is bad for companies."[84]

100. Innovate UK stressed that the deliberate release directive had not been designed with GM insect technologies in mind, but was rather an extension of the legislation for GM crops: "The current regulations pre-date the existence of GM insects and do not seem to effectively accommodate this technology."[85] George Eustice MP, however, disputed the view that the currently regulatory regime could not effectively accommodate GM insect technologies: "from a regulatory point of view, we do not see any reason why the GM process that exists for crops in the EU should not equally be applied to GM insects."[86]

101. We heard repeatedly that there is currently no means to consider the potential benefits of GMOs within the regulatory regime. As such, decisions are made entirely on the basis of risk alone. The National Institutes of Bioscience (NIB) stated:

> "Without considering benefits, one is implicitly comparing the proposed action with a non-existent risk-free alternative—a Utopian fallacy. Benefits, and therefore risk-benefit, could be considered explicitly."[87]

102. Furthermore, we were surprised to learn that new technologies are not evaluated alongside alternative means to address the problem. For example, a potential new GM insect technology to reduce an agricultural pest population would not be compared alongside the insecticide currently used to tackle the pest.

103. The current EU regime operates via a system of process-based regulation. That is to say, the trigger is the process by which a product is made rather than the nature of the product itself. In this regard, Camilla Beech, Head of Regulatory Affairs at Oxitec Ltd., offered the following analogy: "It is

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82 Q 42 (Dr Jack Stilgoe)
83 Q 28 (Prof Rosemary Hails)
84 Q 28 (Camilla Beech)
85 Written evidence from Innovate UK (GMI0008)
86 Q 75 (George Eustice MP)
87 Written evidence from the National Institutes of Bioscience (GMI0012)

like reviewing a book as to whether it has been written on a typewriter or a computer and not on its content."[88]

104. This process-based system would consider population replacement and population suppression GM insect strategies in the same way. John Mumford, Professor of Natural Resource Management, Centre for Environmental Policy, Imperial College London, highlighted a fundamental conflict within the current framework when population replacement strategies were considered:

> "there are seven large areas of technical concern within the deliberate release directive, and persistence is one of those seven. Obviously, with the self-sustaining mode of action for some of these methods, you are starting from an assumption that the whole mode of action is a concern. That is an inherent conflict within the regulation."[89]

In this way, the deliberate release directive is fundamentally not designed to consider self-perpetuating population replacement strategies.

105. The criticism directed towards the regulatory regime raises the question of whether the focus should be on making the current system work better, or seeking to overhaul it entirely. Professor Rosemary Hails argued that there would be merit in trying to make the existing system work as it should:

> "We ought to be proactive on trying to make the current system work more effectively. In essence, we have the evidence that it works more effectively in other countries."[90]

106. The current system is framed around the implementation of the Precautionary Principle. On the use of this Principle, Professor Rosemary Hails stated:

> "the Precautionary Principle properly applied would also take into account the risks of not developing a particular technology and the benefits forgone. It is a misuse of the Precautionary Principle that has led us to this place."[91]

107. The Government maintains that the best course of action is to ensure that the regulatory environment works as it is written. George Eustice MP said: "All the EU has to do is not necessarily rewrite its process but just gain some credibility by sticking to the process that it has written down."[92]

108. George Freeman MP put it in the following terms:

> "GM technology is taking off across the world. The question is not whether we are going to stop it; the question is whether we are going to help contribute to leading it and getting the right regulatory framework in place."[93]

88 Q 35 (Camilla Beech)
89 Q 45 (Prof John Mumford)
90 Q 30 (Prof Rosemary Hails)
91 Q 33 (Prof Rosemary Hails). The Precautionary Principle was the focus of a recent report from our counterpart Committee in the House of Commons. As such we will not focus on it here. For further discussion of the use and misuse of this principle, we refer to their report: House of Commons Science and Technology Committee, *Advanced genetic techniques for crop improvement: Regulation, risk and precaution* (Fifth Report, Session 2014–15, HC 328)
92 Q 81 (George Eustice MP)
93 Q 77 (George Freeman MP)

109. We welcome the Government's endorsement of the potential of GM technologies and its recognition of the importance of a functioning regulatory environment. We are concerned, however, by its view that the most appropriate course of action is only to ensure that the current system proceeds as it is written. This is not sufficient.

110. **GM insects have the potential to help in the control of both insect-borne diseases and agricultural pests, bringing both public health and economic benefits. The UK is a world leader in the development of GM insect technologies and the public good and the commercial opportunities are tangible. However the current EU regulatory regime for GMOs risks this opportunity being squandered. The regime is failing as applied to GM crops and the full potential of GM insects will not be realised if it continues to fail to function adequately.**

111. **We accept that there is some practical merit in the Government's decision to work to ensure that the existing regulatory regime for GMOs at least functions as written. We ask the Government to set out clearly how it intends to do so and to publish annual updates on progress made in improving the operation of the system, starting in the summer of 2016. However, we do not accept that this is sufficient and we advocate a more radical review of the regulatory framework later in this Chapter.**

International regimes

112. By way of comparison, we explored a number of international (non-EU) regulatory frameworks for GMOs in order to ascertain the characteristics of alternative regulatory regimes. Norway was cited as a notable example. Although a non-EU country, Norway is a member of the European Economic Area (EEA). As a member of the EEA, it has incorporated EU-based regulation but has also included an additional component. Professor Rosemary Hails told us:

> "Norway has some additional legislation—the Gene Technology Act 1993—where it considers the benefits also of a particular element to the community and the contribution to sustainable development, but that is in addition to the other regulations."[94]

113. Outside Europe, we were told that Canada has adopted a regime of trait-based regulation. This is effectively the reverse of the system in the EU whereby process-based regulation is used. Dr Jeremy Sweet, an Environmental Consultant with Sweet Environmental Consultants and member of the EFSA GMO panel, said of the Canadian system:

> "they do not discriminate GMOs from other types of engineering or manipulation or technologies. They look at the novelty of a product and say, 'Are we concerned about this and do we need to look at it and regulate it?'"[95]

114. Oxitec Ltd. highlighted the regulatory environment in Brazil. This regulatory system has been tested, unlike that in the EU, and the Brazilian authorities accepted a trial release of Oxitec GM mosquitoes. Oxitec suggested that this successful release in Brazil was due to "a clear regulatory framework based on

94 Q 27 (Prof Rosemary Hails)
95 Q 28 (Dr Jeremy Sweet)

plausible scientific pathways to harm and subsequent evaluation allowed the assessment of the dossier for commercial release in approximately 9 months from submission to approval."[96] From what we heard of the EU regulatory system, such efficiency would seem highly unlikely were a similar application to be received.

115. Oxitec also highlighted the regulatory environment in the USA where, under the National Environmental Policy Act, agencies are required to issue an Environmental Assessment that takes into consideration the alternatives available alongside the GMO application.[97] Thus, GM insects are not considered against an idealised 'risk-free' alternative.

116. The joint submission received from a grouping of eminent Brazilian scientists—Dr Amaro de Castro Lira Neto, Dr Marcia Almeida de Melo and Professor Paulo Paes de Andrade—also highlighted the US system of regulation. They suggested that the main point of success of the US system is:

> "the full independence of the risk assessment procedure against the other risk analysis steps, i.e., risk management and risk communication, and ultimately against political decisions."[98]

Furthermore they stressed that: "No political interference is allowed, at least under normal circumstances."[99]

117. This independence of the risk assessment procedure from political decision-making presents a stark contrast to the picture painted for us of the EU regulatory system. This group of Brazilian scientists also suggested that this independence is the cause of rapid adoption of biotechnology in Brazil and, to a certain extent, in Argentina, Australia and Canada as well.

Alternative regulatory protocols

118. We were presented with a number of alternative regulatory models that may allow for more effective incorporation of GM insects into the general GMO regulations. A number of these have been touched on above. Warnings were issued, however, about the pursuit of a new regulatory regime. George Eustice MP stressed to us:

> "with any European process you always have to be conscious that by taking the lid off things and trying to play around with the wiring, you might end up with something worse. It is a terrible thing to say, but I am afraid there is a track record of trying to tamper with things in Europe that are not quite right, and they end up worse than ever."[100]

119. Although a radical overhaul of the current regulatory process may be unlikely or undesirable at this time, a number of potential alterations to the regulatory process were highlighted to us.

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96 Written evidence from Oxitec Ltd. (GMI0016)
97 *Ibid.*
98 Written evidence from Dr Amaro de Castro Lira Neto, State Institute for Agronomy (IPA), Dr Marcia Almeida de Melo, Federal University of Campina Grande, and Prof Paulo Paes de Andrade, Federal University of Pernambuco (GMI0006)
99 *Ibid.*
100 Q 83 (George Eustice MP)

A trait-based approach

120. A trait-based approach to regulation was raised as a sensible, scientifically-sound alternative to the current process-based regulatory system.[101] In this case, the product, rather than the means by which it has been formed, is considered. This system is in operation in Canada. Professor Rosemary Hails indicated that ACRE would deem this approach to be more scientifically defensible and "more scientifically rational now."[102] Dr Jeremy Sweet also highlighted that trait-based regulation is a "science-based approach".[103]

121. A move to a trait-based system would allow separate consideration of GM insects created via population suppression and population replacement strategies. It would also result in population suppression approaches such as Oxitec's genetic-equivalent of the SIT being considered in the same way as traditional irradiation-based SIT approaches. This may be more rational as the nature and implications of the end products are arguably the same; it is simply that the process to create them is different.

122. Not all the evidence we heard suggested that trait-based regulation is superior to process-based regulation. Dr Jack Stilgoe warned us that there may be good reasons for a process-based system:

> "They are to do with the uncertainties that we might be unable to predict in terms of the products, whether those are the products themselves or the products of that particular innovation in terms of the consequences and ramifications of those traits, and actually paying attention to the processes might better take you into a precautionary approach to governing those uncertainties."[104]

123. New technological developments may be captured within a system of trait-based regulation. For example, both transgenic[105] and cisgenic[106] GMOs would be included. Dr Jeremy Sweet indicated that it is becoming increasingly difficult to draw a distinction between "GM" and "non-GM". He emphasised to us that: "We are getting into a bigger and bigger mess by basing the regulation around the technology."[107]

124. Government Ministers also highlighted to us that new emerging technologies are serving to blur the boundaries between GM and non-GM. However, on the prospect that trait-based regulation could incorporate new (cisgenic) technologies and remove the need for such arbitrary classifications, George Eustice MP stated:

> "We would not want those [emerging technologies] to be treated as GM, otherwise you are going to hold back the development of a very exciting new area."[108]

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101 Our counterpart Committee in the House of Commons included consideration of the merits of a trait based approach in their Report: *Advanced genetic techniques for crop improvement: Regulation, risk and precaution* (Fifth Report, Session 2014–15, HC 328)
102 Q 30 (Prof Rosemary Hails)
103 Q 28 (Dr Jeremy Sweet)
104 Q 42 (Dr Jack Stilgoe)
105 Modified via insertion of genetic material from another organism.
106 Modified via rearrangement of genetic material within the organism.
107 Q 28 (Dr Jeremy Sweet)
108 Q 83 (George Eustice MP)

He continued:

> "Once you start talking about trait-based approaches to this, I think there is a danger that you start to tip some of those other novel techniques too closely to the GM regulatory regime, which is the worst of all worlds, because then you have other exciting new technologies that we hope to protect from this and to maintain an understanding that they are not GM, and get muddled up in this unsatisfactory regime as well."[109]

125. At present, cisgenic organisms, such as those created using gene-editing techniques, including CRISPR, are not considered within 2001/18/EC. We consider this to be correct. We heed the warning that a move to trait-based regulation would alter this situation. However, while we agree with the Minister that new emerging technologies should not be stifled by a failing regulatory system, we do not think it appropriate to ignore the deficiencies of the regulatory regime for other developing (transgenic) technologies.

126. **We urge the Government to monitor the development of new genetic technologies, including GM insects, in order to ensure that the regulatory regime is fit-for-purpose. We recognise that a move to a trait-based system may not currently be appropriate. We see the risk that a move to a trait-based system may be counter-productive in the short term. We acknowledge, however, that trait-based regulation may be a valid long-term aim in order to develop a more scientifically robust, overarching regime once current regulatory barriers within 2001/18/EC have been addressed.**

Monitoring and surveillance of persisting GMOs

127. Persistence is not currently accounted for within the directive 2001/18/EC. The Institute for Science, Innovation and Society at the University of Oxford highlighted that 'future-proofing' would be needed in light of the development of self-sustaining, persistent gene-drive techniques:

> "These 'second generation' varieties will present a radical challenge to existing regulatory frameworks. For one, they will likely require forms of pre-release testing and post-release monitoring yet to be developed."[110]

128. Mechanisms will be required in order to allow for effective post-release monitoring and tracking of new genetic material promoted via gene drives, and designed to persist in the environment, particularly as these may not be included within 2001/18/EC. This could include means to implement both ecological monitoring and GM screening. The Institute for Science, Innovation and Society continued:

> "We need better tools for the monitoring of GM insects in the environment, and the development of these tools needs to be addressed in a public and straightforward manner by the relevant scientific and regulatory institutions."[111]

We are persuaded by these arguments.

109 Q 83 (George Eustice MP)
110 Written evidence from The Institute for Science, Innovation and Society (GMI0030)
111 *Ibid.*

129. **The ecological impact of GMOs designed to persist in the environment presents a new regulatory challenge. In light of the advances in gene-drive research, we conclude that underpinning research is required in order to allow effective monitoring and tracking of this new generation of genetic modifications. The regulatory framework should take persistence into account and stipulate appropriate monitoring requirements.**

Consideration of benefits and evaluation alongside alternatives

130. We heard a number of times that taking into account the benefits of a technology could be a desirable addition to the current regulatory process. ACRE has given thought to how this could work within the existing framework. Professor Rosemary Hails explained to us that:

> "For example, in the whole risk assessment process, the very last question is to characterise the overall risk of a GM organism. Additional information could be provided on context under that question and that context could include benefits also. The reason why that does not happen routinely is the questions leading up to that final question do not put in the building blocks for benefits in the same way as they do for risks."[112]

131. Although any rational approach to deciding whether or not to pursue a given technology would include an assessment of its net benefits, the key element must first be sound scientific risk assessment. Professor John Mumford stated:

> "the risk assessment stage should be independent of values such as benefits. Those may enter at a later stage at the risk management stage, where a decision is made, but not at the assessment stage. Assessment should be objective and management should focus on performance and benefits."[113]

132. We heard different views on how benefits might be considered. Benefits and risk are often considered as opposites. However, Sir Roland Jackson, Executive Chair, Sciencewise, questioned this linkage and stressed that benefit is not the opposite of risk. He urged that benefits and dis-benefits be considered alongside each other. Risks and dis-benefits must not be conflated. He provided us with the following clarification:

> "Questions of benefits encompass a much wider range of issues than the question of science-defined risk. If you are to have a system that looks at benefits as well as risk, you have to look at wider dis-benefits—things like impacts on employment, ways of farming or landscapes, which are not dealt with in a risk assessment."[114]

133. Benefits must be considered at an appropriate stage of the regulatory process and not confused with scientific risk assessment. We consider that benefits and dis-benefits should be considered after the process of scientific risk assessment has taken place, at the risk management stage.

134. As well as confusion surrounding benefits and dis-benefits, more clarity is needed in considering hazard, exposure, risk, and vulnerability. In the

112 Q 27 (Prof Rosemary Hails)
113 Q 40 (Prof John Mumford)
114 Q 21 (Sir Roland Jackson)

Government Chief Scientific Advisor's 2014 annual report *Innovation: managing risk, not avoiding it*, Sir Mark Walport argued that it is vital that these terms are understood.[115] Hazard is frequently equated or confused with risk, and this leads to poor debate, confused communication and flawed decision-making.

135. Professor Austin Burt highlighted the potential perversity in not including consideration of the benefits of a GM insect strategy. He stated:

> "I would not go to a Government in sub-Saharan Africa with this idea of a genetically modified mosquito and not talk about malaria. That does not make sense."[116]

Professor Luke Alphey reiterated this view:

> "If you are not talking about the benefits and the reasons why you are doing it, how will you persuade anybody it is worth doing? At that level it does not make any sense."[117]

136. The Government do not think that considering benefits should be pursued, despite appreciating the logic behind these arguments. George Eustice MP suggested that such a move would be unlikely to make a significant change in ameliorating the current major problems at the EU level:

> "My argument would be if the problem is a political barrier and an overly cautious political culture, to say that we are just going to balance the risk against benefits does not do much to reassure that problem."[118]

137. Dr Ladislav Miko, Deputy Director-General in the DG for Health and Food Safety at the European Commission, corroborated this perspective:

> "In my view, all the experience we have shows that the position of member states which are not supporting the GMs will not be dramatically changed by any socio-economic analysis."[119]

138. Benefits were not the only additional consideration that we were told ought to be incorporated into the regulatory regime. As previously highlighted, in the current regime GMOs are effectively considered against an idealised, risk-free alternative. Obviously such an alternative does not exist. Furthermore, for many GM insect technologies, the alternative presents a number of risks and problems. In many cases, this is the imperative behind the development of the GM insect technology in the first place. A clear example is insecticides.

139. The Institute for Science, Innovation and Society called for evaluation of GM insects alongside alternative approaches to the problem in question. They stated that: "Application of genetic methods of insect control should be evaluated alongside alternative courses of action."[120] While the existing plausible pathways to harm requirements go some way towards

115 Annual Report of the Government Chief Scientific Adviser 2014, *Innovation: Managing risk, not avoiding it* (2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381905/14-1190a-innovation-managing-risk-report.pdf [accessed 9 December 2015]
116 Q 53 (Prof Austin Burt)
117 Q 53 (Prof Luke Alphey)
118 Q 81 (George Eustice MP)
119 Q 92 (Dr Ladislav Miko)
120 Written evidence from The Institute for Science, Innovation and Society (GMI0030)

acknowledging this, we perceive it to be vital that, on a case-by-case basis, appropriate comparators are used.

140. **We consider the argument for including the benefits of a technology within the regulatory process to be entirely valid. Furthermore, we do not agree with the stance of the Government and the European Commission that there would be little to gain in modifying the current framework to include consideration of benefits. We recommend that consideration of benefits and dis-benefits be incorporated into the regulatory regime once the scientific risk assessment has taken place, during the risk management stage.**

141. **Furthermore it is inappropriate that new GMO technologies are considered in relation to an unrealistic, risk-free alternative. We recommend that the regulatory process should acknowledge control methods currently in use, such as insecticides, which a new technology may replace.**

142. It is clear to us that the regulatory regime is failing as it is currently applied to GM crops. Furthermore, we envisage that these failings would likely affect GM insect applications. Views on how the regime could be improved are numerous. Action, as we recommended earlier in this chapter, needs to be taken to try and improve the current system, but this is only sufficient as a first step.

143. We are concerned that a situation has arisen whereby applications are not received due to concerns over the regulatory framework, yet the regulatory framework cannot be tested nor improved until such an application materialises. There are concerns that GM insect applications would likely be subjected to the considerable delays experienced by crop applications. The Minister, George Eustice MP, described such applications to us as being "stuck in limboland."[121]

144. Action needs to be taken to try and breathe new life into this policy area and provide some momentum and a focus for activity. It is with this in mind that we think the Government should initiate an insect trial akin to the Farm Scale Evaluations of new GM crop technologies.[122] In our view, this would represent a positive means of trying to break the regulatory deadlock.

145. **The fact that the current EU regulatory regime remains untested for GM insect technologies is a major barrier to progress. Only when a field trial application has been approved will we be able to move forward. We therefore conclude that action must be taken to instigate a field trial which should also be used to drive public engagement (see Chapter 5).**

146. **We therefore recommend that the Government actively pursues and invests in a GM insect field trial to test fully the science of GM insects, regulatory processes and policies. This trial could be considered as**

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121 Q 75 (George Eustice MP)

122 For consideration of the Farm Scale Evaluations, please see: Maria Burke, *GM crops: Effects on farmland wildlife* (October 2003): http://cib.org.br/wp-content/uploads/2011/10/estudos_cientificos_ambiental_19.pdf [accessed 9 December 2015]. This publication, produced by the Farmscale Evaluations Research Team and the Scientific Steering Committee, and written by Maria Burke, is a summary of the scientific papers published in the *Philosophical Transactions of the Royal Society* (Biological Sciences), Vol. 358, Issue 149, 1775–1889.

a GM insect counterpart to the Farm Scale Evaluations of new GM crop technologies undertaken from 1999 to 2006. Such a trial should be dual-approach in nature and investigate both an agricultural pest and a species of mosquito.

147. **In order to undertake this trial, Government departments, including DEFRA, BIS and DFID, should work together to develop a proposal to be put out for tender to the UK science community. Funding should be drawn from these Government departments as well as Innovate UK (see paragraph 72).**

148. **Alternative regulatory approaches should be considered in the light of this trial, including those highlighted in this report, such as: consideration of benefits, evaluation against real-world alternatives and trait-based regulatory triggers.**

149. **Alongside this trial, with the aim of ensuring that regulation remains relevant and up to date, we recommend that the Government monitors the suitability of the regulatory environment for emerging technologies, such as GM insects, to ensure that the potential benefits they could bring are not stifled at inception due to anachronistic regulation. This includes the development of new mechanisms to allow for effective post-release monitoring and tracking of new genetic material promoted via gene drives. We recommend that the Government issues an annual statement which provides their assessment of the suitability of the regulatory environment for emerging technologies.**

CHAPTER 5: CONCERNS, PERCEPTIONS AND PUBLIC ENGAGEMENT

Anxieties, awareness and attitudes

150. History has shown that genetically modified organisms (GMOs) are an area of high public interest. Possibly more so than any other area of new science and technology over the last 20 years, they have captured public anxieties and sparked concerns about the direction of scientific development.

151. In the UK, public awareness of the scope and potential of GM insect technologies is yet to be mapped. However, during the course of our inquiry it became clear to us that a low level of current public awareness is assumed by those working in the area. Sir Roland Jackson, Executive Chair of Sciencewise, gave a summary of the opportunities provided thus far for the public to learn about GM insects:

> "There has been quite a bit of media comment and reporting about it, but no significant structured public information and engagement in that sense, or dialogue in terms of listening to what people think about the issues."[123]

152. Public attitudes towards GM crops or GM in general are often taken as a substitute for likely public opinion on GM insects. On general attitudes, Sir Roland Jackson stated: "it is quite clear that there is no evidence of overwhelming intrinsic opposition to GM."[124]

153. An example of a specific public outreach initiative on GM insects in the USA was brought to our attention by Dr Sarah Hartley, a Research Fellow at Nottingham University, who is investigating the relationship between science, ethics and public policy in the context of the governance of emerging technologies. She cited an analysis of the public anxieties surrounding the approval of a trial of GM diamondback moths in New York State. This analysis showed that the public was concerned about governance and about GM insects more broadly. On the implications of these concerns, Dr Hartley stated that "there is potential for public rejection of GM insects, particularly within agricultural applications."[125]

154. It was suggested to us that public perception of GM insect technologies is likely to be influenced by attitudes developed in response to the public debate on GM crops. While we recognise that scientific evidence, though central, should not be the sole consideration taken into account, this highly polarised debate was characterised by a dominance of anecdotal information, misrepresentation of scientific evidence and media scaremongering. We agree with the perspective offered to us from Matt Shardlow, Chief Executive, Buglife—the Invertebrate Conservation Trust: "it is a morass of confusion."[126] We are concerned that such a debate could evolve for GM insect technologies and serve to stifle their development. Action should be taken in order to avoid this scenario.[127] In this regard, we are encouraged by a recent GM wheat

123 Q 17 (Sir Roland Jackson)
124 Q 18 (Sir Roland Jackson)
125 Written evidence from Dr Sarah Hartley (GMI0023)
126 Q 64 (Matt Shardlow)
127 For a comprehensive review of the GM crop debate see the recent report by the House of Commons Science and Technology Select Committee, *Advanced genetic techniques for crop improvement: Regulation, risk and precaution* (Fifth Report, Session 2014–15, HC 328)

trial undertaken by Rothamsted Research which caused far less controversy on account of the public engagement strategies that were deployed.[128]

155. We envisage that specific public attitudes towards GM insect technologies may be shaped by a variety of anxieties. A number of such possible concerns were brought to our attention:

- horizontal gene transfer within the environment;
- potential impact on ecosystems;
- effects on predator/prey relationships and the food chain;
- evolution of more virulent strains of particular pathogens following GM control;
- a general feeling that GMOs are unsafe and create risks for individuals and the environment;
- the potential for unknown and unintended consequences;
- questions about intellectual property, patenting and excessive corporate involvement; and
- lack of confidence in scientists, companies and governments to understand and appropriately regulate the myriad possible implications of GMOs.

156. While some of the concerns noted above relate to GM insect technologies as a whole, there are a number of distinct concerns solicited by population suppression and population replacement strategies. In comparing population replacement strategies with population suppression approaches, Professor Paul Eggleston said to us:

> "one key difference is that you would not end up with an empty ecological niche. You will have insects there at the beginning and at the end [with a population replacement strategy], and therefore food supplies for organisms that eat those insects."[129]

157. While population replacement strategies may have different ecological impacts, the release of modified genetic material designed to persist in the environment presents divergent and significant concerns. As previously stated (paragraph 129), we envisage that mechanisms will be required in order to allow for truly effective post-release monitoring and tracking of new genetic material promoted via gene drives.

158. Despite a number of ethical and safety concerns being highlighted to us, we heard no suggestion that these concerns are so great that the use of GM insect technology should not be explored. We recognise, however, and wish to emphasise, that as these technologies develop, consideration of the ethical and safety concerns that surround GM insect technologies will be vital in order to inspire and maintain public confidence. Furthermore, we wish to emphasise that while consideration of the scientific evidence is clearly crucial,

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128 Dr Jack Stilgoe, *A tale of two trials* (4 September 2015): https://jackstilgoe.wordpress.com/2015/09/04/a-tale-of-two-trials/ [accessed 9 December 2015]

129 Q 49 (Prof Paul Eggleston)

we recognise that cultural, historic and economic experience is also relevant and must be considered.

159. Public attitudes towards GM insects will likely differ depending on the proposed use of the technology. We heard that the public may be more welcoming of new strategies to ameliorate threats to health than those that will serve to improve agricultural practices.[130] This may be linked to a perception of the likely beneficiary of the technology; where the benefits are generally seen to be for the producer and not so much for the consumer there may be less support. Professor Sue Hartley, President Elect of the British Ecological Society (BES), elaborated:

> "With agriculture, people fail to see why we need to do this kind of tinkering: the crops are in the fields, the food is in the shops. For medical needs, people can see that this is appropriate, can benefit them and will lead to some real advances that might not have been possible by other techniques."[131]

Dr Sarah Hartley confirmed the agriculture versus public health application dichotomy:

> "In an agricultural context, it is going to be much harder, not just on the back of the GM crops crisis but in general … we will have to approach agriculture in a different way from health."[132]

160. As Dr Sarah Hartley pointed out, the potential lack of public support for agricultural applications may be influenced by the GM crops debate. Much of this debate was hinged on the influence of large multinational companies and the perception of immoral financial drivers. We heard the view from the Pirbright Institute that:

> "a major aspect of public concern about the use of GM products relates to concern about the extent to which such technologies facilitate unethical practices by large corporations."[133]

161. While the potential public health and agricultural applications of GM insect technologies are equally important, we appreciate that the debates are different and that separate strategies should be developed for each when engaging with the public.

Public engagement: what, when and with whom

162. The objective of a public engagement initiative must be clear from the outset. Sciencewise suggested that:

> "it should be clear if the primary purpose of engagement is simply to inform the public about decisions with little room for influence over policy, or whether it is to seek the public's views as an input into decision making."[134]

130 In this context, it is worth noting that insulin has been made for some time using genetically engineered microbes, causing barely registrable public anxiety.
131 Q 20 (Prof Sue Hartley)
132 Q 20 (Dr Sarah Hartley)
133 Written evidence from The Pirbright Institute (GMI0019)
134 Written evidence from Sciencewise (GMI0005)

163. As the development of GM insect technologies is in its infancy, there is potential for early, and sustained, interaction with the public and prevention of an ill-informed, misleading debate. There is scope to enable the public to contribute to the direction of development and regulation of these technologies. Professor Sue Hartley emphasised to us that public engagement should look beyond the science of GM insect technologies:

> "It is important to recognise that the public can engage very effectively, even though they may not understand the science fully, because there are still the wider cultural, socioeconomic and value criteria that the public can engage with."[135]

164. Rather than focusing on the GM insect technologies themselves, it will be important to frame a public engagement initiative around the wider problems that the technologies have been designed to address. Such an approach would naturally separate public health and agricultural applications. On such a consideration of GM insects in context, we heard from Sir Roland Jackson:

> "The message from all the public dialogues around these contentious issues is: start with the problem that is of public interest. You may well find that GM technologies offer one solution or a set of solutions to that, but look at them in context."[136]

165. An open, honest and transparent approach is the best means to develop productive and meaningful engagement. Professor Sue Hartley said that: "one key factor is identifying an honest broker. That, I think, is what the public want to see."[137]

166. One potential candidate for such a role may be Sciencewise.[138] In their written submission to us, they outlined that their expertise is in public dialogue, which is:

> "a particular type of public engagement which brings together members of the public, policy makers, scientists and other expert stakeholders to deliberate and come to conclusions on public policy issues. Well-designed public dialogue allows public participants (usually representative of the public at large) to move relatively quickly from little or no knowledge of, or opinions on, a topic to understanding the key issues of even complex scientific and technological developments and come to a view.[139]

167. We consider GM insect technologies an appropriate topic for public dialogue due to both their complexity and potential for controversy.

168. In terms of timing, not all the evidence we received suggested that a process of early public engagement is appropriate. In specific reference to public engagement on GM insect technologies, George Eustice MP did not necessarily see the case for early-stage intervention but rather thought that public dialogue should be framed around a future application:

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135 Q 19 (Prof Sue Hartley)
136 Q 22 (Sir Roland Jackson)
137 Q 23 (Prof Sue Hartley)
138 Sciencewise is the UK's national centre for public dialogue in policy making involving science and technology issues. It is a BIS funded programme to improve Government policy making involving science and technology by increasing the effectiveness with which public dialogue is used, and encouraging its wider use where appropriate.
139 Written evidence received from Sciencewise (GMI0005)

> "I am not sure that there is a case for a big national debate until there is something that we are willing or able to start bringing forward and consider commercialising."[140]

This is a difficult judgment to make. If the debate is not started at a sufficiently early stage, then there is the risk that uninformed, polarised views may become entrenched before the debate has barely begun. Clearly, however, people may think it curious to be asked to participate in a debate about technological developments and resulting opportunities which do not feel at least reasonably imminent.

169. We have focused thus far on public engagement in the UK. However the immediate beneficiaries from GM insect technologies, particularly in terms of public health, are likely to reside outside the UK and the EU. Clearly engagement will be vital in countries where there is a greater pressing need for GM insect technologies, particularly in areas where insect-borne disease is rife. We determine that it is vital that any overseas contained and/or field trials are accompanied by appropriate public engagement.

170. **We envisage that appropriate public engagement strategies will have a critical role to play in the development and progression of GM insect technologies. Engagement with the public, both in the UK and overseas, particularly in countries where insect-borne disease is rife, will be required. It is vital that the evolution of an inflamed debate like that which has enveloped GM crop technologies in the UK and across the EU is avoided.**

171. **The nature of an engagement initiative and its framing is vitally important. Setting GM insect technologies in the context of the issues and problems they are designed to address is crucial. We envisage that a public dialogue approach would be most appropriate.**

172. **While we recognise the value in early-stage intervention, we are concerned that undertaking a large scale public dialogue in the UK when an application for a GM insect trial is not in train—either at a national or EU level—may prevent the full impact of such an exercise being achieved.**

173. **We therefore recommend that a concomitant public dialogue exercise be a component of the UK-based GM insect trial we advocate in Chapter 4. This exercise should be framed around the context of the technologies and separate the public health uses of GM insects from agricultural applications. It should also allow for public input into the process of the trial and regulatory exploration. The Government should draw on the expertise of a suitably qualified organisation in order to develop this initiative.**

174. **Furthermore, as a long-term aim, we recommend that the Government, via a suitably qualified organisation, monitors the development of GM insect technologies and acts to initiate a broad programme of public dialogue when these technologies are deemed to be nearer to commercialisation.**

140 Q 84 (George Eustice MP)

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Chapter 3: Potential applications of GM insect technologies and prospects for commercialisation

1. We are persuaded of the potential of GM insects as part of a complementary approach to pest and vector control management. The sheer disease burden means that all avenues should be explored, and the positive outcome from Oxitec's dengue fever field trials should be capitalised on. This potential must be explored; it would be a mistake not to pursue GM insect technologies for a range of potential applications. (Paragraph 43)

2. We conclude that the excellence of the science base, investment in infrastructure and the skills pipeline must at least be preserved, and preferably enhanced, in order to maintain the UK's position as a world-leader in GM insect technology development. In this regard, we welcome the Chancellor's announcement in the recent Spending Review that the resource budget for science will be protected in real terms for this Parliament. (Paragraph 70)

3. We also welcome the announcement, as part of the Spending Review, of the new £1 billion Ross Fund which will be used to support the global fight against malaria and other infectious diseases. The Ross Fund will provide an opportunity for further research and development into products for fighting infectious diseases. This will benefit low to middle income countries which bear the greatest burden of infectious diseases. (Paragraph 71)

4. On account of the potential that GM insects offer, both economically and in terms of public health, we conclude that there is a strong case for Innovate UK to invest further in this area to promote commercialisation of UK-based GM insect research. We therefore recommend that Innovate UK, in partnership with the Research Councils, considers providing targeted funding in order to develop the commercial deployment of GM insect technologies. (Paragraph 72)

Chapter 4: Regulation of GM insect technologies

5. We are concerned that the application of GM insect technologies in the countries whose need is greatest may be affected by a lack of international guidance and leadership on the governance and regulation of these technologies. We recommend that the Government, in light of its strong commitment to international development, works through international organisations to help to address challenges of international guidance and leadership. (Paragraph 86)

6. GM insects have the potential to help in the control of both insect-borne diseases and agricultural pests, bringing both public health and economic benefits. The UK is a world leader in the development of GM insect technologies and the public good and the commercial opportunities are tangible. However the current EU regulatory regime for GMOs risks this opportunity being squandered. The regime is failing as applied to GM crops and the full potential of GM insects will not be realised if it continues to fail to function adequately. (Paragraph 110)

7. We accept that there is some practical merit in the Government's decision to work to ensure that the existing regulatory regime for GMOs at least functions as written. We ask the Government to set out clearly how it intends

to do so and to publish annual updates on progress made in improving the operation of the system, starting in the summer of 2016. However, we do not accept that this is sufficient and we advocate a more radical review of the regulatory framework later in this Chapter. (Paragraph 111)

8. We urge the Government to monitor the development of new genetic technologies, including GM insects, in order to ensure that the regulatory regime is fit-for-purpose. We recognise that a move to a trait-based system may not currently be appropriate. We see the risk that a move to a trait-based system may be counter-productive in the short term. We acknowledge, however, that trait-based regulation may be a valid long-term aim in order to develop a more scientifically robust, overarching regime once current regulatory barriers within 2001/18/EC have been addressed. (Paragraph 126)

9. The ecological impact of GMOs designed to persist in the environment presents a new regulatory challenge. In light of the advances in gene-drive research, we conclude that underpinning research is required in order to allow effective monitoring and tracking of this new generation of genetic modifications. The regulatory framework should take persistence into account and stipulate appropriate monitoring requirements. (Paragraph 129)

10. We consider the argument for including the benefits of a technology within the regulatory process to be entirely valid. Furthermore, we do not agree with the stance of the Government and the European Commission that there would be little to gain in modifying the current framework to include consideration of benefits. We recommend that consideration of benefits and dis-benefits be incorporated into the regulatory regime once the scientific risk assessment has taken place, during the risk management stage. (Paragraph 140)

11. Furthermore it is inappropriate that new GMO technologies are considered in relation to an unrealistic, risk-free alternative. We recommend that the regulatory process should acknowledge control methods currently in use, such as insecticides, which a new technology may replace. (Paragraph 141)

12. The fact that the current EU regulatory regime remains untested for GM insect technologies is a major barrier to progress. Only when a field trial application has been approved will we be able to move forward. We therefore conclude that action must be taken to instigate a field trial which should also be used to drive public engagement. (Paragraph 145)

13. We therefore recommend that the Government actively pursues and invests in a GM insect field trial to test fully the science of GM insects, regulatory processes and policies. This trial could be considered as a GM insect counterpart to the Farm Scale Evaluations of new GM crop technologies undertaken from 1999 to 2006. Such a trial should be dual-approach in nature and investigate both an agricultural pest and a species of mosquito. (Paragraph 146)

14. In order to undertake this trial, Government departments, including DEFRA, BIS and DFID, should work together to develop a proposal to be put out for tender to the UK science community. Funding should be drawn from these Government departments as well as Innovate UK. (Paragraph 147)

15. Alternative regulatory approaches should be considered in the light of this trial, including those highlighted in this report, such as: consideration of

benefits, evaluation against real-world alternatives and trait-based regulatory triggers. (Paragraph 148)

16. Alongside this trial, with the aim of ensuring that regulation remains relevant and up to date, we recommend that the Government monitors the suitability of the regulatory environment for emerging technologies, such as GM insects, to ensure that the potential benefits they could bring are not stifled at inception due to anachronistic regulation. This includes the development of new mechanisms to allow for effective post-release monitoring and tracking of new genetic material promoted via gene drives. We recommend that the Government issues an annual statement which provides their assessment of the suitability of the regulatory environment for emerging technologies. (Paragraph 149)

Chapter 5: Concerns, perceptions and public engagement

17. We envisage that appropriate public engagement strategies will have a critical role to play in the development and progression of GM insect technologies. Engagement with the public, both in the UK and overseas, particularly in countries where insect-borne disease is rife, will be required. It is vital that the evolution of an inflamed debate like that which has enveloped GM crop technologies in the UK and across the EU is avoided. (Paragraph 170)

18. The nature of an engagement initiative and its framing is vitally important. Setting GM insect technologies in the context of the issues and problems they are designed to address is crucial. We envisage that a public dialogue approach would be most appropriate. (Paragraph 171)

19. While we recognise the value in early-stage intervention, we are concerned that undertaking a large scale public dialogue in the UK when an application for a GM insect trial is not in train—either at a national or EU level—may prevent the full impact of such an exercise being achieved. (Paragraph 172)

20. We therefore recommend that a concomitant public dialogue exercise be a component of the UK-based GM insect trial we advocate in Chapter 4. This exercise should be framed around the context of the technologies and separate the public health uses of GM insects from agricultural applications. It should also allow for public input into the process of the trial and regulatory exploration. The Government should draw on the expertise of a suitably qualified organisation in order to develop this initiative. (Paragraph 173)

21. Furthermore, as a long-term aim, we recommend that the Government, via a suitably qualified organisation, monitors the development of GM insect technologies and acts to initiate a broad programme of public dialogue when these technologies are deemed to be nearer to commercialisation. (Paragraph 174)

APPENDIX 1: LIST OF MEMBERS AND DECLARATIONS OF INTEREST

Members

Lord Cameron of Dillington
Lord Fox
Lord Hennessy of Nympsfield
Lord Hunt of Chesterton
Lord Kakkar
Lord Krebs (Co-opted)
Baroness Manningham-Buller
Lord Maxton
Duke of Montrose
Baroness Morgan of Huyton
Baroness Neville-Jones
Lord Patel (Co-opted)
Lord Peston
Viscount Ridley
Earl of Selborne (Chairman)
Lord Vallance of Tummel

Declarations of interest

Lord Cameron of Dillington
Farming and landowner (Dillington Farms)
Trustee, Rothamsted
Chair of Advisory Council of Centre for Ecology and Hydrology (CEH)
Chairman, Advisory Board of Global Food Security Programme

Lord Fox
No relevant interests declared

Lord Hennessy of Nympsfield
Fellow, British Academy

Lord Hunt of Chesterton
No relevant interests declared

Lord Kakkar
Professor of Surgery, University College London
UK Business Ambassador for Healthcare and Lifesciences

Lord Krebs
Chairman, Oxford Risk Ltd (15 per cent shareholding; company enables clients make better-informed decisions)
Principal, Jesus College, Oxford (interest ceased 1 August 2015)
Chair, Adaptation Sub-Committee, Committee on Climate Change
Member, Climate Change Committee
Chair, Wellcome Trust Advisory Group on Sustaining Health
Scientific Adviser to Marks and Spencer plc
Scientific Adviser to Ajinomoto Co Inc
President, Campden BRI (advice to food, drink and allied industries) (interest ceased end 2014)
Emeritus Professor of Zoology, Oxford University
Chair, Oxford University Museum of Natural History

Parliamentary Partner, IIED (International Institute for Environment and Development)
Deputy Chair and Trustee of the Nuffield Foundation
Fellow, Royal Society
Fellow, Academy of Medical Sciences

Baroness Manningham-Buller
Chair, Wellcome Trust

Lord Maxton
No relevant interests declared

Duke of Montrose
Livestock rearing of Cattle and Sheep
Member, National Farmers' Union of Scotland
Member, The Moredun Animal Health Research Institute
President, National Sheep Association
Hon. Member, British Veterinary Association

Baroness Morgan of Huyton
Member of Council, King's College, University of London

Baroness Neville-Jones
Council Member, Engineering and Physical Sciences Research Council

Lord Patel
Fellow, Academy of Medical Sciences
Fellow, Royal Society of Edinburgh
Chancellor, University of Dundee

Lord Peston
No relevant interests declared

Viscount Ridley
Ownership of a farm
Fellow, Academy of Medical Science

Earl of Selborne
Farming interests'
Fellow, Royal Society
Fellow, Society of Biology
Vice Patron, Royal Entomological Society

Lord Vallance of Tummel
No relevant interests declared

A full list of Members' interests can be found in the Register of Lords Interests: http://www.parliament.uk/mps-lords-and-offices/standards-and-interests/register-of-lords-interests/

Specialist Adviser

Professor Michael Bonsall

Employment

Professor of Mathematical Biology, Department of Zoology, University of Oxford (2005)
Fellow and Tutor in Biological Sciences, Tutor for Graduates and Professor of Mathematical Biology, St Peter's College, Oxford (2005)

Member of a managing entity or equivalent structure

Fellow, St Peter's College, Oxford (2005–present)

Member, Advisory Committee on Releases to the Environment (2007–present)

Occasional Consultancy

World Health Organisation & Foundation for the National Institutes of Health (2010–2014)

European Food Safety Authority (2011–2015)

Research Funding

BBSRC-LINK Grant: Insect Resistance Management (2014–2017), Biotechnology and Biological Sciences Research Council, (2014–present)

BBSRC iCASE Studentship Award: Insect Resistance Management, Biotechnology and Biological Sciences Research Council, (2013–present)

Future of Food Grant: Role of human demography, pest management and climate change on rice security in Northern Vietnam, Future of Food Grant (2013–2016), Oxford Martin School (2013–2016)

NERC grant: Understanding bird community phylogenetics, Natural Environment Research Council (2012–2015)

NERC Studentship Award: Butterfly Population Dynamics, Natural Environment Research Council, (2009–2013)

BBSRC-LINK Grant: Integrating ecology and genetics for insect pest control (2010–2013), Biotechnology and Biological Sciences Research Council (2010–2013)

Professional Memberships and Affiliations

Fellow, Royal Statistical Society (2006–present)

Fellow, Royal Entomological Society (1994–present)

A full list of Professor Michael Bonsall's interests can be found at: http://www.parliament.uk/documents/lords-committees/science-technology/GMInsects/michael-bonsall-specialist-adviser-interests.pdf

APPENDIX 2: LIST OF WITNESSES

Evidence is published online at www.parliament.uk/genetically-modified-insects and available for inspection at the Parliamentary Archives (020 7219 3074)

Evidence received by the Committee is listed below in chronological order of oral evidence session and in alphabetical order. Those witnesses marked with ** gave both oral evidence and written evidence. Those marked with * gave oral evidence and did not submit any written evidence. All other witnesses submitted written evidence only.

Oral evidence in chronological order

**	Dr Paul Burrows, Executive Director, Biotechnology and Biological Sciences Research Council (BBSRC)	QQ 1–15
*	Professor Tim Dafforn, Chief Scientific Advisor, Department for Business, Innovation and Skills (BIS)	
**	Ian Meikle, Head of Agriculture and Food, Innovate UK	
**	Sir Roland Jackson, Executive Chair, Sciencewise	QQ 16–25
**	Professor Sue Hartley, President Elect, British Ecological Society	
**	Dr Sarah Hartley, School of Biosciences, University of Nottingham	
**	Professor Rosemary Hails, Chair, Advisory Committee on Releases to the Environment (ACRE)	QQ 26–38
*	Dr Jeremy Sweet, Environmental Consultant, Sweet Environmental Consultants	
**	Camilla Beech, Head of Regulatory Affairs, Oxitec Ltd.	
**	Professor Paulo Paes de Andrade, Department of Genetics, Federal University of Pernambuco, Brazil	QQ 39–47
*	Professor John Mumford, Professor of Natural Resource Management, Centre for Environmental Policy, Imperial College London	
*	Dr Jack Stilgoe, Senior Lecturer, Department of Science and Technology Studies, University College London	
*	Professor Luke Alphey, Head of Arthropod Genetics Group, The Pirbright Institute	QQ 48–55
*	Professor Paul Eggleston, Professor of Molecular Entomology, Keele University	

*	Professor Austin Burt, Professor of Evolutionary Genetics, Imperial College London	
**	Matt Shardlow, Chief Executive, Buglife—The Invertebrate Conservation Trust	QQ 56–64
**	Professor Jonathan Montgomery, Chair, Nuffield Council on Bioethics	
**	Professor Christopher Whitty, Professor of Public and International Health, London School of Hygiene and Tropical Medicine	QQ 65–74
**	George Eustice MP, Minister of State for Farming, Food and the Marine Environment, Department for the Environment, Food and Rural Affairs (Defra)	QQ 75–86
**	George Freeman MP, Parliamentary Under Secretary of State for Life Sciences, Department for Business, Innovation and Skills (BIS) and the Department of Health (DH)	
*	Dr Ladislav Miko, Deputy Director General of DG SANTE, European Commission	QQ 87–99

Alphabetical list of all witnesses

**	Advisory Committee on Releases to the Environment (ACRE) (QQ 26–38)	GMI0014
	Agricultural Biotechnology Council (abc)	GMI0018
	Agricultural and Horticultural Development Board (AHDB)	GMI0015
	Dr Marcia Almeida de Melo, Federal University of Campina Grande	GMI0006
*	Professor Luke Alphey, The Pirbright Institute (QQ 48–55)	
	BioIndustry Association (BIA)	GMI0026
**	Biotechnology and Biological Sciences Research Council (BBSRC)—Research Council UK (QQ 1–15)	GMI0017
**	British Ecological Society (BES) (QQ 16–25)	GMI0024
**	Buglife, The Invertebrate Conservation Trust (QQ 56–64)	GMI0011 GMI0031
*	Professor Austin Burt, Imperial College London (QQ 48–55)	
*	Professor Tim Dafforn, Department for Business, Innovation and Skills (BIS) (QQ 1–15)	
	Dr Amaro de Castro Lira Neto, State Institute for Agronomy (IPA)	GMI0006

**	Department for Business, Innovation and Skills (BIS)	GMI0022
**	Department of Environment, Food and Rural Affairs (Defra)	GMI0022
*	Professor Paul Eggleston, Keele University (QQ 48–55)	
*	European Commission (QQ 87–99)	
	Bill and Melinda Gates Foundation	GMI0027
**	Sarah Hartley BSc, PhD, University of Nottingham (QQ 16–25)	GMI0023
**	Innovate UK (QQ 1–15)	GMI0008
	Institute for Science, Innovation and Society (InSIS)	GMI0030
	Professor Anthony James, University of California	GMI0004
*	Professor John Mumford, Imperial College London (QQ 39–47)	
	National Institutes of Bioscience (NIB)	GMI0012
**	Nuffield Council on Bioethics (QQ 56–64)	GMI0020
**	Oxitec Ltd. (QQ 26–38)	GMI0016 GMI0029 GMI0033
**	Dr Professor Paulo Paes de Andrade, Federal University of Pernambuco (QQ 39–47)	GMI0006
	The Pirbright Institute	GMI0019
	Dr Rupert Read, University of East Anglia	GMI0002
**	Research Councils UK (RCUK) (QQ 1–15)	GMI0017
	Rothamsted Research	GMI0007
	The Royal Entomological Society (RES)	GMI0021
**	Sciencewise (QQ 16–25)	GMI0005 GMI0028
*	Dr Jack Stilgoe, University College London (QQ 39–47)	
*	Dr Jeremy Sweet, Sweet Environmental Consultants (QQ 26–38)	
	Target Malaria	GMI0013
	James Thackery, student at University of Sheffield	GMI0003
	Wellcome Trust	GMI0025
**	Professor Christopher Whitty, London School of Hygiene and Tropical Medicine (QQ 65–74)	GMI0032

APPENDIX 3: CALL FOR EVIDENCE

The House of Lords Science and Technology Select Committee, under the Chairmanship of Lord Selborne, is conducting an inquiry into *Genetically Modified (GM) Insects*. This includes use in both human disease control as well as livestock and agricultural crop applications. The Committee invites interested individuals and organisations to submit evidence to this inquiry. The deadline for written evidence submissions is Friday, 18 September 2015.

Background

Genetically modified insects are being developed for a range of different purposes. One important use is in controlling human disease by, for instance, genetically modifying insect disease vectors[141] so that they cannot transmit pathogens[142]. Another important use is in protecting crops, livestock and native species, by modifying their insect pests. Though not currently under development, beneficial insects could also potentially be modified to increase or enhance their function.

Current methods of controlling populations of harmful insects, including disease vectors and crop pests, often involve the use of insecticides, modifying habitats or using biological control agents, including predators and pathogens. Release of insects sterilised by radiation, an approach known as Sterile Insect Technique (SIT), is also used (this technique is not classed as genetic modification). Genetic modification could offer an additional approach which may be effective in controlling insect populations.

Population suppression and population replacement are two approaches that can be used. Population suppression can be achieved by introducing lethal genes, or genes which spread through reproduction, thereby reducing the ability of the insect pest or disease vector to reproduce. With this approach, the pest population declines as these genes spread. Population replacement involves genetic modification that makes the insect no longer able to transmit a harmful pathogen to humans, animals or plants. Here the aim is to replace the wild population with non-transmitting GM insects.

A number of new technologies could find application in the GM insect approaches described above. One such technique is gene drive, a mechanism that increases the transmission of a gene in a population above that which would be expected based on natural inheritance. The regulatory framework for such new technologies is yet to be addressed.

GM insects offer potential for effective control of insect populations and reduction of insecticide use. Particularly in developing countries, there is significant scope for public health benefits from control of diseases such as malaria and dengue. There are, however, safety and ethical concerns and a regulatory environment that is fit for purpose will be vital if this technology is to develop appropriately and with greatest economic benefit.

In the European Union, the release of GM insects is regulated under the Directive for the Deliberate Release of Genetically Modified Organisms (GMOs) (2001/18/EC). The Directive requires that all GMOs undergo an extensive risk assessment prior to any release to the environment. The Directive was not drawn up with GM

141 A vector is any agent (person, animal or microorganism) that carries and transmits an infectious pathogen into another living organism.

142 A pathogen is an organism that causes disease. For example, in dengue infection, the pathogen is a virus whereas in malaria infection, the pathogen is a unicellular parasite.

insects in mind, although the European Food Safety Authority (EFSA) has since produced guidance on the risk assessment of GM animals, including insects.[143] The emergence of resistance is not currently considered within these frameworks. The ability of insects to move freely and widely must also be taken into account.

We are interested in the following questions:

1. Which human diseases, across the world, could be addressed through GM insect technology? Are there any human disease risks in Europe, particularly the UK, for which GM insects are under development?

2. What are the possible livestock and agricultural crop applications of GM insects across the world? Of current livestock disease risks and agricultural insect pests that could be addressed through GM Insects, which should be the highest priority for Europe?

3. Are there likely to be opportunities provided by GM insects that cannot be provided by other approaches, such as biological control methods? How could GM insect approaches be complementary to existing Integrated Pest Management (IPM) programmes?

4. How appropriate are current EU and UK GMOs regulatory frameworks in addressing the issues raised by GM Insects? Are there lessons to be learnt from the regulation of GM insects in other countries such as Brazil?

5. Do the World Health Organisation (WHO) guidelines on the release of GM mosquitoes provide the basis of an effective regulatory framework? How should issues regarding the emergence of resistance be considered?

6. Do the European Food Safety Authority (EFSA) guidelines on the environmental risk assessment of GM Insects for commercial use sufficiently address the different risks from population suppression and population replacement approaches? How should the ecological risks and human benefits that might arise from the application of gene drive techniques to population replacement approaches be assessed?

7. How is research into the development of GM insects currently funded? Are there opportunities to attract more private investment into this area?

8. Given the possible public health benefits of GM insects, should the Government be funding their commercialisation? Would this result in a conflict of interest with regard to regulation of releases? If so, how might this be managed?

9. How could the UK benefit economically from both developing GM Insect technology and its use within the UK?

10. How can the gap between regulatory approaches and public concerns over GMOs be addressed? Is there a role for 'responsible innovation' approaches? What are the critical factors in effective public engagement from lab to final release?

20 July 2015

143 EFSA (2013) Guidance on the environmental risk assessment of genetically modified animals. EFSA Journal 2013; 11(5):3200. http://www.efsa.europa.eu/en/efsajournal/doc/3200.pdf [accessed July 2015]

APPENDIX 4: SEMINAR HELD AT THE HOUSE OF LORDS ON 15 SEPTEMBER 2015

Members of the Committee present were Earl of Selborne (Chairman), Lord Cameron of Dillington, Lord Hennessy of Nympsfield, Lord Kakkar, Lord Krebs (co-opted), Baroness Manningham-Buller, Lord Maxton, Baroness Neville-Jones, Lord Peston, Viscount Ridley and Lord Vallance of Tummel

Presentations were heard from:

- Professor Charles Godfray, CBE, FRS, Hope Professor, Department of Zoology, University of Oxford;
- Dr Anusha Panjwani, Postdoctoral Research Associate, author of the POSTnote, *GM Insects and Disease Control* (2014);
- Dr Simon Warner, Chief Scientific Officer, Oxitec Ltd.; and
- Professor Michael Bonsall, Professor of Mathematical Biology, Department of Zoology, University of Oxford (Specialist Adviser)

APPENDIX 5: ABBREVIATIONS, ACRONYMS AND TECHNICAL TERMS

ACRE	Advisory Committee on Releases to the Environment
AHDB	Agriculture and Horticulture Development Board
BBSRC	Biotechnology and Biological Sciences Research Council
BES	British Ecological Society
BIA	BioIndusty Association
BIS	Department for Business, Innovation and Skills
Cisgenic	Modified via rearrangement of genetic material within the organism
CRISPR	Clustered regular interspaced short palindromic repeats
Defra	Department for the Environment, Food and Rural Affairs
DFID	Department for International Development
DNA	Deoxyribonucleic acid
Endonuclease	An enzyme (biological catalyst) which cuts strands of DNA at specific points
EEA	European Economic Area
EFSA	European Food Safety Authority
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
GM	Genetically modified or genetic modification
GMI	Genetically modified insect
GMO	Genetically modified organism
Inundative	Inundative biological control involves the release of massive numbers of the control agent in order to control the pest rapidly
IPM	Integrated pest management
LMCs	Low to middle income countries
MRC	Medical Research Council
MS	Member States
NERC	Natural Environment Research Council
NIB	National Institutes of Bioscience
Pathogen	An organism that causes disease. For example, in dengue infection, the pathogen is a virus whereas in malaria infection, the pathogen is a unicellular parasite
QMV	Qualified majority voting
RCUK	Research Councils UK

Recombinant	Bringing together genetic material from multiple sources, creating sequences that would not otherwise be found in the genome
RNA	Ribonucleic acid
SIT	Sterile Insect Technique
SWD	Spotted Wing Drosophila
TALENS	Transcription activator-like effector nucleases
Transgenic	Modified via insertion of genetic material from another organism
Vector	Any agent (person, animal or microorganism) that carries and transmits an infectious pathogen into another living organism
WHO	World Health Organisation
WNF	West Nile Fever