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MycoSynVac

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Public and expert concerns

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Foreword

MycoSynVac is a Horizon 2020 funded science project, with the overall aim to develop a serum-free, universal vaccine chassis against Mycoplasma for livestock. Recently both biotechnologies for agricultural industry, such as GM crops, and new kinds of vaccines, such as the Human Papillomavirus vaccine (HPV), have been subject of controversies between lay-publics and scientific experts. Therefore, the MycoSynVac project has included the question of public and expert perceptions of MycoSynVac and the potential ensuing vaccine(s).

This report is the result of a qualitative, cross-European case study of Denmark, UK, Poland, Austria and Spain with the aim of ***Mapping the considerations among lay people, synthetic biology scientists and vaccine scientists that occur in relation to the development of synthetic vaccines for farm animals.***

The study has been performed by a group of social scientists at Department of Food and Resource Economics at the University of Copenhagen between January 2016 and October 2017.

The project would not have been possible without the many lay and expert interviewees from our five case countries – thank you for your participation! We would also like to say thank you to the moderators and translators who copy edited interview guides, translated them and conducted the focus groups in Poland, Austria and Spain: Ally Davies, Kasia Gradzuik, Andrea Schikowitz, Kristina Reinbold and María Gonzáles Hoyas. We also want to say thank you to the partners and scientific advisory board in the MycoSynVac project for helpful comments along the way and to Ruben Ventura for good project management. Finally we would like to thank our colleagues at the Department of Food and Resource Economics for providing useful comments to the interview guides and useful inputs to the analytical perspectives.

Copenhagen, October 2017

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Summary

The overall aim of this project was to:

Map the considerations among lay people, synthetic biology scientists and vaccine scientists that occur in relation to the development of synthetic vaccines for farm animals.

In order to meet this aim, a qualitative study of lay people and synthetic biology and animal vaccine expert perceptions was carried out. The study addresses the vaccines developed within the context of the MycoSynVac project as well as synthetic vaccines in general. Four focus groups with lay participants in each of five countries (Denmark, UK, Austria, Spain and Poland) were carried out. Each group comprised five to ten participants. 22 expert interviews with scientists working with either synthetic biology or animal vaccines in these countries also took place. All interviews were recorded, transcribed and thematically coded as a basis for analysis. The coding software NVivo was used here.

In the following, we will summarize the most important findings from each group of participants followed by a discussion of differences and similarities between the different groups.

Lay people

Lay perceptions of usefulness

The lay participants find synthetic vaccines for livestock useful in two ways. First, they perceive of it as potentially improving animal welfare. Secondly, they consider synthetic vaccines a good replacement for the use of antibiotics within agriculture.

In relation to animal welfare, it is fair to say that most lay participants agree that one of the primary motivations regarding livestock welfare is to prevent and relieve physical pain and other forms of suffering. However, these participants do show some ambivalence as to whether vaccination is the right strategy to achieve this. Where lay participants talk about animal welfare and general farm animal health, they contrast vaccination and other forms of medical care with an active outdoor life for the animals. They believe that such a life prevents the outbreak of diseases and makes the animals healthier, broadly speaking.

However, when the lay participants are faced with a specific case of animal suffering and are told that a synthetic vaccine may prevent the spread of disease and hence suffering, many quickly agree that it is more important to prevent

suffering than to let other concerns stop the vaccination. While the MycoSynVac vaccine is thus in some ways looked upon as a solution to a problem of animal suffering, it is not unambiguously supported.

In relation to the vaccine an alternative to antibiotics, the participants show general concern about what they perceive of as an excessive use of antibiotics in the agricultural sector. This is in turn looked upon as a threat to human health due to a risk of antibiotic resistance. In that perspective, many of the participants welcome vaccines – including synthetic ones – as a way of reducing the use of antibiotics in agriculture.

This support is further underlined by the perception that prevention against disease is better than treatment and thus that vaccines are better than antibiotics, because prevention is considered to be better, including more natural. 'Naturalness' here refers to a perceived similarity to the way the human immune defense system works. A few voices, however, contradict this positive view by insisting that synthetic vaccines are 'unnatural', and thereby not desirable, because they are not based on the original pathogenic variants of Mycoplasma.

Lay perceptions of risks

Some of the lay participants are not that concerned about risks in relation to synthetic vaccines. They express that they have sufficient confidence in the control of drugs and foods that they trust that nothing dangerous would be found in the cold counters.

By contrast, other lay participants are concerned about potential risks for human health, justifying this concern in three different ways. One is that unknowns always accompany new technologies, so we may potentially face side effects despite sufficient controls. Another source of concern is that the vaccine is perceived of as 'unnatural' in various ways, and the participants consider unnatural products to be inherently unsafe for human health. Finally, the participants do not trust the producers (mainly the pharmaceutical companies) to fully care for the safety of their customers rather than for short-term profits, and hence they worry that the new vaccines may prove to be unsafe.

Risk relating to human health is almost the only form of risk discussed in these focus groups. The lay participants rarely mention other areas of concern, but unspecified issues around the environment came up once in a while, as did an interest in the wellbeing of the vaccinated animals. These concerns, however, were very scattered.

Lay perceptions of fairness

Overall, most of the lay participants agree that the pharmaceutical industry and agricultural sector will benefit financially from a synthetic vaccine (if it works). On the other hand, they consider consumers and farm animals as subject to any downsides of the vaccines. It is believed that the consumers are disadvantaged because they could be subject to as-yet unknown potential health risks related to the vaccine, and that the animals are disadvantaged because they do not have the right to refuse to become guinea pigs in an experiment that will benefit others (farmers and industry).

Experts: synthetic biology scientists

Synthetic biology scientists' perceptions of usefulness

The synthetic biology scientists consider the MycoSynVac as useful in four different ways: for society, because it addresses problems of antibiotic resistance and the cure of infectious diseases; as a way of advancing scientific understanding and developing new applications; because it can be used in different contexts (i.e. against different forms of Mycoplasma) and finally as economically beneficial (although this is treated as a minor consideration).

The synthetic biology scientists generally perceive the MycoSynVac vaccine as useful for society because it addresses what they consider to be pertinent societal problems such as antibiotic resistance, infectious disease among animals and other related issues. They generally consider applications relating to the protection and treatment of human health as the most useful areas to work with as scientists. Few of them relate the MycoSynVac project to improvements to human health, but those who do think that we need sound animal vaccines to prevent antibiotic resistance and the spread of dangerous pandemics.

From their professional perspective, they also find the MycoSynVac project useful in advancing basic science in the area of synthetic biology. Many of the interviewed scientists express the idea that scientific advancements are useful because they add to the understanding of biological principles. Many also believe that basic science relating to vaccines and synthetic biology is useful because it is a precondition for better applications in the long term.

Finally, some interviewed synthetic biology scientists mention economic benefits for the agricultural sector as a potential positive outcome of the MycoSynVac project. However, other synthetic biology scientists express strong disagreement that economic usefulness is sufficient to legitimize synthetic biology applications.

Synthetic biology scientists' perceptions of risk

The synthetic biology scientists are concerned about two different forms of risk. One is the unknown effect of deliberate or unintended releases of synthetic organisms into the environment. They do not generally point to very specific risks but share a concern about the uncertainties of any consequences in the event of mutation. However, there is not consensus among the synthetic biology scientists that there should be concern over these issues.

The other issue that the scientists identify as a risk is that of creating resistance against Mycoplasma by developing vaccines. While the scientists are interested in finding replacements for antibiotics, they are also concerned that vaccines may render the bacteria even stronger.

Synthetic biology scientists' perception of 'naturalness'

Some of the synthetic biology scientists use the concept of 'natural' to describe their use of, and ways of working with, biological material. They justify the use of the term with the idea that their output is natural as long as they follow the general laws that guide biological processes without human interference. In their view, this makes their technologies and processes more legitimate than, for example, those based on chemical principles. While they do not explicitly relate this perception to the MycoSynVac project, our findings suggest that they use this perception as a general guideline for assessing synthetic biology applications (positively) against other types of technologies.

Experts: vaccine scientists

Vaccine scientists' perceptions of usefulness

The vaccine scientists consider the MycoSynVac project useful in two ways: for improving animal welfare and as an alternative to antibiotics in agriculture.

In relation to the improvement of animal welfare, many of the vaccine scientists express that animal diseases caused by Mycoplasma are severe, causing physical pain among farm animals, and that it has been difficult to find an effective cure. On that basis, they welcome a vaccine that can prevent suffering and the spread of disease. One scientist does mention, however, that an advanced genetically engineered vaccine should only be developed in the event that other methods for prevention or cure have been tried and found to fail.

In relation to the usefulness of the MycoSynVac product as an alternative to antibiotics, these scientists do not favour this vaccine specifically but do in general consider the use of antibiotics in agriculture as a severe problem. They see a need to move from treatment with antibiotics to protection using vaccines.

Vaccine scientists perceptions of risk

The vaccine scientists express concerns about two possible risks related to MycoSynVac. The first is about unknown consequences of the use of the vaccine and the second relates to the risks to human and animal health linked to the use of livestock vaccines. Despite these specific concerns, the vaccine scientists generally believe that livestock vaccines are a fairly safe way of protecting animals against disease.

Most of the vaccine scientists express some degree of concern about unknowns relating to living genetically modified vaccines (and most of them perceive MycoSynVac as such). They are mostly concerned about the unknown consequences of mutation and any unknown characteristics that the modified organism may possess. A few of the scientists are so concerned that they believe extra control of the vaccine should be in place, but most trust that their colleagues have thought in-depth about these problems and how to handle them.

Only a few vaccine scientists express misgivings over health risks related to livestock vaccines in general or MycoSynVac in particular. However, there are voices expressing concern that adjuvants in livestock vaccines may cause the animals pain and that preservatives in vaccines in general (not just animal vaccines) can cause allergies if injected directly – that is, not via food from vaccinated animals.

Despite these specific concerns, the vaccine scientists assess livestock vaccine technologies as a fairly safe way of protecting animals against illness. Rather than distinguishing between types of vaccines, they suggest that management of risks depends on careful preparation and sufficient public control.

Vaccine scientists views on the feasibility of the MycoSynVac project

In general, we find these vaccine scientists very preoccupied by the feasibility of the project. This is seen in light of their perception of the agricultural sector as dominated by economic drivers and in light of the project's scientific challenges.

They consider it very important that the final vaccines are cheap, because in buying the vaccines the farmer is investing in a product (the animal) from which they need to profit. In view of this perception, they assert that the feasibility of

the MycoSynVac may be high because they consider the ingredients cheap and because healthy animals generally lower costs.

These scientists also share the perception that it will be very difficult to produce an effective vaccine that will cover many or all of the Mycoplasma species. Therefore, while they believe that a vaccine as MycoSynVac is a good idea, many of them also doubt the feasibility of the actual vaccine development because it is so scientifically difficult.

Finally, the vaccine scientists are also concerned about the number of livestock vaccines on the market that they consider to be ineffective. They fear that the MycoSynVac project may end up as yet another one of these. Some justify this concern with the scientific challenges mentioned above, while others believe that farmers will use even partially ineffective vaccines on their livestock as long as they have potential to heighten their ultimate profit from the animal.

Findings and discussion

Based on the analysis, we can assert that the lay people participants are concerned about the same issues that other studies of synthetic biology have showed: usefulness, risk, naturalness and justice. Here it is especially interesting to note that the lay people view the use of vaccines as a potential replacement for antibiotics in agriculture, and that their perception of this as potential benefit coincides with the perception of both vaccine and synthetic biology scientists. It is also worth noticing, though, that neither the lay people participants nor the vaccine scientists unambiguously support vaccines as an alternative to antibiotics. Both the animal vaccine scientists and the lay-people suggest that other strategies for reducing antibiotics could be employed, for example by giving animals more space in order to minimize the spread of disease.

Another interesting issue is perceptions of risks of the three groups. All three groups mention a concern for unknowns in relation to the release of living synthetic organisms, but the lay participants appear to put more emphasis on the issue of these risks than the two expert groups – indeed, demanding caution and control for eventual vaccines.

Furthermore, the lay people are the only ones to connect the subject of naturalness with risks. They believe that the less the active pathogenic organism in the vaccine resembles the one that organically affects and spreads among animals, the greater the risk. This perception is not shared by any of the expert groups.

Finally, it is only the group of lay people who appear preoccupied with questions of fairness around the distribution of benefits or disadvantages caused by MycoSynVac's use. They find that the agricultural and pharmaceutical sectors stand

to gain (financially), while consumers and animals may become subject to unintended vaccine side effects. By contrast, the experts do simply not address the question of fairness.

Introduction

In recent years, a range of new and emerging biotechnologies has raised public debate and conflict between actors such as the public, scientific experts, government and industry. This is for instance the case in relation to the subject of GM crops, where European citizens have been reluctant to accept or buy products related to GMOs – and lay-publics are often sceptical about the usefulness of new biotech applications in agriculture. In some European countries, for instance Denmark, there has also been much debate about vaccines for humans, not the least in relation to the relatively new synthetic vaccine, the Human Papillomavirus vaccine (HPV). As biotech in agriculture and new vaccines are examples of publically contested biotechnologies, it is interesting to consider lay-people and expert perceptions of the MycoSynVac project. MycoSynVac is a Horizon 2020 funded research project with the aim of developing a serum-free, universal vaccine chassis against Mycoplasma for livestock. In that way the project encompasses two features, which have earlier been considered controversial; namely the fact that it aims to develop a vaccine based on very advanced biotechnology and that it is a technology aimed for the agricultural industry.

In this report we will therefore **Map the considerations among lay people, synthetic biology scientists and vaccine scientists that occur in relation to the development of synthetic vaccines for farm animals.**

The report is based on the qualitative interview and focus group interview studies of experts and lay-people in five European countries, namely Denmark, UK, Poland, Austria and Spain (see chapter 2) for further details.

We will first present the existing social scientific knowledge about the area (chapter 1), before moving to our considerations about methods (chapter 2). After these, we will present our results in three consecutive chapters. First we present the findings from the lay-people analysis (chapter 3), then from the synthetic biology scientists (chapter 4) before finally moving to the findings of the animal vaccine scientists (chapter 5). We conclude with a discussion (section 6.2), where we compare the most interesting findings across the different groups of actors.

1 Review of existing knowledge

There is a growing body of studies that have identified recurrent themes and concerns from lay people in relation to new technologies (Irwin & Wynne, 1996). A main finding in this body of literature is that the public not only addresses questions of new technologies from a risk perspective, addressing environmental and health risks, but also considers questions of usefulness, economic perspectives, justice and ethical questions, such as animal welfare and 'naturalness'. The specific content and form of these concerns, however, may vary depending on context and the technology at hand (Lassen & Jamison, 2006). By contrast, concerns addressed by experts and in the policy processes of, for example, food and agriculture biotechnologies typically only address questions of risk and benefits (Boëte et al. 2015).

As a prerequisite for developing the interview guides for the WP 8.2 task, we conducted a review of existing social scientific studies about public and expert concerns over synthetic vaccines for livestock. As the technology is very new, the number of papers was limited. The search was, therefore expanded to cover each subfield of the research question by itself, namely:

- What are the lay perceptions of synthetic biology in general?
- What are public and expert perceptions of livestock vaccines in general?
- And what factors influence public and expert perceptions of emergent biotechnologies.

In the following, we will present the results of the review and show how the findings fed into our interview guides for the public and the experts.

1.1 Synthetic biology

Despite the relatively recent emergence of the field of synthetic biology, the theme has already gained attention among social scientists. There are empirical papers reporting on quantitative and qualitative studies of lay and expert perceptions of synthetic biology, and these are also included in the sample. But there are also some non-empirical papers where scholars from various fields, including philosophy and sociology, propose potential social issues that may arise in relation to the use of synthetic biology methods. As synthetic biology is still a relatively new field, these papers are relevant here as inspiration for what could become issues for public debate, and as the number of empirical papers remains limited.

The sample of empirical papers mainly comprises qualitative and quantitative survey studies of public perceptions of synthetic biology (with a few also addressing the views of synthetic biology scientists; these will be discussed in the section on the papers on expert opinions) and some review papers that seek to draw general conclusions from the studies conducted so far. With a few exceptions (e.g. Starkbaum, Braun & Dabrock 2015) the papers treat perceptions within nation state contexts and do not compare views across borders. Neither do they seem to consider that specific cultural traits of local political situations could frame the perceptions of emergent technologies. The total body of texts consists of several studies from the US and Canada (Dragojlovic & Einsiedel, 2013; Grogan, 2014; Kahan, Braman & Mandel, 2000; Pauwels, 2009) followed by studies from Europe (Royal Academy of Engineering [UK], 2009; Starkbaum et al., 2015) and one from Asia (Amin et al., 2013). Most of the empirical papers report quite limited public knowledge about the subject – at least in the US and EU (Pauwels, 2009; TNS Opinion & Social, 2010). One of the qualitative studies, however, reports that informants without knowledge of synthetic biology quickly associate both negative and positive ideas based on the term alone (Pauwels, 2013). Besides the notion of quite limited public knowledge about the subjects, all papers focus on the psychological or social elements that shape public perceptions in relation to potential applications of synthetic biology.

Several of the papers conclude, in line with earlier studies of public perceptions of biotechnologies, that public attitudes depend on the technologies' perceived utility, justice and risk (Grogan, 2014; Pauwels, 2009, 2013; Starkbaum et al., 2015).

Regarding utility, this means that people are in favour of potential applications in the areas of medicine and alternative energy sources because these applications are perceived as useful by bringing big advances for a large group of people (Pauwels, 2009, 2013; Starkbaum et al., 2015). However, one study still notes that people are ambivalent about the medical applications because they feel uneasy about having 'synthetic' organisms in their body (Pauwels, 2009). Members of the public also appear to be willing to run larger risks in the areas of medicine and alternative energy sources because they believe that the gains are greater. The areas of medicine and energy are therefore considered more legitimate than agricultural applications (Royal Academy of Engineering [UK], 2009). As the field is so new, there is limited knowledge about the perception of more specific agricultural applications such as using synthetic biology in plants as opposed to in animals.

In the case of justice, one paper goes into particular depth with the issue (Starkbaum et al., 2015). Based on focus groups conducted in Austria and Germany, it concludes that participants appear very concerned about the distribution of benefits, especially in relation to synthetic drugs. Here people discussed issues such as global justice and

monopolization based on their distrust of pharmaceutical companies, who were believed to act purely in their own interest, and based on their general dissatisfaction with an accumulation of knowledge and resources in the Western world compared to 'the global south' (Starkbaum et. al., 2015).

All the papers addressing the question of risks report that public participants are very concerned about the risk aspect of synthetic biology. The Eurobarometer (2010) shows that 24% of the population finds it important to know more about potential risks (TNS & Opinion and Social, 2010: 127). Another study from the US combining surveys and focus group material (Pauwels, 2009, 2013) found that around the same number of participants believed that the benefits of synthetic biology outweighed the risks as the other way around. However, risk was a recurrent issue in the focus groups, especially 'unknown unknowns' and how risks would be managed by society and long term effects for humans and the environment (Pauwels 2013, see also Grogan, 2014).

Some of the papers point to the nature of the political processes related to synthetic biology as an important factor in public perception. The studies show that public views on synthetic biology depend on the perceived effectiveness of a sound regulatory framework. In Pauwels 2009 and 2013, the focus group participants advocate for oversight by government (despite some mistrust in its abilities to do it effectively) combined with advice from scientists. The Eurobarometer (2010) reports that in European studies, a majority of people (59%) believe that decisions about synthetic biology should be based on expert advice, while 29% believe that they should be based on what a majority of people in the country think (TNS Opinion & Social, 2010: 167). At the same time, 77% of the respondents state that synthetic biology should be tightly regulated by government and only 11% think that it should be allowed to operate in the market on business terms (TNS Opinion & Social, 2010: 172).

One paper specifically deals with the theme of 'naturalness' (Dragojlovic & Einsiedel, 2013). Naturalness is the idea that the negative or positive perception of a given application or product is dependent on how much humans have intervened. Based on a survey study from Canada, the paper concludes that negative perceptions of a synthetic biology application will increase if the organism has been 'substantially modified' – that is, when the evolutionary distance between host and donor organism is large, such as a mixture of plant and animal material. They also find that respondents who consider nature as 'sacred' or 'spiritual' are more inclined to view a synthetic biology organism as bad based on the argument on 'unnaturalness' than the rest of the respondents (Dragojlovic & Einsiedel, 2013: 562ff).

While the conclusions from the first studies of lay public acceptance of synthetic biology are remarkably similar to previous studies looking at other controversial technologies, some authors point out that many factors have changed

since the studies of public perceptions of GM applications after the so-called 'GMO crisis', where strong public resistance against GM crops surfaced in Europe (Calvert & Martin, 2009; Maurer, Lucas & Terrell, 2006; Torgersen, 2009). Thus the range of aspects considered relevant to include in assessments has expanded and as Calvert & Martin (2009) and Torgersen (2009) observe, demands to consider these wider social implications have become 'institutionalized' (Calvert & Martin, 2009:202) in synthetic biology research. Furthermore, Torgersen (2009) suggests that other more pressing environmental concerns such as climate change have moved focus away from novel biotechnologies and that synthetic biology may seem so similar to other technologies (for instance, genetic engineering) that it does not stir much added public attention.

Turning to the non-empirical papers, most do not treat specific applications of synthetic biology but call for general caution, regulation and public oversight in relation to all the possibilities that synthetic biology offers (Balmer & Martin, 2008; Bhutkar, 2005; Calvert & Martin, 2009; Deplazes, 2009; Deplazes-Zemp, Gregorowius & Biller-Andorno, 2015; Garfinkel, Endy, Epstein & Friedman, 2007; Heyd, 2012; Sanderson, 2009; van den Belt, 2015; Yearley, 2009). Those that do venture into more specific potential applications and associated concerns are mostly focused on the risk of bio-terror (Glick, 2012; Guan, Pei, Schmidt, & Wei, 2012; Kaebnick, Gusmano, & Murray, 2014; Rager-Zisman, 2012). The combination of a growing DIY-biology movement and the possibility of creating synthetic vira cause some concern – not the least among Israeli scholars (Glick, 2012 & Rager-Zisman, 2012). Besides this concern over dual-use, a number of other risks linked to synthetic biology are mentioned, albeit not as frequently. One paper speculatively suggests that synthetic biology could be a potential threat to food security, as the demand for organic raw material will force the prices up which in turn could lead to deforestation (Engelhard, 2010).

Several papers articulate the risks associated with a lack of public debate in relation to synthetic biology. In this way, they focus more on the consequences of different forms of governance of emergent technologies rather than focusing specifically on the risks of the potential applications in themselves. In general, they conclude that consultation with diverse stakeholders must happen as early as possible in order to avoid large-scale public controversies (Dankel et al., 2014; De Vriend, 2006; Grogan, 2014; Heyd, 2012; Hunter, 2013; Kaebnick et al., 2014).

The above-mentioned texts all suggest that the most interesting research prospects lie in the questions about how perceptions of synthetic biology are connected to wider cultural, social and political values.

1.2 Livestock vaccines

There are very few papers dealing with public perceptions of animal vaccines, and none that address the issue from an expert perspective. While several papers assert that vaccines can be a controversial subject (Dankel et al., 2014; Mikulak, 2011; Vanhonacker & Verbeke, 2011), and many also mention development of vaccines as a potential area for synthetic biology and other emergent biotechnology applications (Bonneau & Laarveld, 1999; Knuuttila & Loettgers, 2014; Pauwels, 2009; Starkbaum et al., 2015), very few focus on issues that relate to questions of public and expert perceptions of synthetic animal vaccines. In the following, we present the few that relate to the themes of our research project (livestock vaccines, synthetic biology vaccines and public engagement).

Only one study advocates caution when using genetically engineered living vira for vaccines for animals in general, because we have too limited a knowledge of the risks for humans, animals and ecosystems in the event of environmental release. The authors do not believe that we have sufficient scientific knowledge about the complexity of the ecosystems that will receive these new organisms (Myhr & Traavik, 2007). Another looks at consumer responses for vaccines against boar taint and concludes that consumers prefer vaccines to castration, as they believe the vaccine increases animal welfare (Vanhonacker & Verbeke, 2011). But there seems to be some awareness among social scientists (Dankel et al., 2014; Mikulak, 2011; Vanhonacker & Verbeke, 2011) that the issue of vaccines in general is potentially contentious. Meanwhile, the area of livestock vaccines is so far developing without much public attention or scholarly regard from the social sciences.

1.3 Expert perceptions of emergent biotechnologies

Following large public controversies around new technologies such as the Chernobyl catastrophe, the BSE epidemic and GMO, many studies concluded that public and expert understandings of risk and benefits of new technologies were far apart.

Meanwhile, not that many studies have actually closely studied expert views on emergent biotechnologies (Boëte, Beisel, Reis Castro, Césard & Reeves, 2015). This is slowly changing and an empirically-based field of expert views of emergent technologies has started to take form. The conclusions from these studies vary. One group of studies suggests that the expert views around emergent technologies are very different from the public ones. These studies underline that scientists in general are sceptical towards public involvement, because they are concerned about how that

involvement might influence the regulatory frame pertaining to their area of research (Bensaude Vincent, 2013; Ho, Scheufele & Corley, 2011; Marris, 2014; Mikulak, 2011; Su et al., 2015).

A bigger group of studies suggests that 'scientists' are not as uniform a group as some social scientists may have hitherto thought. On the contrary, both perceptions of emergent technologies and ideas about the governance of technology vary greatly, and are influenced by a number of personal factors. These factors include (among others) seniority, citizenship or disciplinary affiliation (Besley, Kramer & Priest, 2008; Besley & Nisbet, 2013; Corley, Kim & Scheufele, 2011; M. Fisher, 2005; Kim, Corley & Scheufele, 2012; Wilkins, Kraak, Pelletier, McCullum & Uusitalo, 2001). A group of studies concerning transgenic mosquitoes as a way to reduce the risk of dengue fever and malaria suggest that individual relations to or familiarity with the concrete area of application may also be important. These studies suggest that scientists (within research fields relevant to the technology) that come from the countries where a release of the transgenic mosquitoes is mooted are much more sceptical about the idea than scientists from other countries (Boëte et al., 2015; Boëte, 2011; Okorie, Marshall, Akpa & Ademowo, 2014).

Only a few studies directly compare expert perceptions with those of the public. In those that do, nanotechnology and synthetic biology are the technologies in question. Again, the conclusions are conflicting. One survey study suggests that nanoscientists actually worry more than the general public about long-term risks for the environment and for human health, while at the same time being more optimistic about potential benefits of nanotechnology (Scheufele et al., 2007). Meanwhile another survey study reports that scientists find the risks associated with nanotechnology smaller than that found among members of the general public. The same paper also argues that lay people use religious beliefs and heuristics to form opinions, while scientists use their colleagues as sources of legitimization or delegitimization (Ho et al., 2011).

While there are too few studies on the subject to draw general conclusions, the existing studies do indicate that the distinction between the groups of 'scientists' and 'lay-people' (as concerned individuals with a legal right to speak up) may be more blurred than the sociology of science tends to believe. In general, empirical studies of expert perceptions of specific emergent biotechnologies are a rather small field with room for further studies on the gap - or lack thereof - between expert and public perceptions, and on which factors influence these perceptions.

1.4 Concluding remarks

Based on the literature review, we can first and foremost conclude that there is no literature that directly addresses public and expert considerations in relation to synthetically engineered vaccines for animals, but that there are some studies in related areas.

There are a group of papers that study public perceptions of synthetic biology and conclude that lay people in general assess synthetic biology and potential applications based on cultural and ethical values, and that the main issues are utility, justice, risk, naturalness and regulatory frameworks. Meanwhile, there are – based on this literature search – no papers that address the issue of animal vaccines.

In relation to expert perceptions, no papers address the questions of such perceptions of animal vaccines, but one paper advocates caution in relation to the development of living GM vaccines due to limited knowledge about the long-term risks for humans, animals and ecosystems.

While we did not find any papers that treated expert perceptions of synthetic biology in particular, a group of papers do study expert perceptions of various other biotechnologies. These studies in general point to the need for further studies of experts because the perceptions of this group may not be as uniform as social scientists have tended to believe and may be influenced by factors such as citizenship, research area and seniority.

2 Methods

2.1 The study of arguments

The theoretical lenses through which we study perceptions of vaccines and synthetic biology here are arguments. Arguments are rhetorical devices that construct particular relations between a perceived problem and the idea of a solution in an effort to make the audience (of any size) adhere to a particular representation of a specific phenomenon. Studies of arguments have often been used in relation to public perceptions of emergent biotechnologies as they are well suited to reveal the cultural values and positions that guide perceptions of particular technologies (e.g. Mielby et al. 2013; Lassen & Sandøe 2009).

We use the theory of argumentation developed by Stephen Toulmin here. In his seminal work, he studied how arguments are used to justify claims about particular phenomena (Toulmin, 2003 11f). According to Toulmin, an argument is built up of three different elements: a claim whose merits the argument is seeking to establish; the data (examples, anecdotes, information and so on) which supports the claim and finally the warrant, which consists of a general statement reflecting certain political or cultural values which make the argument plausible and legitimate in the eyes of its spokesperson (Toulmin, 90f).

2.2 Population, samples and recruitment

Following our research questions, the study targeted three populations: lay people, experts working as researchers in animal vaccines (vaccine scientists) and experts researching within synthetic biology (synthetic biology scientists). To limit the study, five countries were chosen as cases and within each country interviews with samples of the three populations were carried out. As a result, our total sample comprised 20 focus group interviews with members of the public and 23 expert interviews with researchers in the fields of livestock vaccines and synthetic biology.

2.2.1 Selection of case countries

The selection of case countries was based on a range of criteria in order to secure diversity in factors influencing perceptions of new technology. Based on Mejlgaard et al., 2012, we chose 'public involvement in science and technology decision-making' as the leading principle. In their paper, Mejlgaard et al. develop a typology of public involvement in science governance and group countries in according to the nature of involvement: formal involvement, i.e. involvement that it is initiated and/or funded by government, or informal involvement, i.e. involvement that is based on individuals'

and groups' private initiative. There is also a grouping by degree of involvement: high versus low public participation. The resulting four clusters are presented in Table 1.

Denmark and the UK were selected as representatives of the first cluster (formalized/high involvement). These two countries, however, differed on other parameters, as the relative size of the agricultural sector is small in the UK compared to Denmark (see Table 2) and their economic situations after the financial crisis are different; the UK recovered quickly, while it has taken Denmark some years to recover economically. Spain, Austria, Poland were selected as representatives of each of the three remaining clusters.

Table 1. Segmentation of European countries after nature and degree of involvement

Formalized/ high involvement	Formalized/ low involvement	Not formalized/ high involvement	Not formalized/ low involvement
Belgium Denmark Finland	Albania Croatia Estonia	Austria Iceland	Bulgaria Cyprus Czech Republic
France Germany Italy	Greece Latvia Montenegro		Hungary Ireland Israel
Lithuania Norway Sweden	Poland Portugal Slovakia		Lichtenstein Luxembourg Macedonia
Switzerland Netherlands UK	Slovenia Turkey		Romania Serbia Spain

Adopted from Mejlgaard et.al., 2012 p. 746.

When choosing countries from each cluster we aimed to strengthen diversity by adding additional parameters that we anticipated would influence perceptions:

- Geographical diversity
- Different attitudes to emerging biotechnologies and synthetic biology
- The country's overall economic situation
- Different attitudes to the importance of animal welfare for livestock
- The size of agriculture's contribution to the national economy
- And the presence of one or several public synthetic biology research environments.

We opted for geographical diversity by choosing countries from north, south, east and west Europe. We chose countries where people exhibit different attitudes towards themes such as emerging technologies in general, and synthetic biology in particular, and towards the importance of animal welfare (TNS Opinion and Social, 2010). Finally, we also looked at the economic situations of the countries, including their general economic status after the financial crisis, where the UK, Poland and Spain have recovered quicker than Austria and Denmark. We chose countries where agriculture played different roles in the country's national economy, including countries where it played a very important role (see Table 2).

Table 2. Economic importance of agriculture measured against GDP, exports and the workforce

Country	% of GDP	% of export	% of workforce	Category
UK	0,5	6,2	1,2	Low
DK	1,5	19,2	2,4	Middle
AU	1,0	7,8	4,5	Middle
PL	2,4	11,6	12,6	High
ES	2,1	15	4,2	High

The figure is based on numbers from the report 'Agriculture in the European Union' Statistical and economic information, table 2.0.1.3

While a selection of countries based on several criteria for diversity can never be perfect, we thus tried to balance the selection in order to reach a high level of diversity while maintaining the realistic goal of including five countries in the study.

2.2.2 Recruitment of lay participants for focus group interviews

The recruitment of lay people for the focus group interviews was, as with the selection of countries, intended to reach a high level of diversity among the participants. Diversity was secured based on demographic parameters expected to determine cultural values and positions that matter for perceptions of emergent technologies, namely:

- Gender

- Age
- Place of residence (city or countryside)
- Income
- Level of education.

We hired the recruitment firm Norstat (norstat.dk) to manage the recruitment of participants in the five case countries. A screener of those to take part in the recruitment interviews was done by phone (see Appendix 1), and was developed by the research group in collaboration with Norstat. Individuals working with biotechnology, livestock or public participation and communication were excluded, in part because they as stakeholders were not representatives of lay people, and in part because a high level of technical knowledge could obscure the interviews (which mainly focused on cultural and ethical values). We aimed for six to eight participants in each group, which is considered an ideal number of participants to balance the desire to have as many viewpoints as possible represented and giving the participants enough time to develop their arguments (Halkier, 2006). In order to ensure that six to eight participants would attend the meetings, ten people were recruited for each focus group. In practice, most groups consisted of eight participants with a small number only consisting of five people and some of ten people. All participants were given guarantees that they would appear without name or professional affiliation in the final report and papers.

2.2.3 Recruitment process for expert interviews

The experts were recruited for single interviews because the schedules of such professionals make focus groups difficult to realise. We aimed for 25 experts in synthetic biology and vaccines for livestock, which is considered a sufficient sample size for obtaining knowledge about the varieties of positions while still being realistic given the timeframe of the research project (Kvale & Brinkmann, 2009).

The expert sample was limited to scientists employed in the public sector (universities and government research institutions). Although private sector scientists could have contributed with further aspects, the decision to limit the sample in this way was partly based on the concern that private sector scientists could suffer from limitations in their freedom to express their views. To ensure diversity within the sample of experts, participants were recruited with reference to factors such as disciplinary affiliations, seniority and focus on basic or applied science.

The recruitment of experts began with the use of web searches to map the five countries' expert communities in relation to animal vaccines and synthetic biology. Key organizations or research groups were identified in each country, and research managers of relevant groups were asked to participate and recommend two of their juniors or peers for interviews.

Five scientists working with different aspects of synthetic biology or animal vaccines were recruited in each country except Poland, where it proved very difficult to establish contact with the research community and only three scientists were recruited. Out of the 22 expert interviews undertaken, 12 were with experts in animal vaccines and ten were with synthetic biology scientists. The vaccine scientists had training either as vets or immunologists, while the synthetic biology scientists came from various disciplinary backgrounds such as chemistry, biochemistry, physics or computer engineering. All experts were assured that they would appear without name or affiliation in the published material. In the analysis, we broadly refer to the experts as either 'synthetic biology scientists' or 'vaccine scientists'. After the quotes, we refer to them with the country they work in. As science is a global profession, their nationality may not match the country, where we interview them.

2.3 Interview guides and interviews

The review of existing literature on public and expert perceptions of synthetic biology and animal vaccines suggests that a relevant overall theme for interviews is participants' cultural values, where these values include perceived ideas of utility, risks, naturalness and justice. We also focussed on if and how values vary between experts and lay people.

More specifically, it seems pertinent for all interview guides to include topics related to questions of the utility of the technology and its beneficiaries; environmental and health issues related to the technology; regulatory frameworks around the development and use of the technology and justice in the ways that benefits and risks are distributed when the technology is used. In relation to this particular technology, there also seem to be unanswered questions about how livestock vaccines are considered in relation to public perceptions of animal welfare.

In relation to the expert interviews in particular, there seems to be a knowledge gap about the differences and similarities of concerns among groups of lay people and the relevant experts and how their ways of arguing about cultural values in relation to technologies differ. We will here describe the translation of these overall research interests to the specific interview guides.

Because we find the populations of lay people, synthetic biology scientists and vaccine scientists quite different , three separate interview guides were developed: one to be used for the focus group interviews with lay people, one for the individual interviews with synthetic biology scientists and one for the individual interviews with vaccine scientists. All interview guides were developed based on the literature reviews. In this way, concerns that have previously been identified as central for lay people and experts inspired the interview themes included in the guides. The guides were developed to make sure that interview themes and questions were open enough for new considerations or new interpretations of known concerns to surface. All focus group interviews with lay people were conducted before the expert interviews, and it was therefore possible to ask the experts about concerns expressed by lay people. This allowed us to gather material to use in an analysis comparing the viewpoints of experts and lay people. A noteworthy difference between the lay people and expert interviews is that we talk about synthetic vaccines in more general terms with the lay people, whereas we describe the MycoSynVac project in more detail for the experts, as we expect the experts to (also) establish their perceptions based on technical details. Tables 3-5 show how different dimensions of concerns were deployed as interview themes within the three guides. Full interview guides are included in appendix 2, 3 and 4.

This study focuses on claims about synthetic vaccines for livestock, and on warrants. In the results section we present the common claims about synthetic vaccines for livestock and issues linked to this area, such as animal welfare, synthetic biology or the use of antibiotics in farming. We show the different warrants that the informants use in order to justify their claims, and in that way, move beyond an idea of either negative or positive perceptions of synthetic vaccines for livestock. Instead we focus on the underlying values relating to issues such as modern agriculture, government regulation, the role of science in society or risks associated with meat consumption that guide participants' perceptions.

Table 3. Deployment of dimensions of considerations into interview themes in focus group interviews with lay people

Dimension of concern	Interview themes
Risks	• Perceptions of risks in general • Risks related to consumption of animal products from vaccinated animals • Risks for the animal itself • Risks related to animal diseases • Risks related to new biotechnologies
Regulation	• Control and regulation of the production of vaccines • Control and regulation of the use of the vaccine
(Mis)trust	• Perception of trusts of central actors related to the vaccine, e.g. farmers, retailers, government or pharmaceutical companies

Animal welfare	• Understanding of animal welfare • Diseases among farm animals • Strategies for maintaining a healthy livestock
Usefulness	• Vaccines as a helpful technology • Synthetic vaccines as a helpful technology • Synthetic biology as a helpful technology
Justice	• Perceptions of fairness and unfairness related to the production and use of the vaccine • Distributions of downsides and benefits among central actors such as animals, farmers, producers and consumers

Table 4. Deployment of dimensions of concerns into interview themes in individual interviews with vaccine scientists

Dimension of concern	Interview themes
Risks	• Perception of risks related to animal diseases • Perception of risks related to animal vaccines • Perception of risks related to synthetic vaccines
Animal welfare	• Perceptions of animal welfare for farm animals • Animal disease and health as part of general animal welfare • Strategies for maintaining healthy livestock
Usefulness	• Vaccines as a potential helpful technology • Synthetic vaccines as a potential helpful technology
Justice	• Perceptions of fairness and unfairness related to the production and use of the vaccine • Distributions of downsides and benefits among central actors such as animals, farmers, producers and consumers
Regulation	• Control and regulation of the production of vaccines • Control and regulation of the use of the vaccine

Table 5. Deployment of dimensions of concerns into interview themes in individual interviews with synthetic biology scientists

Dimension of concern	Interview themes
Risks	• Applications of synthetic biology in general • Applications of synthetic biology in the expert's own research project • Unintended side-effects in general and in relation to the expert's own project
Usefulness	• Useful outcomes of synthetic biology projects • MyCoSynVac as a potential useful technology
Fairness	• The public's access to synthetic biology applications • Collaboration with industry

	• Distribution of benefits and downsides of the technology among central actors
Regulation	• Government regulation of new technologies • Government regulation as a barrier to innovation

Post doctoral student Cecilie Glerup conducted eight of the 20 focus group interviews (in Denmark and the UK). Moderators who spoke the language of participants conducted the interviews in Austria, Poland and Spain. Cecilie Glerup was present during all focus group interviews. The interviews were either video or audio recorded and subsequently transcribed. The interviews from Austria, Poland and Spain were furthermore translated to English to facilitate the analysis. Cecilie Glerup conducted all 22 expert interviews, all in English except three interviews in Danish with Danish-speaking scientists. The expert interviews were audio recorded and transcribed as preparation for analysis.

2.4 Data analysis

Focus group and expert interviews were analysed using thematic coding by means of software for analysing qualitative interviews, NVivo. Thematic coding prepares the data for further analysis by identifying and compiling data addressing common themes (i.e. sections of the interviews where respondents present arguments about similar issues). Themes create patterns across the dataset, which are important to describe in order to answer the research questions (Daly, Kellehear and Gliksman, 1997). It should be noted that even though themes for the interviews were developed based on the literature review, the explorative nature of the interviews allowed new themes to emerge. The emergence of these themes is the result of an inductive process based on the data found in the interviews.

Practically speaking, this part of the analysis included a thorough reading of all the transcriptions to get an impression of the most interesting themes emerging from the material. Afterwards, NVivo was used to organize relevant quotes from the interviews into folders and subfolders. Based on our initial readings of the material, we also developed new sub-questions for the material with a focus on the most relevant aspects of the data material. Some themes from the interview guides (for instance the theme about business plans from the interviews with synthetic biology scientists) were not included in the final analysis, because the answers from the interviewees were too un-related to the overall research question: **Map the considerations among lay people, synthetic biology scientists and vaccine scientists that occur in relation to the development of synthetic vaccines for farm animals.** Here we present the final sub-questions for each group of actors (lay-people, synthetic vaccine scientists and vaccine scientists):

Sub-questions for lay-people:

- In which ways do the lay-people consider synthetic vaccines as useful?
- What are the lay-people's perceptions of risks related to synthetic vaccines?
- What are the lay-people's perceptions of the distribution of benefits and downsides among central actors in relation to the introduction of synthetic vaccines for livestock?

Sub-questions for synthetic biology scientists:

- In which ways do the synthetic biology scientists consider MycoSynVac useful?
- What are the synthetic biology scientists' perceptions of risks related to MycoSynVac?
- What are the synthetic biology scientists' perceptions of naturalness in relation to synthetic biology applications?

Sub-questions for vaccine scientists:

- In which ways do the vaccine scientists consider MycoSynVac useful?
- What are the vaccine scientists' perceptions of risks related to MycoSynVac?
- What opportunities and barriers do the scientists consider in relation to an eventual realization of one or more MycoSynVac vaccines?

In the final part of the analysis process, the quotes within each theme (folder/subfolder) were further scrutinised. In this part of the analysis, Toulmins' argument analysis was applied to identify the different positions within a theme by identifying claims, backings and warrants. This part of the analysis sought to identify patterns, similarities and/or differences within each theme. The results section presents the common claims about synthetic vaccines for livestock or related issues such as animal welfare, risks or the use of antibiotics in farming.

Since the aim of the project was to describe the range of perceptions, the analysis targeted the entire dataset for each of the three samples across countries. Furthermore, the analysis presented in the following section is limited to

'common themes' - i.e. themes that appeared with some emphasis across the interviews. Common themes were defined as themes that emerged in at least three different countries within each of the samples. This delimitation was necessary in order to focus on the most pertinent themes, but it does mean that minor concerns, for instance public concerns about the environmental risks related to synthetic biology, are not treated in this report as the concern was only expressed in 2 countries. In the presentation of the results, we have not made explicit 'how many' in particular of the interviewed actors (lay people or experts) who articulated a specific perception, but merely referred to general expressions such as 'many', 'most' or 'few'. In line with the traditions of qualitative studies, we do not consider the exact numbers to be of importance as the study is not representative. Instead we focus broadly on the more or less common perceptions and focus on the content and justifications of the arguments rather than their frequency.

3. Results: Lay people analysis

3.1 Perceived benefits of synthetic vaccines for livestock

This section focuses on the perceived utility of synthetic vaccines for livestock. In general, the participants think that the vaccine of use in two instances: when such vaccines could be used to relieve animal suffering and when they could be used as an alternative to antibiotics.

3.1.1 Synthetic vaccines and animal suffering

Participants in the focus groups are asked to discuss whether they believe that a synthetically engineered vaccine should be used in a hypothetical case of an outbreak of 'a lung disease among pigs' in the country where the focus group was taking place. While this always spurs discussion about several other strategies for the prevention and treatment of animal diseases, the participants also express a very positive attitude towards the synthetically-engineered vaccine. At times they even seem a little surprised about the moderator's question of use, as if it would be foolish not to vaccinate. Phrases like 'I don't see why not' or 'yeah why not' (Focus Group 2,UK) and 'of course, poor animal' (Focus Group 2, Spain) are some of the immediate responses.

These answers are somewhat surprising since participants in discussions of other interview themes, for instance comparing synthetic vaccines with other types of vaccines or in general discussion of costs and benefits of new forms of vaccines, voice many concerns. It seems that in this context, the concern about animal welfare as the absence of pain and suffering is more important for the participants than concerns about, for example, risks or justice (for discussion of these themes, see 3.2 and 3.4). The warrant for the relatively unproblematic use of the vaccine is that concern for the basic physical welfare of the animals is valued highly; for instance in a Danish focus group:

Moderator: 'And the first situation is that a lung disease affecting pigs is spreading in Denmark. It is not fatal for the animals, but painful. Should we use a synthetic vaccine?'

> *Ø.: 'if you can't use anything else.'*
> *Moderator: 'Mmm, if you can't use anything else. Or if there isn't other options. What do the rest of you say?'*
> *J.: 'I think you should use the vaccine. Because – again – it falls back on what I've already said about respect for the animals. If you have the responsibility for the animals, then you're responsible for their*

> *wellbeing, as long as they are yours to take care of. And if you can hinder that they suffer by vaccinating your animals, then I believe you should do it…'*
> *(Focus Group 2, Denmark)*

The owner of animals, according to the participants, bears responsibility for taking care of the herd and this responsibility includes the prevention of pain. The protection of the animals against physical suffering is in this context more important than other considerations. As in several other interviews, one of the participants underlines that the support for the synthetic vaccine is on the condition that there isn't any other medication.

The willingness to use a synthetic vaccine like MyCoSynVac is to some extent moderated by the condition that there are no alternative – and perhaps more well-researched – methods of prevention or treatment. While this condition is mentioned at times, however, it does not change that one of the warrants for using the vaccine is the concern for animals' wellbeing. This is also supported by more general support for all kinds of animal vaccines as a solution to suffering for livestock. For instance:

> *RA: 'The vaccine (…) is a bit of a stumbling block at the moment 'cause there are some things that can be vaccinated against, but which are not, because the markets that the meat would be sold into don't accept the vaccine. Because there's a thing about the… the tuberculosis can be dealt with that way, but we don't vaccinate because - I believe you can also do it for foot and mouth - but we don't, because the other countries (export partners) won't accept it. So... that's a... 'cause I would like the vaccines used a lot more to be honest, 'cause it would minimise the suffering the animals go through.'*
> *(Focus Group 3, UK)*

Again, the warrant for using vaccines is that they minimise suffering for animals and in this context the specific type of vaccine is not important; thus it does not matter if it is synthetic or not, or whether it is new on the market or has been used for a long time. Instead, vaccination as a method of preventing animals from becoming sick of various diseases becomes central.

Interestingly, some of the participants do reflect on the fact that they had some reservations about using vaccines in other contexts, but suddenly do not. As one of the British participants says, laughing, 'huh, so we didn't like that one [the synthetic vaccine] before, but now we like it' (Focus Group 4, UK). Their reservations are cast aside in the light of an animal in pain:

Moderator (to all participants): 'Yes. So we don't have full knowledge. We have sick, suffering animals, suffering from lung disease. Are you willing to use the [synthetic] vaccine?'
M.: 'I would assent, because suffering animals for me is already such a situation in which I would not think too much. If I could provide relief to an animal in suffering, then …'
Moderator: 'But the effect is not known'.
M.: 'It's an experiment, well. Well, I wouldn't know the effect, but why does an animal have to suffer? I would prefer to use the vaccine.'
(Focus Group 2, Poland)

Animals in physical pain are, according to M. here, a matter where she 'doesn't think too much'. The concern for the animal's wellbeing overrules possible concerns, even though she does acknowledge that it is 'an experiment'. While the participants thus reflect on the fact that they were sceptical about the synthetic vaccine in contexts where sick animals are not the theme of the discussion, they do maintain that the subject of pain to animals is of a sufficiently grave character that they should not dwell too much on these other possible concerns.

In some respects, the fact that the concern for animal welfare overrides doubts about the vaccine is supported by the way the participants discuss animal welfare for livestock in general. Here one of their primary concerns is whether the animals were suffering from physical pain. This concern is often backed up with anecdotes referring to specific cases of mistreatment of livestock animals and how immoral they find this behaviour in general - as here, where J. talks about bad conditions for turkeys:

J.: 'Well if I may add something (…) for me it is about the ethics. The ethic about the animal, how we handle the animal. And in general the turkey [has] a really non-ethical history. Well, that means those turkeys…or… poultry are only bred to literally stand in the farmer's stable. The farmer's only interest is to give them an as high weight as possible. In general the legs of those animals break before the slaughtering…endless pain.'
(Focus Group 1, Austria)

They also assert that an important part of the concern about animal welfare for farm animals is to monitor, prevent and treat physical disorders in animals. One of the participants from the UK sums this up when discussing what is important in order to keep the animals healthy:

F.: 'I've got, erm, (…) make sure they [the farmers] have an eye on the actual things that are going in their animals. I've wrote down "get them, develop them jabs and injections that they may need in order to keep them healthy". And, I've written down "health checks", I guess that's the same thing. And the last thing I wrote was "environment"; the environment that they're reared in and do all the things in... That's about it.'
(Focus Group 2, UK)

So, on the one hand, the participants consider that monitoring, prevention and medical treatment of animal diseases is central to healthy animals and to animal welfare. In that regard, it may not be that surprising that many of them also look favourably at the use of synthetic vaccines when confronted with a narrative about animals in pain.

On the other hand, the data shows some ambiguity as the participants have some concerns about animal health and welfare that point in a very different direction. Following this line of argument, they find that medication and medical prevention is in opposition to animal welfare and health. This is visible, for example, when participants argue that a different lifestyle for the pigs - one where they are outside and less medicated - is desirable. This is exemplified here, where participants discuss vaccines in general as opposed to other strategies for maintaining healthy livestock:

> *J.: 'Vaccines are… they are something different. A vaccine is not really medication in that way.'*
> *B.: No, but I don't like… I mean I can't see why we have to… My position is that it's…'*
> *Moderator: 'You would rather change the agricultural sector?'*
> *B.: 'Yes, I would rather have those small pigs with their snout in the soil and eating roots…'*
> *E.: 'Yes!' [agrees]*
> *J.: 'And the pigs would be so sick of tetanus from it (from living outside without vaccination). And you could have prevented that so easily, but now, all of the sudden, you have ten pigs that lie down and are so sick and you could have prevented that so easily'*
> *B.: 'Yes.' [laughs].*
> *(Focus Group 2, UK)*

So one of the participants considers vaccines to be keeping the pigs from being sick, but another considers it from quite a different perspective. Here the outdoor life with 'the snout in the soil' is considered the best life for pigs, and this way of raising pigs is also considered as excluding vaccines and perhaps even other sorts of medication. As an Austrian participant with the same perception of animal welfare makes clear, then:

> *A.: 'If we would give the animals a living area as close to nature as possible… then most vaccines would be pointless…'*
> *(Focus Group 1, Austria)*

So some consider being outside and having a life 'as close to nature as possible' as a way of life which renders medical interventions such as vaccines unnecessary. We will look further at this way of arguing in the section about 'naturalness' (see 3.3.2). Here, suffice to say that most participants agree that one of the primary concerns regarding animal welfare is to prevent and relieve physical pain and other forms of suffering. Participants may, however, disagree in some contexts whether vaccination is the right strategy to achieve this.

3.1.2 Synthetic vaccines and antibiotic resistance

One of the concerns which surfaces in many of the focus group discussions is a problem related to the use of antibiotics in agriculture. Again (synthetic) vaccines are here seen as a solution, because the benefits outweigh the concerns.

The use of antibiotics in agriculture is brought up when participants are invited to discuss different ways of maintaining farm animal health as well as in other contexts. Here is an excerpt from a discussion in one of the Austrian groups:

> *S.: 'Well, I consider vaccines as being better than antibiotics'.*
> *P.: 'Well antibiotics for me are at the very end'.*
> *A.: 'Yes for me too'.*
> *M.: 'A nightmare'.*
> *A.: 'A nightmare yes'.*
> *(…)*
> *M.: 'Why?'*
> *J.: 'Well, actually even worse than doing nothing'.*
> *Moderator: 'Why do you see it as being so bad'?*
> *J.: 'Simply because it is dangerous for us'.*
> *Moderator: 'So when consuming it?'*
> *J.: 'Yes, because it goes directly into the food chain.'*
> *(Focus Group 1, Austria)*

Antibiotics are called 'a nightmare' and are considered 'even worse than doing nothing' and thereby failing to take care of the animals. Similar strong negative expressions are used in other focus groups. Antibiotics should always be 'the last resort' (Focus Group 1, Poland) and one participant exclaims that he would 'strictly reject to use antibiotics at all' (Focus Group 2, Austria).

When participants justify their concerns about antibiotics, they usually refer the problem of the growing resistance to antibiotics and the risk this poses to human and animal health, though human health seems to be the biggest concern:

> *B.: 'I think you formulated it so well in the last exercise, or whatever it was [points at J.]: when you said that thing about us developing resistance, right. I think that is really, really… that's a threat I believe in… against animal welfare and humanity…'*
> *(Focus Group 2, Denmark)*

The risk of a future where you cannot cure ordinary human disease scares many of the participants and it seems to be a subject most are aware of:

> *A.: 'We're all taking antibiotics regularly and the GPs are complaining that we're asking for antibiotics for more and more stuff. And actually, diseases are mutating so that they're not… Now, antibiotics are less and less effective on certain diseases. Because we've filled ourselves up with them.'*
> *(Focus Group 3, UK)*

So the main warrant for concerns about antibiotics is the risk of antibiotic resistance for humans. While some participants, as in the quote above, do mention that the intake of antibiotics by humans is also very high, most blame the agricultural sector for the problems. Most also consider farm animals as 'pumped with antibiotics' and maintain that antibiotics are 'used liberally' (Focus Group 2, Denmark) by farmers and vets alike:

> *A.: 'Yeah. My wife's just finished a big project at a veterinary, a major veterinary practice, and it's erm, what they pump into our farm animals is quite horrendous. I'd rather not see antibiotics...'*
> *RA: 'No.'*
> *S.: 'No I'd rather not.'*
> *A.: '… only very, very sparingly.'*
> *RA:' Yeah.'*
> *S.: 'Only when they're needed.'*
> *[Assent]*
> *S.: 'You don't just give out antibiotics for the sake of it, and then they don't work after a while do they, and then it's going into us.'*
> *SP: 'Definitely.'*
> *RS: 'Well that's the issue, that's the issue.'*
> *(Focus Group 3, UK)*

Reading the quote above, the risk of humans developing resistance against antibiotics is closely linked with mistrust in the veterinary and agricultural sector. According to many of the participants, much more antibiotic treatment than needed is distributed to farm animals and ends up 'going into us' as S. puts it.

This is viewed as a general problem across most of the animal farming sector. Here, we see it in a discussion from Poland, where the participants move from poultry to salmon and talk about the problem of antibiotic resistance due to excess consumption:

M.: 'While I have to say here that this topic is of such a great importance not only when considering poultry. Because when it even comes to fish, we know what Norwegians do with salmons, in those closed water reservoirs, fj…'
F.: 'Fjords.'
M.: 'They close these fjords, and fish are so pumped with antibiotics there, that it exceeds all limits, acceptable limits.'
(Focus Group 2, Poland)

So all in all, there is an impression of an extreme excess consumption of antibiotics across terrestrial farm animals and aquaculture. While a few exclaim that antibiotics should be prohibited entirely, most agree that they should just be used much more sparingly and that an alternative to antibiotics in animal health care is greatly needed.

Interestingly, from that perspective vaccines become a solution to a problem rather than – in some other contexts (e.g. 3.3.1) – a problem in itself. As one of the Polish participants says, directly comparing vaccines and antibiotics:

D.: '… Well, yes, but that's it with antibiotics, it helps but it also harms. So it helps to treat one thing, but it harms another. While a vaccine's task is to protect. So here, (I'm) more for vaccines than for antibiotics. Antibiotics help but also destroy an organism. It is not so that antibiotics are "oh so good".'
(Focus Group 1, Poland)

So according to D., antibiotics have severe side effects as the medication 'helps to treat one thing, but harms another'. Vaccines are in contrast perceived as having the 'task to protect'. When participants discuss the strategy of antibiotics versus the strategy of vaccines, the vaccine is generally favored because it strengthens the animal's own immune defense system. We can see that argument in this excerpt from a focus group in Austria:

S.: 'But for the synthetic ones, we do not know it yet [if the synthetic vaccines are dangerous].'
A.: 'A certain fundamental research is already there. And vaccinate in general means not… in comparison to the antibiotics… that the consequences of the antibiotics will be transferred to the human but every vaccination means first of all that your own immune system is strengthened. That is the first priority that is given.'
(Focus Group 1, Poland)

So while antibiotics are treating illness and used in excess, vaccines are helping the animal's immune system to work by itself. As A. says, 'every vaccination means first of all that your own immune system is strengthened'.

In this way of arguing, the participants seem to refer to a principle of medical care where the treatment is considered better if it is closer to the way the body could react by itself without help. One of the participants in the same Austrian focus group as above refers to this as vaccines being better 'from a biological perspective':

> *J.: '… well vaccines are probably better from a biological perspective, because… well vaccinate means for me that we receive antibodies and through that the immune system is strengthened so thinking about that is a good approach. If it is feasible for the farmer - considering the cost of the vaccine - … I do not know, but it would be reasonable.'*
> *(Focus Group 2, Austria)*

The participants thus seem to be in favor of using vaccines – even synthetic ones – as a replacement for antibiotics. The structure of the argument is that they define the problem as being that of an excess use of antibiotics in the agricultural sector (and in human healthcare). The warrant for this problematic use of antibiotics is articulated as the risk of antibiotic resistance among humans, and to some extent among animals as well. Seen from that perspective, animal vaccines – including synthetic vaccines – are perceived as a solution rather than a problem. This support is further underlined by the perception that vaccines are better than antibiotics due to the way they work in the animal's body. Some participants cite the view that whereas antibiotics work as a treatment that battles a disease, vaccines are healthier because their only effect is to make the animal's body (the immune system) work the way it would do if it encountered the 'real' disease . In that way, participants refer to an idea of what is the most 'natural' way to avoid or to treat diseases. They consider vaccines to be more natural than medicines such as antibiotics.

3.1.3 Relation to other vaccine controversies

While the participants thus find the vaccine quite useful as a replacement for antibiotics, it should be noted that this support of vaccines is not unambiguous. While most are very concerned about the use of antibiotics, not least in animal production, a few, as we will show here, are unsupportive of vaccines in general – even if this theme was seldom raised by the participants.

Surprisingly few made connections between the theme of livestock vaccines and other debates over vaccines, considering the intense public debates over the HPV vaccine and MMR vaccine for humans. But comparisons are occasionally made. References are made both in order to support synthetic vaccines and to discredit them, but the latter seems to be the purpose in most cases. In this conversation from the UK, participants discuss eventual risks related to vaccines and reflect upon vaccines for humans:

S.: […] 'I just, I find you know the vaccines you have as children, I don't necessarily agree with those. It's the knock-on effect years later, I don't think enough research is done to-'
SP: 'So what knock-on effects have there been from vaccines then?'
S.: 'I think that, you know, it's all the ADHD isn't it, the autism, it's all linked, and somebody said there is, somebody said there isn't, and it's you know – '
D.: 'No one knows the answers do they, to be – '
S.: - '[…] huge increase in autism –'
RA: 'On the other hand, it has pretty much eradicated polio.'
SP: 'Absolutely.'
RA: '[inaudible] some certainly do work, and measles yes.'
S.: 'But that's what I mean, it eradicates one thing but then I think it raises another issue which might be worse for the person –'
SP: '- it might be that we've got more ADHD because we're diagnosing more.'
S.: '[inaudible] people older, than, people you know, they had, was it against polio they had, women had vaccines, and when they were pregnant and then these, I can't remember how many years, it wasn't actually that long ago was it?, 'cause they had the vaccines their children were being born with really horrendous [abnormalities] –'
A.: 'That was thalidomide –'.
(Focus Group 3, UK)

In this conversation the participants are quite agitated, speaking loudly, interrupting each other and appearing divided about the subject. They contribute many stories to support their arguments. S. is very sceptical of vaccines, not the least the MMR vaccine, which she links with ADHD and autism and she also (incorrectly) mentions the thalidomide scandal which caused children to be born with ''really horrendous abnormalities' as being about a vaccine. Others, such as SP and RA, are more in favour, and RA refers to the polio vaccine as a success as it has 'pretty much eradicated polio'. So some consider vaccines to be a successful way of preventing various diseases for humans and use that as an argument in favour of vaccines in general, whereas S. points to unknown risks and uncertainty (also discussed in section 3.3.1): '…It eradicates one thing but then I think it raises another issue which might be worse for the person' as a reason for not trusting vaccines. The same division between sceptics and supporters is present in other focus groups. Here, in a focus group in Austria:

G.: '…And many infectious diseases reappear, because people have become tired of taking vaccines, especially those eco-friendly mothers, who do not let their children get vaccinated against measles, what can be a deadly disease for a small child and measles etc. that is so dangerous, so those come back again and the children, who are now in school, many of them are not vaccinated and measles are an upcoming trend and that is a dangerous disease'.
(Focus Group 3, Austria)

G. is worried by the increasing amount of people ('those eco-friendly mothers') who do not vaccinate their children against measles, and she justifies this concern in the risk of contracting the disease which can be 'deadly'. But W. contradicts her:

> *W.: 'Well, measles are not deadly and one says that child diseases are necessary for the development of the child and I do not believe that, because there are some like polio, where you should vaccinate, but in general I do not think my children should take all vaccines'.*
> *(Focus Group 3, Austria)*

He states that it is important to consider the vaccine options independently as there are some diseases where 'you should vaccinate', but that this is not a general rule and he would not let his own children 'take all vaccines'. He justifies this argument by suggesting that some diseases may be necessary for the 'development of the child', a similar argument to the one described in section 3.1.3 about the benefits of an active immune defense system which functions better if exposed to real disease compared to a vaccination.

As the references to other vaccine debates and vaccines for humans in general are quite scattered, it's difficult to draw general conclusions about the patterns of arguments in these discussions. But we can see that when the discussion about animal vaccines becomes entangled with discussions about humans, it becomes polarized and agitated. We can also see that even though synthetic vaccines are considered useful as a tool for fighting antibiotic resistance, they are not seen as entirely unproblematic. We will go into more depth about the perceived problematic aspects of the technology in the following sections.

3.2 Imagined risks

The participants often discuss whether synthetic vaccines and vaccines in general are dangerous. This proves a contested subject. While some participants in some contexts see the use of vaccines in agriculture as posing severe risks, in other contexts others present as quite calm about them. The next sections present the arguments pertaining to risks, first analysing the claim that there are no risks related to the use of synthetic vaccines and then by presenting three ways in which the participants find that synthetic vaccines do in fact pose a risk.

3.2.1 Synthetic vaccines? No risks to speak of

Some participants find the use of synthetic vaccine fairly unproblematic and do not worry about its safety. This viewpoint usually appears in discussions about the participants' willingness to buy meat from animals treated with a synthetic vaccine. One of the Danish participants responds:

> *Pe: 'I don't think I would mind that much. If I could read the information on the package and it said that it was either an annotated vaccine, a GM-modified vaccine or a synthetic vaccine… I don't think I would have enough of an opinion of any of them – to count out one of them, if it's a product I buy in the supermarket. Because I still assume that it's tested [enough] so when they sell it to me, even though it's vaccinated either with a "natural" or a synthetic vaccine, then they wouldn't sell me anything which would make me fatally ill. So I think I believe that they have removed what would be dangerous for me, if there was anything. So I don't think I would put that many thoughts into it, if I was out there'.*
> *(Focus Group 1, Denmark)*

Pe is reflecting on her consumer habits and concludes that she would not actually think that much about it, as long as she had knowledge about the synthetic vaccines. She does envision a potential risk, namely that she could become 'fatally ill', but does not find it plausible. The reason that she does not worry appears to be a general trust in the control of foods and technologies: '… I think they would have removed what would be dangerous for me, if there was anything' she says. 'They' are not further defined, but seems to be a mixture of the retail trade and public authorities performing control of food safety.

> *E.: 'It's good that no matter whether the attenuated, the genetically modified or the synthetic one would be used (…) it seems to me it is somehow tested, right. Well, it shouldn't have any harmful effects. Of course the best would be if there were no vaccines at all, right? '*
> *Moderator: 'Why? '*
> *E.: 'Because it is an interference. While if they have to be, I guess they are tested somehow. They shouldn't harm us'.*
> *(Focus Group 3, Poland)*

Here we see this argument further underlined. E. does not necessarily like the idea of animal vaccines as she considers them 'an interference' (a subject we will return to in the section on 'naturalness', 3.3.2). And like Pe, she imagines a hypothetical threat against human health. But that does not mean that she considers them as a risk, because she – in line with Pe – believes in the 'tests' of new technologies. She too expresses a basic trust in the system, which is even stronger than her immediate dismay over the use of vaccines. Even if she finds them an 'interference', it does not

shatter her trust in a system that protects her against 'harmful effects'. S. from Austria enumerates more specifically the group of different actors who together she believes form a safety net against harm:

> *S.: 'Well, when it is used area-wide I think then [there must be] so many researchers and vets together with the farmer, so they know to a certain extent if it exposes a danger to the human being or not. So in that case if it would be used area-wide [it wouldn't make] a difference how it would be vaccinated, if I would know that the quality of the meat would be good. If it has a AMA-quality label and everything fits, then I wouldn't care how it was vaccinated.'*
> *(Focus Group 1, Austria)*

Where Pe talked about trust in 'them' and E. uses the passive '…they are tested…', S. names those actors whom she believes form the network that makes her trust the use of synthetic animal vaccines: the researchers, vets, farmers and AMA (Agrarmakt Austria Marketing, gmbH). While the list of potential actors has of course not been exhausted, we will argue that what she is pointing to is a trust in basic societal institutions such as science (the researchers), government control (vets), the producers (the farmers) and industry (AMA).

What we can see from these three examples is that the interviewees share an idea of a possible danger, namely that the synthetic vaccine may somehow harm human health, but that they immediately set that risk aside based on the warrant of a basic trust in society's institutions to discover and prevent harm against consumers and lay people. In this sense, it seems that some of the participants share a basic trust in the regulation of foods and retailers and this guides the perception that the consumption of meat from synthetically vaccinated animals is unproblematic.

3.3 Same risk – three warrants

While some participants in some contexts are unconcerned about risks in relation to synthetic vaccines, others do not have the same faith in the ability of authorities to protect consumers and lay people against harm.

As described in the previous section, some participants mainly express that they are concerned about the risk that the vaccine poses for human health. However, in contrast to the views expressed above, they do not trust that authorities are capable of protecting consumers against that risk. Instead they present three distinct warrants that motivate their worry: a) the basic condition that we never have full knowledge about effects of new technologies; b) that products that are not 'natural' pose a risk and c) a mistrust in producers making the vaccines and their assurances that the product is safe. The next sections will take a closer look at these three arguments relating to concerns for human health.

3.3.1 Warrant 1: Unknown unknowns: 'we don't know, if they are dangerous'

Some of the participants express concern about the effect of vaccines on human health, but do not point to a specific reason why the synthetic vaccine that they were presented with is particularly dangerous. Rather, they justify their concern with the need to be particularly careful in relation to emergent technologies:

> *J.: 'Yes, the safest are the inactivated and the attenuated vaccines – '*
> *S.: 'The genetically modified and the synthetic ones are dangerous.'*
> *J.: 'Dangerous.'*
> *E.: 'This is already… I mean, we don't know if they are dangerous.'*
> *M.: 'I mean, it's dangerous because it's new, according to me.'*
> *E.: 'That it is genetically modified, yes.'*
> *M.: 'And this is the danger. Because [the synthetic vaccine] is new and […] was not launched yet, right? So in fact it's not known what kind [of] results and effects it can have.'*
> *(Focus Group 3, Poland)*

As we can see here, some of the participants do not distinguish between a genetically modified vaccine and a synthetic vaccine, considering them both as 'dangerous' - and just the mere fact that one of them is genetically modified makes this so. But as M. underlines, the main reason for calling the synthetic vaccine 'dangerous' is that it is 'new'. The uncertainty about how the vaccine will work makes it dangerous in itself. Participants from Denmark elaborate on this perception:

> *N.: 'Well, but we have to assume that all four kinds of vaccines - even though it says that this one is rather new – then we agree that it's something, which is tested through and through; that people don't get sick. Well, also this one [points at the description of synthetic vaccines]. But what you can argue is that what you don't know about this one (points to the description of synthetic vaccines again) is, if there maybe are some other…'*
> *Pe: 'Some unknown substances, which you can't at all…'*
> *N.: '…Some other… err…. What's it called? Side-effects, long term side effects which you don't think about, right?'.*
> *(Focus Group 1, Poland)*

So, the viewpoint that vaccines in general are thoroughly tested is presented again, as in 3.2.1. But the claim is immediately rejected (by the participant herself), because tests cannot account for things you 'don't think about', 'unknown 'substances' or 'long-term side effects'.

What the interviewees all seem to imply is that the simple fact that we are dealing with a new technology means that we have to take the uncertainties about long-term effects on human health into account, and that the technology being

new gives rise to risk. The concern about these unknown unknowns is enough to make some of the participants agree that they would actually not buy products from vaccinated animals:

> *F.: 'Since there are no results, it is not known what effects it has on us. If it is unknown what effects it has on an animal, so what [effects can it have] in the next link of a chain. I don't know. I would rather not take a risk.'*
> *Moderator: 'Mm hmm.'*
> *F.: 'Until everything is proved.'*
> *Moderator (to Ma): 'And you?'*
> *Ma: 'I wouldn't buy it either for the very same reason.'*
> *A.: 'I wouldn't either.'*
> *M.: 'Absolutely not.'*
> *(Focus Group 2, Poland)*

So the risk that comes with something being new and untried makes one of the participants exclaim that he would 'rather not take the risk', and the rest of the group quickly agree. While there is nothing yet to suggest that there may be any health risks related to the vaccine, the mere fact that the participants do not know more makes the meat too risky to buy. As we see in the next section, this scepticism about the new and unknown becomes further supported by the fact that some of the participants consider the vaccine to be 'unnatural'.

3.3.2 Warrant 2: Naturalness: the artificial as dangerous or wrong

The second warrant for the participants concern about health-related risk is that of the vaccine being 'unnatural' or, as they often say, 'artificial'.

> *Pe: 'You can always be unlucky with vaccines, you just need to look at the statistics'.*
> *Le: 'But I think there's a greater risk of getting sick by this one [pointing at the description of the synthetic vaccine] exactly because it's something… artificial'.*
> *(Focus Group 2, Denmark)*

So it seems that another way of arguing for the health risk related to synthetic vaccines is to point to the notion that they are 'artificial'. However, what this implies and how it relates to synthetic vaccines or additives in food is viewed differently among the participants.

Some participants relate the concern about unnaturalness to the synthetic vaccines themselves. They distinguish between vaccines that they consider as having been made from scratch in a laboratory and those containing elements that they believe can be found in nature in some form. Participants from Poland elaborate on this point in the following

example, when they claim that what is 'natural' is better because there is more uncertainty connected to what is 'unnatural':

> *E.: 'Everything that's natural is better…'*
> *W.: 'What's natural will always be better'.*
> *E.: '…so, with the synthetic one, we don't know how it affects customers.'*
> *(Focus Group 1, Poland)*

Again, the main concern is the effects of the 'customers'' health. This concern is justified by the fact that the vaccine is based on synthetic biology rather than that it is a new method. 'Natural' is 'always' considered to be the safer choice, because something defined as 'natural' is assumed to be more predictable than synthetic products where you just 'don't know'. Others share this line of argument and explicitly attribute different degrees of naturalness to different types of vaccines:

> *Moderator: 'Which (vaccine) would you prefer?'*
> *D.: 'The inactivated or attenuated one'.*
> *Moderator: '(…) Why is that?'*
> *D.: 'It's allowing the body to build up a natural resistance to a natural disease, whereas the other one is genetically modified. It's fake.'*
> *(Focus Group 3, UK)*

D. comments on the difference between an inactivated or attenuated vaccine and a genetically modified one, but the logic of the argument seems to be the same whether they refer to GM vaccines or synthetic ones. Inactivated or attenuated vaccines are considered 'natural' because they activate the body to do what it has always been able to do (activate the immune system) to target a sickness, which is the same chemically regardless of whether it's injected through a vaccine or contracted by accident. In contrast, the genetically modified version is perceived of as making the body react to something that doesn't occur in nature, whereby the response in itself becomes less natural – and this is considered risky.

This differentiation between 'real' (weakened or dead) vaccines as opposed to genetically modified or synthetic imitations is often made among the participants. Very few are opposed to vaccines in general, but many show concern about risks related to vaccines containing synthetic or genetically modified material. There are further ways that the participants connect 'unnatural' and 'risk' in relation to livestock vaccines. One of the Austrian participants for instance states that:

> *A.: 'I am not a vet, but everything that changes the natural food chain, can be potentially dangerous.'*

(Focus Group 1, Austria)

Here, the interpretation of unnatural is not related to what the vaccine is made of, but rather that it is something that changes the way foods are produced from a (presumably) well established method of food production and thereby changes the apparently 'natural' food chain. Similar viewpoints are seen across the focus groups, where several participants warn against synthetic vaccines by making a parallel to additives in food products. This is justified by the unnaturalness of additives. Here it is in one of the Danish groups:

> *Le: 'To make a comparison [to her scepticism against synthetic vaccines] then I make my own skincare products of natural ingredients, for instance. And my own toothpaste. Exactly because you don't know what you buy. There are all sorts of things in the stuff you buy at the supermarket (…). When I make it myself, I know exactly what's in it. So I don't put all sort of weird things in it, which is not healthy for my body. So that's why that anything artificial, is something that I'm against'.*
> *(Focus Group 2 Denmark)*

Le is against 'anything artificial'. In this excerpt, she expresses that 'artificial' is 'all sorts of things in the stuff you buy at the supermarket'. She refers to things that have been added that may be unknown and might pose a health threat. and says she considers additives to foods and other products as 'artificial'. She contrasts these products with her own homemade skincare products and toothpaste, which she doesn't consider unnatural as she knows what they contain. Additives of various kinds are considered unnatural and thereby dangerous. Indeed, additives and the uncertainty of what's contained within consumer products are considered to pose a risk towards the human health. Synthetic vaccines for livestock in this perspective become an unwanted additive, and this increases the suspicion of consumer products bought in stores.

The last, and least present, understanding of unnaturalness is that of the unnatural as morally inferior to the natural. Here it is in a discussion from Denmark, where the participants discuss pros and cons of the vaccine. They have just agreed that meat will perhaps become cheaper due to the vaccine and then AM adds:

> *AM: '(the customers will get) …a healthier cow'.*
> *Pe: '…And a healthier cow!'*
> *AK: 'A healthy cow!'*
> *LE: 'Do you become a healthier version of you, if it (the vaccine) is artificial?'*
> *Pe: 'If the cow is healthy, then I shouldn't become unhealthy?'*
> *LE: 'It's not necessarily… you can get cured for an illness with something artificial, which makes you healthy… but inside you there is something… err… wrong'.*
> *(Focus Group 1, Denmark)*

So here, three of the participants agree that the cow will become healthier due to the vaccine, but one, LE., objects because she is concerned about human health. In her perception, humans cannot be considered 'healthy' if there is some kind of unnatural – 'artificial' – entity in your body. She does not specify how or relate this to unintended consequences or vaccines per se. Rather, she justifies her argument with the notion that no matter if people (or cows?) are treated, if there is something artificial inside them it will still be 'wrong'.

This argument goes beyond the ideas of the unnatural as unpredictable in comparison with natural products or additives. Instead it seems that 'natural' becomes a value in itself, something that is inherently better than 'unnatural' products that – purely because of their status as artificial – pose a threat against the human body.

3.3.2.1 'Being a bit ill is ok'

Related to the perception that the unnatural is inherently wrong is also the participants' perception that naturally occurring diseases are actually positive, because they are healthy for the overall working of the body. The participants consider the construction of a good health to be dependent on an active immune defense system and not a system made redundant by vaccines. In that line of argument, illness also becomes a good thing, something an organism (animal or human) needs to encounter and outlive in order to survive. Here is a discussion from one of the focus groups in the UK:

> *SP: 'I think if an animal's not, if it's not gonna change its productivity and you know, we all get ill from time to time, you have the flu, it's not very nice, and yes you might vaccinate the very elderly, well you don't have very elderly animals anyway. Erm... but actually they'll get over it. Being a bit ill is ok. Getting Mad Cow Disease is not ok'.*
> *S.: 'I think if you over-vaccine you're not allowing them to build up a natural resistance to your disease, so I think they have to be ill at some point to build up…'*
> *SP: 'You can't have them perfectly healthy all the time.'*
> *S.: 'Yeah'.*
> *(Focus Group 3, UK)*

SP and S. express a viewpoint that was frequently uttered in the focus groups: that (synthetic) vaccines prevent the animals, and humans for that matter, from developing the ability to 'build up a natural resistance against disease'. The assumption seems to be that the animals will actually become weaker from the vaccines because they need a 'real' illness to strengthen the immune system and not the weak copy from a vaccine. This is why they claim that 'being a bit ill is ok'. As in similar discussions about the desirability of being ill, the participants often moderate their claims and underline that this is on the condition that the illness is not very serious or fatal – as SP remarks, 'Getting Mad Cow

Disease is not ok'. This idea that diseases are 'ok' as long as they are not too severe is supported in many of the other focus groups. Here it is in an excerpt from a conversation in Spain:

> *N.: 'I think it depends on the illness, if it's not harmful, maybe I would eat that meat… but, of course, about what disease we are talking about!?'*
> *G.: 'Not all diseases have to be bad!'*
> *(Focus Group 2, Spain)*

Interestingly, the participants also use this idea of the 'natural' reaction of the body to rank different types of vaccines . Here, R. from Austria comments on different vaccine types:

> *R.: 'Artificial (the synthetic vaccine) would be the one […] that I would least like, but I would still try what helps the best. But the artificial would always be my last thought, because it is artificial. The others are better, because it is better when we treat animals…in 'quotation marks'… a natural way. So that the body can react itself, and can handle it. But there are some kinds of disease that develop themselves further so that the second type (genetically modified) should rather be used. But for me the artificial would always be the last method.'*
> *(Focus Group 2, Austria)*

R. states that an 'artificial' (i.e. synthetic) vaccine is the one she prefers the least, simply because she considers it artificial. She further justifies her argument by comparing the synthetic vaccine against the other ones and considering them preferable because they help animals in a more 'natural way'. We interpret this remark as supporting the perception that the closer the vaccine components are to the real disease, the more natural they are considered to be and thus also more helpful for the animals because they help the immune system to react in a better way. This does not mean that the participants reject the use of synthetic vaccines entirely. R. for instance believes that diseases can change so it is necessary to use a genetically modified version. But in general they agree with R. that 'the artificial would always be the last method'.

A participant from Denmark makes the ranking even clearer:

> *T.: '(…) But I think that if we assume that [the vaccines] work equally well, then as you say, then we know this one the best' [points at the card that describes dead or attenuated vaccines]. Well, then I would rank them according to the principle of naturalness, and then I can't see any reason to…' [Shrugs and opens his arms]*
> *R.: 'No, then there's no reason that we go out and produce something new in order to… It's easy to make up a problem in order to [construct] a solution for it'.*
> *(Focus Group 2, Denmark)*

T. explicitly states that the vaccines should be ranked 'according to the principle of naturalness' and R. supports him by suggesting that new kinds of vaccines should not be made unless it is strictly necessary, maintaining that '… it's easy to make up a problem in order to [construct] a solution for it'. So synthetic vaccines are again considered as unnatural and thereby less desirable, but the idea of synthetic vaccines is not entirely rejected. Participants just make clear that what they consider to be less natural vaccines should only be made if other types are not an option – if the different kinds of vaccines do not work 'equally well'.

Overall, many of the groups do seem to exhibit some reservation towards synthetic vaccines on the grounds that they are unnatural and it is considered healthier to use a vaccine where the active component resembles the original version of the active organism the most.

3.3.3 Warrant 3: Lack of trust in producers

A third way that the participants discuss risk is by relating it to their lack of trust in vaccine producers. As in the two previous sections, they still appear to imagine a risk against human health and they relate this risk to the perception that pharmaceutical companies, in particular, do not have customers' interest at heart. This perception is summarized by one of the British participants:

> *K.: '(…) One thing about the consumer is they've got the least, apart from the animal, the least choice? They're not involved in it, kind of, so you kind of get what's being made. (…). Like always consider the consumer, 'cause at the end even if it's like three months later, the animal's gone, the businessman is on a new contract, they're doing something else, that consumer could still have that meat in the freezer, poor thing! [Laughter] It's just, do you know what I mean?'*
> *(Focus Group 2, UK)*

Many participants, like K. above, articulate the consumer as without power compared to the 'businessman' who helped develop the vaccine. Where the consumer never receives full information and could end up with dangerous meat in the freezer due to the vaccine, the ones who produce the vaccines and thereby the risk can easily escape the responsibility: 'The businessman is on a new contract'. By contrast, the consumer lacks knowledge of the risks that can keep them safe. This notion of consumers as powerless compared to pharmaceutical companies is underlined by a discussion in one of the Polish groups:

> *D.: 'We [consumers] are the only possible group which can lose.'*
> *M.: 'Yes, our health' [chuckles].*
> *D.: 'The only possible.'*

M.: 'We don't know that'.
D.: 'But as long as we don't know the effects'.
(…)
D.: 'If not (us), then our generations, our children and...´
M.: 'We don't know that'.
D.: 'It is difficult to say'.
M.: 'But they (the pharmaceuticals) don't have a good reputation.'
D.: 'It's not that we are somehow prejudiced against pharmaceutical companies in general, however they don't have a good reputation.'
(Focus Group 2, Poland)

Again, human health, including in generations to come, is articulated as being at risk and this is connected to a lack of knowledge of 'the effects'. The reason that consumers are articulated as 'the only possible group which can lose' is the same as in the last quote. They lack the knowledge that can keep them safe from eventual risks. But the notion that there are risks related to vaccines in the first place is related to the producers – 'the pharmaceutical companies' – who 'don't have a good reputation'. It is common across the focus groups to connect potential health risks with lack of trust in pharmaceutical companies:

D: 'I don't want them to trade with my health. Maybe for the pharmaceuticals it's more profitable if I have cancer because they can continue selling me drugs. So, they could give us something to get us sick'.
(Focus Group 3, Spain)

So D. justifies his lack of trust in pharmaceutical companies by his perception that pharmaceutical companies are more interested in profit than in the health of people – if they can earn more by not curing people for cancer, they would, he claims. A large portion of the participants across all focus groups back this justification. M. from Poland sums the argument up:

M: 'Well, I mean, a private company will always be driven by profit in the first place and then by the good for the people, right? As some things can appear in the fifth generation, or fourth, (…) where we're not here anymore, while a company will gain money, right?'
(Focus Group 2, Poland)

The reason that consumers cannot trust pharmaceutical companies is structural, according to M. They are, according to her, 'driven by profit in the first place and then by the good for the people'. Consumers' interests are simply not the first priority of the pharmaceuticals', and it therefore cannot be trusted that their products are safe. Some participants even suspect them of making unnecessary or downright dangerous products on that account. The third way of justifying a

concern for risks towards human health is thus that pharmaceutical companies do not have the customers' interests at heart but are motivated by gaining profits, and this may ultimately prove a health risk to humans.

In relation to this finding, it is worth noticing that while participants express mistrust in private (pharmaceutical) companies, they are – as we showed in 3.2.1 – more trusting of public authorities and their ability to manage risks in relation to synthetic vaccines and food safety. This perceived risk related to the pharmaceutical companies profit interests may therefore be mitigated by the greater trust in public authorities' ability to control and secure foods. .

3.4 Perceptions of justice and injustice

In relation to emerging biotechnologies, recurrent themes are questions of justice and fairness in relation to who would benefit from the introduction of the technology in society, and who would be disadvantaged by its introduction. This, for example, was one of the big issues in relation to the introduction of GM crops in Europe, where the question of ownership of crops and multinational companies formed part of the public debate (Lassen & Jamison 2006). The participants seldom bring up the subject of justice unprompted, but they express strong opinions about the subject when the moderator introduces the subject.

While there are different ideas of justice among the participants, one specific perception of how the introduction of synthetic vaccines to the market could produce injustice prevails in all focus groups. This perception is that producers (i.e. pharmaceutical companies) and to some extent farmers will gain from the vaccine, whereas consumers and, to some extent, animals will 'lose out'. This perception is informed by specific ideas about benefits and disadvantages of the vaccine, and these are grounded in the perception of an unequal distribution of resources across different kinds of societal actors.

In the next sections, we will show how the lay people participants build up this argument. First we will demonstrate how they attribute benefits to the pharmaceutical industry and the farming industry, and then we will show how this is justified by the perception that synthetic vaccines actually have the ability to change the market of vaccines and optimize the farming industry. We will then show that participants mainly perceive the downsides as risks and that these risks are attributed to consumers and farm animals. We will also show how they justify these perceptions with two different beliefs: that consumers are the victims of a dubious industry's experiments and that farm animals do not have the freedom to choose whether they want to be vaccinated or not.

3.4.1 Benefits and privileged parties

When the participants talk about the vaccine's benefits, they mainly interpret 'benefit' as financial profit. As L. from Denmark says:

> *L.: 'I can't recall having ever heard about a medical company that didn't profit by inventing some kind of vaccine that no one else had figured out how to make. I mean, financially speaking, anyway. No, I've never heard about that. It almost becomes… a career opportunity for life for I don't know how many people [in the pharmaceutical industry].'*
> *(Focus Group 1, Denmark)*

For L. it is almost impossible to imagine that the pharmaceutical industry would not gain from the invention of a new vaccine. She clearly defines the advantages as being economic, saying that she means 'financially speaking'. Inventing a new vaccine is for her 'creating a career opportunity' for people working in the pharmaceutical industry. This perception is recurrent throughout the interviews and underlined by the language that the participants frequently use when they discuss benefits. This is dominated by economic terms - for instance in these comments from two of the Austrian participants:

> *B.: 'If I have the serum that I can make artificially and that only costs 1/10 of the natural agent then the pharma producer has a certain profit margin'.*
> *S.: 'Yes the pharmacy is the one that profits from it'.*
> *(Focus Group 1, Austria)*

Terms as 'profit margin', 'costs' and 'competitive advantages' (Focus Group 3, Austria) are often mentioned in relation to benefits from the vaccine and are made in connection to the pharmaceutical companies. Disadvantages for the industry are seldom mentioned. When they are, it is either in the event that the vaccine turns out to have serious side effects (whereby the industry will lose profit), or how the vaccine will oust less effective options and thereby drive some companies out of the market:

> *G.: '(…) We are talking about the synthetic vaccine, right? '*
> *Various: 'Yes.'*
> *G.: 'I think the one who will be worse off is the producer of the traditional vaccines'. [Laughter]*
> *(Focus Group 2, Spain)*

As such, the participants are generally very certain that producing synthetic vaccines will put the medical company in an advantageous position – and they interpret these advantages as financial. As we shall see in the next paragraphs, participants consider the farmers in the same way, albeit that they do not talk as much about how farmers gain as much

as they do the gains to the pharmaceutical companies. Here, some of the Polish participants describe 'modern' farmers and how they will benefit from the vaccine:

> *W.: '[The] farmer will benefit. If we are talking about large scale farmer[s].'*
> *E.: 'Well, these synthetic[s] are cheaper and this is farmer who is paying for the vaccines.'*
> *A.: 'The farmer will benefit. He is modern, right. He is adopting new solutions.'*
> *W.: 'He is modern (…). The synthetic (vaccine) will be cheaper. They will flood the market.'*
> *(Focus Group 3, Poland)*

Both large-scale industrial farming and very small family-run farms exist in Poland. The participants differentiate between the two kinds and focus on the 'large scale farmer', as one of the participants puts it. They picture 'him' as one who is 'modern' and who adapts to new technologies in order to gain competitive advantages, because the synthetic vaccines will be cheaper. A similar way of perceiving the farmer and farming can be seen among the Danish participants:

> *Moderator: 'Who wins or who gets some advantages?'*
> *E.: [Shows a post-it] 'Mine says the consumer [with a] direction indicator pointing downwards and the farmer [with a] direction indicator pointing upwards.'*
> *Moderator: 'So the farmer wins and the consumer loses to put it bluntly?'*
> *E.: 'Yes. I mean, it's a question of standardizing the production machinery, which happens to be animals'.*
> *(Focus Group 2, Denmark)*

So the farmers are portrayed as quite industrialized - as having 'production machinery' (the animals). The synthetic vaccine is then considered helpful, and as a means of 'standardizing' the production. The perception of farming as an industry and the vaccine as a means to enhance the production prevails across all focus groups:

> *K.: 'I thought farmers would win. Because they'd loose less, they'd have more readily available livestock at that time, to meet like the mass consumption they need to meet, 'cause the demand of meat's crazy'.*
> *(Focus Group 1, UK)*

Farming is thus described in economic and industrial terms, and the participants justify their perception of farmers as benefitting from the introduction of the vaccine in the belief that it will optimize their production line.

In general, no matter whether the participants are considering the pharmaceutical or farming industries, they mainly consider the benefits to be economic in some sense. This may be either by being directly profitable (for the pharmaceutical industry) or as a means to optimize the animal production (for the farming industry).

3.4.2 Downsides and the aggrieved parties

While the participants consider the pharmaceutical industry and the farming industry as potentially gaining by the introduction of synthetic vaccines, they are generally concerned that consumers and farm animals may be less fortunate:

> *E.: 'The producers and farmers would be better off because this vaccine is supposed to be more effective than the previous one… And the most disadvantaged would be, in my opinion, because it is not well studied, the animal… due to the side effects, that they are not known right now… and the consumer. If the vaccine is not fully tested, there may be side effects that we do not know yet.'*
> *(Focus Group 4, Spain)*

So many participants are concerned about animals and consumers because of the 'side effects that we do not know yet' and the concern that the vaccine is not 'fully tested'. We can therefore see that these concerns relate to the risk perspective about 'unknown unknowns' (see section 3.3.1 about risks). Considered from a justice perspective, though, this also turns into indignation on behalf of the consumers whom the participants consider to be guinea pigs in an experiment - one that will ultimately benefit others than themselves. As a participant from the UK puts it:

> *N.: 'Who's like the first person who's gonna buy that [meat from vaccinated cows]? Even if it's like a massive success with the animals and the farmers and the farmer guys and the [pharma] people? Who's gonna be the first consumer, I don't think this blonde woman [referring to a picture of a consumer on the table] is gonna be like "oh yeah, let me try some of that"?!'*
> *(Focus group 2, UK)*

This sentiment of indignation on behalf of the consumer is shared among many of the participants:

> *W.: 'The consumer is the loser.'*
> *Moderator: 'Why would you say that?'*
> *W.: 'Because I think the pharma industry is paving a way that more vaccines than needed are used and the consumer suffers from that, because the quality [of the meat] suffers from it.'*
> *(Focus Group 3, Austria)*

As we have already seen in the discussions of risk (3.3.3), there is a lack of trust in the pharmaceutical industry's intentions which here turns into a perception of the consumer as a 'loser'. They will lose, so to speak, because they are at the receiving end (buying and eating the meat) of the pharmaceutical companies' dubious inventions. Most people consider the issue of human health as the biggest risk, but a few, as in the quote above, are also concerned about how

the vaccines will affect the quality of meat. It is worth noting that this is a rare concern in the data. What is most important is that the participants perceive customers as being victims of the pharmaceutical industry's experiments.

We now turn from the consumers to another group whom the participants suggest as being aggrieved by the farmers' and pharmaceuticals' interests, namely the farm animals. Here we can see that the concerns differ slightly. While the participants do at times worry about the health of the animals in the same way as they worry about human health, they attribute their perception of unfair treatment of farm animals with the fact that animals do not have any freedom to decide their own fate. In that way they become helpless victims of others interests, as this conversation from Poland illustrates:

> *J.: 'The poorest is this poor cow, who doesn't know what she is doing'.*
> *Moderator: 'Exactly. What about that cow?'*
> *L.: 'The cow will be the worst off.'*
> *W.: 'What they will give her, she will have to accept.'*
> *J.: 'Right. And, poor her, she will either take and survive or…'*
> *D.: 'The cow has a the biggest minus [compared to] everyone else (…) because she…'*
> *W.: 'Right.'*
> *D.: 'Poor her…'*
> *B.: 'She doesn't make a choice.'*
> *D.: '…will be used in an experiment…'.*
> *(Focus Group 1, Poland)*

They specifically discuss a cow because are given pictures of different actors who could either benefit or lose by the introduction of MycoSynVac, and farm animals are represented by the cow. According to the participants here, the cow will be 'worst off' compared to everyone else because farm animals cannot choose if they want to be 'used in an experiment' or not. Many of the participants echo this sentiment of pity for the animals, citing that they do not have the right to say no and can therefore be used for other means as it pleases more powerful actors:

> *J.: 'Firstly, it is the cow who gets the most disadvantages of the vaccine… They are guinea pigs; scientists use them to test the vaccines…'*
> *[Laughter]*
> *P.: 'But they are gonna be eaten… it doesn't matter!!'*
> *(Focus Group 4, Spain)*

Farm animals (here, cows) are portrayed as experimental animals, subject to the interests of others (those who are going to 'test' whether the vaccine works or not) without having the resources to say yes or no. But, as we can also see from the conversation above, some also protest against the claim that the farm animals will be great victims of the

vaccine. The justification for this lies in the fact that they are helpless and at the mercy of others anyway, as they are ultimately taken to be slaughtered:

> *G.: 'The cow, with this vaccine, is going to be healthier! [laughs]'.*
> *P.: 'The cow doesn't care about vaccines!! [laughs]… It's gonna be eaten anyway!!'*
> *N.: 'Poor cow!'*
> *P.: 'Yeah…'*
> *P.: 'Once the cow is healthy, it goes to the slaughterhouse…'*
> *P.: 'Yeah… the cow doesn't care about one vaccine or another…'.*
> *(Focus Group 2, Spain)*

So if the animals do not 'care about one vaccine or the other' it is not because they do not care about being relieved of pain, but rather that the animals are already victims of others' interests, namely humans. Overall, most of the participants agree that the pharmaceutical industry and the farming industry will benefit greatly from the synthetic vaccine (if it works) because they will gain financially. On the other hand, they consider consumers and farm animals as subject to downsides of the vaccines. While the participants do not straightforwardly say that they consider this an unjust distribution of benefits and downsides, they still express worry on behalf of consumers and farm animals and to some extent resent the farmers and especially the pharmaceutical industry for putting them in that position. This is also underlined by the analysis of risks perceptions (3.3.3), where one of the justifications for participants' concern of health side effects is a lack of trust in pharmaceutical companies.

4 Results: Expert analysis – synthetic biology

4.1 Introduction

This is the first of two chapters analysing expert perceptions in relation to the MycoSynVac project. It is focused on how experts working in the field of synthetic biology, but not necessarily with vaccines, interpret the prospects of synthetic biology projects in general and the MycoSynVac project in particular. Similar to the public participants, the expert interviews were based on a guide containing a range of discussion topics to assess different aspects of synthetic biology such as usefulness, risks, naturalness and varying business models. In the next sections, we will present the results of the topics that were most pertinent to the participants.

4.2 Usefulness

During the interviews, we studied how the experts interpret usefulness in relation to synthetic biology. In the following we present the four forms of usefulness articulated by participants, with varying degrees of reflection. These are: societal usefulness (which we first will present as a rather abstract and general concern before focusing specifically on human health as a form of societal usefulness, which was found especially important); scientific advance; universality and finally, we have a small section on economic usefulness, which is mentioned by a few of the participants.

4.2.1 Societal usefulness

Most of the scientists that were interviewed are preoccupied with synthetic biology being able to solve a societal problem. It varied, however, what they consider to be legitimate significant social problems. There does seem to be a general consensus that it is a good idea to try to develop technologies that will somehow address a serious problem in society. In the following, we will first show how the scientists try to explain what a societal need is generally, before moving on to describe human health as the specific form of societal usefulness with which they are mostly preoccupied.

When the scientists try to explain what they mean by such a problem-solving agenda, they usually consider it as something that benefits human beings in the not too far future – as one of them states when we ask about what she means by solving ‘pressing needs’:

> *G.: 'I think it's a combination of who's gonna benefit the most and perhaps even how quickly they are going to benefit from it'.*
> *(Scientist, UK)*

As an example, she speaks very fondly about one of the synthetic biology applications that we bring to the table, namely the construction of synthetic vanillin (see appendix 3 for exact case description):

> *G.: 'Erm, vanillin being so widely used, it seems obvious as something that, even if it's [only] a little bit un-environmentally friendly, or expensive, or something, [then] 'cause it's used on such a large scale, there must be quite a large problem there. So I can see the solution being more immediately needed there.'*
> *(Scientist, UK)*

The scientist thus considers synthetic biology useful if it solves a 'large problem' where the solution is 'more immediately needed there'. So usefulness is here defined as something which solves a serious societal problem, such as an 'environmental friendly' production of an industrial commodity on a 'large scale'.

Other scientists articulate understandings of usefulness that support this idea. A Polish scientist tries to define the idea of immediate social need during our conversation:

> *E.: 'When we consider the problem to solve and if we can't survive without having this application then of course […], this can be useful for the broader community…'.*
> *(Scientist, Poland)*

So useful outcomes of synthetic biology are here understood as something where 'we' as humans or citizens 'can't survive without having this application' – that it is severely needed in order to benefit the human race. Again, this points to a sense of urgency; synthetic biology is supposed to solve problems where there is an urgent need for something to be done. The problems would preferably be of a quite large scale and benefit 'the broader community'.

Interestingly, these scientists do consider the MycoSynVac to fulfil these criteria for solving a 'pressing problem,' as one of the scientists puts it. A British scientist comments on the problems that MycoSynVac could potentially solve:

> *B.: 'Well, […] [farming is] the source of a lot of problems; particularly in antibiotic resistance, and even environmental problems, a lot of it starts with farming? Especially because of the scale we're doing it on. So anything that you can do to improve the state of farming I think is really interesting and really important…'.*
> *(Scientist, UK)*

Therefore MycoSynVac is considered a useful synthetic biology project because it addresses the root cause of problems such as 'antibiotic resistance and even environmental problems' which, according to the scientist, have their roots in farming and the its industrial scale. The scientist mentions antibiotic resistance as a problem, and there is a general agreement that MycoSynVac is useful in the fight against infectious diseases and the problems humans face due to antibiotic resistance. Another scientist adds to that impression:

> *J.: 'First of all, [...] [the MycoSynVac project] is clearly relevant and […] it's going to be more and more relevant as time goes, because we'll, we'll have to face a lot of problems with, you know, infectious diseases, for sure. So anything that goes into this direction is going to be economically important and for health very important…'.*
> *(Scientist, Spain)*

As such, among the interviewed scientists MycoSynVac is generally perceived as useful because it addresses pertinent societal problems such as antibiotic resistance, infectious diseases and other related problems linked to the unwanted effects of industrial farming.

4.2.1.1 Human health

Many of the scientists are particularly preoccupied with societal use in relation to medicine, where applications can be used to save human lives or improve health. A Polish scientist employs this reasoning when comparing an application where genes from the plant 'Poisonous Carrot' are inserted into moss in order to produce a biological component to be used in cancer treatments and other applications:

> *E.: 'It's very hard to compare, but I would keep my fingers crossed for this […] plant therapy to work, because it can have the greatest benefits for, for the community'.*
> *C.: Yeah, […] because of the cancer potential, the curing of cancer potential?'*
> *Y.: 'It's, it's hard to compare, because we're comparing something that we can survive without and with something that should eh, serve as eh, treatment for cancer. That's, that's difficult. So it would be cool if it works.'*
> *(Scientist, Poland)*

While she believes 'it's hard to compare', she distinguishes between applications that she considers as livesaving, such as cancer treatments, and those that we can 'survive without'. It often seems that improvement of human health is intuitively considered as the most useful application of synthetic biology methods – or the 'coolest', in this dialogue:

> *G.: 'OK, er, the plant therapy is the coolest!' [Laughter]*
> *C.: 'Why is that?'*

> *G.: 'Well, healthcare is something that I'm most driven by, so simply by the fact that it's aiming to solve a healthcare problem, it's something I'd be most in [favour of]'.*
> *(Scientist, UK)*

Most of the scientists agree that healthcare is one of the most important and useful applications of synthetic biology. They often consider it more important than other potential areas of application, such as environmental issues. As the British scientist cited earlier puts it:

> *G.: 'Erm... I suppose […] healthcare is more hitting it home, everyone's affected by it? I know we are all affected by environmental [inaudible] but the effects of, yeah, vanilla for example, are somewhat removed away from the effects of cancer to the everyday person.'*
> *(Scientist, UK)*

Like many of the other scientists, his argument is that curing diseases or helping with human health problems in other ways are issues that give an immediate feeling of making a difference. As he says, health is something where 'everyone is affected by it', whereas he feels more detached from environmental problems – or at least the problems related to the production of vanilla and vanillin, because they are 'removed away' from the everyday life of people. The impression from the interviews in their entirety was that the scientists consider applications of synthetic biology in healthcare to be very important; as one scientist says, for example: '[I] generally rank erm, most medicine things higher, because I think it's very important' (Scientist, Austria).

Some of the scientists also consider the MycoSynVac an important application in relation to human health. As one of the Austrian scientists comments after she has read the case description of MycoSynVac:

> *Cl: '…Recently, I've listened to a lot of erm, podcasts and things about, on one side how important it is to combat this growing antibiotic resistance and on the other side also that we have […] neglected kind of the animals that, that we eat, but also wild animals erm, many diseases come from [animals]. It's even in our own interest to keep them healthy. And we don't know a lot about it. And I think it's actually very, very important to our health'.*
> *(Scientist, Austria)*

While the synthetic biology scientists often on comment antibiotic resistance, they rarely make connections between the use of animal vaccines, antibiotic resistance and human health. But when they occasionally do, as in the quote above, the MycoSynVac project is considered useful because it could potentially improve human health. In the few instances where this connection between human health and animal vaccines is made, it is as above - by considering the

'growing antibiotic resistance' but also acknowledging that 'many diseases come from animals'. It is therefore pertinent to develop technologies that can help battle animal diseases.

4.2.2 Scientific advances

The scientists also evaluate synthetic biology projects from the perspective of how useful they were in relation to the advancement of science. They both argue that they can be useful from a professional perspective, because they advance scientific knowledge, but also that great scientific advances lead to societal use because they pave the way for more and better applications.

Most of them mention the MycoSynVac project as very interesting in regards to scientific advancement. Here, a scientist from Austria comments on why MycoSynVac can potentially make a scientific advance:

> *CG: 'Do you consider [the four cases] scientifically interesting'?*
> *Ca:[…] 'I think the vaccines, yes, because you learn something about the immune system. Right. Erm, all the other things are very engineering kind of things, I would say. You know, erm. I mean, you do learn something about the biology of things eventually, but I think the vaccines one, mostly - has, has the biggest impact [from a scientific perspective]'.*
> *(Scientist, Austria)*

From this Austrian scientist's perspective, the MycoSynVac project is interesting because you learn something 'about the immune system' that could be fundamentally new knowledge – that is, that 'has the biggest impact'. He works in basic science himself and mostly values projects that expose the potential of advancing profoundly new knowledge. Several scientists agree with him, saying that many so-called synthetic biology projects are not really synthetic biology from a scientific perspective because they do not create fundamentally new organisms in order to understand different aspects of organic life.

Every time synthetic biology is criticized for not contributing truly original science projects, the MycoSynVac project is mentioned as an exception because the project is constructed in a way where it is imperative to learn new things about the immune defense system or, as one Spanish scientist put it, because 'here we have evolution' – moving from one kind of organism to another.

Thus to some scientists, projects applying synthetic biology in a context of vaccines are useful in themselves simply because they advance science and the understanding of the biological world. Often, however, when the scientists have

to justify why scientific advancement is actually important, they refer to how basic science is useful as a precondition for applied science:

> *Ca: 'Once you understand […] at a very fundamental level, many, many more applications can emerge. You see. Whereas, if you always try to- Er, it's a little bit like medicine, right? A lot of medicine tries to deal with, erm, the effect of disease, but not necessarily the cause. Right. And once you understand the causes, the chances that you heal something are much, much bigger than if you constantly try to, to deal with the effect. In some sense, right?'.*
> *(Scientist, Austria)*

Therefore according this scientist, the potential for 'many, many more applications can emerge' this way than if we start with applied science and do not go in-depth with a basic understanding of the relevant elements. Many of the scientists interviewed agree with this perception of the connections between basic and applied science, although those of them who work in basic science themselves say it most explicitly. One of the Spanish scientists relates the point to the MycoSynVac project directly:

> *R.: 'Well, we are facing now the problem of going to some new class of vaccines, beyond what is the standard. So I think an immune system is also... […] We need to really figure out how it works in many ways, so yeah, definitely, it's [the MycoSynVac project] scientifically interesting and, and I'm sure that it's going to be important'.*
> *(Scientist, Spain)*

He supports the view that the best application – a 'new class of vaccines' - needs to be based on solid knowledge about the immune defense system: 'we need to really figure out how it works'. Basic understanding becomes a prerequisite for useful applications – and in this case, new vaccines.

4.2.3 Universality of synthetic biology constructs

When talking about scientific advance in general, it's interesting to note how one specific aspect of scientific advancement seems especially interesting for the scientists; namely that a specific synthetic biology development can be useful in several contexts. This idea of universality is expressed, for example, in the British laboratory, where several of the scientists mention 'synthetic yeast' as a very useful application because it can be used as a 'factory' for producing many different useful materials. These range from medicines and biofuels to flavours and dyes.

Even if the scientists are not engaged in research projects that can develop synthetic organisms for use in producing a range of materials, most of them seem to consider these as the most useful. In interviews, they often judge specific

research projects based on whether the organism in question could have a wider set of uses. As one of the scientists puts it:

> *T.: 'For me, with synthetic biology, we want to be trying to do applications, or we want to be pushing things in a way where more things can be built upon what we've done, and not just go for one kind of thing?'.*
> *(Scientist, UK)*

The idea that synthetic biology is 'pushing things in a way where more things can be built upon what we've done' is very common among these scientists and often guides their perception of the usefulness of synthetic biology. This is clear in the following excerpt from the interviews, where the scientists have been asked to rank different synthetic biology applications against each other. This example is from a dialogue in Austria where the scientist is in the middle of ranking different applications against each other:

> *CG.: 'So, [you want to rank them] like this?'*
> *Cl: 'Oh, erm, this one is higher up'.*
> *CG.: 'Okay. Why is that?'*
> *Cl: 'Ehm, I think that this, this, this has potentially more applications, so it seems to be more versatile. […]'*
> *CG.: 'So is it also because this can be used for like, yeah, exactly, I mean, various applications?'*
> *Cl: 'Yeah.'*
> *(Scientist, Austria)*

So the applications that potentially have a range of different uses seem more 'versatile' to the scientists and are therefore perceived as more valuable.

Generally, the universality of MycoSynVac makes the scientists perceive this project as valuable because of the potential for a range of other uses. As a British scientist comments when asked which project out of the four examples he prefers:

> *T.: 'Er... the probably the Myco one because it's more general. So the technology is... you know, this [the MycoSynVac) is talking about a universal vaccine chassis, whereas this one [plant therapy in cancer treatment] is talking about a new treatment - well, it says new 'treatments', but my guess would be that there's not gonna be, there's gonna be one or two active components at the most. […]Whereas if you're going here for a universal chassis and things, that can work against lots of different things, that's worth going for more, in my opinion.'*
> *(Scientist, UK)*

So 'the universal chassis' makes the MycoSynVac project useful compared to other projects, because the chassis potentially can be used for a range of vaccines rather than only target one specific disease. In that respect it is ranked

higher than a project which studies cancer treatment, because this project targets very specific forms of cancer and is thus not 'universal' and does not 'work against a lot of different things'. The British scientist's assessment of MycoSynVac reflects most of the interviewed synthetic biology scientists, who all consider the project as one of the more useful ones based on its universality.

4.2.4 Economic usefulness

The last form of usefulness that we will go through here is economic. The scientists seldom mention it as a form of usefulness, but once in a while it comes up as an explicit value. This is for instance the case in this quote from a Spanish scientist:

> *J.: 'First of all, [...] [the MycoSynVac project] is clearly relevant and […] it's going to be more and more relevant as time goes, because we'll, we'll have to face a lot of problems with, you know, infectious diseases, for sure. So anything that goes into this direction is going to be economically important and for health very important'.*
> *(Scientist, Spain)*

He expresses that MycoSynVac can be 'economically important' and this perception is related to his initial diagnosis that 'we' as society will face increasing problems with infectious diseases. He does not make it explicit for whom they will be economically important, but in contrast to most of the other interviews, the value of economic usefulness is present.

Other scientists, in contrast, actually devaluate economic usefulness and express that they do not consider that form of usefulness as legitimate. One Austrian scientist, for instance, favours the MycoSynVac project over the case of synthetic vanillin, stating that the former is 'not just making money with more vanilla'. A Danish scientist describes his own project as not being as useful as some of those cases we show him:

> *F.:'…Erm, so [my] research project is, is also not necessarily addressing directly human [needs], it's, it's addressing quality life for the […] for the wealthy population in the world. It's targeting- it's trying to make probably the most economically independent part of the world even more independent.'*
> *(Scientist, Denmark)*

The reason he ranks his project as less valuable than, for instance, MycoSynVac is that it is mostly useful for 'mak[ing] probably the most economically independent part of the world even more independent'. While he at other times justifies his project as scientifically interesting and good for his career, he does not value the economic benefits it may have for the already wealthy. As one of the few synthetic biology scientists, he thereby also relates the de-legitimization of economic value to the issue of global justice – a subject that the scientists in general are not that preoccupied with.

4.3 Risk

Another central theme in relation to synthetic biology is the subject of risks connected to emerging biotechnologies. Although the interview guide invited the participants to comment on the risks, it is also something that some scientists also bring up spontaneously during the interviews. As we shall see, the scientists are somewhat worried about the general risk of releases of synthetic organisms to the environment. But on the other hand, they never worry about the risk of release in relation to their own research projects because they trust their own ability to follow good laboratory practice and rules for handling potentially dangerous material.

Below we will present the scientists' reflections over risk in three subsections: a focus on the scientists' concern for unknown risks in relation to release, a focus on the perceived safety of their own projects and a final focus on risks relating to the spread of disease.

4.3.1 Unknown effects of releases

Some of the interviewed scientists express concern about the risks of synthetic biology. While our sample is too small to make generalizations, it seems that those scientists working with basic science were the most particularly concerned. Several of these participants state that scientists working with synthetic biology applications should be more concerned in general, because the ways living organisms interact in a larger (eco) system is quite unpredictable. One of the scientists working with basic questions about evolution using synthetic biology complains about other research communities:

> *Ca: 'Well, so I think most people define [synthetic biology] as, it's almost like the communist party. Synthetic biology is the engineering of blah blah, so there is a very strict definition. And in my opinion that's a bit bullsh*t, because in order to engineer something, you have to understand the component. And we don't, we are far from. Okay. Erm, and often times people make these analogies to, eh, computer circuits and all this stuff.'*
> *CG: 'Lego.'*
> *Ca: 'Exactly. But you know in a Lego, your pieces don't depend on the context. Neither in the computer. Whereas in biology they do. All the time.'*
> *(Scientist, Austria)*

So the Austrian scientists believe that everyone working with synthetic biology should be more careful because 'in order to engineer something, you have to understand the component. And we don't, we are far from'. He does not explain the specific risks about which he is worried, or whether these are environmental or otherwise, but he does express general

concern as he finds that biological components are very unpredictable and their behaviour depends on the biological context – in contrast to 'Lego' or 'computers'.

He's supported by another scientist, also working with basic science, who concurs that there is an inherent risk to making synthetic organisms. He points to the fact that even organisms that have been produced with a specific (and harmless) ability may be risky, because once they escape our control, forces of evolution may develop them into problematic organisms:

> *Ja: 'Plants or bacteria or whatever you want, something that you release and then you- the thing escapes from your control. And why? Because in synthetic biology, we try to, to design things, we try to build a device that does blah, blah, blah something. And we decide these things from a rational point of view and we forget about the evolution. […] Ah, evolution is the enemy, we don't like evolution, but evolution is there. And if you build a thing that works and okay, this bacteria can be used to clean the sea, just to release the bacteria, great and probably it will work, but when the sea is completely cleared, what will happen with this bacteria? […] I'm sure that this bacteria will evolve and will transform into another thing'.*
> *(Scientist, Spain)*

So according to Ja, there is always an inherent risk that something will happen when you release synthetically engineered organisms, because they can potentially 'evolve and will transform into another thing' and we lack the knowledge to foresee what will happen. This very general worry about what can happen in the long term when synthetic organisms are released or escape into ecosystems outside the lab or production facilities is shared by many of the scientists who investigate the conditions and possibilities of life by studying 'simple' organisms (as well as some of the scientists working in other areas). One of the Danish scientists comments on the different applications of synthetic biology with which she is presented in the interview, assessing that the biggest risk is connected to the idea that a range of substances can grow in synthetically constructed algae in big green houses:

> *Ca: 'So I'll consider the one with the green houses as the most risky, if we need to be sorry that things escape. […]'*
> *C.: 'Yes, yes.'*
> *Ca. 'But then again, how bad is it that it escapes?'*
> *C.: 'Yes, yes.'*
> *Ca: 'What would happen if it got away, well- well, then we would have enriched nature with yet another plant, which can- well a moss that can make something specific. Then it's not until later that you find out that then perhaps some animals die- Well sometimes animals die when you commercialize a new pesticide. Perhaps some bacteria will become resistant towards specific kinds of antibiotics, because it resembles […] something that they have experienced from an algae or*

something else, which we have been able to grow out there. It's difficult. We wouldn't know it until 20-30 years after it has happened.'
CG.: 'Yes. No- and it's also difficult to know-'
Ca: 'It's like the effects of Chernobyl, you don't know these until in a hundred years'.
CG.: 'No.'
Ca: 'Well, and yes, that's also a part of the precautionary principle- to make a risk assessment of something, which is so unknown that we cannot know. Then you have a principle about it not getting out. Because it's better that we don't have to take that discussion later.'
(Scientist, Denmark)

We see Ca discuss with herself whether it is a problem if the synthetic algae or moss escape the lab. She suggests that it – like other technologies – may have unforeseen consequences; that, for example, 'animals die', or that they result in 'bacteria becoming resistant towards specific kinds of antibiotics'. The observation of the possibility of unknown risks makes her defend the precautionary principle in cases where a risk assessment cannot assure safety.

We have seen that several of the scientists are concerned about the effects of deliberate or unintended releases of synthetic organisms. In general, they do not point to very specific risks but seem to share a concern of what can happen in the event that the organisms mutate - and they occasionally give examples such as a spread of antibiotic resistance or the development of new organisms with unwanted properties.

4.3.2 Human health risks

A few of the scientists mention the spread of disease as a serious risk in relation to synthetic biology applications. They describe this risk in different ways. Some refer to unintended risks, like this one pointing out that scientists were deliberately reconstructing the strains from the Spanish Flu, which he finds risky:

Ca: 'Well yes I mean look there were people who are trying […], to build back what, whatever these strains of influenza from the Spanish influenza right'.
CG.: 'I actually, I remember that, yes'.
Ca: 'Right, so these things er, you know if they are not done under highly regulated ways- er, there has to be a very good reason why to do such things. This can be very dangerous'.
(Scientist, Austria)

So in this case, where scientists want to rebuild a virus that killed millions of people globally, the interviewee expresses concern and underlines that there should be 'a very good reason to do such things' and therefore an experiment like that also needs to be 'highly regulated'.

Others articulate a concern for risks that are results of intended actions, such as the use of synthetic biology in bioterrorism to produce viruses to do deliberate harm:

> *T.: '…Someone wrote an essay about three or four years ago of "what if a virus was designed specifically to recognize the President of the US's DNA?", so that it was just like a cold, like I've got now, that you could pass on from one person to another, and then finally when it gets to the President of the US, it's fatal for them but not for anyone else, because they know the DNA of the president. And when I read that, I obviously thought of Obama and I thought "this is terrible" […] But if you think of something even more disgusting than that; you might have a virus specifically designed to target one race or from one [inaudible] or, or one sexuality, or something.'*
> *(Scientist, UK)*

Again, we see a concern for the risk of the spread of virus. But where the first example related to scientists making a virus in order to study it, T. considers the risk that dangerous vira could be developed and used in bioterror to target specific individuals or groups. This is a concern shared by some of the scientists who mention dual use; that the same technology can be used for hostile and peaceful ends (McLeish and Nightingale, 2005). This is presented as one of their main concerns, with bioterror mainly used as the example of a hostile application.

A third category of concerns is about risks of mutation or development of resistance when the potential vaccine is in use. A few scientists mention this risk, interestingly, in relation to the MycoSynVac project – it is the only risk that they explicitly relate to the project. One of the Spanish scientists comments:

> *N.: 'Sometimes you think about this Mycoplasma and they can go to the humans or they can mutate and then keep changing all things and then the same vaccine can make a, I don't [know], make another resistant [bacteria].'*
> *(Scientist, Spain)*

Her concern is that the synthetic Mycoplasma for the livestock vaccine somehow finds its way to humans, where they become perhaps not as trivial as they are believed to be. Alternatively, they could 'mutate' and the vaccine will thus been the cause of the creation of another resistant mycoplasma. Another Spanish scientist adds to this concern:

> *C.: '…is there anything you think about like, here I have to be a bit precautious [in relation to the synthetic biology cases I've shown]'?*
> *J.: In the case of cancer, I think that erm, probably not, but in the case of, for instance, the […] vaccines, this could be a problem.'*
> *C.: 'Yeah, why is that?'*

> *J.: 'Because you are selecting for the most erm, strong strains, the more resistant ones and this is dangerous. Actually, we… […] well, we have- in the 21st century, erm, a serious problems will be […] to find antibiotic candidates to fight against bacteria, because we are selecting for the most resistant.' (Scientist, Spain)*

The scientist points to a risk of creating resistance against Mycoplasma by developing vaccines, because scientists always work with the strongest and most resistant bacteria but are thereby also unintentionally 'increasing the selective pressure and you, you will have a monster there'. So while he, as other scientists before him, acknowledges the challenge of finding a replacement for antibiotics, he is also worried because these replacements (for instance MycoSynVac) may over time make the bacteria even stronger.

4.3.3 Synthetic biology as not risky: my projects

While many of the scientists thus express some degree of concern about the risk of disease spread and release of synthetic organisms, they do not relate this general concern to their own project. As one of the scientists says:

> *B.: 'Now, I'll get involved in a project that I think is scientifically risky, right, that's fine, I don't mind scientific risk, but I wouldn't be keen on getting involved in a project where I consider that there would be an environmental, ethical something that I was not happy with. Er, you know, the concept of that, then actually: no'.*
> *(Scientist, UK)*

So being part of a scientific project that is 'environmental, ethical, something that I was not happy with' is unattractive for this and other scientists.

When asked directly why they are not particularly worried about the risks of their own projects, many reduce risks to a question of basic laboratory safety, where the argument is that their project does not pose a risk because they observe basic principles of safety in the lab and of sharing organisms with other labs:

> *T.: '…Yeah, so I mean, we would just be, so the number one thing we do is pretty much everything stays in the lab, we don't take anything out […] So there's just the general security that almost everything is for show, and so it stays in the lab. And then there's the next major consideration we always have is what if people ask us for something? So, ok, it's science we want to share; so we need to send - we need to do a background check, pretty much, you have to like have a look, 'ok, where, is this person really running a research group or they just wants a yeast that makes an illegal drug?'. You've made it, they know you've made it, 'cause it's one step towards making another kind of drug, and then they could get it and then made their own illegal drugs, or something.'*
> *(Scientist, UK)*

According to T., the most basic rule is that 'we don't take anything out' and they make sure to follow procedures so that their synthetic organisms do not accidently end up outside secured areas. That also means that they run background checks if other scientists want to see their synthetic organisms, even though this runs slightly against what he considers to be a basic value in science - that 'we want to share'. Several of the participants agree with the perception that basic lab security works as a safeguard against potential risks:

> *C.: 'Is there anything when you have been working with this basic project, where you thought, ok, I need to be extra careful here eh, in relation to risks?'*
> *E.: 'What do you mean risks?'*
> *C.: 'It could be everything, like I need to remember that this shouldn't get out of the lab or, or hey, actually perhaps we know too little about this work, so I need to be [extra careful about applications].'*
> *E.: 'It's not the case of our project, but we're following this good laboratory practice rules and eh, […] as I said; I trust that people know what they're doing and my coworkers and me, we know what we're doing, so we, we're aware of er, of the risks, but we take care of it and it doesn't matter if it's this project, you know, if it's basic science; application or whatever. We're just following this good laboratory practise rules […]'.*
> *(Scientist, Poland)*

E. elaborates on the perceived connection between low risk, good laboratory practice and trust in her colleagues. Like many of the others, she asserts that in the case of her particular project there is no cause for concern. The reason for this, in her opinion, has nothing to do with future applications: 'it doesn't matter if it's this project, you know if it's basic science; application or whatever'. The bottom line is that concerns over risks are close to eliminated as long as good lab practice is followed.

4.4 Naturalness

A curious aspect of the way that scientists talk about synthetic biology projects is that some of them at times refer to organisms constructed using synthetic biology methods as 'natural'. As we saw in the previous chapter (section 3.3.2) lay people used different and almost opposite interpretations of 'naturalness' – or lack thereof – when they discussed synthetic biological vaccines.

In general, the scientists who use the term 'natural' do so to distinguish between chemical methods for extracting substances, for instance vanillin, and methods where synthetically constructed organisms produce the desired substance. Hence 'natural' is used to describe things and phenomena that belong to the biological world, while the use

of chemicals makes it 'unnatural'. Here, a Spanish scientist explicitly tries to compare her understanding of 'natural' with her interpretation of lay people's understanding and implies that her understanding of 'natural' is more accurate:

> *N.: '[…] speaking to someone, then […] I am trying to be very careful with my words, because I have noticed that they [lay people] got a huge mess in the head. They can actually not tell what's natural and what's not. So, if I change plants [in order to] to produce vanillin and it's done by the plant, [to me that's] more natural [than] if I do it in a chemical lab and then [the lay people] can't [understand] that. They are broken in their head. [So], for me natural means that you have not […] done any intervention, but then still, there is not vanillin alone. So you have to purify it.'*
> *(Scientist, Spain)*

For this scientist, 'natural' means that chemicals have not been used to synthetize vanillin but that the production is 'done by a plant', as she puts it, whereas 'an intervention' in the 'natural' has occurred if you have used chemicals to purify substances. In her interpretation, 'natural' is thus in opposition to 'chemical'; when substances are produced using biological methods, she considers them to be natural.

This idea of biological processes as 'natural' is shared among the scientists. Here a Danish scientist explains her sympathy for synthetic biology methods having a 'naturalness':

> *Ca: 'Well. But I like that because we work with this, yes, this biosynthesis way for Dhurrin, because there are three enzymes and one protein, which donates some electronics, […] because otherwise it doesn't work […] I like that we learn so much by doing it. […]. When we then have to transfer it to another biosynthesis way, which perhaps consists of nine steps […] instead of only three […] then I kind of like that it's easier to work with […] in some way, because we have simplified things, but it's still natural, it's still something that goes on in nature'.*
> *(Scientist, Denmark)*

In Ca's perception, what they do in the laboratory is 'natural' because it does not differ from the biological processes that go on without any human interference; 'it's still something that goes on in nature', and therefore she finds it more enjoyable to work with. In other parts of the interview, she expresses more scepticism towards those synthetic biology projects that, for instance, mix plant and animal material because they are less 'natural' and will invite more criticism from the public. Those scientists in our research who justify their perceptions with naturalness all share the idea that their organisms are 'natural' as long as they follow those laws, which guide biological processes. In their eyes, they are just trying out new combinations that have not yet been seen.

5 Results: Expert Analysis – vaccine scientists

In the next sections, we will present how the interviewed vaccine scientists perceive issues relating to synthetic vaccines and the MycoSynvac project. Before we treat the questions of risk and usefulness (the specific themes addressed by the informants) there are three general findings that we believe are important to flag up.

The first is that, based on the case description (see appendix 4), many of the vaccine scientists do not consider MycoSynVac to be a synthetic biology project. Rather, they believe that the vaccine(s) based on the chassis should be classified as genetically modified vaccines. Many of their claims regarding MycoSynVac are therefore based on that perception.

That said, the second general impression is that the vaccine scientists do not necessarily distinguish strongly between the different vaccine types that were presented as part of the interview guide: live, attenuated, genetically modified and synthetic vaccines (see appendix 4). During the interviews, these participants quickly begin talking about vaccines in general, and express perceptions of - for instance - risks or usefulness as closely related to MycoSynVac specifically only relatively infrequently (and we will show when they do). They speak more frequently about general considerations that they share in relation to livestock vaccines. As such, many of the considerations presented here do not relate closely to the fact that MycoSynVac will be a specific (and rather new) type of vaccine, but rather 'just' to the fact that it is a livestock vaccine.

This also relates to the third general finding: that the vaccine scientists often assess MycoSynVac in light of their perceptions of the structural conditions of modern agriculture in the Western world, and of the pharmaceutical industry, rather than in light of methods and technologies relating to the construction of the vaccine in itself. We have therefore included a section, 'Animal vaccines – a realistic project?' (5.3) where we discuss the scientists' perception of the necessity to produce cheap vaccines due to the economic rationales that permeate the agricultural industry. We also present the scientists' concern that the MycoSynVac project is so scientifically difficult that the goal of producing a universal vaccine may be too ambitious. Finally, we also explore the scientists' concern that vaccine(s) resulting from the MycoSynVac project will be inefficient – in line with their perception of many other vaccines on the market.

5.1 Usefulness

This section explores how the vaccine scientists perceive of the problems that (synthetic) animal vaccines may solve and of the usefulness of these vaccines. In general, the scientists consider the vaccine useful in two ways: for improving animal welfare and as an alternative to antibiotics.

5.1.1 Usefulness in an animal welfare perspective

In general, the scientists consider animal welfare as quite important. While they mention aspects of animal welfare that relate to the psychological wellbeing of the animals (such as that they need to be '*happy*' – a British scientist - and that pigs need toys and exercises to stimulate their brains), in fact what they all express most interest in is that the animals are not suffering physically. Here, a Polish scientist comments:

> *P.: 'And of welfare, you know, it is erm, I think, is the most important to limit the infection, the spread of infections, of infectious disease, so, well, it is the most important, I think.'*
> *(Scientist, Poland)*

According to him, the most important thing to secure '*welfare'* is to limit the spread of '*infectious diseases'* that will make the livestock suffer. Other scientists agree with him. Here, for example, in an excerpt from a dialogue with a British scientist:

> *CG: 'What is important for you in order to have animal welfare for farm animals, for livestock?'*
> *[…]*
> *M.: 'From my research point of view, would be-'*
> *CG: 'That's what I'm looking for.'*
> *M.: '- yeah, that the animal is as healthy as possible. […] So I would say, good control and surveillance of most of the pathogens that are circulating in farms.'*
> *(Scientist, UK)*

All in all, most vaccine scientists are preoccupied with good animal health as a very important aspect of animal welfare. In that context, they do consider MycoSynVac to be a useful project. As one of the Danish scientists comments:

> *G.: 'If it's a pathogen which creates problems at the expense of the animals' welfare, then a vaccine could definitely [be useful]'.*
> *(Scientist, Denmark)*

G. here comments directly on our written description of MycoSynVac. She does find this useful if Mycoplasma *'creates problems'* for the welfare of farm animals. It's the general perception among most of the scientists that MycoSynVac can be useful for improving animal welfare. Here a British scientist explains it with an example:

> *B.: 'There's a mycoplasma that's particularly prevalent in Africa that causes a very severe pneumonia; the animals are really sick, and don't get better. […] Very unpleasant slow death, you know? And [this is] another example of a disease where, using conventional methods, the vaccines don't work that well. They don't work well. And so there are groups who are using this type of approach, erm, because mycoplasm is so small you can actually make the whole genome, so you can synthesise it from scratch in a lab. And, erm, and I think that's going to be the only way, it seems to be the only way at the moment of producing a vaccine, by removing parts of that genome that make the virus - the mycoplasma - not cause disease but stimulate immune response. So, erm, I think this fits, you know, very nicely into the category of "we tried all the traditional methods, they don't work, so you have to apply these new methods", and, erm, we're very fortunate to live in an era where those methods are possible.'*
> *(Scientist, UK)*

B. considers the vaccines as useful because they can help to solve problems of animal disease, suffering and death. As he says, using the example of a Mycoplasma disease in Africa, *'… the animals are really sick, and don't get better.* […] *Very unpleasant slow death, you know'.* So a potential vaccine is of use because it helps to solve a grave animal welfare problem that cannot be solved using '*the conventional methods'*. It's also worth noticing, however, that he states that other means must be exhausted before '*you have to apply these new methods'.* While he doesn't justify this opinion, he does by expressing it caveat his idea of usefulness with some caution.

5.1.2 Useful as an alternative to antibiotics

The vaccine scientists all show a preoccupation with the topic of excess use of antibiotics. Most quickly point to antibiotics as one of the big problems in modern agriculture. Here a British scientist expresses her concern:

> *M.: '…China has a terrible problem for example, they use antibiotics in kilograms, and erm... actually I read a report recently where they saw that in one of these big rivers, the Yellow River, one of these rivers, because there is a farming area somewhere, actually the river has an enormous concentration of antibiotics in the river! Imagine all the fish and the, you know, wildlife and everything, I mean this is uncontrolled at the moment, so... This is an area that even though EU has made a lot of, you know, steps forward, I think it needs vigilance in that area.'*
> *(Scientist, UK)*

According to M., there is a huge problem of overuse of antibiotics in agriculture. She gives an example in China where they '*use antibiotics in kilograms'* and antibiotics spread to the environment, which is also very problematic: *'Imagine all the fish and the, you know, wildlife and everything'* which absorb antibiotics. She is very concerned about this spread and considers the area as '*uncontrolled'.* In her view, the problem of antibiotics in agriculture is thus an environmental issue as it threatens the animals that come in contact with the overspill of antibiotics from agriculture.

Curiously enough, the scientists seem to find the problem of antibiotics so self-evident that they seldom justify why it is a problem and for whom. The few that do, however, offer very different justifications. A Polish scientist here points to the growing resistance of bacteria due to overdosing as the main concern:

> *Y.: 'Well, antibiotics. As you know, there are more and more erm, microorganisms and bacteria not […] susceptible to antibiotics or resistant to […] a number of […] antibiotics, […] so it is a very risky […] point and I know that sometimes antibiotics are found in […]… Well, the levels of antibiotics [that] are found in [poultry] because they are, let us say, overdosed-'*
> *X.: 'Yes, yes, even though it is illegal-'*
> *Y.: 'Yes, and overdosing is, I think, is the biggest issue in, in the livestock production and also in welfare and in veterinary control and treatment, overdosing'.*
> *(Scientist, Poland)*

In his opinion, the '*biggest issue in the livestock production*' is '*overdosing*' of antibiotics – even though it is illegal in the EU. He justifies this perception by citing that '*more and more microorganisms and bacteria [are] not susceptible to antibiotics or resistant to a number of antibiotics*'. He considers this a '*very risky point*' although he does not makes it explicit for whom it is risky. In a dialogue about the necessity of antibiotics in agriculture, an Austrian scientist compares livestock vaccines with antibiotics by making a comparison to human health:

> *K.: 'Er, also like compared to … the human side. Like if you want to protect your child or whatever, you then-'*
> *CG: 'They are vaccinated.'*
> *Y.: 'They are vaccinated. And then to keep them healthy, of course you regularly go to the doctor and control the animal or whatever. And if something arises, then you treat, but if everything goes well, you only need to have controls, but never a treatment'.*
> *(Scientist, Austria)*

K.'s claim is that if you are parent wishing to protect your child, you vaccinate them in order to '*protect*' rather than having '*treatment*'. She implicitly suggests that the same should be the case for farmers: if they want to '*protect*', then they should vaccinate animals rather than give antibiotics. She hereby expresses an independent preferencre for the prevention of sickness rather than of treatment.

A Polish scientist offers a different line of argument for why vaccines in general are preferable to antibiotics:

> *P.: 'Well, application of, for example, antibiotics, does it mean we produce healthy foods? So at least, I think is, the main issue here. Because the vaccines, well, they, in general, they are safe for, for humans […] and you get healthy food, at least, the most, but I think antibiotics are, important and risky [in foods]'.*
> *(Scientist, Poland)*

P.'s argument is that it is doubtful whether antibiotics in human foods are actually '*healthy'.* He makes a contrast to livestock vaccines, where he is much more convinced that they are not unhealthy '*for humans'.* His argument thus advocates for the usefulness of livestock vaccines as a way of protecting human health.

Overall, the vaccine scientists favor vaccines and believe them to be a good substitute for antibiotics. They do not explicitly include MycoSynVac in this assessment, but they generally point to a need to move from treatment with antibiotics to protection using vaccines.

5.2 Risk perceptions

The scientists express some general concerns about both vaccines. These especially relate to the use of vaccines and the effects on the animals and, in relation to MycoSynVac, to the unknown consequences of using a modified organism on livestock. A few of them also consider some health risks to humans and animals related to the additives of vaccines, but not to MycoSynVac per se. But while they point to some health risks to humans and animals and to the possibility of unknown consequences, they also emphasise that in the big picture, vaccines are safe.

They justify this perception with different warrants; trust in the regulative system, that vaccines are safe as long as they are carefully prepared and with the justification that the amount of active ingredient in vaccines is tiny. Below, we first present the perception that vaccines are generally safe to use. We then go on to present the perception of risks to human and animal health that some participants voiced.

5.2.1 Risk of unknowns

The vaccine scientists do express concerns about some risks, especially in relation to live genetically modified vaccines that they consider similar to MycoSynVac. As a Danish scientist says:

> *G.: 'It demands enormously amounts of consideration, when you […] use a living organism as a platform for vaccines, because of the biology, I mean, it can change over time, right?'*

CG: 'Yes.'
[…]
G.: 'But the risk is that you develop something, which you perhaps didn't- which wasn't your intention to develop from the beginning'
CG: 'Yes.'
G.: 'Or it changes over time and then you have it out there in the herd [of animals] […] I mean, it definitely raises some challenges, I mean, I don't necessarily believe that it's a bad idea, it just demands a lot of considerations about design and stuff like that.'
(Scientist, Denmark)

So one possible risk that we cannot foresee, according to G., is that the organism used as the platform could mutate and develop into something that '*it wasn't your intention*' to develop, and which may be less desirable than a vaccine. She points to the possibility that the organism will mutate while it is in use, causing unpredictable consequences for the animals that have been vaccinated and which now carry a mutated organism. Like several other scientists, she explains this risk with the observation that '*biology*' is notoriously unstable and organisms can '*change over time*'. A Spanish scientist has similar concerns about unknown consequences, especially relating to the mutation of living genetically modified vaccines:

A.: 'A live modified vaccine like [inaudible] is extremely efficient. Most of the time, it's extremely efficient. But it's not … to apply, because it's a genetically modified virus, genetically modified'.
CG: 'Yeah'.
A.: 'So what will be the consequence for you?'
CG: 'Yeah. If it's out there-'
[…]
A.: 'And you start to vaccinate millions and millions and millions all over the world.'
CG: 'Yeah, you would be like-'
A.: 'Hmm?'
CG: 'A bit worried about mutation?'
A.: '[that could be the] consequence'.
(Scientist, Spain)

While A. underlines several times that he is '*not against*' genetically modified or synthetic vaccines, he does – as here – express some concern about the consequences of spreading genetically modified vaccines among '*millions and millions*' of animals across the world, because he believes that there is a risk of mutation of the modified organism. Another Danish scientist does not point so much to the risk of mutation as he does to the possible undesired features of the modified Mycoplasma:

P.: 'I mean, you could theoretically imagine that if you introduce new genes and thereby new proteins… There could be a combination of the new proteins with the old ones that are already present, which together made a new organism, which you just hadn't anticipated…'
CG: 'Yes.'
P.: '…that they would go well together in that way.'
CG: 'Yes.'
P:: 'But I'm pretty sure that they have considered this in great detail.'
CG: 'Yes.'
(Scientist, Denmark)

So P. also expresses some concern about the unknown properties of the modified Mycoplasma, which could have characteristics that '*you just hadn't anticipated*'. In line with most of the other scientists, this does not seem a great concern but mostly something that he considers '*theoretically*'. Here he shares a basic trust in his fellow scientific colleagues, stating that *I'm pretty sure that they have considered this in great detail*'. In spite of this confidence, he (along with some of his colleagues, though this view proves far from universal) suggests extra control of new vaccine technologies like MycoSynVac:

CG: 'Do you think that there should be extra control in relation to a vaccine like this. For instance in relation to the small risk for reversion to a pathogenic variant?'
P.: 'Well yes, I actually believe that when you make something so radically different as this. Not because it… I don't believe that it will revert back to pathogenic, but it could give some other problems which we haven't anticipated.'
(Scientist, Denmark)

P. is so concerned about unknown consequences - '*problems we haven't anticipated*' - that he believes some form of extra control of this vaccine should be put in place. He argues that this is because of the extra uncertainty about consequences inherent when we construct something '*as radically different*' as MycoSynVac.

All in all, most of the vaccine scientists show some concern about the unknowns relating to living genetically modified vaccines (and most of them perceive MycoSynVac in this way). They frequently observe the possibility of unknown consequences caused by mutation, and reflect on the unknown characteristics modified organisms may possess.

5.2.2 Health risks

Another type of risk mentioned by some of the vaccine scientists is health risks for humans and animals. The references to these risks by vaccine scientists are scattered and brief, but they all relate to additives in vaccines in general and we think it is fair to include them here.

One scientist expresses general concern about adjuvants in vaccines because he believes that the rules are not strict enough, and the animals therefore may physically suffer as a result:

> *P: 'There's a problem – or there can be a problem about adjuvants in some of the vaccines that contain adjuvants.'*
> *CG: 'Yes.'*
> *P.: 'They may even be the cause of abscesses […] and they can cause fever, inflammation and that can't be pleasant for the animal.'*
> *CG: 'No.'*
> *P.: 'And, I mean, that's why they are not allowed for humans.'*
> *(Scientist, Denmark)*

According to P., some adjuvants cause health problems such as fever, inflammation and abscesses and he believes that this is an animal welfare problem. During the interview he also mentions that he believes the rules for adjuvants should be stricter in order to avoid that kind of suffering. But he is the only one who mentions this problem in relation to animal vaccines.Another scientist is worried about additives in vaccines more generally:

> *A.: ….'They [pharmaceutical companies] will introduce preservatives. They will introduce preservatives like er, formaldehyde […] which are terrible, which were not included previously.'*
> *CG: 'Ah okay. Why would they do that?'*
> *[…]*
> *A.: Because then they can keep their vaccine, they can keep it longer.'*
> *CG: 'Ah!'*
> *A.: '[So] they don't have to produce, and produce, and produce.'*
> *CG: 'Okay. And what does it do, like adding formaldehyde for instance, what does that do?'*
> *A.: 'Erm, allergies.'*
> *CG: 'Uh, for the animals?'*
> *A.: 'For the animals, and the humans.'*
> *CG: 'Ah, when you eat the meat of?-'*
> *A.: 'No, no, when you are injected.'*
> *(Scientist, Spain)*

A. is concerned about additives in vaccines in general, not just in livestock vaccines. He claims that pharmaceutical companies add preserving agents to the vaccines and that these can cause allergies – and he mentions later in the interview that some are also suspected to cause cancer. In his opinion this is only a risk '*when you are injected*', not something to be concerned about as a consumer of meat products. Hence, in relation to the MycoSynVac project, this perception of allergy risks relates only to animals. As with the concern about adjuvants, this is the only informant to actively address additives as a risk in relation to vaccines.

5.2.3 'Virtually zero' risk

As we saw in the previous section, while the vaccine scientists express some concern over risks they also seem to agree that as a rule, livestock vaccines are a fairly safe way to protect animals. Here a Spanish scientist considers the risk of livestock vaccines:

> *CG: 'Yeah. But what about the vaccines on the market […] those [vaccines that] are "out there", are there any of them where you are thinking, oh this one is a bit too, is a bit risky?'*
> *A.: 'If they're properly, if they're properly done, they are not risky. I mean there is always a risk; the risk zero doesn't exist. But if they're properly prepared that, it's okay.'*
> *CG: 'Yeah, and do you think also that the-'*
> *A.: 'It's a manageable risk.'*
> *(Scientist, Spain)*

So according to A., livestock vaccines are generally '*not risky'.* He acknowledges that '*risk zero doesn't exist*' and that the risk depends on whether the vaccines are '*properly prepared'.* But even if that isn't the case, he asserts that the risk is '*manageable'.* This perception is widely held among the vaccine scientists. Another scientist adds to the argument, this time specifically in relation to animals:

> *M.: 'There could be in some types of vaccines, they could have some inflammatory... effect. Erm, you know the same as humans, when you get a vaccine sometimes you've got a reaction towards that. So... But yeah, we tend to counter these kinds of things when you prepare a vaccine, so... The issue with the animals is that, depending on the animal, they have a certain period of life[span]'.*
> *CG: 'Yeah'.*
> *M.: 'So it's not like... something that, you know, a vaccine will prevent it from a certain period from getting certain diseases, [inaudible]. So I don't see many risks from the animal point of view'.*
> *(Scientist, UK)*

M. does mention side effects related to the injection of vaccines, such as '*inflammatory effects'*, but she quickly reassures us that these side effects are taken into account in the vaccine preparation. She also argues that the lifespan

of a farm animal is limited, so long term effects for the animals are negligible. Her conclusion is therefore that she doesn't '*see many risks from the animal point of view'.* Most of the scientists share the perception that risks for the animals are manageable.

These vaccine scientists are equally unconcerned about risks for humans consuming animal products. In general, they either believe that there won't be any residues of vaccine left in the products or they consider the amounts to be so small as to be insignificant. As a British scientist explains:

> *B.: 'Well, antibiotics may last, anti-parasitic agents may last. I mean usually the amount of active ingredient in vaccines is tiny, you're talking about micrograms, not even milligrams. So... a millionth of a gram, it's tiny. The immune response doesn't need to see very much foreign to stimulate a response, so I would have said I think the risks to the consumer are virtually zero'.*
> *(Scientist, UK)*

B. distinguishes between antibiotics and anti-parasitic agents on the one hand and vaccines on the other. Where there may be residues of the former in consumer products, he does not recognize this as a problem related to vaccines, where he believes that the risk to the consumers is '*virtually zero'.* In this he resembles his colleagues across the case countries; all shared a perception of (no) consumer risks. Besides arguing that the amounts of vaccine residues are very tiny or non-existent, the scientists in this case also point to trust in the regulative authorities as a guarantee for safety. As B. points out:

> *B.: 'Well again, I've got faith in the regulatory authorities; medicines are very tightly regulated in Europe and other countries, so it costs millions to get a product onto the market, 'cause of all the safety testing, residue testing, etcetera. So, erm... if it's a disease that's, we've already discussed, a disease causing a problem, and the vaccine provides a solution to that problem, and it's cost effective, I don't see a negative side to it at all.'*
> *(Scientist, UK)*

He doesn't see a problem with the use of vaccines in agriculture because '*medicines are tightly regulated in Europe and other countries'.* While some of the other scientists at times consider regulation insufficient in relation to the issue of ineffective vaccines, as discussed in section 5.3.3, they are all in agreement when it comes to safety. On this issue they believe that government regulations, at least in Europe, are so tight that nothing risky for consumers will escape their attention.

5.3 Animal vaccines – a realistic project?

One of the biggest concerns among the vaccine scientists was actually the feasibility of the MycoSynVac project in regards to developing vaccines for use in agriculture that at the end of the day will have an effect on animal health. During the interviews, they often commented on the general conditions of Western agricultural industry, the difficulty in making effective vaccines and the role of pharmaceutical companies. In these sections, we will present three structural conditions that the scientists were concerned about as barriers for realizing an effective vaccine against Mycoplasma.

We will first consider the vaccine scientists' perception of the agricultural sector as being permeated by economic interests, and the ensuing consequence that livestock vaccines need to be very cheap for there to be uptake. Secondly, we'll present the perception that the MycoSynVac project is so scientifically difficult that some scientists question whether it can succeed. Finally, and linked to the second section, we will present the perception that (in part because vaccines are so difficult to make) there are many ineffective vaccines on the market – and that MycoSynVac is perceived to potentially become yet another one of those.

5.3.1 'Affordability is key'

The vaccine scientists share a perception of the Western world's agricultural sector as dominated by economic rationales. This means that all of them – without being prompted – also assess the chances of MycoSynVac on the market for livestock vaccines. This is visible in this dialogue with a Danish scientist about scepticism in relation to the use of vaccines:

> *P.: 'Animal vaccines, there's an entirely different, I mean not "real-world" scepticism, it's more the farmers who complain that they are too expensive, right…'*
> *CG: 'Yes.'*
> *P.: '…Compared to using antibiotics and all that stuff, right. So it's a completely different history and if I had been in the companion animal business, then [the debate] had probably been more like what you see with [human vaccines]'.*
> *(Scientist, Denmark)*

According to P., the main barrier for using vaccines for livestock is thus not a resistance from lay-people, '*real-world scepticism'*, but rather the issue of cost-effectiveness, because farmers will always compare the price of vaccines with other forms of medical treatment such as antibiotics. Several others agree with this perception of farmers and

agriculture as being predominantly occupied by concerns about efficiency. Here is an excerpt from an interview where we discuss how to maintain a healthy livestock:

> *M.: 'It is very tough [how to maintain healthy animals], but usually, numbers gives it. So how much do you waste, or use, how much money you use in killing everything that is infected and the surrounded; and how much money you waste by vaccination, so you put these two together, how much is it […]?'*
> *CG: 'Yeah, yeah, so it's economics-'*
> *M.: 'It's money, yeah, it's driven by economics. And depending on the country, you could go one way or another. Very much depends on the country's economy'.*
> *(Scientist, UK)*

M. asserts that the choices made about the health of farm animals are '*driven by economics.'* All considerations about maintaining healthy livestock and the varying methods for this – '*how much money you waste in killing everything that's infected*' versus '*how much money you waste by vaccination',* for instance –are subject to economic estimation.

This point is put in perspective by a Spanish scientist who compares '*first world*' and '*third world*' agriculture:

> *A: 'Because here in our first world, we […] pay a lot of attention to diseases, which are not… which are diseases of productivity'.*
> *CG: 'Yes, they come out of the-'*
> *A: 'They are not [fatal] diseases, but erm, [the farmers] sometimes breed the animal to reach an optimal weight in six months.'*
> *CG: 'Yes, so it's more about them being er-'*
> *A: 'Mycoplasma is for example- […] mycoplasma is of pigs. They are perfectly healthy. 99 percent- they are just, okay generally.'*
> *CG: 'It's just because they are-'*
> *A: 'But that's it. What's the problem? They have lost thirty grams of weight during the first two months or what […] and in the first world, because we are more or less, more or less able to manage disease. So then we pay attention to the product, if diseased. Where, in the other worlds, [the] […] diseases are important, and productive diseases are … secondary'.*
> *(Scientist, Spain)*

In comparing the *'first world'* and *'third world'*, A. asserts his opinion that Western farmers are concerned if the pigs '*have lost thirty grams of weight during the first two months'* because this is not the perfect weight of '*the product*'. So according to A., livestock in the Western world are considered as commodities. The diseases, such as those related to '*Mycoplasma',* are '*production diseases'* related to the fact that pigs are production animals. In that way, he questions what kind of problem MycoSynVac is supposed to solve; to protect animals against suffering or to heighten economic

benefits to farmers. The quotes above and general impression from the interviews reflect that the vaccine scientists look at the agriculture sector as being thoroughly permeated by economic motivations , at least in the Western world.

Several of the scientists point to the necessity of vaccines for upholding economic sustainability of agricultural industry in the Western world, and to the economic gains of farmers and producers if the MycoSynVac project is successful. Here, an Austrian scientist considers usefulness on a range of parameters:

> *K.: 'Er, there are I think, a lot of different aspects [of use]. Of course from the beginning […] the animal welfare of course, the animal, will really have - It would have a positive effect. They are not suffering, they are not getting ill [if they were vaccinated]. Of course for the farmer, because there is no economic loss [if they are not ill]. And of course for the company that develops it. Or releases it'. (Scientist, Austria)*

K. mentions that MycoSynVac could potentially *'have a positive effect*' on animal welfare, in line with the vaccine scientists in the previous section (5.1.1). But she also reflects upon MycoSynVac as having potential use of farmers and the pharmaceutical industry; the farmer will have '*no economic loss*' if the vaccine is realized and the pharmaceutical company responsible for the release will '*of course'* also gain from it. A British scientist comments on affordability as key to the success of the MycoSynVac project:

> *CG: 'I was just going to ask about that; is [the MycoSynVac] affordable, then?'*
> *B.: 'Yeah, yeah. Affordability is key. Otherwise people can't afford to use them.'*
> *CG: […]*
> *B.: 'You can produce proteins and nucleic acid in some cases very inexpensively'. (Scientist, UK)*

He, like others, underlines that '*affordability is key'* and that seen in that light, MycoSynVac may be feasible because some of the key ingredients are not costly.All in all then, the vaccine scientists consider choices of prevention and treatment of livestock animals as being premised on economic calculation. In the light of this general perception, they assert that the feasibility of the MycoSynVac project depends on affordability. This may be successful, because ingredients can be cheap and healthy animals lower general production costs.

5.3.2 MycoSynVac as scientifically difficult

Some of the vaccine scientist participants assert that the MycoSynVac project sounds useful if it's possible to make it work. They express doubt about this, however; a Polish scientist, when asked whether the vaccine eventually resulting from the MycoSynVac project will work, says:

> *P.: 'Well, difficult really to… it is very difficult to predict, but it is, […] extremely difficult to construct something which is, which is efficient and unified for any […] host. Because well, some microorganisms, as well [as] mycoplasma, have very limited scope of the […] host, so, I don't think […] it could be possible to, […] develop vaccines against for example all fevers of pigs, or all mycoplasma species. I don't know, probably it is possible […] to construct something which will be partially efficient, I think.'*
> *(Scientist, Poland)*

In his view, it will be '*extremely difficult*' to construct a vaccine that can protect against all species of Mycoplasma. This is because the scope of the Mycoplasma organism is very limited and therefor the design of the properties of the synthetic organism will be very difficult. A British scientist adds to that impression. When asked whether the vaccine can improve the welfare of farm animals, she says:

> *M.: 'If they manage to get it, yes. But that would be very difficult. Because they are using Mycoplasma Pneumoniae as a chassis, and then try and introduce, I guess, some of the proteins as specific from all the mycoplasma species-'*
> *CG: 'Yeah, exactly-'*
> *M.: '- so they can protect […] against a wide range of Mycoplasma infections. If they manage to do it, that would be, that would have a very high impact in farms'.*
> *CG: 'Yeah'.*
> *M.: 'But I see that there could be problems in protecting against one, and not another, I mean, [inaudible] protection is an area that we don't fully understand. So I think it's a good idea and a good hypothesis, erm, until you prove it I can't say whether - but if they manage to protect against two or three? That would be, you know [something]'.*
> *(Scientist, UK)*

M. perceives the MycoSynVac as '*a good hypothesis*' and asserts that such a vaccine would have '*a high impact in farms'.* But she is more sceptical when it comes to the question of actually being able to make the vaccine, saying that it is an area that '*we don't fully understand*' and she thus believes that there '*could be problems in protecting against one and not another'.* One of the Danish scientists also questions whether the vaccine is actually scientifically feasible (even if he thinks it is an '*interesting strategy*'):

> *P.: 'They could be, bluntly speaking, indifferent about what it [the organism] will be used for, they could just think that it's hilarious to work with it, right?'*
> *CG: 'Yes.'*
> *P. 'And see if it's possible to make a living organism which is something completely different from what you have seen before'.*
> *(Scientist, Denmark)*

P. also perceives the project as being very difficult and with many unknowns. In fact, he thinks of it as so difficult that he wonders if the scientists might be '*indifferent*' about the potential vaccine technology and in reality are just interested in seeing whether it is '*possible to make a living organism which is something completely different*'.

This impression is further reinforced by the fact that many of the scientists point to synthetic vaccines as being inefficient because the immune defense system does not react sufficiently to them. They also point to genetically modified vaccines as being the most difficult to make. There seems to be some discussion of whether the vaccine resulting from the MycoSynVac project is a synthetic vaccine or a genetically modified one, but most of them consider the vaccine to be genetically modified. One of the scientists puts it very bluntly:

> *CG: 'There's some discussion among the scientists I talk to whether [MycoSynVac] is a [genetically modified vaccine][1] or [a synthetic vaccine]. Because it's alive. […]. How would you… what would you…?'*
> *P.: 'It's clearly [a genetically modified vaccine.]'*
> *CG: 'Yes?'*
> *P.: 'Yes, er, then they have fitted it into the other category in order to get the grant'.*
> *(Danish scientist)*

In the perceptions of P. and most of the other scientists, the MycoSynVac project '*clearly*' points to the making of a genetically modified vaccine. But regardless of whether it is viewed as a synthetic vaccine or a genetically modified one, they consider it a challenge to make it work properly because they regard it as very difficult. A Spanish scientist explains what he sees as the challenges with genetically modified live vaccines:

> *A.: 'You have still to do a lot of progress on adjuvant and delivery systems […] on all, to deliver them properly and to create new generation of vaccines.'*
> *CG: 'Yeah, so there is quite a lot of basic science needed?'*
> *A: 'Yes. Needed […] to make it work.'*
> *CG: 'Yeah, okay. Yeah, that-'*
> *A: 'Well I'm not saying that I'm against them!'*
> *CG: 'No, no, no.'*
> *(Scientist, Spain)*

What A. and several other scientists point to is that there are still issues with making the immune defense system react to the modified organism and that therefore, work is needed on '*adjuvant and delivery systems*'. If this is not solved it will be difficult to realize '*a new generation of vaccines*' (such as MycoSynVac) that actually work well. This impression is

[1] In the interview, we have written descriptions of the different vaccine types, so P. And CG point to these instead of actually saying the names.

reinforced by other interviews, where the vaccine scientists question the possibility of developing a well-functioning vaccine. A Polish scientist comments here on the project after he has read a brief description:

> *P.: 'Okay […] in my opinion it would be impossible, to prepare [the MycoSynVac] vaccine, for all species the same [time].'*
> *CG: 'Yeah.'*
> *P.: 'Because […] it would be impossible to create vaccines for all species [of Mycoplasma].'*
> *CG: 'Yeah. Why do you think, do they have that ambition then?'*
> *P.: 'Erm, I would tell why they have such ambitions […] In my opinion, I am very critical […] and I am convinced that very often you do not succeed, but [in order to] to receive grants you should create something original'.*
> *CG: 'Yeah'.*
> *P.: 'And finally after five years of work, you say "oh, we don't succeed, but we tried".'*
> *CG: 'Yeah'.*
> *P.: 'But […] it will be not successful.'*
> *(Scientist, Poland)*

In P.'s view, it's '*impossible*' to create a vaccine that will cover '*all species*' of Mycoplasma. He believes that the reason for the project's attempt is that without an '*original*' ambition, the Commission would never have issued the grant. He also comments directly on the vaccine's prospects for animal health:

> *CG: '[…] Do you think from a scientific point of view, [that] it is an interesting project?'*
> *P.: 'From a scientific point of view, maybe'.*
> *CG: 'Yeah, yeah. But not from an animal health perspective?'*
> *P.: 'No.'*
> *(Scientist, Poland)*

While other scientists perhaps are less harsh in their judgment of MycoSynVac, considering it as having potential benefits in improving animal health, they share the perception that it will be very difficult to produce an effective vaccine that will cover many or all of the forms of Mycoplasma. As such, while most of the scientists do believe that a vaccine such as MycoSynVac is a good idea, many also doubt the feasibility of the actual vaccine development because it is so scientifically difficult.

5.3.3 Ineffective vaccines

The scientists point to yet another factor that makes them doubtful about the need of a vaccine such as MycoSynVac: the general problem of ineffective vaccines for livestock on the market. A Danish scientist takes up the subject himself in the beginning of the interview:

P.: 'Vaccines, that's a very broad definition, right.'
CG: 'Yes.'
P.: 'Because there are some… there are actually surprisingly many of those vaccines in use that don't work at all.'
CG: 'Yes.'
P.: 'So…'
CG: 'I've heard it before.'
P.: 'It's pretty, pretty, pretty bad, really.'
(Scientist, Denmark)

Therefore in P.'s perception, there are '*surprisingly many*' vaccines for livestock that '*don't work at all'.* Many vaccine scientists across all countries support this viewpoint. Here it is an Austrian scientist who elaborates on the point:

A.: '… The vaccines, the animal vaccines, some of them are not ready, they are unstable. Some of them are not very good. We have to keep that in mind, but some of them are really successful.'
CG: 'When you are saying that they are not very good, that means they are ineffective? Or- ?'
A.: 'Some of them are ineffective, some of them […] are not able to, to make a long-time protection. Full support…'.
(Scientist, Austria)

According to A., animal vaccines may be ineffective – some simply do not protect, others cannot '*make a long-time protection'*, so the animals need to be vaccinated several times. This problematic concern is repeated across all countries. The scientists have different explanations for why so many vaccines do not work very well. Some of them believe it is because the science behind them is so complicated, as we pointed to in the last section:

P.: '…Well, the, […] the farmers or veterinarians, they put the blame on producers of vaccines. But, in fact, it is not the- […] they shouldn't do it, because it is not the […] main problem, I think, in vaccines. It is some points in vaccines or the preparation of vaccines or the producing of vaccines [that] are not possible to predict. It is some, I think-'
CG: 'Yes, yes, so, it is a very difficult field to work with-'
P.: 'Really difficult.'
(Scientist, Poland)

P. argues that the reason for ineffective vaccines on the market is that it is a difficult scientific area. There are points in the production of vaccines that are just '*not possible to predict',* but the vaccines still end up on the market. So for him the main problem is the scientific uncertainty in relation to vaccines. Others look at it differently. One Spanish vaccine scientist claims that '*multinationals do what they want*' - implying that these companies intentionally put ineffective vaccines on the market. Another criticizes the entire agricultural production:

P.: 'Yes, it's about these margins all the time, right? So, it's not even a question about sick or healthy, it's… Your pig is there and it needs to gain weight and it goes around and is in poor health and has a hard time. If you can do it just a little better, just like a few percent.'
CG: 'Yes, that makes sense, then it gains weight.'
P.: 'Well, yes… So it's also about the farmer who can feel even the slightest advantage, as tangible profit.'
CG: 'So it's all about grams?'
P.: 'Yes it is, quite simply.'
(Scientist, Denmark)

While the Polish scientist points to the scientific uncertainties tied to vaccines, P. is instead pointing to the agricultural industry and the economic rationales that guide it as the problem (see also 5.3.1). Even very ineffective vaccines may have a small effect, perhaps adding '*a few percent*' to the weight of the pig, and that is what makes it possible to have vaccines on the market that do only give incomplete or temporary protection. If they work well enough to add a small profit for the farmer, they will be used.

Regardless of the justification used, most of the scientists agree that there are too many ineffective vaccines for livestock on the market. Just one scientist disagrees. She believes that precisely because farming in the Western world is economically determined, farmers will not buy vaccines that do not work properly. However she is an exception; the general picture is that the vaccine scientists are concerned about too many ineffective vaccines.

6 Concluding discussion

This chapter will focus on the most important findings from the analyses of the perceptions of synthetic vaccines and the MycoSynVac project expressed by lay people, synthetic biology scientists and vaccine scientists.

We started with a research task to:

Map the considerations among lay people, synthetic biology scientists and vaccine scientists that occur in relation to the development of synthetic vaccines for farm animals.

Before discussing our findings, we will briefly summarize the concerns raised by the three stakeholder groups.

6.1 Findings

Based on the analysis, we can now assert that the lay participants find synthetic vaccines for livestock useful in two ways. Firstly, that they perceive these as a good replacement of antibiotics in agriculture, and secondly that they perceive them as a way to improve livestock welfare by relieving animals of physical suffering. It should be noted, however, that the usefulness related to animal welfare is not unambiguous. The participants believe that an alternative to medical prevention and treatment could be to change the living conditions of livestock animals to give them more space and outdoor life. In the view of these participants, this could also hinder the spread of disease. It should also be noted that some participants are sceptical about the use of vaccines in general for both humans and animals. These participants rarely consider the MycoSynVac project as useful.

Most lay participants show concern about risks related to human health if MycoSynVac is used on livestock animals, and justify this concern in three ways. First by pointing to a general uncertainty around emerging technologies, suggesting that you can never be sure that the new technology is completely safe. Second, by justifying their concern with a perception that a vaccine like MycoSynVac is 'unnatural' in various ways, and asserting that unnatural products are likely to pose risks to human health.

Finally, they express mistrust in the producers' (pharmaceutical companies) attention to safety. They hold the belief that the producers are more interested in profit than in the health of consumers.

The lay participants also are concerned about fairness in relation to the commercialization of MycoSynVac. They feel fairly certain that both farmers and the pharmaceutical industry will benefit financially from the vaccine if it works. On the other hand, they worry that animals and consumers will potentially suffer due to as-yet undiscovered vaccine side effects. They consider this an unfair distribution of benefits and disadvantages and view themselves and the animals as involuntary participants in a veterinarian experiment that is driven by economic interests of others.

Synthetic biology scientists are generally relatively impressed by the MycoSynVac project, considering it useful in several ways.First, they view it as of use to society. This is because it helps to lower the level of infectious diseases for both humans and animals, and because it's a good replacement for antibiotics – although the latter was only mentioned by a small number of scientists. Additionally, they believe that the project advances the knowledge of biological systems, and that this is useful for developing more and better synthetic biology applications. They also consider the project of use because it focuses on building a platform (the chassis) that can be used in several contexts (i.e. for different Mycoplasma infections). Finally, a few also mention that the vaccine could be economically beneficial, but it is contested whether this form of usefulness is legitimate; some of the other synthetic biology scientists scorn such projects with too much focus on profits.

The synthetic biology scientists are, as a rule, not concerned about risks related to synthetic biology projects in general, or to MycoSynVac in particular. They believe that following rules for laboratory safety makes synthetic biology broadly safe. However, when asked directly, they do reflect upon some potential risks related to MycoSynVac even if they do not seem to attach much weight to these. One risk is the unknown consequences of mutation; the other is the risk of making bacteria resistant to the vaccine in the long run by using it on livestock on a global scale.

A surprising finding is that some of synthetic biology scientists use 'naturalness' to assess and compare biotechnology projects with other technologies, such as chemical extraction. They consider synthetic biology methods to be 'natural' – and thereby better – as long as they follow the general laws of biology. This perception is also what makes them consider potential synthetic biology projects as good replacements for existing – and more 'unnatural' – chemically-based technologies.

The vaccine scientists do view MycoSynVac as useful - if the vaccines are realized. They believe that MycoSynVac is useful as a relief from pain and suffering for livestock animals, and they too consider vaccines (here not just MycoSynVac) as a good replacement for the use of antibiotics in agriculture.

The vaccine scientists do express concerns about two possible risks relating to MycoSynVac. One is about the unknown consequences of using MycoSynVac vaccines in agriculture in general; they mention mutation and as-yet unknown characteristics of the designed organism as potential threats. The other risk is about human and animal health in relation to the use of vaccines in general (not just MycoSynVac or animal vaccines) due to unhealthy additives and adjuvants. While these scientists therefore point to specific risks around vaccines in general, and MycoSynVac in particular, these concerns are somewhat offset by the fact that they express faith in their fellow colleagues and public authorities to control vaccines. The vaccine scientists therefore assess livestock vaccines as a fairly safe way of protecting animals.

This group of scientists is quite preoccupied with the MycoSynVac project's feasibility. They consider the agricultural sector (at least in the Western world) to be dominated by economic rationales, and therefore they think that the vaccines need to be very cheap for farmers to invest in them. The vaccine scientists are also concerned about the amount of ineffective livestock vaccines on the market and fear that MycoSynVac could represent yet another, because farmers are easily persuaded to buy ineffective products if they believe they will result in a higher profit margin on their animals. Finally, the vaccine scientists are also concerned that the basic science involved in the MycoSynVac project is so challenging that it will prove impossible to ultimately manufacture the vaccines.

6.2 Discussion

We will now go into some depth about the findings of most interest. By way of introduction, our results from lay people and experts will be compared with the review of existing knowledge as presented in chapter 1. After that, four interesting similarities and differences between the perceptions of lay people and experts will be discussed.

The first to be discussed is that lay people and experts share a perception of antibiotic resistance as a problem and of vaccines as a possible solution. Secondly, it will be noted that lay people and experts share some concerns about the risks relating to new kinds of vaccines but also differ in some aspects. Finally, we will reflect that there is a difference between how lay people and experts assess the distribution of benefits and disadvantages.

6.2.1 Vaccines as a solution

In the review of existing literature (chapter 1) we explored how studies of lay people's perceptions of synthetic biology found dominant themes of usefulness, risks, naturalness and fairness (Grogan, 2014; Pauwels, 2009, 2013; Starkbaum et

al., 2015). Based on our current study, we can conclude that these issues also prove to be the most important in relation to livestock synthetic vaccines for our lay participants.

Regarding the concept of usefulness, several of the papers in the review suggest that people consider medical applications for humans as the most useful (Pauwels, 2009, 2013; Starkbaum et al., 2015). Based on our study of disease prevention for livestock (rather than humans), we can conclude that lay people do indeed also find this application useful because it can enhance animal welfare and reduce the use of antibiotics in agriculture. However, this support is not unambiguous, with two queries raised. Firstly, lay people believe that there could be better strategies for preventing animal diseases and lowering the use of antibiotics, such as more space and more outdoor life for the animals. Secondly, because some lay people show scepticism about vaccines in general and relate the issue of livestock vaccines to controversies over human vaccines.

When comparing the perceptions of the lay participants with those of the expert groups, it is of interest that all three groups share a common perception of vaccines (and for the lay people and synthetic biology scientists, of MycoSynVac in particular) as a useful alternative to antibiotics. This perception seems to be of greatest importance to lay people and vaccine scientists in our study, but is also articulated by some of the synthetic biology scientists. It should be noted, however, that the support of new forms of vaccines is not unambiguously supported by lay people and vaccine scientists. Both groups suggest that improving the living conditions for livestock animals, especially the amount of space for each animal, could be another solution to minimize the spread of infectious diseases and antibiotic use.

Linked to this idea of vaccines as a solution to important problems, it's also interesting to note that vaccine scientists are much more preoccupied with the structures of the particular societal contexts in which their findings have importance (i.e. the agricultural sector and the pharmaceutical industry). In our interviews, they often relate their assessments of specific technologies to the possibilities of their success in light of modern farming conditions. This is in stark contrast to most of the interviewed synthetic biology scientists, who seem unaware of the societal contexts and structures of the technologies they were developing.

In this regard, our findings suggest that differences between experts do not only reflect differences in demographic factors such as seniority and nationality as we saw in the review (Boëte et al., 2015; Boëte, 2011; Okorie, Marshall, Akpa & Ademowo, 2014), but also the specific disciplinary culture around relations between science and society. Our study thus reinforces the need for more studies that scrutinise differences in experts' perceptions of emergent technologies, because 'experts' are here not found to comprise a uniform group

6.2.2 Concerns about risks

Compared to the lay people's perceptions of risks presented in the review, similarities and divergences are found in our study. As in, for instance, the 2010 Eurobarometer research (TNS Opinion & Social, 2010), the present study finds lay people have some concern about risks - and especially about risks in the shape of unknown consequences of synthetic organism releases.

Contrary to the studies reported in the review lay participants in our study primarily associate human health risks with MycoSynVac technology, where other studies also point to environmental risks as a concern (Pauwels 2013; Grogan, 2014). 'Naturalness' is also a major concern for the lay participants in our study, as when lay people discuss synthetic biology in general (Dragojlovic & Einsiedel, 2013). In relation to the specific MycoSynVac technology compared to other vaccine types, the lay participants in our study often favour dead or attenuated vaccines over synthetic ones because they consider these as more natural and thereby also safer.

There are very few studies into, and thus limited knowledge about, expert perceptions of synthetic biology and livestock vaccines (as demonstrated in the review section). In relation to risks, we see that both of our expert groups agree that risks relating to synthetic biology and synthetic biology vaccines are minor - but they equally acknowledge the need to find alternatives to antibiotics and cures against infectious diseases.

It is striking that all three interviewed groups mention a concern about unknowns relating to the release of living synthetic organisms. For lay participants, however, this appears as a much more important risk than for the two expert groups. The experts seem to take it as a precondition for all technological development that zero risk is impossible, but they also give higher weight to the potential benefits and consider synthetic biology and synthetic vaccines as fairly safe, even where risks exist. By contrast, the lay people do not seem to accept risks related to synthetic vaccines as readily and generally emphasise a need for caution and control of new vaccines.

Furthermore, the lay people group is the only one to connect naturalness and risk. They believe that the risks become greater the less the active pathogenic organism in the vaccine resembles the one that normally affects and spreads among animals. The synthetic biology scientists also consider naturalness important, but they view synthetically constructed organisms as 'natural' because they follow general biological laws and do not involve the use of chemicals. For the vaccine scientists, naturalness is simply not a relevant issue.

6.2.3 Justice and fairness

It's fair to say that our study demonstrates that fairness and justice are issues that only the lay people participants show concern about. They believe that the (financial) gains and unknown harmful side effects of the vaccines are unevenly distributed, with pharmaceutical companies and the agricultural sector on one side and consumers and animals on the other. By contrast, the interviewed synthetic biology scientists never mention the issue of justice. Although the vaccine experts share the observation that there are structural conditions of modern agriculture and pharmaceutical markets with the lay people, they don't frame this as an issue giving rise to injustice.

As in other studies (e.g. Starkbaum et al., 2015), our analysis points to the fact that issues around the fair distribution of new technologies' benefits and disadvantages play an important role for the lay participants. Studies looking at synthetic biology as a general phenomenon find that fairness is closely connected to questions of global injustice, especially where medical technologies are discussed. The concern expressed is that there is an unfair distribution of efficient medical technologies between the western and global south.

This perspective is, however, missing in the lay discussions of MycoSynVac technology in our study, where no considerations about fairness in a global perspective are expressed. Rather, lay participants are preoccupied with the idea that pharmaceutical companies and the agricultural sector will gain financially at the expense of (western) consumers and farm animals, both of whom unwillingly and unwittingly will become subject to unknown risks.

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Appendices

Appendix 1: Screener for recruitment of focus group participants

Random sampling

Hello, my name is… I'm calling on behalf of the University of Copenhagen. We are conducting a study about foods and new technologies. Can I speak with a person in the household, who is between 18 and 69 years old?

(Speaking with the right person)

Hello, my name is… I'm calling on behalf of the University of Copenhagen. We are conducting a study about foods and new technologies. May I, as part of this study, ask you a couple of questions? The maximum duration of the call is 5-7 minutes.

Exclusion of 'experts'

1. Do you or anyone in the household work with one of the following fields?

Marketing -> conclude call

Market research -> conclude call

Journalism/PR/consumer research? -> conclude call

Biotech science or –industry? -> conclude call

Manbufacturing of meat or dairy products? -> conclude call

None of these? -> continue

2. Are you a member of the Norstat's consumer panels?

Yes -> conclude call

Do not know -> conclude call

No -> continue

Age and gender composition (Participants between 18-69 years and variation needed)

3. What is your age?

4. What is your gender?

Man

Woman

Education (variation needed)

5. What is your highest completed educational degree (note)?

7th grade or less

Elementary School

Basic Vocational Training

Short post-school education programme

Bachelor degree

Higher education (graduated or still studying)

Don't know/not replying -> conclude call

Participation in focus groups

6. Have you ever participated in a focus group before?

Yes -> conclude call

Don't know -> conclude call

No -> continue

7. (in case the person fits all criteria) *Would you be interested in participating in a focus group about foods and new technologies for the University of Copenhagen?*

Appendix 2: Interview guide for lay focus groups

Welcome (3 minutes)

Dear all,

Thank you to all of you who came here today to be part of the focus group. Before we begin, I just want to give you some information about the project and a few other practical pieces of information.

My name is Cecilie Glerup (or name of other moderator). I'm a researcher at Copenhagen University, Department of Food and Resource Economics. The department is part of an EU-funded science project about new health initiatives for farm animals, where we are doing focus groups in five European countries. I will not go into details with the specific themes of the project, as you will hear more about it during our discussions. And you are of course welcome to ask all that you want about the project after the interview.

The idea with focus groups is to get knowledge about people's viewpoints and arguments. So I have made different kinds of questions and exercises that are supposed to get a dialogue going among you. It is not about right or wrong answers at all. I am interested in what you think about different subjects and why you think so. I am going to record the session, but if we use quotes from you in our published work, you will be thoroughly anonymized.

I will initiate the dialogue and sometimes interfere, but in general I will try to stay as much out of the conversation as possible and let all of you do the talking. I have a favour to ask you and that is to try to speak one by one and not interrupt, even though it can be difficult. Otherwise it can be hard to listen to and transcribe the content afterwards. In addition, English is – as you can hear – not my first language, so I may ask you to repeat points or questions, if I cannot follow the argument.

Please help yourself with the refreshments. If you need it during the session, the toilets are…

Intro (explorative): 5 minutes

Moderator: 'Well, as a start, I would like to take a round where each of you tell me your name and something you like to do in your spare time'.

Round where everyone tells their name and something they like to do in their spare time.

A. Consuming Animal Farm Products (25 minutes)

Purpose: To explore people's perceptions of quality and safety in relation to food and particular in relation to meat and meat products. The first exercise (1) is made in order to make people relate their grocery shopping habits to their concerns and the second (2) is made in order to explore concerns in relation to animal products more in-depth.

1.1 (association exercise) Moderator: The first thing I want you to do is to think about the last time you were shopping meat or meat products. Note down the kinds – one or more – of meat that you bought and why you bought them. Were you shopping for a special occasion? Do your kids like that kind of meat – or something else?

½ minute to note down

1.2 (presentation) 10 minutes where everyone describes their shopping and rationales. Ask about details especially regarding quality and safety.

2. (association exercise). Moderator: We have talked about the considerations from the last time you bought meat. There were many very different considerations. Now we move to meat shopping in general. I want you to note all the things down, that you consider important when you choose what kind of meat or meat products that you buy. Here are some cards. You can note down as many things as you want, but only one important issue on each card. It can be something, which have already been mentioned or it can be new considerations.

- ½ minute to note down

2.2 (ranking exercise). Moderator: You have to put all your cards in the middle of the table.

Moderator First you have to sort the cards, so all the issues that are very much alike are piled together. (The idea is that we want each issue represented at only one card. The moderator can help with the sorting).

Moderator: Now we'll make a ranking exercise. The concern you agree upon being the most important, you place here by the end of the table and then the other follows, so the one you agree upon being the least important is placed here, by the other end of the table.

- 10 minutes to do the ranking. Moderator takes a photo of the final result

2.3 (Discussion). Moderator: Prompts: Do you all agree with this ranking? If food safety or something similar is not mentioned, ask about it and provide a card: Where would that fit the ranking?

B. Animal Welfare for farm animals (30 minutes)

Purpose. In this section, we move from the consumer context to the production context. The exercises here mirror the exercises from section A, in so far as the exercise is explorative and meant to map the concerns about animal welfare broadly. We study 1) people's perceptions of problems with animal welfare and their arguments for their concerns and 2) how they specifically look at animal diseases in relation to animal welfare and 3) if and how they relate animal welfare problems to the products they eat.

3. (Association exercise). Moderator: We move on to another subject namely that of animal welfare for farm animals, that is animals like cows, pigs and chicken. Now, I have a pile of cards here and you have write down the issues that you find most important regarding animal welfare for farm animals. One issue per card.

½ minute to write

3.1 (presentation): 10 minutes where everyone presents their biggest concern regarding animal welfare. Moderator asks about interesting subjects, especially relating to (lack of) 'natural' living conditions. Moderator also asks about justifications of their concerns by asking follow-up questions as 'why do you feel this way', 'why is that important to you', 'why is it so', etc.

3.2 (sorting and ranking): Moderator Similarly to the previous exercise, you have to sort the issues, so that issues that are alike are put in the same pile. (Moderator can help with the sorting. We only want one representation of each issue).

Moderator: Now you have to rank these concerns together as a group. From your perspective as a group, what is the most important animal welfare issue? Make a list in the middle of the table with the most important by one end and all the way down to the least important at the other end.

- 10 minutes to do the ranking. Moderator takes a picture of the final result.

3.3 (discussion). Prompts for moderator: if the participants are not making many arguments about their concerns ask 'why is this important?', 'why is this one placed at the bottom?', 'why is this one placed at the top?', 'why is this so important to all of you?', 'do you all agree? Why/not?'. If animal diseases have not been mentioned, ask about them and provide an 'animal disease' card, they have to place in the ranking. Moderator takes a picture of the final ranking. Again:

4. (discussion). Moderator: Now we have talked about important issues concerning animal welfare for farm animals. 'But what about eating meat and other products from those animals?'. 'Do you think about these issues, when you shop groceries?'

C. Strategies for maintaining a healthy livestock (20 minutes)

Purpose: This section looks at people's knowledge and perceptions of the maintenance of healthy livestock and how they relate health issues to a) animal welfare, b) eating and drinking animal products c) risk and d) if the concept of 'naturalness' occur. In the last part of the section (7.2) we will test, if consumers will buy animal products from animals injected with synthetically engineered vaccines in order to connect the production context with the consumer context.

5. (Association exercise) Moderator: We are now moving on to the subject of maintaining a healthy livestock for farm animals. As you perhaps know, farm animals are – like the rest of us – prone to a range of diseases. But in order to prevent and treat these, farmers use a range of strategies. I want to start with a brainstorm. Note all the things down, that you think farmers can do in order to prevent diseases among animals

- 2 minutes to note down

5.1 (Presentation and discussion) Moderator asks two or three people around the table about what they have written, before opening up for comments. Prompts for general discussion: Are there any of these strategies that you like better than others? Why? Again, remember to ask about justifications, by always inquire into why people have specific opinions.

6. (ranking exercise). Moderator: I have five different strategies for maintaining a healthy livestock here. I'm going to present them to you one at a time. You will have to rank the different strategies against each other.

Moderator presents the strategies in the order:

'vaccines',

'change of feed',

'antibiotics',

'not do anything',

'strict indoor containment of all animals',

'kill infected livestocks'.

- Discussion and ranking among the participants (10 minutes). Moderator breaks in, if the discussion ebbs out and ask questions such as 'why do you think x is better than y?', 'what about kill infected livestock – why is that good/bad', 'why do you not like/why do you like vaccines so much?', 'Isn't it better to change the feed than to give them antibiotics?', etc.

7. (ranking exercise) Moderator: We talked about vaccines for animals in the previous exercise and I want to talk a bit more about that, because there are different kinds of vaccines for animals. I'll present 4 different kinds of vaccines for you one by one and you have to rank, which ones you prefer as a group.

BIG CARD (to be put on the table) Moderator also reads aloud:

VACCINES

VACCINES WORK BY STIMULATING THE BODY TO BATTLE A DISEASE. VACCINES TYPICALLY CONTAIN A SMALL AMOUNT OF THE AGENT THAT CAUSES THE DISEASE.

Moderator reads the next cards up one by one and puts each card on the table:

1. Some vaccines are based on small amounts of weakened or dead microorganisms that cause disease. For instance the Cholera vaccine.

2. Some vaccines are based on a genetically modified version of the microorganism, which causes the disease. That means that only a protein or something similar from the microorganism is in the vaccine. The Hepatitis B vaccine is an example of a vaccine like that.

3. Some vaccines are based on genes that are made artificially in the laboratory. They are called synthetically engineered vaccines. The genes resemble the microorganism, which causes the disease. This method is very new and there are not that many examples from the medical sector.

5 minutes for the participants to discuss and do the ranking.

7.1 (discussion). Prompts for the moderator: Why do you prefer X over Y? Why do you not prefer Z? Why do you prefer A? Specifically ask about the placement of the synthetically engineered vaccine. What do you prefer as consumers? If they say anything about 'risk' or naturalness' inquire into their opinions.

7.2 (discussion) Moderator: Would you ever buy or eat meat or meat products, if the animals had been injected with synthetically engineered vaccines? Note your answer and reasons for it down before we start the discussion.

- 30 seconds to write

- 5 minutes to discuss. Discussion initiated by moderator asking one or two participants about their views and following up by asking about other viewpoints.

D. Fairness (30 minutes)

Purpose: 1) To study the participants' perception of fairness regarding the distribution of benefits and downsides with the vaccine and 2) to study the participants' perceptions of fairness regarding the conditions for development and ownership of the vaccine.

8. (Weighting exercise) Moderator: Now we will move on to another subject, namely the practical development of synthetically engineered vaccines for animals. You know the third kind of vaccine which we discussed before. This is a fairly new way of making vaccines and therefore the knowledge about costs and benefits are limited. I want you to consider, whom you think could be benefitting from the development of these vaccines and whom you think will be worse off with the development of vaccines like that? Take a couple of minutes to consider this. Note down, what you think.

Two minutes to note down. Moderator: Now we'll take a round, where each of you tell, what you have written down and why.

Moderator asks everyone around the table about their opinion.

8.1 I have five pictures here. One of a farmer, one of a cow, one of a consumer, one of a scientist and one of an owner of a medical company. I also have a blank piece, where we can write down other actors that I haven't thought of, but you have. I want all of you to draw a green cross on the actor you think benefits the most from the development of the vaccine and a red one in the actor you think will get the most disadvantages of the vaccine. And I'll write down additional actors if you tell me to do so.

- 1 minute to make cross.

- 5 minutes to discussion. Discussion initiated by moderator asking one or two individuals about their placement of pins and their justifications. Ask about other opinions. If there are pictures without pins ask why no-one placed a pin in them.

9. (association exercise). Moderator: Who should make vaccines? I give you two minutes to note down suggestions.

- 2 minutes to note down suggestions

- 6 minutes where everyone tells about their suggestions

9.1 (Ranking exercise) Moderator: Now I'll give you three options on who could develop the vaccine and you have to rank it together. The options are: 'Public universities', 'private companies' and 'public universities and private companies together'. Try to rank them together.

Paper with the three options is placed on the table.

- 7 minutes to do the ranking and discussion.

E. Appropriate use, security and regulation (20 minutes)

Purpose: To explore if and when the participants find it appropriate to use a synthetically engineered vaccine for farm animal and how the participants consider safety and the need for a regulatory framework around the vaccine.

10(scenario exercise/discussion) Moderator: We have talked about vaccines for animals in many different ways now. What I want you to consider now, is when it's ok to use synthetically engineered vaccines. I'll tell three stories now and after each one, you are going to discuss if the vaccine should be used.

Story 1: A lung disease is spreading in the UK. It is not fatal for the animals, but painful. Should the vaccine be used?

- Discussion for approx. 5 minutes.

Prompts for moderator: 'why do you think so?', 'but the animals are suffering?', 'but the vaccine is very new?'

Story 2: Other EU countries are afraid that their livestock will catch the disease. Therefore they decide to close export of meat from UK until the outbreak is contained and over. Should the vaccine be used?

- Discussion for approx. 5 minutes.

Prompts for the moderator: 'but what about the farmers' economy?', 'but what about the risk of containment?', 'why do you think so?', 'why is that an important aspect?', 'is that important for everyone?'.

Story 3: The virus has become more serious, so now infected animals in the UK are dying. Should the vaccine be used?

- Discussion for 5 minutes

Prompts for the moderator: 'why is that important?', 'what else do you think could be done?', etc.,

Story 4: The virus causing the disease has mutated and can now affect humans. Approximately one out of 100.000 UK citizens will die from it. Should the vaccine be used?

- Discussion for approx. 5 minutes

For all four scenarios: If there is too much agreement about the choice, the moderator should try to induce more conflicting points of view by asking questions.

11. (Weighting exercise) Moderator: Now we have talked about when animal vaccines could be used. But usually, when we are in the area of advanced medicine, some kind of control with the development and use are also put in place. I have 5 pictures here. One of a public scientist, one of a state-employed vet, one of a farmer, one of an industrial scientist and a blank paper resembling 'no-one' – and a paper, where you can make suggestions. I want all of you to draw a green cross on the person, whom you believe has the primary responsibility for the security of the vaccine.

People choose pictures and make a green cross.

11.1 (discussion) Moderator asks 3 people (preferably three who have put their pins in different actors) about why they have chosen as they have and follows up by asking about different view points. Important to ask about the justifications of their choices: 'why, why why'. Also important to remind them that the vaccine is synthetically engineered. Does that influence, who should be responsible?

F. Synthetic Biology

Purpose: To explore, how the participants perceive of 'synthetic biology' – especially how they connect potentials or risks to the term and the description of the technology.

Moderator: We are going to talk about one last issue, namely a technology called 'synthetic biology'.

12. First I want to hear if any of you have heard about it before today?

12.1 Moderator: Ok, some of you/all of you/none of you have heard about it. I want you to take two minutes to note all the things down, that the term 'synthetic biology' makes you think about.

Two minutes to note down.

12.2 (Sorting exercise) Moderator: Now you have to sort all the different things you wrote down in different themes, so those things you thought about, that you believe are similar, are put in the same group. You decide yourself how many themes there's going to be.

10 minutes to do the sorting.

12.3 Moderator: You have many ideas about what synthetic biology is about. Now I am going to present you with one definition (Big Card with the definition is put on the table. Moderator reads aloud):

Synthetic biology is a new field of research bringing together genetics, chemistry and engineering. The aim of synthetic biology is to construct completely new organisms to make new life forms that are not found in nature. Synthetic biology differs from genetic engineering in that it involves a much more fundamental redesign of an organism so that it can carry out completely new functions.

(ranking exercise) Moderator: 'Now you have a definition of synthetic biology. I want you to take two minute to note down what you believe this technology can be used for?'

Two minutes to note down.

Moderator OK, now we'll again sort all similar ideas in groups and then you have to rank all your ideas, so the one you like the best is up here and the idea you like the least is down here. Moderator asks about the ranking 'why is this a good application?', 'why is this a bad application?', 'do you all agree? Why not?', etc.

(5 minutes to do the ranking)

Moderator: Now I'm adding the card 'animal vaccines' – where would it fit the ranking?

Prompts for moderator: Why/why not do you like the idea about animal vaccines? Why are x and y better applications? Why are a or b worse applications? Should a technology like that be used at all?

Outro

Moderator: Thank you so much for participating. It was very interesting – at least for me. And if you have any questiond, you are welcome to ask – or email me; here's my card.

Appendix 3 Interview guide for synthetic biology scientists

Welcome

My name is Cecilie Glerup, I'm from the University of Copenhagen. My research group and I are part of an EU-funded project where we – among other things – are looking at expert and lay perceptions of synthetic biology in five EU-countries. So I'm interviewing you as a specialist in synthetic biology.

The interview is scheduled to run for around an hour. I'm recording our conversation as I'm going to use it as part of the analysis. If I use one of your quotes directly in a journal paper, you will be anonymous. That means that you will not appear with your name and specific research field (apart from synbio), but perhaps nationality. I hope that is ok with you.

If you're interested, I can send you our papers as we publish them.

A. Professional role and work

Purpose:

To obtain knowledge about the informant's professional position, area of research and the formal organization of the workplace. To understand how they position their work in relation to basic and applied science, because I expect that the closer you are to potential (or actual) users of an application, the less foreign is the idea that public (or users') opinions matter. To explore if it is important for their professional interest in synbio that they make something, they perceive of as useful.

- Describe your area of work?

    - Ask about the organization; what kind of projects/areas, they work with; the informant's official position and academic interests

- Why have you chosen to work with synthetic biology?

(prompts for discussions: academic interest, funding purposes, better solutions for society, good possibilities for applications, etc)

    - Which academic field do you come from? (as most people come from another discipline)

    - Why did you move to synthetic biology? (focus the conversation on advantages and disadvantages with synbio and previous field in relation to the purpose of research)

    - Would you say that your work is more applied science than basic science?

B. Outcomes of synbio research

Purpose: To explore if any talk about risks (as unintended sideeffects) come up in the talk. To explore how the scientists' define 'usefulness' in relation to synbio science and what criteria they use to assess usefulness.

1. I have four cases here, where synthetic biology is used in a novel or emerging technology. I want you to look at the texts and rank them, from the best application to the least good application. You decide yourself, how you want to define 'best'. I will ask some questions to the ranking as you go along.

The informant is presented with four different cards, with the following texts:

a) **Algae compounds**: A group of synbio scientists are modifying algae, so it can be used as compound for the production of various substances such as dye colour for foods or enzymes for detergents. According to the scientists, then algae have a potential for a climate-friendly way of producing a whole range of important substances that we use in everyday life. The reason is that that they grow very fast, and that some algae species only need salt water (not drinking water) and sunlight to grow.

b) **Synthetic Vanillin**: A group of synbio scientists has created a vanilla flavour compound (synthetic vanillin) from the synthetic biology methods. From the scientists' point of view, the synbio vanillin is an attempt to create a cheap and yet environmentally friendly vanilla flavor. Vanilla is one of the most used flavors in the world. Vanilla is extracted from two kinds of Vanilla Orchid and it is very expensive. Therefore Vanilla has been substituted with the chemically synthesized Vanillin. However, there are some environmental drawbacks to the chemical synthesis. Thus, there have been numerous calls to find other ways to produce vanillin.

c) **Plant therapy**: New cancer treatments could be produced from a weed known as the 'death carrot'. But these highly poisonous plants are hard to grow and they only produce the important component in small amounts. A team of synbio scientists is trying to insert genes from the plant into moss, which can be grown in closed containers. The hope is to extract large amounts of the active biological component from the moss, so that it can be used in cancer treatments.

d) **Animal vaccines**: Many farm animals are suffering from lung and throat diseases due to the Mycoplasma bacteria, which are resistant to most antibiotics. So far it has not been possible to create an effective animal serum-free vaccine against Mycoplasma. An animal serum vaccine is both expensive and there is a risk of contamination with animal vira. Therefore a group of synthetic biologists are developing a serum free universal vaccine chassis to use against different Mycoplasma bacteria.

Discussion points for the exercise (depending on their answers)

- Why did you choose X as the best? Why Y as the least good, etc? What are your criteria for good synthetic biology applications? Why are these your criteria?

- What if you look at it from a strictly scientific perspective – which one is the best and which one is the least good? What if you look at it from the perspective of whom the technology is going to help (animals, humans, the environment, industry)? Which perspective are you mostly interested in? Why?

- Some experts talk about applications from synbio as 'natural' because they do not use non-organic materials to start chemical processes – for instance in relation to the production of Vanillin. What do you think about that?

- Can you describe your current research project for me? (if they have not done so in section B)

- What do you hope to achieve with your own research project? (if outcomes besides scientific papers are not mentioned, ask about new technologies, products, patents, etc)

- You have ranked four different applications of synthetic biology from best to least good. Where would you place your own work?

    - Why?

    - Do you have any examples of synbio research, which you would rank lower than yours and the four others?

    - Do you think that there are any limits to what it is ok to invent and produce? What/Why?

C. The use and business plans of synbio technologies

Purpose: To explore the perceptions of fairness in relation to the scientist's own research project. To study the perception of fairness of the MyCoSynVac project. I To study the perceptions of barriers to innovation with a focus on the role of government regulation.

- Describe your current project – why are you engaged in that specifically?

    - What have your considerations been in relation to commercialization of the eventual technology?

    - Who will benefit from your research project (and eventual application)? Why?

    - Can you think about anyone who may be worse off due to the research project (or the eventual output)?

- (if not, then make suggestions based on the area of research, for instance related to risks)

- Who is supposed to use the application? Can you describe the user?

- Now we are going to look at the four synbio cases from before. But this time, we are focusing on the journey from the lab to society, so to speak instead of the application in itself. I want you to rank the four cases from the best form of innovation to the least good form of innovation. You decide yourself, what you mean by 'best'. I will ask some questions through the ranking process.

The informant is presented with four different cards with the following text:

Algae compounds: The algae are supposed to grow in large transparent tanks in green houses. The scientists have contacted local farmers who own big green houses across the country. Many of the green houses are not in use, because fruit and flower production is not a rentable business in Denmark anymore. By establishing contact with the farmers, the scientists hope to make room for a new kind of agriculture in Denmark, which potentially could create profit and new labour opportunities.

Synthetic vanillin: Synthetic vanillin grown in yeast was invented by a group of public scientists, where one of them holds the patent. The scientists have had long-term collaboration with the small-sized company Evolva and they collaborate on creating the product. For the large-scale production of vanillin, Evolva collaborates with the US based international company 'International Flavours and Fragrances'.

Plant therapy: A group of different stakeholders have been involved in the development of the cancer treatment based on the synthetically engineered plant 'Poisonous Carrot', namely a Danish public scientist, the Danish Cancer Society (NGO), the Danish Strategic Research Council and the international company, Genspara. The public scientist holds the patent and has created a start-up, which will have the main responsibility for exploiting the possibilities of making cancer treatment with poisonous carrot.

MyCoSynVac: The development of the animal vaccine is funded by the European Commission (a Horizon 2020 project). It is mandatory that both public and private actors collaborate on the development. A range of public research units, two SME's are and the world's second-largest pharmaceutical company for animal pharmaceuticals are involved in the research and development of the vaccine. The final stages of the product development will be taken care of by the pharmaceutical company.

Questions to the ranking: Why is this the best way of bringing a technology to the user? Why is this the least good one? What is important for you in relation to innovation? Who will benefit from each of these ways of developing the applications? Who will loose?

- Where would your own/the project's ideas about innovation fit the ranking?

- Do you think it's the best way? Why/not? What about from the user's perspective?

- Could it be more fairly done seen from society's perspective?

- What is the biggest barrier for you in relation to developing the actual application? (ex. Resources, regulation, public support)

- What about government regulation – have that ever had any influence on how your research?

D. Concerns for risks

Purpose: To study the perception of risks in relation to the scientist's own research, to ynthetic biology more in general and to the MyCoSynVac project specifically.

- In relation to your own research, are there any particular parts of it, which you think calls for special precaution from your side?

- Why/not?

- Have you ever been extra precautious in relation to your research? Why/not?

- (Depending on answer) why/not? Ask about knowledge of the precautionary principle.

- Can you imagine any form of synbio research, which you would not approve of because it could be dangerous?

- Can you think of any limits to what should be studied and developed in synthetic biology?

- If we look at the four cases again (showing the four cases as described in section B), is there anything in any of them, where you at first glance would think about risks related to the development of the technology?

- (if the informant answers 'no') then give examples: dual use in relation to the vaccine; the spread of a living synthetic organism outside the lab (all of them); that it is unhealthy to eat synthetically engineered organisms (all of them besides the cancer treatment); that it is unhealthy to treat the body with synthetic medicine (cancer treatment)

I think that I am actually done for now. Thank you. Do you have anything to add to any of the questions?

Outro:

Thank you for participating. That was very interesting. I will send you the published papers, so you can see, what came out of this. Here's my email address, if you have any questions, etc.

Appendix 4 Interview guide for vaccine scientists

Intro

My name is Cecilie Glerup, I'm from the University of Copenhagen. My research group and I are part of an EU-funded project where we – among other things – are looking at expert and lay perceptions of animal health among farm animals in five EU-countries. I'm interviewing you as a specialist in animal vaccines.

The interview is scheduled to run for around an hour. I'm recording our conversation as I'm going to use it as part of the analysis. If I use one of your quotes directly in a journal paper or report, you will be anonymous. That means that you will not appear with your name but perhaps nationality or field of expertise. I hope that is ok with you.

If you're interested, I can send you our papers as we publish them.

A. Professional role and work

Purpose: To position the expert's professional position, the organisation that he or she works in and area of research, including basic or applied science.

- Describe your area of work?

    - Ask about the organization; what kind of projects/areas, they work with; the informant's official position and academic interests

    - Why have you chosen to work with animal vaccines?

(prompts for discussions: academic interest, funding purposes, job opportunity, important area, for instance because of animal welfare, security, food security) It is important that we touch on the users or citizens during this discussion.

- There have been some discussions about vaccines for humans and some people are sceptical about vaccines in general. Have this public scepticism ever affected your work?

    - if yes, what was the issue? Make the informant describe the case.

    - What did you do/ what do you think should be done in relation to public resistance or scepticism?

B. Animal welfare and animal health

Purpose: To study the informant's perception of animal welfare for farm animals. To study if and how the informant connects animal welfare with animal health. To study the informant's perception of vaccines as part of securing animal health and animal welfare. To study how useful the experts find vaccines in relation to maintaining animal health.

- From a strictly scientific point of view, what is important for you in order to secure animal welfare for farm animals?

    - Why?

    - Would that differ from your personal point of view?

- I have six suggestions for what could be important concerning animal welfare for farm animals. I would like you to rank them from the one you find most important to the one you find the least important?

Interviewer presents six options on six sheets of paper:

Space

Access to outdoor facilities

Healthy food

Humane killing methods

No transportation

Veterinary control and treatment

Other suggestions (pieces of paper, where informant can add important aspects)

Prompts for interviewer: Why is X the most important, why is Y the least important? Does the different suggestions make sense from a professional point of view? Especially ask about the veterinary control and treatment. Is it important that the animals are healthy?

The ranking is left on the table.

- What do you consider important for maintaining healthy farm animals?

    - Why?

    - I have five different strategies for maintaining a healthy livestock here. I want you to rank them:

Five pices of paper on the table:

Biosecurity

Antibiotics

Vaccines

Probiotics

Kill infected livestock

Other suggestions (pieces of paper provided for the informant)

Prompts for moderator: Why X as the best, why Y as the least good? Does this ranking make sense to you? Why/not? Ask about the placement of vaccines.

The ranking is left on the table, next to the ranking of the animal welfare issues.

- Now we have two rankings. One, where you have ranked animal welfare issues and one, where you have ranked health strategies. Are there any of the health strategies which is in conflict with your ideas about animal welfare?

    - Why/not?

    - What about the vaccines?

C. Different types of vaccines

Purpose: To study the informant's perception of risk in relation to different forms of vaccines.To study the informant's justifications for her or his risk perceptions. To study the informant's perception of the usefulness of synthetic animal vaccine.

- Are there any risks related to the use of vaccines for farm animals?

    - For the animals?

    - For the consumers?

    - For the environment?

- I have three descriptions of different animal vaccines here. I would like you to rank them from most safe to least safe:

Written descriptions for the informant:

a) Some vaccines are based on small amounts of weakened or dead microorganisms that cause disease.

b) Some vaccines are based on a genetically modified version of the microorganism which causes the disease. That means that only a protein or something similar from the microorganism is in the vaccine.

c) Some vaccines are based on genes that are made artificially in the laboratory. They are called synthetically engineered vaccines. The genes resemble the microorganism that causes the disease.

Prompts: Why do you consider this one the safest? Why do you consider this one the least safe? What about from the animals' perspective? What about the consumers' perspective?

- Does a ranking like this even make sense to you? Why/why not?

Keep the ranking on the table.

- Have you ever encountered examples of vaccines that you found too risky to use?

- Why?

- Have you ever encountered vaccine research projects that you didn't think should be completed because it sounded too risky?

- Why?

- Let's look at the ranking again. I asked you to rank the vaccines from most safe to least safe. But what if you have to rank from most important to use in farming to least important. How would the ranking then look?

Prompts: Does this question even make sense to you? Why is x the most important? Why is y the least important?

- Have you ever encountered vaccines on the market that you found unnecessary for maintaining animal health?

- I have a description of a vaccine, which is under development. I'm reading the description aloud and afterwards we are going to talk about it.

Description of MycoSynVac:

A group of scientists are developing a universal Mycoplasma chassis to be used in a pipeline to vaccinate farm animals against Mycoplasma species. By genome comparison, metabolic modelling and rational engineering of the M. Pneumoniae genome, the scientists will create a vaccine chassis to be introduced into an industrial pipeline.

Description of the vaccine is left on the table.

-Do you think it can improve animal health? Why?

- Can it improve animal welfare? Why?

- Can it improve food safety? Why?

D Benefits and downsides

Purpose: To study the informant's perceptions of who is benefitting from developing a synthetic vaccine for farm animals – and who will be subject to eventual downsides. It is the informant who decides what is meant by 'benefits' and 'downsides'.

- Looking at a vaccine as the one I just described. That's a synthetic vaccine. What are the advantages of synthetic vaccines in your opinion?

    - can you think of any downsides?

    - If a vaccine like that is introduced to the market, who will benefit from it?

I have five suggestions here:

(pictures)

Cow

Consumer

Owner of medical company

Scientist

Farmer

A blank sheet where new suggestions may be written

- Are there any of them who will be subject to any downsides due to the vaccine?

(if the informant looks bewildered, suggest: risks, price, health, etc.)

E. Regulation

- Who, in this country, are overseeing the safety of animal vaccines?

- Is that a sufficient way of controlling vaccines?

- Do you think there is a need for extra government regulation of synthetic vaccines to ensure safety?

- Why/not?

- Sometimes I get the impression that scientists may see government regulation as a barrier to innovation – do you agree with that viewpoint?

3- Have you ever been special precautious in your work with vaccines due to risk? How/Why?

- Are you familiar with the precautionary principle? Have you worked with it?

F. Outro

I think that's all for today. Thank you so much for letting me take your time. I can send you our papers as they get published. You can also see mycosynvac.eu for more information.