The Royal Academy of Engineering

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## public dialogue on synthetic biology

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## Acknowledgements

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# Executive summary

## Background and context

This report presents the findings of an exploratory public dialogue project, commissioned by the Royal Academy of Engineering (the Academy) and conducted by People Science and Policy Ltd (PSP) to explore uninformed and informed perceptions of and attitudes to synthetic biology in the UK. To our knowledge, this is the UK's first public dialogue on synthetic biology.

Synthetic biology is an emerging multidisciplinary research area that is underpinned by both engineering and science. It aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems. As with any new technology, it brings both potential benefits and societal, ethical and regulatory implications.

This study was carried out to complement the Academy's inquiry into synthetic biology, published in May 2009 (www.raeng.org.uk/synbio) which recommended that:

"an active and ongoing public engagement programme must be established which creates platforms for various stakeholders and publics to share their views on both the potential benefits of synthetic biology and their concerns as the technology develops".

This report gives an early and preliminary insight into public perceptions and reactions to synthetic biology and reveals some issues and themes worthy of further exploration. The findings also provide a baseline measure of awareness in the UK which will be useful for comparing changes over time.

## Methodology

The research comprised two strands, the first of which was an exploratory dialogue activity with 16 members of the public attending two evening meetings at the Academy's offices in London. The public dialogue activity provided an opportunity to begin exploring people's perceptions, aspirations and concerns on the development of synthetic biology.

The second strand was a telephone omnibus survey of 1,000 adults in the UK, which included three questions and three attitude statements. This quantitative survey was designed to provide a representative early insight of awareness and attitudes to synthetic biology, at a national level, as well as to provide context to, and verify, some of the dialogue findings.

Throughout this report we refer to those who took part in the dialogue meetings as **participants** and those who were interviewed for the quantitative survey as **respondents.**

Where appropriate the findings are compared with those from the US study *Awareness of and Attitudes Towards Nanotechnology and Synthetic Biology* conducted in 2008 for the Woodrow Wilson International Center for Scholars[1] .

1. *Peter D Hart Research Associates Inc (2008) "Awareness of and Attitudes Towards Nanotechnology and Synthetic Biology", Woodrow Wilson International Center for Scholars*

## Awareness, perceptions and understandings – participants and respondents

Awareness of synthetic biology in the UK is low. None of the 16 public dialogue participants had heard the term 'synthetic biology' along with two thirds of the nationally representative survey respondents (which is identical to the US study). One in three people in the UK said they had heard of synthetic biology, but only 3% had heard 'a lot', 19% said that they had heard 'a little', with another 10% saying that they had heard the term but did not know what it meant.

The most common survey response to the question 'What words come to mind when I say synthetic biology?', was "don't know" or "nothing" (49%) which corresponds with the low level of awareness. The second most common reply was a set of words relating to "artificial", "unnatural" and "man-made", with nearly one in seven (13%) giving this response. The third most commonly cited words related to genetics, cloning and embryos (9%). This matches well with the word associations provided by the dialogue participants.

The participants also mentioned "replacement" in the sense of tissues, organs and limbs such as "new [heart] valves and things like that" or "artificial legs". Similar responses were mentioned by 6% of the survey respondents, when asked 'What do you think synthetic biology might be?'.

The survey showed that only 4% of respondents associated the term synthetic biology to manipulating nature in some way, while 3% felt it had something to do with creating life.

The dialogue participants had some difficulty in understanding the concept of synthetic biology at first. Participants were initially more likely to equate it with tissue transformation (more similar to stem-cell technology), but there were few associations with genetic modification. This is perhaps due to the focus of the synthetic biology applications that were presented being on fuels and medicine, rather than food.

## Attitudes to modifying and creating life – participants and respondents

Creating life was seen as "very futuristic", "exciting" and "more exciting than destroying life" by most of the dialogue participants. Over six out of ten (63%) survey respondents agreed with the statement 'creating new man-made micro-organisms that will produce medicines or biofuels should be supported', with a third (33%) agreeing strongly.

Survey respondents revealed an apparent difference in attitude between the creation and modification of micro-organisms. More of the survey respondents, (46%) disagreed rather than agreed (24%) with the statement 're-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed'. However, this is less than the 63% who supported the statement regarding the creation of new man-made organisms, mentioned above. The dialogue participants indicated that there was more support for the creation of completely artificial organisms, partially because these were perceived to have less chance of survival in the event of an accidental release.

It should be highlighted that where support for the notion of creating new life was shown, it was in the context of micro-organisms which could be designed to produce useful products. Dialogue discussions indicated that one factor for this support could be that these organisims were not seen to be 'alive'. Furthermore, there were no objections to using yeast and bacteria as a means of production, indeed, participants noted that this already happens (for example, bread making).

However, with regard to creating or modifying higher-life forms and humans by synthetic biology, the dialogue participants were not at all supportive.

About four in ten (39%) respondents agreed with the statement 'The idea of creating man-made micro-organisms is worrying'. Thus while there was a majority positive response to the concepts of creating and modifying micro-organisms to produce medicines and biofuels, there is still some concern over the technology.

### Views on the development of synthetic biology - participants

The dialogue participants were largely supportive of the idea of micro-organisms being engineered to live in controlled conditions, such as vats to create products like drugs or biofuel, and able to accept the risks associated with the possibility of accidental release. However, some were extremely resistant to the concept of these organisms being deliberately released into the environment for bioremediation purposes, because of the unknown consequences. Some participants were also concerned that the side effects from drugs produced using synthetic biology processes might be different from drugs produced using other methods.

Bioterrorism was not spontaneously considered, but the stimulus information provided in the meetings did raise this issue on a number of occasions. On balance, the participants felt that the potential of benefits of synthetic biology for society outweighed the risks.

Regarding open access and so-called 'garage biology', some participants felt that synthetic biology should only be conducted in professional laboratories and not in unstructured or unregulated environments, even if the research was aimed to be for public good. It was felt that otherwise this would result in poor quality, and possibly harmful, synthetic biology products being sold via the internet (for example, untested drugs).

Participants wanted regulation but were concerned that regulations should not stifle development. Concerns were also raised as to whether the Government could control synthetic biology and especially whether it could keep up with the speed of development.

Despite some hostility towards the idea of patenting, there was a belief that investors are entitled to a return on their time and money. However, there was a sense that there should be a balance between returns on investment and social responsibility.

## Participant priorities, recommendations and expectations

The majority of participants prioritised the development of biofuels over medical uses, as this application was deemed to impact on more people. The application with the least support was development of synthetic biology for bioremediation because it involves deliberate release into the environment.

Control, safety, regulation and testing of both synthetic biology production methods and their products were seen as paramount.

Generally, it was expected that the media would react negatively and participants recommended that scientists work to raise public awareness. They also thought it was important for other members of the public to keep an open mind and not be unduly swayed by media reports.

Government funding was thought to be important, not only because participants believed that this was a field worthy of further development, but also because this would give the Government influence over developments.

## Further research

A number of different themes emerged that would be worthy of further exploration:

- How people determine whether something is alive and whether micro-organisms are seen to be alive.
- Further exploration of philosophical questions surrounding the creation of 'new life' with other groups (for example, religious groups).
- Why there appear to be different reactions to modifying existing organisms and the creation of new ones.
- The apparent differences in opinion between men and women and between age groups.
- Regional differences in attitudes across the UK, as well as a comparison of those from rural and urban locations.
- How and if people view this technology as different to that of 'GM' and why.

# 1. Introduction

Synthetic biology is an emerging multidisciplinary research area that is underpinned by both engineering and science. It aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems.

The scientific community is aware that the development of synthetic biology brings with it a number of societal implications that need to be explored by social scientists, philosophers, ethicists and the wider public. The Royal Academy of Engineering (the Academy) recently published a report of its 18 month inquiry into synthetic biology (www.raeng.org.uk/synbio). The report notes, as several other commentators have done, that although synthetic biology can be separated from genetic modification (GM), by its sophistication and its genuine grounding in engineering principles, the fact that it involves the creation and manipulation of living organisms is likely to give rise to many of the same fears that were encountered with 'GM'. The report recommends that:

"an active and ongoing public engagement programme must be established which create platforms for various stakeholders and publics to share their views on both the potential benefits of synthetic biology and their concerns as the technology develops".

This study presents the findings of an exploratory public dialogue project, commissioned by the Academy and conducted by People Science and Policy Ltd (PSP), to explore uninformed and informed perceptions of and attitudes to synthetic biology in the UK.

To our knowledge, this is the UK's first exploration of public attitudes to this emerging technology. A report has been published previously in the USA entitled "Awareness of and Attitudes Towards Nanotechnology and Synthetic Biology," conducted in 2008 for the Woodrow Wilson International Center for Scholars[2] .

This study gives an early and preliminary insight into public perceptions and reactions to synthetic biology and explores initial hopes, concerns and expectations regarding its development through a dialogue activity. The findings also provide a baseline measure of public awareness in the UK which will be useful for comparing changes over time, and reveals some issues and themes worthy of further exploration.

## 1.1 Method

The findings reported here are based on a dialogue activity with 16 members of the public, and a nationwide representative survey of 1,000 adults aged 18 and over.

The 16 participants for the dialogue activity, recruited from the Greater London area, attended two three - hour meetings hosted at the Academy. The sample was as diverse as possible regarding age, social grade and ethnicity, given the small number of people invovled. However, the dialogue activity did not aim to be based on a representative sample, but aimed to recruit a cohort of people

*2. Peter D Hart Research Associates Inc (2008) "Awareness of and Attitudes Towards Nanotechnology and Synthetic Biology", Woodrow Wilson International Center for Scholars*

with whom to begin exploring attitudes to this emerging technology in more depth. As such, we are unlikely to have identified all the issues of public interest or concern. As with any dialogue activity, the nature of the themes that emerge and the points made during the discussions would have been influenced by the format and content of the information and stimulus materials provided (all of which are available in the appendices).

The quantitative nationally representative survey was carried out by telephone interview and consisted of a limited number of questions about awareness and perceptions and some attitudinal statements which aimed to cover the some of the basic principles of synthetic biology, without asking respondents to comment on a lengthy complex definition.

### 1.2 Project objectives

The objectives of the project were to:

- determine public awareness of synthetic biology
- explore public perceptions of synthetic biology
- explore uninformed and informed public attitudes to synthetic biology
- identify particular hopes, expectations and concerns relating to the development of the technology
- identify issues that merit further research and/or dialogue activity.

### 1.3 Structure of the report

The next section of this report (section 2) outlines the methodology used in order to meet the project objectives above. Section 3 provides details of the dialogue participants and the survey respondents and sets the context for the findings. Section 4 looks at awareness, perceptions and understandings of synthetic biology. Section 5 reports on attitudes to creating and modifying life and section 6 focuses on the views of the participants regarding the development of synthetic biology. Section 7 provides an overview of some of the particular hopes and concerns that the dialogue participants have for synthetic biology. Section 8 draws together some conclusions and suggests some issues for further research to address.

### 1.4 Terminology

As a rapidly emerging research area, there are currently a number of definitions of synthetic biology in use. In this study we used the definition agreed in the Academy's inquiry (www.raeng.org.uk/synbio), which is:

"Synthetic biology aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems."

Throughout this report we refer to those who took part in the dialogue meetings as **participants** and those who were interviewed for the telephone survey as **respondents.** By **observers** we mean Academy staff, presenters and researchers who were present at various session during the dialogue meetings.

# 2. Methodology

## 2.1 Public dialogue

A group of 16 members of the public (nine men and seven women) attended two evening meetings at the Academy's offices in central London.

Eighteen individuals were recruited and 16 attended the first meeting and 15 the second, all of whom received an incentive for attending. The group comprised:

- nine men and seven women (one woman did not return for the second meeting due to illness)
- a spread of ages between 20 and 70
- a spread of social grades
- representation from white, black and other minority ethnic groups.

At the recruitment stage participants were told that the meetings were about new developments in scientific research.

## 2.2 Public dialogue – meeting 1

The first meeting took place on the evening of 19 March 2009 and lasted three hours and was divided into five sessions with refreshment breaks (see appendix 2 for a full topic guide).

Session 1 provided a short introduction to the project, explained the broad objectives (without mentioning synthetic biology specifically) and introduced the team.

Session 2 was conducted as two breakout groups - one of men, the other of women and focused on establishing:

- general understanding and views of scientific research
- current levels of awareness of synthetic biology
- initial reactions to, and understandings of the term 'synthetic biology'

After session 2 there was a 20 minute break for refreshments.

In Session 3 two invited speakers presented an overview of the science of synthetic biology and an introduction to its applications and associated societal, ethical and regulatory implications. Time was provided after the presentations for questions. The speakers were:

Professor Paul Freemont, (Co-Director of the EPSRC Centre for Synthetic Biology and Innovation, Imperial College London) who provided an introduction to the science and applications of synthetic biology.

Dr Jane Calvert, (RCUK Academic Fellow, Research Centre for Social Sciences, School of Social and Political Science, University of Edinburgh) who presented the social and ethical issues that have been raised by various academics and commentators.

The full presentations can be found in appendices 3 and 4.

For Session 4 the participants were randomly divided into two groups. This session focused on discussing social and ethical implications in light of the presentations. Professor Freemont and Dr Calvert joined the discussion groups, as did Professor Richard Kitney FREng, (Professor of Biomedical Systems Engineering at Imperial College London) who was attending the meeting as an observer.

Session 5 brought all the participants back together for a final session during which they were given some background and context to the purposes of the public dialogue activity. For the two and half week period until the second dialogue session, the participants were encouraged to view or contribute to the internet forum that was set up specifically for this study (see section 2.4). In addition they were encouraged to talk to their friends and family about the topic as well as reflecting on what they had learned from each other and the presenters. Print outs of the presentations were available for participants to take away.

### 2.3 Public dialogue – meeting 2

The second meeting took place on the evening of 7 April 2009 and also lasted three hours. At the beginning of the meeting, the participants completed a short questionnaire to evaluate their attitudes to scientific research in general (see appendix 1)

The meeting was divided into four sessions (see appendix 5 for a full topic guide). An Academy representative was present for sessions 1 and 4 but sessions 2 and 3 had no observers. Professor Freemont was also present for session 4.

Session 1 began with a round robin of participants' thoughts about synthetic biology since the first meeting to provide an overview of the issues that were 'top of mind'.

For Session 2 the group was divided into two breakout groups to each discuss two case studies. Part way through, each group was re-divided to discuss a further two case studies. The case studies (full details provided in appendix 6) provided a way to further inform the participants about the science, potential application and industrialisation of synthetic biology products, and to discuss some of the ethical, regulatory and societal issues associated.

The case studies covered:

- the production of artemisinin
- detecting toxins and diseases, including an example of a woman conducting synthetic biology at home (so-called 'garage biology' or 'biohacking')
- the production of biofuels
- bioremediation.

Following a break of about 30 minutes, Session 3 began by dividing the participants into four breakout groups in which they were asked to consider and address the following questions and provide feedback to certain target audiences:

- Hopes - of the four case studies, which would you most hope to succeed?
- Hopes - is there anything else you hope that synthetic biology will achieve?
- Expectations - what do you expect synthetic biology to achieve in the next 10 years?
- Expectations - how do you expect the media to react?
- Concerns - of the four case studies, should any be stopped?
- Concerns - your biggest worry about synthetic biology?

What would you say to each of the following, including any specific recommendations that you would like to make:

- scientists and engineers
- Government and policy-makers
- friends and relatives

Session 4 began with a representative from each breakout group feeding back the outcomes of their discussion to the other participants.

The participants were then asked to each describe synthetic biology in their own words.

Before closing the session, the participants were provided with an opportunity to ask Professor Freemont any last questions, were informed about the publication of this report and encouraged to maintain contact on the forum as any comments received within a week would be incorporated into the final version.

Participants completed a short evaluation questionnaire on their experience of taking part in this dialogue activity (see appendix 7).

### 2.4 Internet forum

An internet forum was set up on the PSP website to allow participants to continue the dialogue online, between the meetings and after the second dialogue event. The participants, presenters, PSP staff and Academy staff were encouraged to post comments and questions onto the internet forum, along with any online resources or media articles that they found useful.

In total 12 participants used the forum, six posted a question or comment and one posted further references.

### 2.5 Omnibus survey

Following the second meeting, three questions and three attitude statements (the design of which were informed by the findings of the dialogue activty), were included on a nationally representative telephone omnibus of 1,000 adults[3] aged 18 and over in Great Britain on the weekend of 18/19 April 2009.

*3. ICM Research, High Holborn, London, UK*

This element of the project allowed us to begin to explore awareness and attitudes to synthetic biology within a nationwide context and to verify some of the findings from the public dialogue discussions.

These questions can be found below (and in full in appendix 8).

- How much would you say that have you heard about synthetic biology? (from heard a lot to heard nothing)
- What words and phrases come to mind when I say synthetic biology?
- What do you think synthetic biology might be?

Respondents were then asked the extent to which they strongly agreed, agreed, neither disagreed or agreed, disagreed or strongly disagreed with each of the following statements:

- Re-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed
- Creating new man-made micro-organisms that will produce medicines or biofuels should be supported
- The idea of a man-made micro-organism is worrying

Within the resources available, it was not possible to ask questions about the two selected applications separately (i.e. biofuels and medicine). It should be noted that there may be differing public attitudes towards these two applications when they are examined in isolation.

# 3. Context

## 3.1 Introduction

This section provides background information on the participants and respondents and therefore provides context to the project findings. As mentioned previously, we use the term 'participants' to refer to those that took part in the public dialogue activity and the term 'respondents' for those who took part in the telephone survey.

## 3.2 The participants

The public dialogue group was made up of 16 members of the public (nine men and seven women) living within a daily commuting distance of London. The characteristics of the participants are outlined below.

**Table 3.1**

| Group | |
|---|---|
| Men | 9 |
| Women | 7 |
| 18-24 | 3 |
| 25-34 | 1 |
| 35-44 | 6 |
| 45-54 | 4 |
| 55-64 | 2 |
| AB[3] | 4 |
| C1 | 7 |
| C2 | 1 |
| DE | 4 |

Base: All Participants (16)

The participants in the public dialogue meetings were asked to complete a short questionnaire (appendix 1) at the start of the second meeting to explore their general attitudes towards scientific research. Most participants agreed that 'science and engineering make our lives healthier, easier and more comfortable', while none felt that 'science is getting out of control and there is nothing we can do to stop it'. For a full set of responses to the attitude questionnaire from participants in the public dialogue meetings see appendix 1.

The responses showed that this group, as a whole, were generally fairly positive about scientific research and technology in general, and the findings of the public dialogue activity should be judged with this in mind.

The evaluation questionnaire (see appendix 7), completed at the end of the second dialogue meeting. shows that nearly all of the participants felt that the information overall, provided a balanced view. One participant did, however,

*3. Social grades are based on standard grades used in survey research (A: Professional (Non-manual), B: Middle Managers (Non-manual), C1: All other non-manual workers, C2: All skilled manual workers, D: All semi-skilled and unskilled manual workers, E: On benefit/unemployed). It is standard practice to combine groups A, B and D, E.*

**Table 3.2**

| Group | |
|---|---|
| Men | 48% |
| Women | 52% |
| 18-24 | 12% |
| 25-34 | 16% |
| 35-44 | 20% |
| 45-54 | 17% |
| 55-64 | 15% |
| 65+ | 21% |
| AB[4] | 26% |
| C1 | 29% |
| C2 | 21% |
| DE | 24% |

Base: All respondents (1,005)

feel that the presentations were very positive and three thought that the case studies were a bit too positive.

### 3.3 The respondents

The telephone omnibus sample was a nationally representative sample of at least 1,000 adults aged 18 and over. Table 3.2 above shows the profile of respondents after the data was weighted to be representative of the population of Great Britain.

Differences between subgroups have only been reported where they are statistically significant.

### 3.4 Other research

Where appropriate the findings from this UK project are compared with those from the US report *Awareness of and Attitudes Towards Nanotechnology and Synthetic Biology* conducted in 2008 for the Woodrow Wilson International Center for Scholars[5] . This US report is based on a nationally representative survey conducted in 2008 among 1,003 US adults about awareness of, and attitudes towards nanotechnology and synthetic biology. It is the third in an annual survey about nanotechnology but the first year that questions were asked about synthetic biology. Two adult focus groups (one all-male group; and one all-female group) were also conducted in Baltimore, Maryland in 2008 to explore both uninformed and informed impressions of synthetic biology. The findings from this project will be referred to as the **'US study'** throughout this report.

*4. Social grades are based on standard grades used in survey research (A: Professional (Non-manual), B: Middle Managers (Non-manual), C1: All other non-manual workers, C2: All skilled manual workers, D: All semi-skilled and unskilled manual workers, E: On benefit/unemployed). It is standard practice to combine groups A, B and D, E.*
*5. Peter D Hart Research Associates Inc (2008) "Awareness of and Attitudes Towards Nanotechnology and Synthetic Biology", Woodrow Wilson International Center for Scholars*

### 3.5 Findings

The basis for the content of the stimulus and information materials used in the public dialogue were influenced by the findings of the Academy's synthetic biology report, which can be found at www.raeng.org.uk/synbio. The applications and social and ethical issues raised in the public dialogue activity have also been raised by other commentators in academia and the media.

## 4. Awareness, perceptions and understandings

This section describes the initial awareness and perceptions of synthetic biology of both participants and respondents. We then go on to briefly discuss how participants' understandings evolved during the dialogue project.

### 4.1 Perceptions of scientific research

An initial brainstorming exercise on the term 'scientific research' revealed that there was a good appreciation amongst the dialogue participants regarding the diversity of scientific research. All the areas below were mentioned:

- Medical research
- Energy research
- Chemical research
- Environmental research
- Technological research
- Astronomy

The all-male group in particular showed an understanding of the diversity of organisations that could be involved in scientific research mentioning the motor industry, universities, Government, and chemical companies.

The men focused more on the process of scientific research mentioning "collecting data", "testing", "experimenting", "analysing" and "measuring". The all-female group focused more on the progress made by scientific research, particularly in relation to medical research.

"You sort of think of the progress of DNA type research, and cures and medical conditions and things like that."
Female

Both groups were aware of the benefits brought by scientific research but both were also conscious of the risks involved.

### 4.2 Awareness of synthetic biology

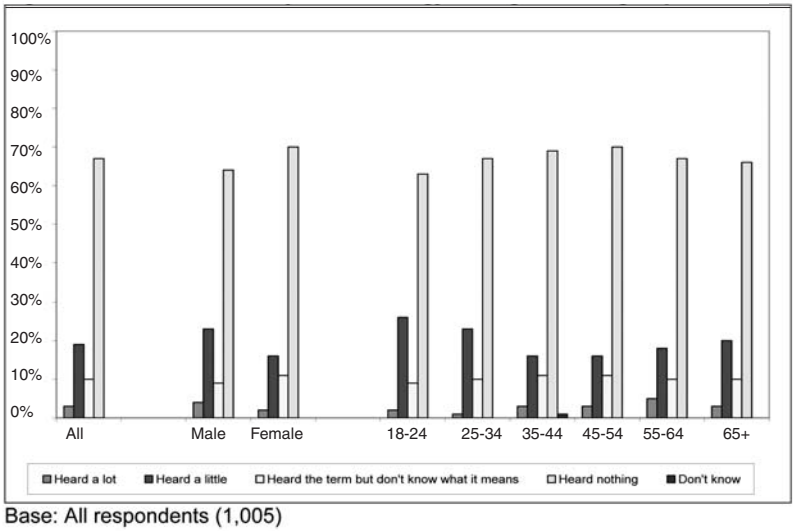
None of the 16 participants had heard the term 'synthetic biology' and neither had two thirds of the respondents (see fig 4.1). This is identical to the findings from the US study, which also found that 67% of their telephone survey respondents had heard nothing at all about synthetic biology.

The UK survey found that a third of respondents said that they had heard of synthetic biology. While only 3% had heard a lot about synthetic biology, a further fifth (19%) in the UK said that they had heard a little, with another 10% saying that they had heard the term but did not know what it meant. It should be noted that some respondents may have had a tendency to say they had heard of the term, although they may have been commentating on their familiarity with the words 'synthetic' and 'biology'.

As figure 4.1 shows, men were more likely to say they had heard a lot or a little about synthetic biology compared with women (27% compared with 18%).

Overall, awareness was highest among the youngest groups, with 28% of those aged 18 to 24 saying that they had heard a lot or a little.

**Figure 4.1 Awareness of synthetic biology among different groups**




Base: All respondents (1,005)

## 4.3 Perceptions and understandings of synthetic biology

Almost half of the telephone survey respondents (49%) said "don't know"or "nothing" when asked 'What words come to mind when I say synthetic biology?'. This compares with just 30% of respondents to the same question in the US study. Respondents over the age of 65 were more likely to say "don't know"or "nothing" compared with those in other age groups (60% compared to the average of 49%). Those in social grades DE were more likely to say "don't know" or "nothing" compared with those in other social grades (60% compared with the average of 49%).

The other responses to this question were first analysed by counting the frequency of the words. The most common responses were "man-made", "synthetic", "biology", "genetic", "cloning" and "body"which were all mentioned between 30 and 50 times by the 1005 respondents[6]. This can be seen in illustrative form in figure 4.2 below which presents the results in word cloud[7] . The responses were then coded into thematic groups for further analysis. The

**Figure 4.2 'What comes to mind when I say synthetic biology'**


Base: All respondents (1,005)

*6. Common english words such as 'and' and 'something' have been removed from this list along with terms relating to 'don't know' and 'nothing'*

*7. The more frequently a word appears the larger it appears in the word cloud. The word cloud was created by http://www.wordle.net/.*

most common group, was related to "artificial""unnatural" and "man-made" with nearly one in seven (13%) responses. This compares with nearly three in 10 (29%) of US adults who mentioned that synthetic biology was something "man-made", "artificial", "fake", "not natural" or "not real". This was also a strong theme in the UK public dialogue meeting. Some 4% of respondents to the survey, and the dialogue participants also said something related to man-made materials or fibres.

The second most commonly cited set of words and phrases in the UK survey was related to genetics, cloning or embryos. Nearly one in ten (9%) said something related to these topics, which is identical to the US survey. Cloning and genetic modification of embryos was also discussed by participants in the dialogue meetings as likely to be in some way related to synthetic biology.

Respondents to the survey were also asked 'What do you think synthetic biology might be? 'The responses were very similar to responses to the previous question that was asked, including the percentage of don't knows and nothing (49%). There were however, a few differences in responses to these two questions that are worthy of mention.

Some 6% of respondents to the 'what do you think synthetic biology might be?' question stated that it had something to do with transplanting synthetic or animal body parts into humans.

The concept of 'transplantation' was also raised by the dialogue participants who associated synthetic biology with human tissue/ parts replacement such as "new [heart] valves and things like that" or "artificial legs", "pace-makers" or hip replacements, synthetic blood, skin and cosmetic surgery.

The dialogue participants also considered the concept of 'replacement' in terms of developing new materials, including those that were in short supply, such as fuels.

"Fuel is getting more scarce and it's synthetic fuel, obviously that's the thing that they're looking at nowadays".
Male

New medicines or ways of producing medicines were also mentioned by those who took part in the dialogue meetings and a small proportion of the survey respondents.

There were also some associations with food processing, crop spraying and GM foods which were raised by some of the women who took part in the dialogue meetings. It was suggested that while medical applications impacted on one individual at a time, the consequences of an error with food modification would impact negatively on a large number of people at once. The importance of the scale of the impact is returned to in section 6.

The women also mentioned that they associated the term with 'alive' and 'living'.

"I meant a living being, or a plant or something, something that's alive, you know that's what I associate biology with."
Female
The survey also showed that 4% of survey respondents related the term

'synthetic biology' to manipulating nature in some way, while 3% felt it had something to do with creating life. Attitudes to modifying and creating life is discussed further in section 5.

### 4.4 Informed perceptions and understandings of synthetic biology

Participants in the dialogue meetings found it fairly difficult to understand the essence of synthetic biology. Initially, some perceived synthetic biology to be more similar to the transformation of stem cells into other tissues.

"Do you actually engineer that type of cell, like a brain cell, instead of using a stem cell?"
Female to one of presenters

"[That's] the future of genetic manipulation and stem cells. What I'm describing is more an engineering perspective, making things using biological parts".
Presenter's response

Over the course of the two dialogue meetings, participants came to understand that while the outcomes of stem cell transformation and synthetic biology could be similar in some instances (for example, production of synthetic blood), the methodology was quite different. They concluded that stem cell-type technology was "more personal" and of direct benefit to specific individuals and therefore had a more limited impact. Synthetic biology was seen as something operating at a societal level because of its potential to mass-produce medicines, biofuels or to be used for the purposes of environmental clean-up and therefore likely to impact on very large numbers or people, albeit indirectly. The scale of the impact , in terms of societal/ global impact and/ or the numbers of people that could benefit was important to the participants.

At the second meeting, a series of four cases studies (see appendix 6) proved to be a very effective way of informing the participants about the science and nature of synthetic biology, alongside its applications and societal, regulatory and ethical dilemmas. At the end of the second meeting participants were asked to sum up how they would describe synthetic biology in a sentence and participants were also asked 'how would you 'explain synthetic biology to a friend?' in the evaluation questionnaire. The responses demonstrated that the majority had a very clear idea of the technology at the end of the dialogue activity, some of the responses are outlined below:

"Tweaking an organism to do something different."
Male

"Artificial biology, engineering an organism to produce something."
Female

"Applying engineering principles to the fundamental concepts of biology"
Anonymous

"Re-engineering biology/organisms to perform in a way specified by scientists and act in a particular and predictable way to improve an area of application"
Anonymous

"Changing an organism to produce something it wouldn't have done naturally"
Anonymous

"The engineering of micro organisms to perform the exact task you want it to perform"
Anonymous

The scale of a synthetic biology operation impacted on how risky some participants perceived it. This was particularly the case with respect to the production of biofuels.

"I can't comprehend the amount of organisms that need to be produced when you think that a million barrels a day or something are produced."
Male

"But a glass full of microbes could make millions of gallons of biofuel."
Female

Overall, even in early discussions participants were not surprised by synthetic biology and thought it some what excepted, following on from the cloning of Dolly the sheep, stem cells and GM.

Some participants mentioned that synthetic biology could not now be stopped, irrespective of any concerns they might have.

"To be honest with you I think this is going to happen if we like it or not."
Female

### 4.4 Summary

Participants showed a good awareness of the diversity of scientific research, with the male group focusing more on the process of scientific research and the female group focusing on the progress made.

None of the participants in the public dialogue had heard the term 'synthetic biology' before although a third of the survey respondents said that they had heard the term, which is similar to the results from the US study. Our survey found that men and younger people were more likely than women and older people to say they had heard the term.

About half of the survey participants answered "don't know" when asked, 'what words come to mind when I say 'synthetic biology'?'. This was also true for the question 'what do you think synthetic biology might be?'.

The words most frequently associated with synthetic biology in the survey were "man-made", "synthetic", "biology", "genetic", "cloning" and "body". Once coded into thematic groups, the most common reaction was a set of responses grouped into "artificial", "unnatural" and "man-made" followed by genetics, cloning and embryos. This was also reflected in the US Study and came through in the dialogue meetings.

Participants in the public dialogue also related the term to replacement organs or limbs as one possible application of synthetic biology. This was also mentioned by some of the survey respondents in response to what they thought synthetic biology might be.

The public dialogue participants found it difficult to understand the concept of synthetic biology at first but most had grasped the basic principles sufficiently to take part in the informed discussions, especially during the second meeting when their understanding was further boosted by the use of case studies.

# 5. Attitudes to creating and modifying life

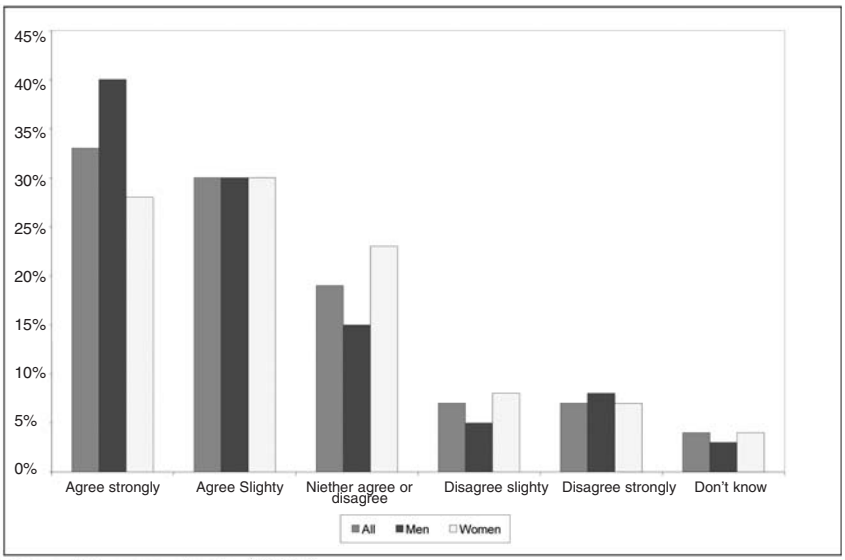
Section 5 looks at the findings from the survey and the dialogue activity in the context of attitudes to creating and modifying life.

## 5.1 Creating life

Creating new life was seen as "very futuristic", "exciting" and "more exciting than destroying life" by most of the dialogue participants. Nine participants agreed with the statement: 'the idea of creating life is exciting', three disagreed and three replied that they did not know. This majority positive reaction was also reflected in the attitudes of the nationally representative survey respondents, as can be seen in figure 5.1. Over six out of ten (63%) respondents agreed with the statement 'creating new man-made micro-organisms that will produce medicines or biofuels should be supported', with a third of all respondents (33%) agreeing strongly.

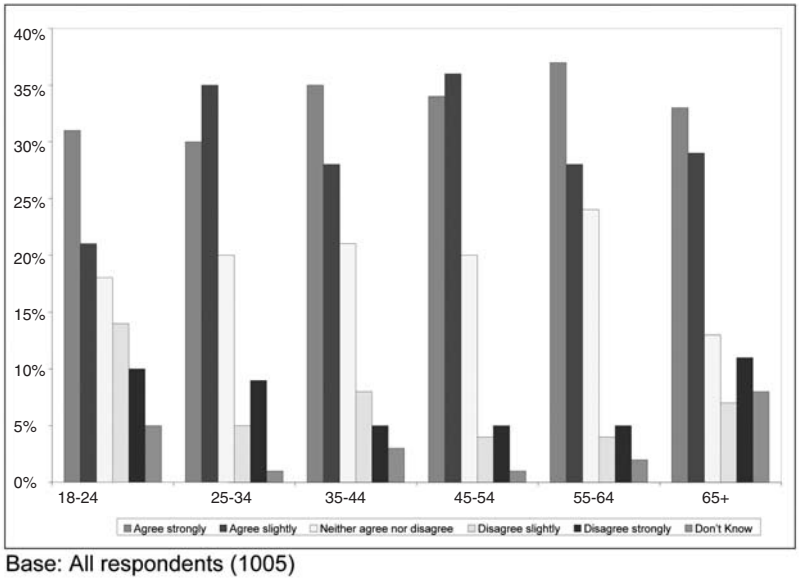
Figure 5.1 shows that men were much more likely to agree strongly than women (40% compared with 28%) with the statement 'creating new man-made micro-organisms that will produce medicines or biofuels should be supported'. Other differences between groups demonstrate that younger respondents were also more likely to disagree (24% of 18-24 year olds compared to an average of 14%)(see figure 5.2). There were also some interesting regional differences in responses to this statement, which are highlighted in figure 5.3. Over three-quarters (77%) of survey respondents in Scotland agreed that this sort of work should be supported. Those in London and the south-east were the least likely to agree (57%).

**Figure 5.1 'Creating new man-made micro-organisms that will produce medicines or biofuels should be supported' – differences between men and women**



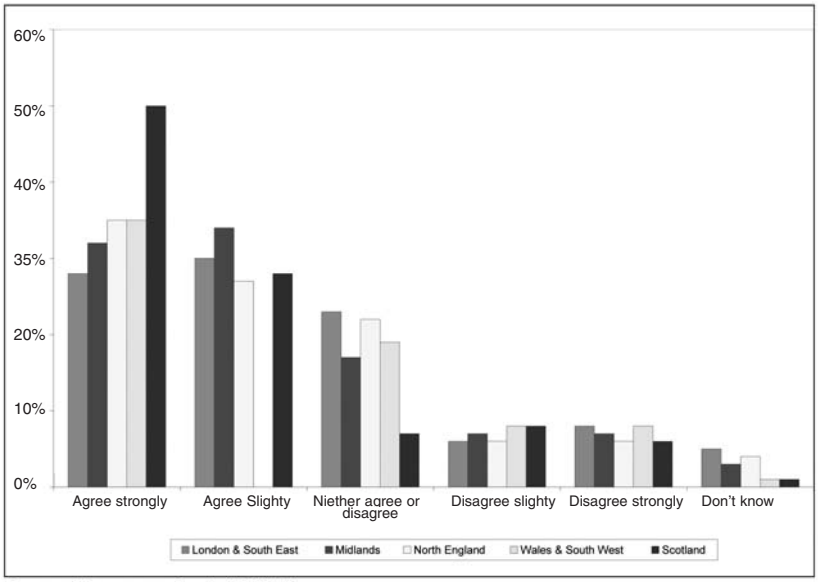

Base: All respondents (1005)

**Figure 5.2 'Creating new man-made micro-organisms that will produce medicines or biofuels should be supported' – differences between age groups**




Base: All respondents (1005)

**Figure 5.3 'Creating new man-made micro-organisms that will produce medicines or biofuels should be supported' – differences between UK regions**




Base: All respondents (1005)

It should be noted that this support, evident from the survey findings, for the notion of creating new life was referring to microbial life-forms that could manufacture useful products. The same level of enthusiasm for creating 'new life' in the dialogue sessions was also within the context of designing useful micro-organisms. The latter is possibly because the participants did not see these organisms as 'alive'. Furthermore, there were no objections to using such organisms as a means of benefiting society, indeed, participants noted that this was already happening.

"If you look at yeast, you put yeast in to make a cake, so no, it's not really alive, no."
Female

"These things have no feelings"
Male

"…we use bacteria for all sort of water purification systems and things..."
Female

Participants in the dialogue meetings clearly stated that creating higher- level organisms, especially humans was in a very different category and it was understood and accepted that using synthetic biology to create human life was not what was being considered at present.

"Making humans would worry me."
Male

"…but you don't know where these things will end-up…maybe creating babies …in two weeks…"
"There are nicer ways to create babies."
"Not at my age!"
Exchange between female participant in her 50s and an observer.

### 5.2 Modifying life

With regard to modifying rather than creating humans participants in the dialogue meetings were concerned about eugenics and 'designer' children.

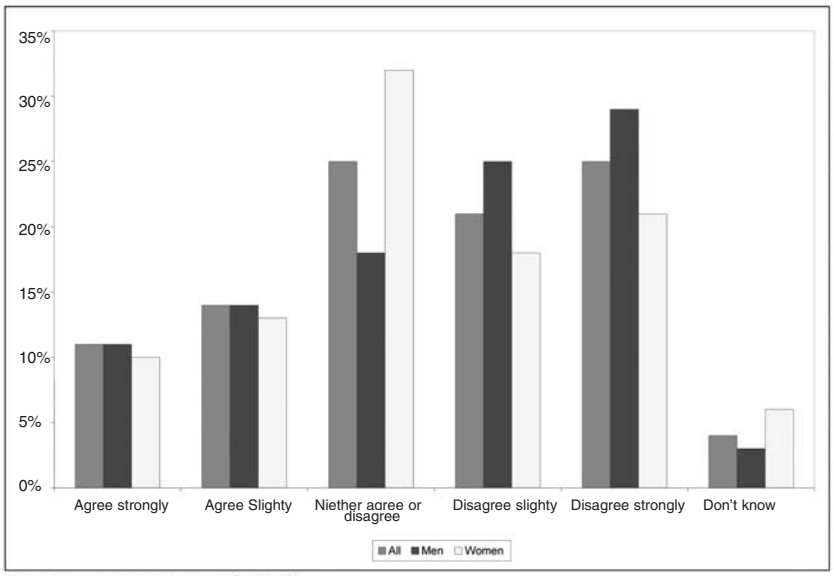
"I can see like the benefits of it, but what about what it could lead to? You know, like genetic engineering of humans? It can lead to eugenics, you know, what you had in World War II, you know, survival of the fittest, designing your baby to be the fittest."
Male

Moreover, survey respondents also revealed an apparent difference in attitude between creation and modification. Nearly half (46%) of all survey respondents disagreed with the statement 're-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed', as shown in figure 5.4. However, this is considerably fewer than the 63% who agreed that the creation of micro-organisms for these purposes should be supported. This difference may have influenced somewhat by the statement being phrased in the negative (i.e. should not be allowed) which may be more difficult to clearly agree or disagree with, as opposed to the statement regarding life, which is postive.

As with the creation of new micro-organisms, there were noticeable differences between men's and women's survey responses to the modification of micro-organisms. Over half of the men (54%) disagreed with the statement, four out of ten women (39%) did so and far more women neither agreed nor disagreed (32% of women compared with 18% of men) (see figure 5.4). Similarly, young people appeared less favourable towards modifying micro-organisms but the difference between the 18-24 age group and other age groups (see figure 5.5) was less than that in relation to supporting the creation of micro-organisms.

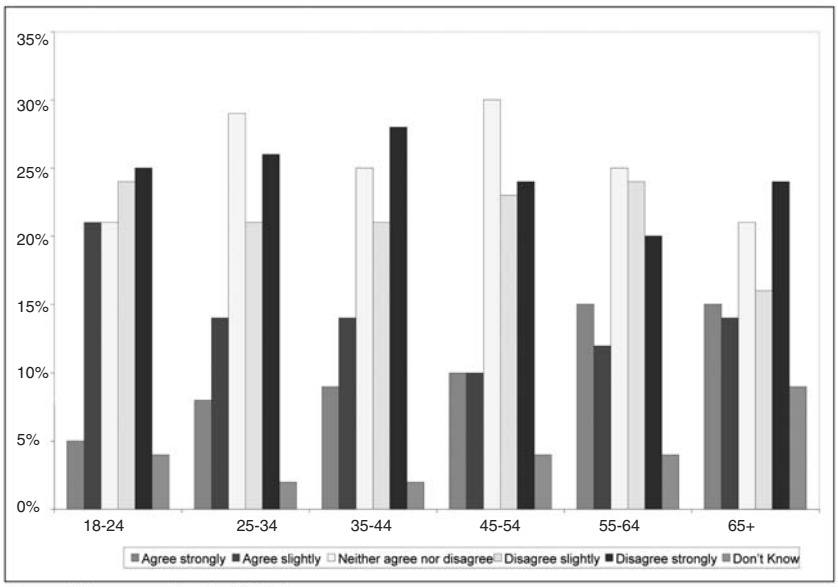
The regional differences in responses were also similar, although again the difference was less. In Scotland 54% of the people disagreed with the statement 're-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed' compared to 44% of those in London (see figure 5.6).

**Figure 5.4 'Re-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed' – differences between men and women**



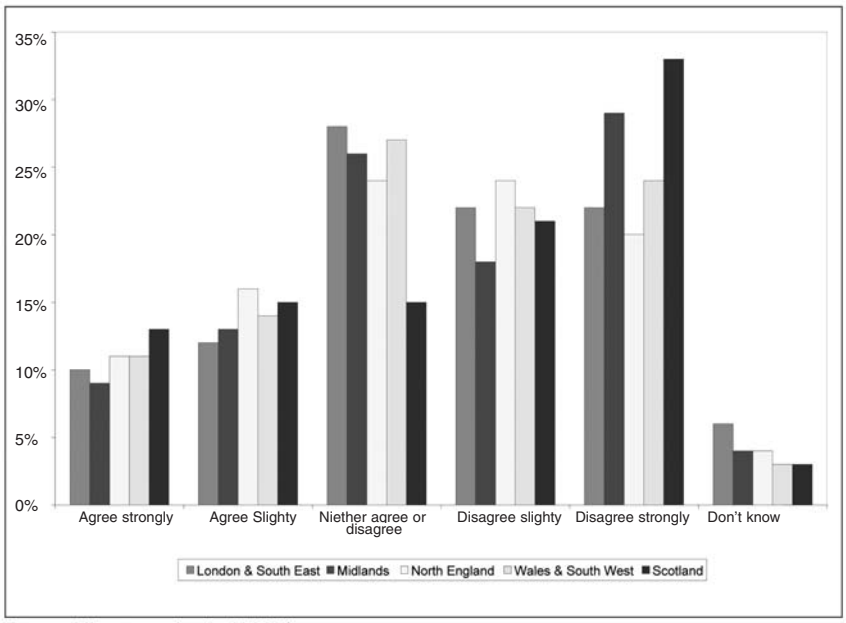

Base: All respondents (1005)

**Figure 5.5 'Re-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed' – differences between age groups**




Base: All respondents (1005)

**Figure 5.6 'Re-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed' – differences between regions**



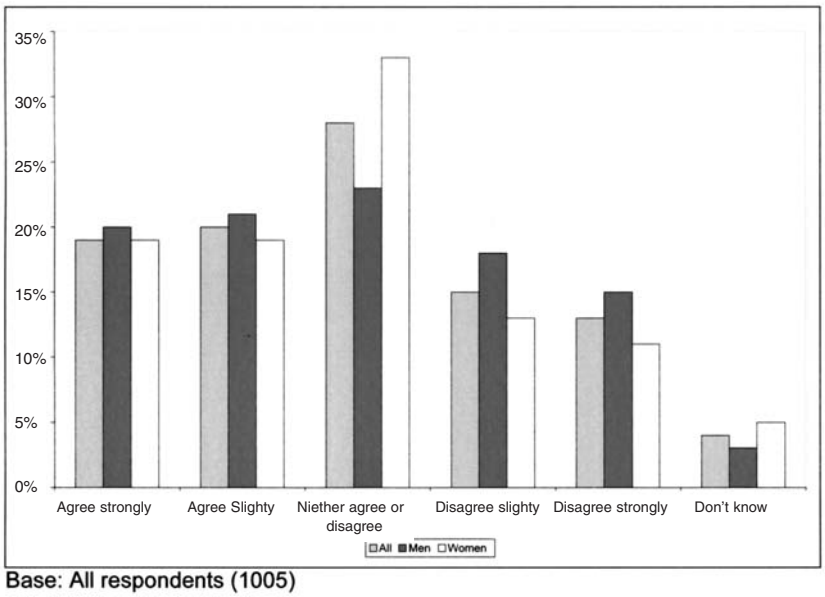

Base: All respondents (1005)

## 5.3 Man-made organisms

The third attitude statement used in the survey tried to explore how worried the public more generally might be by the concept of man-made organisms. Using a statement absent of any context or purpose regarding possible applications, about four in ten agreed (41%) that 'the idea of man-made micro-organisms is worrying' and significant proportion (28%) neither agreed nor disagreed.

As would be expected from responses to the other two statements, men were more likely to disagree than women, a third of men (32%) compared with a quarter of women (24%) and again, women were more likely to neither agree

**Figure 5.7 'The idea of man-made micro-organisms is worrying'**




Base: All respondents (1005)

nor disagree – a third of women (33%) compared with a quarter of men (23%) (see figure 5.7). The differences between age groups and regions were less stark in response to this statement compared with the other two statements.

Overall, the responses to the three statements indicate that while there was generally a more positive response to some of the principles of synthetic biology there is still concern relating to man-made organisms.

There was a relatively high proportion of respondents neither agreeing nor disagreeing with each of the three statements – one in five (19%) with respect to creating micro-organisms, one in four (25%) with respect to modifying organisms and nearly three out of ten (28%) with respect to whether the idea of creating man-made micro-organisms is worrying. This, taken with the findings from the earlier questions on awareness and understanding suggests that a lot of people had not given the issue much, if any, consideration.

Those who indicated favourable opinions towards modifying and creating micro-organisms and were not worried by man-made micro-organisms tended to be 'professional young men' – that is men in social grades AB, aged 25-34, university educated and working full-time. 20% of men who responded to the survey but only 12% of the women, supported creating and modifying micro-organisms to produce medicines and biofuels and were not worried by the idea of man-made micro-organisms.

With respect to creating organisms or man-made organisms, the idea that scientists were 'playing God' was put to dialogue participants on more than one occasion and each time it was rejected.

"I don't believe that a scientist is playing God. I believe they are doing what they think is best for us humans as in terms of living a better life..."
Female

"I think scientists [are] thinking about their children and families just as much as we are."
Male

### 5.4 Summary

The participants and the majority of survey respondents were positive about creating micro-organisms to produce medicines and biofuels. Participants in the dialogue said it was "very exciting", while 63% of survey respondents agreed that 'creating a new man-made micro-organism that will produce medicines or biofuels should be supported'.

The survey respondents appeared to be less favourable towards modifying micro-organisms with fewer than half (43%) disagreeing with the statement 're-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed'.

# 6. Views on the development of synthetic biology

This section explores issues and views relating to the potential development of synthetic biology, discussed by those who attended the public dialogue meetings.

## 6.1 Biosafety – environmental releases

Here we discuss reactions to environmental releases due to accidents from controlled environments and those which will involve a deliberate release (for example, bioremediation).

Due to the potential industrial scale of synthetic biological production, there was some concern that any accidental release would correspondingly be large, widespread and significant. This was exemplified by reference to events such as the escape of the foot and mouth virus from the Pirbright laboratory in 2007, Chernobyl and the Bunsfield oil storage depot fire in Hertfordshire.

"If this technology does become widespread, do you think there's a danger of releasing engineered bacteria into the natural environment? Won't it just mess with eco-systems and, you know, us as well?"
Male

Despite being provided with the information that such micro-organisms could potentially be engineered to reduce their likelihood of survival outside the laboratory or processing facility, some participants were concerned that scientists do not know enough about the natural environment to feel confidence in such assurances.

"...we don't actually know the risks because we know so little about the eco-systems and the environment...I mean, you know, the risk could be misread."
Male

Some participants also commented on the speed at which micro-organisms could mutate and evolve and therefore could become capable of living outside the environment for which they were designed. Others were aware that not all microbes are "dangerous" and that therefore an accidental release might not be a cause for concern.

Some participants demonstrated a high level of trust in synthetic biologists and commented on:

- the long development stages and testing of new products before any commercial uses
- an expected high level of control over the organisms created to ensure that there would be no danger from any accidental release
- their confidence that micro-organisms could be designed so that they would not be able to survive outside their intended environment. In this argument it was important that the organism in question was, 'purpose built' and therefore incapable of doing what a natural organism might.

Those who had more confidence in the ability of scientists and engineers to control engineered micro-organisms were very positive about their use in bioremediation, although others felt that this application would be of huge benefit but with a significant risk and controls must be tight. Comments were also made that effort should instead be focused on not creating polluted environments and to the prevention of accidents, such as oil spillages.

### 6.2 Biosafety - outputs

A topic we have not seen in the literature but which concerned some participants greatly was the testing of medicines produced by synthetic biology. There was concern about how side effects might differ when products are made using a synthetic biology approach rather than more traditional methods. While some participants were reassured by the rigorous testing drugs must go through, others were concerned that the side effects from drugs produced using synthetic biology processes might be different.

### 6.3 Biosecurity

Biosecurity refers to issues around the use of synthetic biology by the military and by terrorists and this topic was explored in the public dialogue meetings. Although it was mentioned that the military were interested in synthetic biology, participants seemed uninterested in discussing this issue further. From the dialogue with this particular group of participants it would seem that the use of synthetic biology by state military was largely expected.

Bioterrorism however, was an issue which prompted further discussion. On balance, participants felt that the potential benefits of synthetic biology for society outweighed the risks of possible bioterrorism, especially considering that other dangerous bioweapons (anthrax was given as an example in one of the presentations) were already available. One woman did point out that using synthetic biology for bio-terrorism could result in a "more surreptitious way of doing it ".

### 6.4 Microbes within the body

One of the case studies put forward a more futuristic application whereby an engineered microbe would live within the body and identify the cancerous cells. There was some resistance to this idea which was thought to be "repulsive", "unnatural" and possibly resulting in unforeseen and unwanted changes to the human body. Others immediately saw the benefits and persuaded some of those who were more negative that this application could be worth the risk.

The issue as to whether the health service could cope with the potentially high level of requests for such treatments was raised. However, others felt that earlier detection of diseases such as cancer might instead lessen the load on the health service.

### 6.5 Regulation and access

In the discussions, some of the participants focused on regulation of the research process while others considered regulation of the outputs and outcomes.

When asked explicitly about regulation, participants felt that they did not know enough about the subject to comment, although they certainly wanted

regulation to be in place. Some raised concerns as to whether the Government could control synthetic biology and especially whether it could keep up with the speed of development. There was also the question of a gradual decline of day-to-day regulation and maintenance of safeguards.

"Things tend to get very lax, don't they…then it's too late."
Male

Over-regulation was considered to be a threat to security if those intent on breaking the law could advance their knowledge ahead of legitimate researchers, which was viewed as "very terrifying". Concerns were also raised that regulations should not stifle development.

"It's very difficult, 'what regulations would you like to see?', because regulations, as well as safeguarding things, they shouldn't actually stop things going forward..."
Male

The participants appreciated that people from outside the field could bring new insights and recognised the benefits of open-access synthetic biology, as opposed to being patented and available to only the big companies. While open-access was generally felt to be equitable, there was however considerable concern about the lack of control that this implied.

On balance, participants were not in favour of individuals that were outside of controlled environments (such as laboratories) being able to access materials (such as equipment, DNA sequences and 'bioparts') to conduct their own synthetic biology research (so -called garage biology, or 'bio-hacking'). Restricting access was important to participants, which was linked to regulation.

"I'm pretty sure there's a regulation about people mixing fertiliser and making home made bombs….people have to be stopped from getting access."
Male

They were concerned about terrorists getting access but the participants seemed to give more thought to less 'sensational' risks. For example, it was felt open access could allow poor quality and possibly harmful synthetic biology products to be sold via the internet (for example, untested drugs).

There was agreement that those working in the field should be registered in some way and inspected. The safety inherent in registration and traceability was felt to be essential, but it was thought to be hard to police.

### 6.6 Intellectual property

Participants held different views regarding intellectual property, with some demonstrating hostility to patents, which were thought to hold-up research and development, and others believing that investors are entitled to a return on their time and money.

"...why should all my hard work be given away..."
Male

"If they're going to invest in it [biofuel] I don't see why they shouldn't get a return on what they're investing in because they're pioneering …possibly save life…"
"….and the environment.."
Two women

In general, however, there was a sense that there should be a balance between returns on investment and social responsibility and that any benefits should be accessible to a wide range of people and not just to "the rich".

To some extent participants recognised that control by a few multinational companies over a particular technology was nothing new, and cited examples such as pharmaceutical and petrochemical companies.

### 6.7 Developing countries

One of the case studies promoted discussion about the production of the anti-malarial drug precursor artemisinin using synthetic biology rather than by farmers in the developing world who were harvesting the chemical precursor from their crops of Artemisia absinthium (wormwood).

While some were concerned that these farmers in the developing world might lose their livelihood, others felt that the benefits from producing artemisinin more quickly, easily and cheaply outweighed this disadvantage. Some proposed that farmers and their local communities could be compensated by the producers of synthetic biology artemisinin.

Some also felt that production using synthetic biology technology would benefit poorer countries as this would release land, previously dedicated to wormwood, for growing food crops.

### 6.8 Funding and support

Participants were surprised to be told that big companies were not investing heavily in synthetic biology worldwide and that in the UK and the USA, much of the research was still being done by academics. Indeed, some participants recommended that industrial funding be sought.

There was also support for UK Government funding for what was seen to be a field with considerable potential to generate health and environmental benefits. Interestingly, the question was raised about how the Government would judge whether progress is being made in the field and whether or not it is getting value for the money it is providing.

As the conversations developed, participants realised that the field was at the stage where proof of concept had been achieved but there remained a lot more development work to be done. They identified investment in the field as risky because they appreciated that the benefits may not be realised and decided that companies were waiting to see how they could benefit before investing.

Some participants were impressed that the UK was thought to be as high as second to the US in this field, especially given what they perceived to be a less favourable funding situation on this side of the Atlantic.

"I thought we'd be in the top six, so to speak, but number two is very good in view of all the funds that America has at their disposal, because they pour dollars into it, whereas everyone has to go with a begging-cup over here."
Male

### 6.9 Communication and information

The participants were aware that others would be resistant to the technology and were therefore keen that the public should be informed. In particular, two potential dangers were noted: that people would reject something they did not understand and that the media would sensationalise the technology:

"..it's typical human nature, what you don't understand, you push it away.."
Male

"...the newspapers will blow it up as 'oh, we're going to be with aliens coming out of our heads', this sort of thing."
Male

However, there was a feeling that if the outputs from synthetic biology have a "feel good factor", for example with respect to medical uses, then the media would react positively. Generally, participants expected at least some negative media.

By the second session some participants had searched the internet for 'synthetic biology' and reported back that they could not find information that was targeted at a lay audience. Others, however, said that what mattered for them was not developing an understanding of the science, but whether the benefits outweighed the risks.

"We're not scientists. I don't think we need to understand all the letters and how it all works. It's really what it's trying to do, the benefits and how it's trying to solve problems around the world that's of interest to me, rather than the nitty gritty of the science."
Male

Nevertheless, there was a demand from participants that scientists and Government should take time to explain synthetic biology to the public, including its purpose and the controls that are in place.

"Everything they do has to be safe and beneficial – that's how they will win people over."
Male

### 6.10 Summary

The dialogue participants could see great potential benefits arising from synthetic biology but were very wary of releases into the environment. While some believed that synthetic biologists could 'control' created and modified organisms, others were more sceptical. There was considerable support for applications where micro-organisms would be contained, but the use of synthetic biology for bioremediation purposes was a concern.

There was comparatively little concern from participants about bioterrorism, and this was at least partly because existing bio-weapons (such as anthrax) were already available. Nevertheless, regulation was deemed to be very

important but the difficulties of policing it led participants to stress that access to synthetic biology technology should be limited to 'legitimate' users in established laboratories. They could see that over-regulation could stifle positive developments. Testing of the outputs was thought to be vital, irrespective of whether or not an existing product (such as artemisinin) was produced.

There was support for Government funding because of the potential of the technology but also so that Government would have some control over the direction of the research.

Detailed analysis of the dialogue discussions has identified a number of perspectives and revealed that there are two main dimensions on which participants views depended:

- trust in synthetic biologists to be in control of the re-designed/created micro-organisms
- the degree to which they felt the outputs would be beneficial.

The extent to which individuals understood the process of synthetic biology was secondary in determining attitudes. A more powerful driver of attitudes to synthetic biology seemed to be whether an individual felt (or trusted) that synthetic biologists could successfully control the behaviour of modified and created micro-organisms.

# 7. Participant priorities, recommendations and expectations

During the final session of the second meeting participants were split into four groups and asked to discuss their specific hopes, expectations, concerns and recommendations for the future of synthetic biology. The participants' feedback is presented below.

## 7.1 Hopes – of the four case studies, which would you most hope to succeed?

Throughout the meeting participants appeared most positive about the medical applications of synthetic biology. In the final sessions however, three of the four groups chose biofuels as the case study they would most like to succeed. This was primarily because they felt it would impact on the largest number of people.

"We picked biofuel, basically because we felt it would have the biggest world impact of the four, because of the global concern about fuels in general and the $CO_2$ emissions that it would actually save."
Male (from mixed presentation group)

"It will have the biggest impact on individual users. I know the anti-malarial drug is fantastic but it only will hit three or four million people, whereas there's millions and millions of car drivers."
Male (from mixed presentation group)

## 7.2 Hopes - is there anything else you hope that synthetic biology will achieve?

Specific medical hopes for synthetic biology included: detecting toxins and disease, producing synthetic organs, curing Parkinson's disease; curing Cancer; and impacting on global diseases more widely.

Other hopes for the implementation of synthetic biology included: purification of water systems and the elimination or redesign of harmful bacteria for positive functions.

In the discussions participants also hoped that there would be cost savings in the production of medicines and biofuels using synthetic biology, although there was some scepticism as to whether these would be passed on to the consumer. This was especially true of biofuels where some thought that the Government would tax biofuels so that prices to consumers remained unchanged from present levels.

The evaluation questionnaire asked participants 'what are your hopes, if any, for the technology?'. Responses reflected those given during discussions, with medical advances, saving lives, protecting the environment, and solving the energy crisis all mentioned.

### 7.3 Expectations - what do you expect synthetic biology to achieve in the next 10 years?

Participants' expectations varied across the group with some of the breakout groups focused more on the drivers of research while others looked at the specific applications they felt would be realised.

One breakout group felt that pharmaceutical and other multi-national companies would drive investment and developments in synthetic biology. Another felt that the 'qualified' scientists would be developing the field and not the 'bio hackers'.

Specific applications expected in the next ten years included: the production of artemisinin, the production of biofuels, increasing food production, detecting MRSA in hospitals; and detecting infections on urinary catheters. Much of this was specifically stimulated by the information presented in the case studies.

One breakout group went further and explored the impact they felt developments in synthetic biology would have on wider society. For example, they put forward that there would be fewer deaths from malaria, and that more people would be driving bio-diesel cars.

### 7.4 Expectations - how do you expect the media to react?

There was a consensus among the breakout groups that although the media may report on some of the positives of synthetic biology they were more likely to focus on the negative aspects of the technology.

"We expect the press to be very positive of the successes, but as the press do like to pick up on the bad points they will be really focusing on the negatives, the costs involved, anything that goes wrong, anything that doesn't go right, if there's a deadline that is missed etc they will be very quick to publish that and highlight all of those things and they'll go in much more detail about the negatives and skip over the detail about the positives."
Male (from mixed presentation group)

One breakout group discussed GM crops as an example of the media's past negative reaction to scientific developments and highlighted that this made a big difference to public perceptions of the technology. Others were hopeful that if the benefits, in particular medical benefits such as detecting MRSA, were highlighted, the media would be more positive towards the technology.

### 7.5 Concerns - should any of the four case studies be stopped? What is your biggest worry about synthetic biology technology?

None of the breakout groups felt that research into any of the applications detailed in the case studies should be stopped completely, however, all the groups were wary of bioremediation because this involved deliberate release into the environment.

"We didn't think that any needed to be stopped, but the huge benefits also carry great risks with the bioremediation. It's outside of the lab; it's in an uncontrollable area, if it's in water it's very easy to move around, so it's going to be much harder to control. So we'd definitely want to have very tight safety and control regulations."
Male (from mixed presentation group)

Bioremediation was highlighted as a potential use where testing would be vitally important and testing was highlighted by the whole group as very important in general. The fact that the technology was so new meant that participants expected thorough testing and they felt it was important to allow time for this and not rush progress. They also felt that controls should be introduced to ensure that any new applications are safe.

"We felt that none of them should be stopped really, just controls put in place to make sure things go at a slower pace and testing is done rigorously to make sure there are no leaks and stuff."
Male (from mixed presentation group)

The evaluation questionnaire asked participants 'what are your concerns, if any for the technology?'. Participants expressed concern surrounding: the side effects of any technology, the need for strict regulation, the technology falling into the wrong hands, lack of adequate testing, exploitation by multi-nationals, interaction of new organisms with the eco-system, lack of controls in other countries and terrorism.

### 7.6 Recommendations to scientists and engineers

The main recommendation for scientists and engineers was to raise public awareness and provide some kind of information for the public that presents both the benefits and the risks.

"Open dialogue, highlighting the benefits and also highlighting the risks"
Male (from mixed presentation group)

One breakout group felt that it was important to fund this area of research, however they believed that it was important that scientists should be guided by their morals and not motivated by business and money.

### 7.7 Recommendations to Government and policy-makers

Participants encouraged the Government to act in the best interests of the population and ensure that appropriate controls and regulations were in place and enforced. There were also calls from two of the breakout groups for the Government to invest money in synthetic biology because this would give the Government influence over developments in the field.

### 7.8 Recommendations to friends and relatives

All the breakout groups called for the public to be open-minded and to learn more about synthetic biology because of the impact it will have on day-to-day life. Participants felt that the public need to be fully informed of the benefits and the negatives of the field.

"Be open to the change, make time to understand what's happening, 'cos whether we like it or not, there are going to be things coming out that are going to affect us and the more we understand it, the easier it is to take it in and actually appreciate the work that's going on and how it's going to affect our lives."
Male (from mixed presentation group)

One breakout group also called for the public not to be swayed by media coverage and to consider the issues more independently.

"We felt that a lot of people close down, again because of the bad press about GM crops, and people need to think more about the positives rather than the negatives. It's just a case of listening and understanding. Whatever the media puts out there can have a significant impact and people just sort of switch off. So we felt people need to be a lot more open minded about the whole concept."
Male (from mixed presentation group)

Some participants called for education on synthetic biology in schools, so that students could feedback information to parents and information could be shared.

### 7.9 Summary

Participants had high hopes for synthetic biology and the potential healthcare benefits were identified as being important. However, when participants considered prioritisation of the case study applications, the key consideration was the number of people who would benefit. By the end of their discussions the participants therefore prioritised the development of biofuels over medicine because of the environmental benefits, because they were aware that oil is a finite resource and there is a fairly urgent need to find alternatives and because of the number of people who would benefit.

Control and safety of both synthetic biology systems and their products were seen as paramount. Participants were content that research on a range of applications and products was appropriate, provided that appropriate controls and tests were in place. They were most concerned about the development of bioremediation applications because they involve deliberate release into the environment of modified or created organisms.

Generally, it was expected that the media would react negatively and participants recommended that scientists work to raise public awareness. They also thought it was important for other members of the public to keep an open mind and not be unduly swayed by media reports.

Government funding was thought to be important, not only because participants believed that this was a field worthy of further development, but also because this would give the Government influence over developments.

# 8. Conclusions

## 8.1 Attitudinal groups

Based on the findings from the public dialogue activity, we have identified a number of attitudinal typologies. The exploratory scale of this dialogue activity, in terms of length, depth and numbers of participants, means that it is not possible to say anything about the prevalence of each perspective or whether there may be others. Indeed, the survey strongly indicates that there are other attitudinal groups in society who were not represented in the meetings, and who were more concerned about the creation and modification of organisms than those who took part in the dialogue meetings. However, from this particular exercise, the findings indicate that the participants could be loosely grouped into four different attitudinal types:

- Those who may or may not have understood the science behind synthetic biology but explicitly decided that they did not need to understand the details and instead focused on the outputs and decided that the benefits outweighed the risks.
- Those who were at least somewhat confident that synthetic biologists would be in control of their creations especially in controlled conditions, and consequently that the risk was very low. However, some had concerns over the consequences of an enviromental release (accidental or intentional) and felt that the risk was too high.
- Those that were more cautious and who needed more convincing that the outputs would be safe and wanted to see more testing before products were released to the market.
- Lastly, there was a group who struggled to understand synthetic biology, appearing at some points to have grasped it and at others not to have done so. This group's attitude fluctuated and was influenced in the same direction as the general 'gist' of the discussions, although on balanced, did seem to be more positive than negative.

Participants universally supported restricting access and only allowing research in properly regulated facilities and proper testing of processes before large scale production.

## 8.2 Further research

This study has been small scale and exploratory, but given the potentialy controversial nature of this technology, this was an important and appropriate first step in understanding public reactions to synthetic biology. Furthermore, it provides a baseline of UK perceptions and awareness of this emerging technology at an early stage of its development and was completed at a time before it had attracted widespread media coverage. Hence it will be useful for comparison with future studies and public attitudes research over the coming years, as the technology develops and media coverage (presumably) increases.

This work has also provided a focus for further work and identified some interesting themes that are worthy of further exploration:

- how people determine whether something is alive and whether micro-organisms are seen to be alive
- further exploration of philosophical questions surrounding the creation of 'new life' with other groups (for example, religious groups)
- why there appear to be different reactions to modifying existing organisms and the creation of new ones
- the apparent differences in opinion between men and women and age groups
- attitudinal differences of people across the UK, in different regions, as well as a comparison of those from rural and urban locations
- how and if people view this technology as different to that of GM and why.

## Appendix 1: Participant questionnaire

Below are some statements. Please indicate whether you agree or disagree with each by circling the number in the right hand column.

**Q1**
I am not interested in science and I don't see why I should be

| | |
|---|---|
| Agree | 1 |
| Disagree | 14 |
| Don't know | 0 |

**Q2**
Because of science engineering and technology there will more opportunities for the next generation

| | |
|---|---|
| Agree | 14 |
| Disagree | 0 |
| Don't know | 1 |

**Q3**
Science and technology are making our lives healthier, easier and more comfortable

| | |
|---|---|
| Agree | 12 |
| Disagree | 1 |
| Don't know | 2 |

**Q4**
In general scientists want to make life better for the average person

| | |
|---|---|
| Agree | 10 |
| Disagree | 0 |
| Don't know | 5 |

**Q5**
It is important to know about science in my daily life

| | |
|---|---|
| Agree | 13 |
| Disagree | 1 |
| Don't know | 1 |

**Q6**
The more I know about science the more worried I am

| | |
|---|---|
| Agree | 0 |
| Disagree | 14 |
| Don't know | 1 |

**Q7**
I cannot follow developments in science and technology because the speed of developments is too fast

| | |
|---|---|
| Agree | 1 |
| Disagree | 9 |
| Don't know | 5 |

**Q8**
Science is getting out of control and there is nothing we can do to stop it

| | |
|---|---|
| Agree | 0 |
| Disagree | 13 |
| Don't know | 2 |

**Q9**
The speed of development in science and technology means that it cannot be properly controlled by the Government.

| | |
|---|---|
| Agree | 3 |
| Disagree | 5 |
| Don't know | 7 |

**Q10**
The idea of creating artificial life is really exciting

| | |
|---|---|
| Agree | 9 |
| Disagree | 3 |
| Don't know | 3 |

**Q11**
Most scientific research can be used for good or ill.

| | |
|---|---|
| Agree | 15 |
| Disagree | 0 |
| Don't know | 0 |

## Appendix 2: Topic guide – Meeting 1

**6.30 - 6.45pm**
**Welcome and introduction**

Introduce self

Introduce PSP and independence from the client

Introduce anyone else who is observing or helping

The format this evening will be

- After this short introductory session we will break into 2 groups for about half an hour's discussion.
- We will then reconvene in this room for a presentation of about 10 minutes with time after that to ask questions.
- At 8pm we will break for about 15 minutes to get something to eat and resume with another presentation. You'll be able to bring your food in here for the presentation. This presentation will also last about 10 minutes with time for questions.
- Then we have about half an hour for a more general discussion and more questions or other points you want to raise.

There are no right or wrong answers. Everyone is entitled to their own view, so I'd like to hear from everyone because everyone's view is valid.

You don't have to answer all of the questions and you are free to leave before the end of the session, if you wish.

As you have been informed, we are audio recording the discussions, so that we don't miss anything that is said but no one will be identified in the report. All the information will be collected together and anonymised.

Please could everyone turn off their mobile phone because it interferes with the recording, even on silent.

Standard warm up round the room of introductions

Introduce the project

The report will be published in May/June time and will be available from the Royal Academy of Engineering website – we will tell you more about that next time.

Make it clear PSP is independent of the client

RAEng representative to say more about why they are sponsoring the project.

**6.50 – 7.25pm**

**BREAK IN TO 2 GROUPS BASED ON GENDER**

Break into 2 groups for brain storming on:

Scientific research:

- What words and phrases come to mind when I say scientific research? (Write on board and go through interesting ones)
- What do you understand scientific research to be/ what do you think scientific researchers do?
- Do you think it is a good thing or a bad thing? What is good about it, if anything? What is bad about it, if anything?
- How front of mind is scientific research, is it something you think about?

**Synthetic biology:**

- What words or phrases come to mind when I say synthetic biology? (write on board and go through) (If no-one can think of anything take a couple of minutes to talk to the person next to you to think about the things it could be)
- What do you think it is? – If necessary – it's an area of scientific research
- What do you think is being studied? Why?
- What do you think synthetic biology could be used for? Why?
- What tools do you think synthetic biologists use to carry out their research? Why?
- What people do you think work in synthetic biology? (physicist, biologists, doctors, chemists, engineers) why?
- Do you think synthetic biology is a good thing or a bad thing? Why?
- What do you think the benefits of synthetic biology could be? Why?
- What do you think the risks of synthetic biology could be? Why?
- Do you think synthetic biology is relevant to your life? How interested are you in it? Why?
- How knowledgeable do you feel about synthetic biology? Why?
- Has anyone heard anything about synthetic biology in the news? When/what was the source?

**7.30 – 8.00pm**

Presentation on synthetic biology – Professor Freemont, with time for questions

(10 minute presentation, 20 minutes for questions)

**8.00 – 8.15pm**

Break

**8.15 – 8.45pm**

Presentation on the social/ethical issues – Dr Jane Calvert
(10 minute presentation, 20 minutes for questions)

**8.45 – 9.15pm**

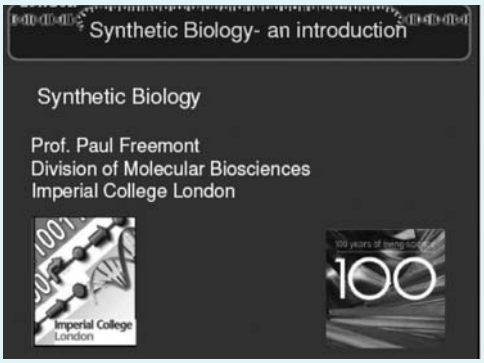
General discussion on information presented by both presenters
This may be run as one group or as two groups, depending on how many people are contributing. If in two groups possible questions:

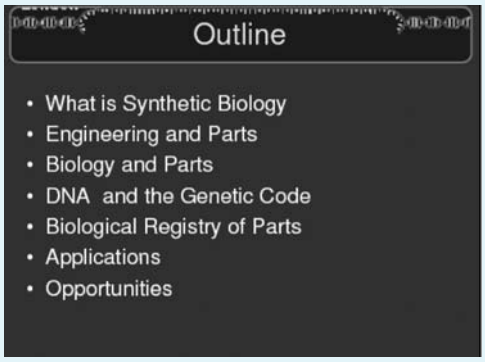
- What did you think of those presentations?
- What did you think was particularly interesting?
- Did you learn anything you didn't know before? What?
- Has the presentation made you think differently about synthetic biology?
- Is there anything you didn't understand or would like to ask another question on?

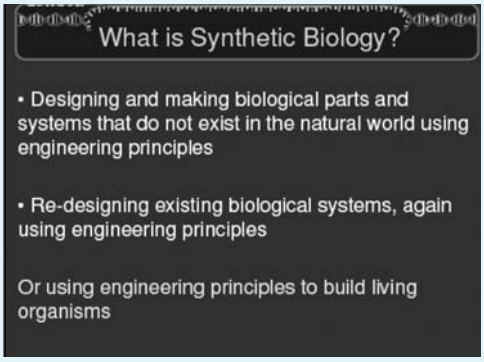
**9.15-9.30pm**

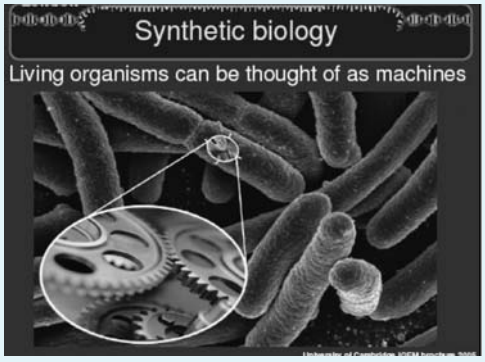
Briefing for next meeting

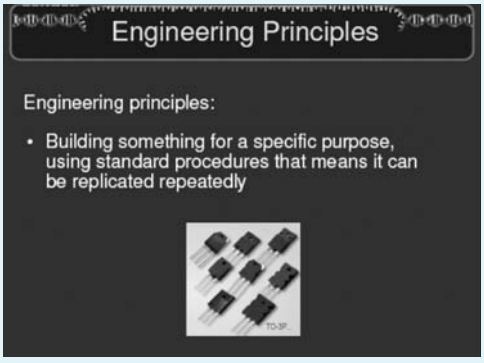
## Appendix 3: Professor Paul Freemont's Presentation

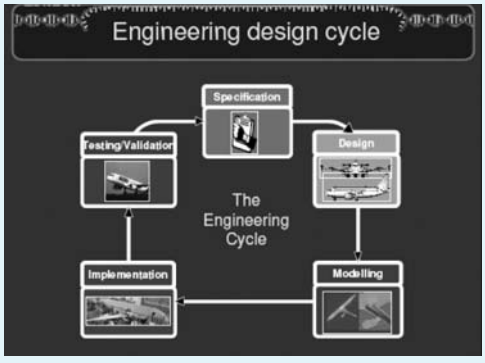


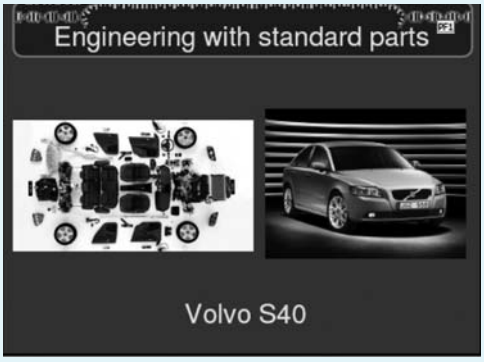



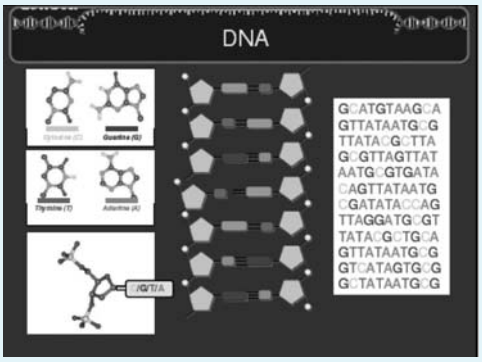



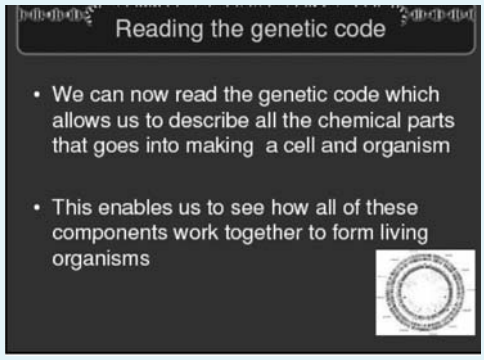



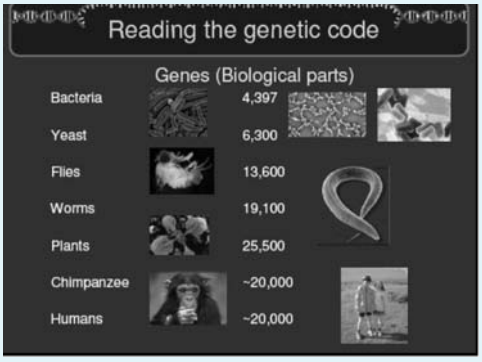



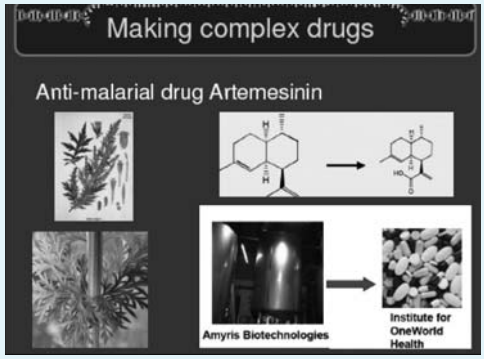


DNA

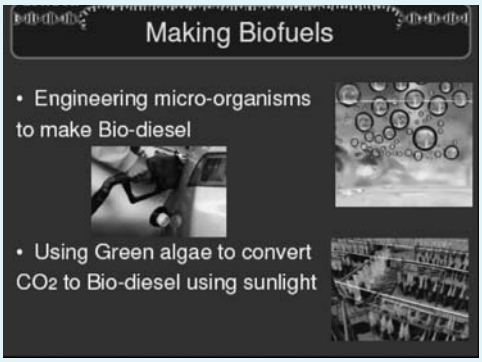

Reading the genetic code
• We can now read the genetic code which allows us to describe all the chemical parts that goes into making a cell and organism
• This enables us to see how all of these components work together to form living organisms

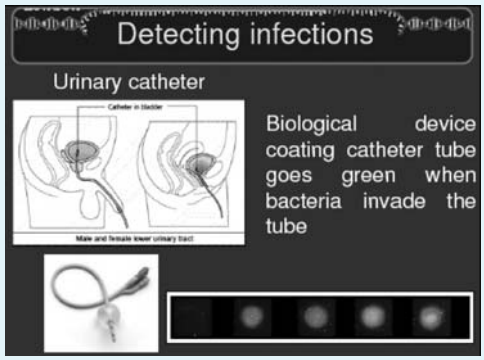

Reading the genetic code
Genes (Biological parts)
Bacteria 4,397
Yeast 6,300
Flies 13,600
Worms 19,100
Plants 25,500
Chimpanzee ~20,000
Humans ~20,000


Making DNA to order
• Synthetic DNA can now be chemically made to order
– type in the sequence GCGCTATCGCGG.....
– Get the DNA by mail order


Registry of Standard Biological Parts
Catalogue of Biological Parts

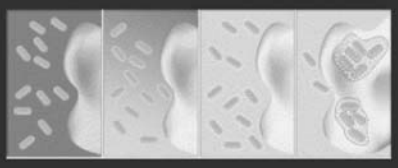

Making complex drugs
Anti-malarial drug Artemesinin
Amyris Biotechnologies
Institute for OneWorld Health


Making Biofuels
• Engineering micro-organisms to make Bio-diesel
• Using Green algae to convert $CO_2$ to Bio-diesel using sunlight


Detecting infections
Urinary catheter
Biological device coating catheter tube goes green when bacteria invade the tube

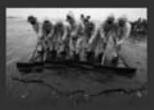
## Invading cancer cells

- Engineered bacteria to detect and invade cancer cells



## Removing environmental pollution

- Bioremediation
  - Oil spills
  - Land and water pollution



## Opportunities - 1

- Bio-energy and Pharmaceuticals
  - Re-programming cells for bio-catalysis (pharmaceuticals, fine chemicals, bio-fuels)
- Environment
  - Re-programming cells for bio-degradation; cleaning up man-made waste (industrial pollution)

## Opportunities - 2

- Biomedicine
  - Re-programming stem cells, smart delivery of drugs, cancer therapy
- Food
  - Re-programming plants for antibiotic production, efficient food production
- Biosensors
  - Toxins, pollutants in water, TNT

## Appendix 4: Dr Jane Calvert's Presentation

innogen

### Synthetic biology: social and ethical issues

Dr Jane Calvert
ESRC Innogen Centre
University of Edinburgh

Public Dialogue on Synthetic Biology
19th March 2009
Royal Academy of Engineering

ESRC genomics network

### Outline

- The synthetic biology approach
- Social and ethical issues
  - Biosafety
  - Biosecurity
  - Intellectual property
  - Natural/unnatural

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### The synthetic biology approach

- Synthetic biology: 'the engineer's approach to biology'
- An annual undergraduate competition – the international genetically engineered machine competition (iGEM)
- Attempt to build a new community of researchers
- Heavily influenced by analogy with computer software, where amateurs made significant advances
- Students are getting involved in synthetic biology, enthusing a new generation

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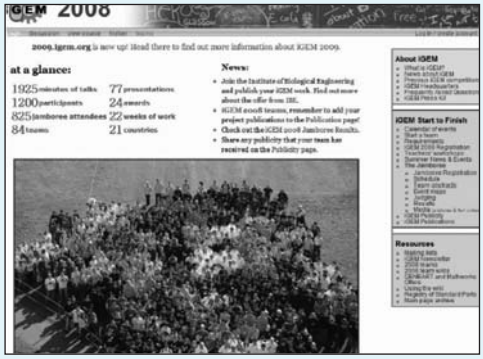


### Biosafety

- Synthetic biology could involve the production of replicating living organisms
- The accidental release of synthetic organisms could have unintended harmful effects on the environment or on human health
- New organisms could have unpredictable properties
- But it is currently much easier for a synthetic microorganism to survive in the lab than in a natural environment
  - They could be made to be dependent on nutrients that are not found in nature
  - They could have built-in safety features such as 'fail-fast' mechanisms

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### Biosafety

- Some people think that we should ban all uses of synthetic biology in the open until a risk assessment is conducted for each proposed application
- Others think that this would make research expensive and restrict synthetic biology to a few labs

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### Biosecurity

- Synthetic organisms could be created for harmful purposes
- Concerns that 'biohackers' could use synthetic biology to recreate known harmful organisms (perhaps even making them more dangerous)
- We have already seen the synthesis of some harmful viruses:

Poliovirus, using only DNA sequence information from the internet and mail-ordered raw materials

The 1918 flu virus

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### Biosecurity

- Currently much easier ways of obtaining harmful viruses than synthesizing them
- But the ease of synthesizing them will change with time
- Relatively easy to get a DNA sequence made by a specialist company
- These technologies are becoming available to an increasingly wide range of people
- This leads to concerns about 'garage biology' and 'biohackers'
- Although it is still much more expensive to set up a biology lab than to programme a computer…

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## Biosecurity

- Different options put forward for controlling DNA synthesis such as:
  - Security screening of customers by DNA synthesis companies
  - Education of scientists on biosecurity issues
  - A biosafety manual for synthetic biology laboratories

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## Intellectual property

- Aim is to develop some form of protection of intellectual property without stifling progress
- Patents already exist that could inhibit research in synthetic biology
- Worries about these potentially restrictive patents are closely linked to concerns about large companies dominating the field
- A foundation has been set up to try to ensure that biological parts are freely available in the public domain

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## Intellectual property

- The intellectual property issues raised by synthetic biology are closely linked to ethical concerns about 'patents on life'
- Synthetic biology is very likely to involve the creation and the patenting of novel living organisms
- The 'unnaturalness' of the creations in synthetic biology may make it easier to patent them – they are clearly human inventions, rather than products of nature

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## Natural/unnatural

- Synthetic biology raises ethical questions about the role and responsibility of human beings in creating novel living things
- Where should the line be drawn between what is 'natural' and what is not?
- Is it helpful to draw such a line at all?
- Should we distinguish between totally synthetic organisms and modifications of existing organisms?
- Lots of issues to discuss…

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## Appendix 5: Topic guide – Meeting 2

**6.30-6.50pm**

**GIVE OUT ATTITUDE QUESTIONNAIRES TO BE COMPLETED WHILE WAITING FOR START**

Introduce self

Introduce PSP and independence from the client

Introduce anyone else who is observing or helping

The format this evening will be

- Some time together here reflecting on last time
- Break into two groups to discuss in more depth
- Recap presentation on synthetic biology back here as one group
- Presentation from xxx of xxx also as one group
- Break out into two sessions for more discussions

**RE-ITERATE GROUND RULES:**

- There are no right or wrong answers. Everyone is entitled to their own view, so I'd like to hear from everyone because everyone's view is valid.
- You don't have to answer all of the questions and you are free to leave before the end of the session, if you wish.
- We are audio recording the discussions, so that we don't miss anything that is said but no one will be identified in the report. All the information will be collected together and anonymised.
- Please could everyone turn off their mobile phone because it interferes with the recording, even on silent.

Round robin asking each person to say their name and what has struck them in particular from last time and why.

In pairs, participants to think of benefits and risks likely to arise from synthetic biology.

**FLIP CHART RESPONSES TO TAKE INTO BREAKOUT GROUPS**

**7.15 – 7.50pm**

**BREAK INTO 2 GROUPS**

In 2 groups work through two case studies in the following order, allowing about 20 minutes for each:

Artemesinin
Detecting infection

For each one ask:
Initial thoughts/comments
What do you think the risks are and why?
What do you see as the benefits?
Do you think the benefits outweigh the risks?

Draw out disagreements/variations in views. How would you maximise the benefit/mitigate the risk?

**7.50 - 8.05 pm**

Break

**8.05 – 9.00 pm**

In 2 groups work through the other 2 case studies in the following order, allowing 15-20 minutes for each:

Bioremediation
Biofuels

Last 15 – 20 minutes – discuss all four case studies together focusing on the issues that have arisen.

**9.15-9.30 pm**

**RECONVENE AS ONE GROUP**

**GIVE EVERYONE A FEEDBACK FORM**

The Internet forum will be open until 14 April, in case anyone has any further comments they would like to have included.

Lesley to say something about the report and the RAEng inquiry – publication date and where it will be available from. There will be a link from the Internet forum.

The report will be published in May/June time and will be available from the Royal Academy of Engineering website. We will let you know when it is available. It will be downloadable from the RAEng website and via the forum. The forum will be taken down at the end of September.

Thank everyone for coming and taking part.

# Appendix 6: Case studies

### 1. Production of Artemisinin - (anti-malaria drug)

Malaria kills between 1 and 3 million people per year, mainly in Africa but it is also a big problem in Latin America and Asia. Malaria is caused by a parasite and is transmitted when an infected female mosquito bites someone. There is currently no vaccine for malaria. Also, the parasites evolve quickly and become resistant to drugs, so there is a need to find new treatments.

The anti-malarial drug artemisinin is over 90% effective and is found in extracts of the plant Artemisia annual, (Wormwood). Since 2001 the World Health Organisation has recommended using artemisinin-based drugs in combination with other therapies for the treatment for malaria. However, supply is not meeting demand and extracting it from the plants is complex, time-consuming and expensive.

Using the principles of synthetic biology, scientists are re-engineering an existing organism to mass produce artemisinin. Synthetic biology differs from conventional genetic engineering in that it involves a much more fundamental redesign of an organism to carry out new functions. In this example, the aim is to re-design yeast microbes into living minianti-malaria drug factories.

For large scale production of the anti-malaria drug, the re-designed yeast organisms are grown in huge fermentation vats. This technology has the potential to produce artemisinin more cheaply and efficiently.

There are concerns as to whether this is the best use of resources when there are other ways to prevent malaria such as using bed nets.

There are concerns about producing the drug in developed countries. At present farmers in East Asia and some parts of Africa are growing wormwood for medical production. But producing the drug by synthetic biology methods may deter developing countries from growing artemisinin locally and developing their own industry.

Some people object in principle to changing the genetics and functions of living organisms and some people are concerned about the unexpected consequences. In particular there are concerns about the possible consequences of an accidental release of the redesigned micro-organisms into the environment.

This technology is on the verge of going into production and it is planned to be on the market in 2010/2011.

### 2. Detecting toxins and disease

Last year melamine was found in baby milk in China. It is a toxic chemical that led to kidney damage and in some cases to the death of babies and young children.

A woman in San Francisco has set-up a laboratory in her dining room to attempt to engineer a new biological organism that will turn fluorescent green if melamine is present in food. She is experimenting by modifying jellyfish

genes and adding them to yoghurt. If she is successful she plans to make the design publicly available. She is using basic household equipment (a salad spinner and plastic bags) and some scientific equipment she bought from eBay. This has come to be known as 'garage biology' or 'biohacking'.

A community is developing that is taking advantage of off-the-shelf genetic parts that can be bought easily and cheaply via the Internet. There are some companies that will produce 'made-to-measure' DNA and biological components for anyone and it is increasingly easy to order these by post. This means that synthetic biology could potentially take place in people's homes.

Some people think that this is putting power into the hands of the people and taking away power from big multinational companies which own the patents. Others believe that people working alone at home cannot be regulated and that there are risks that something could go wrong. Also, people might try to manufacture organisms to do harm, rather than good.

In Britain the regulations are far stricter than in the US. There is very little that can be done at a home address here – this area of work is regulated by the Health and Safety Executive. Some feel regulation is important because the organisms created could escape and grow and we don't know what would happen if they did.

Using synthetic biology techniques, within the next ten years it is likely that micro-organisms will be re-engineered to be able to detect a range of toxins and heavy metals. For example, work is taking place in the UK to design and re-engineer bacteria that can detect arsenic in drinking water.

Looking further into the future, it is possible that within 25 years micro-organisms could be designed or created that could permanently live in people's bodies to detect a particular type of abnormality; for example a type of cancer.

### 3. Biofuels

The vast majority of climate scientists agree that burning fossil fuels like coal, petrol and gas, which release carbon dioxide and other greenhouse gases into the atmosphere, is causing the climate to change, with potentially disastrous consequences. Hence the search for alternatives, such as biofuels.

The two common ways of producing biofuels are to derive ethanol from sugar cane or to derive oil from crops such as soybeans but this has resulted in some farmers in developing countries choosing to grow biofuel crops instead of food crops. Also, growing biofuel crops is a very inefficient way of producing fuel.

Synthetic biologists are working on re-designing micro-organisms (bacteria or algae) to become mini-biological factories that will produce bio-diesel.

Once these synthetic organisms have been developed, the aim will be to produce huge numbers of these synthetic organisms which would live in large fermentation vats and produce biodiesel. Enabling industrial-scale production is no easy task.

A number of biotechnology companies are researching how to produce biofuels using bio-engineered organisms, and it's possible that they could be available on the market within 5 years. Patents for micro-organisms that can produce ethanol or hydrogen have already been filed.

Some scientists argue that synthetic biology is at such an early stage that inappropriate patenting could stifle progress in this field. One campaigning group worried about the commercial monopolisation of such globally important products as biofuels, says that some companies are aiming to monopolise the technology. In response, companies say they want to know that their 'discoveries' are protected so that if they invest heavily in research and development (which will amount to millions of £'s) they will get a financial return.

### 4. Bioremediation

Bioremediation is the use of biological organisms to treat environmental contamination such as that found in landfill sites and other places where there have been industrial plants or oil spills.

Synthetic biologists are looking at how bacteria could be engineered to take-up the pollutants in contaminated sites, degrade it and thereby remove it from the environment.

This would involve creating new organisms capable of living outdoors (as opposed to being contained in the laboratory or in industrial vats) and there are concerns that these organisms would escape into the wider environment beyond the site. Because these organisms would be alive they could potentially grow, reproduce and evolve and no one would know how they would react with the wider environment and existing living things, such as plants and animals as well as other bacteria.

To counter these concerns, measures have been proposed like engineering the bacteria to be dependent on nutrients that are not widely available and designing them so that they self-destruct if their population gets too large. But some fear that they could evolve to eat more commonly available nutrients.

Such bioremediation organisms could be available within 10 years.

Looking further into the future, as well as re-designing existing micro-organisms, synthetic biology also aims to create new DNA building blocks and 'bioparts' and to build synthetic organisms from 'scratch'. Some people say creation of new and artificial life its unnatural and raises questions over 'what is life' and 'playing God'.

## Appendix 7: Evaluation questionnaire

Thank you for taking part in this project. PSP and the Royal Academy of Engineering are interested in your views in the event and how it was run. Your answers will be anonymous.

**Q1 Were you able to express your views freely and openly in the main sessions?**

| | |
|---|---|
| Yes completely | 15 |
| Yes but sometimes I felt nervous | 0 |
| Not as much as I would have liked | 0 |
| Not at all | 0 |
| Don't know | 0 |

**Q2 If not, please say why in the box below.**

0

**Q3 Were you able to express your views freely and openly in the breakout sessions?**

| | |
|---|---|
| Yes completely | 15 |
| Yes but sometimes I felt nervous | 0 |
| Not as much as I would have liked | 0 |
| Not at all | 0 |
| Don't know | 0 |

**Q4 If not, please say why in the box below.**

0

**Q5 Did you find Professor Paul Freemont on the science of synthetic biology.....(Please tick all that apply)**

| | |
|---|---|
| Helpful | 14 |
| Able to answer my questions | 8 |
| Self Important | 0 |
| Did not want to listen to my opinions | 0 |

**Q6 Were you able to understand the information he presented?**

| | |
|---|---|
| Yes, all of it | 3 |
| Yes, most of it | 13 |
| A little of it | 0 |
| None of it | 0 |

**Q7 Do you feel he gave...**

| | |
|---|---|
| Too much information | 0 |
| About the right amount of information | 15 |
| Not enough information | 0 |

**Q8 Did you find Dr Jane Calvert on the issues raised by synthetic biology.....(Please tick all that apply)**

| | |
|---|---|
| Helpful | 15 |
| Able to answer my questions | 4 |
| Self Important | 0 |
| Did not want to listen to my opinions | 0 |

**Q9 Were you able to understand the information she presented?**

| | |
|---|---|
| Yes, all of it | 6 |
| Yes, most of it | 9 |
| A little of it | 0 |
| None of it | 0 |

**Q10 Do you feel she gave...**

| | |
|---|---|
| Too much information | 0 |
| About the right amount of information | 14 |
| ,Not enough information | 1 |

**Q11 Do you feel that there was conflicting information presented which it was difficult to reconcile?**

| | |
|---|---|
| Yes, often | 0 |
| Yes, sometimes | 3 |
| No | 9 |
| Not sure | 3 |

**Q12 Taking the presentations together, do you feel the overview of synthetic biolgoy was balanced?**

| | |
|---|---|
| No, it was very positive | 1 |
| No, it was a bit too positive | 0 |
| Yes | 14 |
| No, it was a bit too negative | 0 |
| No, it was very negative | 0 |

**Q13 Did the case studies help you understand the issues raised by synthetic biology?**

| | |
|---|---|
| Yes completely | 7 |
| Yes to some extent | 8 |
| Not sure | 0 |
| Not really | 0 |
| Not at all | 0 |

**Q14 Taking all the case studies together, do you feel that the overview of synthetic biology was balanced?**

| | |
|---|---|
| No, it was very positive | 0 |
| No, it was a bit too positive | 3 |
| Yes | 12 |
| No, it was a bit too negative | 1 |
| No, it was very negative | 0 |

**Q15 Do you feel there has been enough time for debate and discussion with the presenters?**

| | |
|---|---|
| Yes | 9 |
| No | 4 |
| Not sure | 2 |

**Q16 Do you feel that there has been enough time for debate and discussion with the other members of the public?**

| | |
|---|---|
| Yes | 8 |
| No | 3 |
| Not sure | 4 |

**Q17 On balance would you say that you now feel...**

| | |
|---|---|
| Positive about synthetic biology | 15 |
| Negative about synthetic biology | 0 |
| Neutral about synthetic biology | 0 |
| Not sure | 0 |

**Q18 Overall, how well do you feel the event was run by the facilitators?**

| | |
|---|---|
| Very well | 13 |
| Fairly well | 2 |
| Not very well | 0 |
| Not at all well | 0 |

**Q19 Overall, how do you rate the venue and the facilities?**

| | |
|---|---|
| Excellent | 9 |
| Very good | 5 |
| Fair | 1 |
| Not very good | 0 |
| Poor | 0 |

**Q20 Did you use the internet forum provided by PSP?**

| | |
|---|---|
| Yes I contribtued to the forum | 6 |
| Yes I looked at the forum | 6 |
| No | 3 |

**Q21 If you did use the internet fourm how easy did you find it to use?**

| | |
|---|---|
| Very easy | 4 |
| Fairly easy | 5 |
| Fairly difficult | 1 |
| Very difficult | 0 |

**Q22 How would you explain synthetic biology to a friend?**

15

**Q23 What are your hopes, if any, for the technology?**

15

**Q24 What are your concerns, if any, for the technology?**

14

**Q25 If you have any further comments, please write them in below.**

5

**Thank you very much for your help. Please hand this form to one of the project team on your way out or leave it on your seat.**

**Note: For Q22-Q25 the number relates to the number of responses given.**

# Appendix 8: Omnibus

## Survey Questions

| | |
|---|---|
| **Client** | People Science & Policy |
| **Survey Name** | Synthetic Biology Survey |
| **Dates** | 17-19th April 09 |
| **Sample** | 1000 GB Adults 18+ |
| **Methodology** | Telephone Omnibus |

**Q1 How much would you say that have you heard about synthetic biology?**
**READ OUT- SINGLE CODE**

1. Heard a lot
2. Heard a little
3. Heard the term only but don't know what it means
4. Heard nothing
5. Don't know (Do not read out)

**Q2 What words or phrases come to mind when I say 'synthetic biology'?**
**CODES OPEN – CLIENT TO CODE RESPONSES**

**Q3 What do you think synthetic biology might be? INTERVIEWER: PROBE FOR EXPLAINATION**
**CODES OPEN – CLIENT TO CODE RESPONSES**

**Q4 I am now going to read out some statements and I would like you to tell me the extent to which you agree or disagree with each?**

**READ OUT – ROTATE ORDER**

A. Re-designing an existing micro-organism so that it produces medicines and biofuels should not be allowed
B. Creating new man-made micro-organisms that will produce medicines or biofuels should be supported
C. The idea of a man-made micro-organism is worrying

**SINGLE CODE**

1. Agree strongly
2. Agree slightly
3. Neither agree nor disagree
4. Disagree slightly
5. Disagree strongly
6. Don't know (do not read out)

INTERVIEWER NOTES:
4a ASKS ABOUT CREATING NEW MICRO-ORGANISMS;

4b ASKS ABOUT CHANGING EXISTING ORGANISMS
AN EXAMPLE IS BACTERIA

# The Royal Academy of Engineering

As Britain's national academy for engineering, we bring together the country's most eminent engineers from all disciplines to promote excellence in the science, art and practice of engineering. Our strategic priorities are to enhance the UK's engineering capabilities, to celebrate excellence and inspire the next generation, and to lead debate by guiding informed thinking and influencing public policy.

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