Seeding Moral Responsibility in Ownership
How to Deal with Uncertain Risks of GMOs

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Seeding Moral Responsibility in Ownership

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How to Deal with Uncertain Risks of GMOs

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Contents

To my family Sonia, Philippe, and Alexandre

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1 Introduction

1.1. GMO OMG![1]

One could argue that agriculture represents one of the earliest human endeavours to use technology to tame natural life for its benefits. This taming has increasingly specialised through history, as technology developed from the construction of tools, to scientific knowledge utilized for breeding new seeds. Today, some of this taming of nature is considered traditional, or even, natural, while other ways of taming nature fall in the realm of biotechnology and are considered unnatural (cf. Thompson 2007a, p.21-22; Van den Belt 2009). As a field, biotechnology comes with a specific range of paradigms and techniques that differ from what is referred to as conventional methods. With the advent of modern biotechnology, the genome is being considered as a sequence of information that can be re-arranged for achieving desired goals.

There are at least two types of ethical issues when considering the use of biotechnology in agriculture: fundamental ones, and practical ones. Fundamental issues concern philosophical questions regarding what life is and what humans can or cannot morally do with it. This thesis will not address these issues although they do underlie many of the disagreements when considering biotechnology applications. Instead, this thesis will focus on the practical issues with a focus on the domain of agriculture and food. For instance, instead of asking whether we should allow the use of modern biotechnology, this thesis looks at how we should use modern biotechnology.

The use of biotechnology in agriculture and food related applications is often presented as having the goal of feeding the world. Also, agriculture is strongly engrained in culture, and with modernity; agriculture has become a scientific and technological endeavour, be it through genetics, advanced harvesting machinery, or new ways of farming such as hydroponics and precision farming. This provides a fertile ground for an investigation in the ethics of technology.

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1 This is a reference to my colleague Virgil Rerimassie who was interviewed on radio and this quote made the final cut, representing the continued media attitude towards genetically modified organisms. It is also the title of a 2013 movie GMO OMG by Jeremy Seifert.

Researching how to develop new food has slowly moved from the land to the laboratory with the advent of modern biotechnology. The promises of seeds with better yields, more efficient water use, less pesticides, better nutritional content, and even pharmaceutical properties: biotechnology offers the potential to greatly enhance human and environmental health (see Hansson, 2014 for an exhaustive overview of these beneficial applications). With all these positive uses, what is there to worry about?

In fact, the list of oppositions might be even longer than the list of benefits. Some notable rejections of biotechnology in food include the refusal of Zambia to receive genetically modified organisms for food aid while in a food crisis (BBC News 2002), and Filipino farmers destroying experimental fields of Golden Rice (McGrath 2013), a vitamin A enhanced rice, claiming they did not want the Golden Rice as a solution (Tickell 2014). So if these technological advances are so good, why do those who would seem to need them the most reject them? Thompson (2007a) disentangles the many issues of opposition to the use of biotechnology in agriculture and explains where they stem from. Some of the issues Thompson mentions are food safety, the ethical significance of the environment, socio-economic impacts and social justice, impacts on farms and farm communities, shifting power relations and intellectual property.

Currently, discussions around the use of modern biotechnology in agriculture are very polarized. Some believe these technologies will eradicate world hunger and enhance global health[2], while several civil society organizations, local and global, militate against them. This thesis in ethics of technology aims to create a space for discussion between these extreme positions. Indeed, Hansson underlines that, “Many technologies can be used in a large number of different ways, some of which may be beneficial and others harmful. If current uses of a technology have adverse effects, the solution may either be to stop using the technology or to ensure that it is used in better ways” (Hansson, 2014, p.67). This observation comes to no surprise for people in the field of ethics of technology, or science and technology studies but it is a very important one that underlines the general aim of this thesis. In addition, what the field of ethics of technology can add to the discussion is the issue of design.

[2] In Summer 2016, Nobel Laureates wrote a letter slamming Greenpeace for their campaign against GMOs (more precisely the Golden Rice), calling opposition to the Golden Rice a crime against humanity (Support Precision Agriculture).

Indeed, we can integrate values in the design or in other words, design for certain values. These are the fundamental issues that this thesis will touch upon.

Before continuing this introduction and further revealing to the reader the exact intent of this work, I would like to make a distinction on the use of terms. In these first lines, I have used the term 'use of modern biotechnology in agriculture and food', because there are many varied uses that fall under this label. However, the discussions and controversies are often on the term of 'GMOs', i.e. genetically modified organisms. This is also the label used in regulation of these technologies. This is what the popular expression GMO OMG refers to, read, 'genetically modified organisms, oh my God!' [3] underlining all the controversies and range of reactions around the use of GMOs. When looking at the debates, we can differentiate different fields of applications with GMOs. Most of the mainstream controversies revolve around genetically modified organisms, and what people are actually talking about are the main crops of rice, maize, cotton, and others, that are the yield of genetically modified seeds. Therefore, in this thesis, for the sake of precision, I will refer to genetically modified (GM) seeds, or GM seeds, instead of the broader but more common term of GMOs. GM seeds are one instance of GMOs and they are the focus of chapters 2,3, and 4. I also have a case with a food sensor resulting from genetic engineering, which is also considered a GMO, described in chapter 5.

1.2. Why do we need an ethics of technology account for GM seeds?

The debates around GM seeds are not new (Wynne, 2001) There are already many important accounts describing their dynamics and problems such as Jack Kloppenburg's *Political Economy of the Seed* (1988), or Paul B. Thompson's *Food Biotechnology in Ethical Perspective* (2007b), Vandana Shiva's *Stolen Harvest* (1999), and several other important articles by STS scholars. These accounts have inspired this thesis to a great extent, as they describe social, legal and economical processes in the use of GM seeds.

Despite the scholarship on the matter, controversies have continued to stagnate, and positions have crystallized. For instance, the rift in attitudes and in regulations between the US and the European Union (Ramjoué 2007) has had implications in the developments and regulations of GM seeds. Due to strict

3 Referring to the 2013 movie GMO OMG by Jeremy Seifert.

regulations in the European Union, some agro-chemical companies have moved their developments to the other side of the Atlantic (Laursen 2012). Problems therefore change place, but are not resolved.

Which of these regulations is appropriate? Or rather, how can we regulate new technologies with uncertain risks? This is one of the questions addressed by the research project in which I undertook my thesis, but I will return to this later. GM seeds can pass existing regulatory risk assessments, but many of the worries stem from uncertain and unknown consequences that are both physical and societal. Regulation becomes a field of experimentation (Millo and Lezaun 2006; Levidow and Carr 2007) where dealing with uncertain risk presents a challenge to how regulatory institutions normally function (van Asselt and Vos 2008). These effects are also more likely to appear on the long run, and as use of GM seeds will become more prominent. In addition, not all GM seeds are the same. Different types of modifications might call for different types of concerns.

In the scholarship on the ethics of risk, asking questions such as how to deal ethically with risk imposition, risk taking, and risk management have been an issue of investigation (Hayenhjelm and Wolff 2011). More recently, the field has started to turn to questions of uncertainties and ignorance. One definition of the term risk is "known probabilities of expected events" (cf. Felt et al 2007). This allows one to deal with them to the best of one's knowledge. However, uncertainty and ignorance both remain a field of struggle, as they represent, respectively, unknown probabilities of expected events and things we just cannot anticipate (ibid.). How shall one act when neither the consequences nor the probabilities of one's action are known? This question has been troubling our modern times as it points to the limits of knowledge and to the unintended consequences technologies may have – technologies that are supposed to make our lives better. GM seeds are one of many examples of this tension.

When dealing with uncertainties, several approaches have been discussed in the literature. For instance, Thompson lists cost benefit analysis, the precautionary principle, and facilitating consumer choice through labels as approaches (2007c). There are, however, problems with these approaches. Cost-benefit analyses cannot deal with uncertainties, there are a plethora of problems with applying the precautionary principle (Sunstein 2003) and labelling and autonomy is problematic (see for instance Spruit et al 2016 on asymmetries in informed consent). Other approaches are adaptive management and participatory technology assessment as other venues of dealing with uncertainties but they also have their issues (see for instance Robaey and Simons 2015).

So it seems there are ways to deal with uncertainties but none of them is satisfactory. This is where the ethics of technology can come to support the debate on how to deal with uncertain risks of GM seeds. Those uncertain risks concern possible impacts on human health, on environmental health, on social justice, just to name a few. Throughout this thesis, a few of these uncertain risks will be discussed in specific cases. It is difficult to provide an exhaustive list of what these uncertain risks might be since they might differ between GM seeds and between contexts. This is why I will refer to these uncertain risks more generically. If we look at the recent history of introducing new technologies in society, we see how technological interventions in society have had major unintended negative impacts. Just to name a few: the Bhopal disaster, Chernobyl, and more recently Fukushima, or the mad cow disease. Climate change is another even more systemic example of how engineering decisions shape socio-technical systems that may have terrible consequences for humanity at large, although they were not to be predicted.

In recent years, the scholarship on engineering ethics has made important contributions to the concept of moral responsibility by reflecting on such events. Who are we to blame for these events? Who should or could have prevented them? And how can we make sure they do not happen again? With the increasing complexity of technologies, issues of moral responsibility have also become more difficult to evaluate. I will introduce the reader to the differences in definitions of moral responsibility in this introduction and throughout this thesis. For now, it suffices to say that ethics has brought a radical change in how medicine was practiced after the cruel experiments during WWII and even later in the US with the Tuskegee syphilis experiment. The medical field is now a well-defined profession, and the issue of moral responsibility of physicians to their patients has been institutionalised. The introduction of technologies in society can be compared to a medical intervention that bears potential benefits but also harms. Engineers, therefore, also have a responsibility to society, that their inventions or interventions do not harm people. This thesis contributes to the field of ethics of technology by making novel suggestions outlined in the coming pages.

1.3. Moral responsibility in the social experiment with GM seeds

In this thesis, there are four main concepts in ethics that underlie the research presented:, the social experiment, moral values, moral responsibility, and epistemic virtues. Here, I provide a brief overview of these issues, as they set the stage for this investigation. In the chapters of this book, each of these concepts is discussed in greater depth.

1.3.1. The Social Experiment[4]

It has been argued that the introduction of new technologies in society takes the form of social experiments (cf. Martin and Schinzinger 1983; Krohn and Weingart 1987; Krohn and Weyer 1994; Levidow and Carr 2007; Jacobs et al. 2010; Van de Poel 2011, 2013b, 2016). The argument is based on the observation that the outcomes of technological innovation processes cannot fully be apprehended beforehand. Whether and how a new technology works and which side effects it has can only be determined in practice. Learning about the functioning of new technologies thus takes place under real-world conditions and implies a trade-off between potential gains and harmful side effects. This is problematic in so far as potential failures and harmful side effects of new technologies cannot be contained within safe boundaries, as in classical laboratory experiments. Instead, such side effects are felt directly by the society into which the technology is introduced – sometimes even by more distant societies, as the case of Chernobyl has demonstrated. Introducing new technologies into society therefore raises a number of ethical concerns, but conceiving of these processes as social experiments also allows developing new perspectives on how to deal with potential harmful side effects.

Why do we need to talk of social experiments, or social experimentation when talking about introducing new technologies in society in the first place? Living in a techno-scientific world means that science and technology have, on the one hand, helped to solve major problems and brought about great benefits to societies, and on the other hand, have created a whole range of new problems. And since many of these new problems are unknown until they occur, the term social experiment is justified when talking about the introduction of new tech-

4 Part of this section is an excerpt of Robaey and Simons 2015, written by the author of this thesis.

nologies in society. Knowledge of the real impacts of technologies can often only be gathered after or during introducing that technology into society. Many debates could be had on the use of the word experiment here, but its meaning can simply be understood as to do or to try something with the aim of learning about its effects. The notion of 'social' experimentation denotes the situation that the experiment is carried outside a laboratory, in society that is.

Given the problems underlined above about GM seeds, it is easy to make the case that the introduction of GM seeds in agriculture can be conceived of as a social experiment. This will also be expanded upon in the pages of this book, especially in Chapter 3.

The concept of the social experiment does not only entail that uncertainties and ignorance will reveal themselves as technology is used in practice. It also means that we are consciously taking chances with new technologies. We want to do social experiments because we strive to minimize negative side effects. Considering the introduction of new technologies in society a social experiment, allows making adjustments and minimizing unwanted side-effects. At the crux of the experiment is the realization of the limits of knowledge and the recognition of things that are uncertain and ignored and therefore need to be learned about and corrected for, as the experiment unfolds. In this context, Van de Poel (2011; 2013b; 2016) suggests a set of conditions for morally responsible experimentation (see Table 1.1) and describes how these conditions all relate to moral principles. Principles are here understood at the rules that derive from moral values.

Table 1.1
An ethical framework for experimental technology (Van de Poel, 2016)

1	Absence of other reasonable means for gaining knowledge about risks and benefits
2	Monitoring of data and risks while addressing privacy concerns
3	Possibility and willingness to adapt or stop the experiment
4	Containment of risks as far as reasonably possible
5	Consciously scaling up to avoid large-scale harm and to improve learning
6	Flexible set-up of the experiment and avoidance of lock-in of the technology
7	Avoid experiments that undermine resilience
8	Reasonable to expect social benefits from the experiment

9	Clear distribution of responsibilities for setting up, carrying out, monitoring, evaluating, adapting, and stopping of the experiment
10	Experimental subjects are informed
11	The experiment is approved by democratically legitimized bodies
12	Experimental subjects can influence the setting up, carrying out, monitoring, evaluating, adapting, and stopping of the experiment
13	Experimental subjects can withdraw from the experiment
14	Vulnerable experimental subjects are either not subject to the experiment or are additionally protected or particularly profit from the experimental technology (or a combination)
15	A fair distribution of potential hazards and benefits
16	Reversibility of harm or, if impossible, compensation of harm

1.3.2. Moral values[5]

In the context of this thesis, I understand moral values as values that represent societal goals, and as such, they give a desired direction to the social experiment. I will not go into the debates on value theory but will rather take on a definition that underlines that values are good and desirable states of affairs (for a recent and complete discussion of value theory, see Schroeder 2016). Moral values are important because they allow a fundamental, shared, and stable base for moral judgment. In fact, important institutions rely on moral values, such as the Treaty of Lisbon, which emphasizes freedom, equality, and democracy, among many others, as core values. With questions of new technologies, values can serve as guideposts for acting in the face of uncertainty. If we cannot know or anticipate everything, then at least we can act according to a set of moral values that make our actions responsible. This need for morally responsible action also takes an increasingly important place in research and development as the recent agenda for responsible research and innovation (RRI) within the European Union shows. But what other values might be important for dealing with uncertainties? Also, how can these values be designed into the technology (Van de Poel 2013a; Van de Poel and Kroes 2014)? These are some of the issues explored in this thesis.

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5 Part of this text is an excerpt from Robaey and Simons 2015, written by the author of this thesis.

1.3.3. Epistemic Virtues

Another important notion that comes in the context of the social experiment, and that I will suggest as an addition to understanding the social experiment, is epistemic virtues. Epistemic virtues are virtues that an agent might possess and develop in order to learn, reflect and become wiser. Virtue epistemology is a complex field with different schools of thought. This thesis will not engage with the virtue epistemology debates. Rather, the notion of epistemic virtues will help define moral responsibility in the social experiment. In this thesis, we only consider the virtue responsibilists, which consider the development of virtues as traits (Greco and Turri 2015). Examples of such virtues are impartiality, intellectual courage, and community (Montmarquet 1987). It is important to note that some scholars such as Greco (2000) claim that these types of virtues are neither necessary nor sufficient for knowledge. In this work, epistemic virtues are not considered truth-conducive but rather responsibility-conducive.

1.3.4. Moral Responsibility

The term responsible appears many times in the previous sections, but what does moral responsibility mean? For instance, if an agent were fulfil all of Van de Poel's conditions for morally responsible experimentation (2011; 2013b; 2016), would it then mean that she is responsible? The issue of moral responsibility is more complex than that. Indeed, in its broad formulation, moral responsibility is defined as 'an agent X is responsible for φ'. Within this broad definition, there are several ways to define moral responsibility. Van de Poel and colleagues (2015) provide for a typology of moral responsibilities making distinctions that will become helpful in the analysis. Details of this typology are explained in the chapters of this book and will be expanded upon. For the moment, it suffices to underline that the type of moral responsibility that is mostly at stake here is a forward-looking one, also called active responsibility. There are quite some recent developments in ethics with regards to this type of responsibility but there is still a lot to be discussed with regards to what these forward-looking responsibilities entail. Forward-looking moral responsibility contrasts with accounts of backward-looking moral responsibility, which look into whom bears what kind of blame and why when things go bad, but also who deserves praise when things go well.

Considering the need for further clarification with regard to what moral responsibility means, it is only fair to argue that each of the conditions presented by Van de Poel call for discussing what kind of responsibilities should be bestowed upon whom. It is one of his conditions to have a “clear distribution of responsibilities for up, carrying out, monitoring, evaluating, adapting, and stopping of the experiment”. But what type of responsibility is being referred to in this condition? This condition calls for more investigation, but so do other conditions. One condition that will be particularly under investigation in this thesis is the condition on “fair distribution of potential hazards and benefits”. This condition is important because those who benefit from new technologies are not necessarily those who are exposed to their hazards. In order to rectify this imbalance, I suggest looking at how responsibilities are allocated and distributed amongst those who benefit from them. One avenue to do so is to look at ownership.

Who makes decisions in the social experiment? And for whom? Who decides what the new technologies are that we are going to develop and for what goals do we develop them? Social experiments are labeled as such because they take place in society, but are they ‘social’, as in *for* society? This suggested framework is meant for technologies with great potential benefits for society, and if it were to be translated to the policy world it would imply that new technologies would actually come to create these great benefits for society. For now, this framework only provides an analytical lens and allows us to ask, that if society does indeed benefit from a new technology, then who actually benefits from it first and foremost? Are the benefits fairly distributed? Who makes these decisions?

These questions underline that more specification is required in order to allocate various responsibilities. This is where the focus of this thesis comes in: ownership of GM seeds. First, the focus on ownership plays an important role in the distributions of risks and benefits. Second, in this thesis, I will argue that ownership entails moral responsibility.

1.4. Owning GM seeds and their uncertain risks

Inspecting the landscape of GM seeds today, it is striking that questions of ownership are at least as problematic as questions of uncertainties. If we look at the journey of a GM seed, it starts by being developed in a laboratory that quite often will be part of a private company, or in collaboration with a private company (for instance see Jefferson et al. 2015 on how patents play out in agriculture). These actors will then go on to secure intellectual property rights on the GM seed, and run it through the regulatory process that will eventually allow its commercialization to farmers if all conditions are met.

While the experiment takes place in society, it starts in the private realm, with investments and expected returns. The protection of the invention through intellectual property rights is said to be a driver for innovation. In addition, ownership rights are the main tool used to distribute economic benefits. This is especially true for the case of GM seeds. Indeed, Buttel and Belsky (1987, p.32) point out that "Intellectual property statutes enable an individual seed company to develop new knowledge and products that can be denied to competitors. Thus, a seed company will have a greater incentive to develop new plant varieties than would otherwise be the case if there were no intellectual property restrictions." Since then, this belief has been disputed in the field of biotechnology (see for instance objections in Timmerman 2015). Buttel and Belsky also underline that the commercial and private nature of this enterprise require ethical and socio-economic assessment. Indeed, this private enterprise underlines rights but not responsibilities.

As mentioned earlier, one of the conditions of the social experiment that will guide this investigation is the fair distribution of risks and benefits. Since we were just considering private ownership of GM seeds as a means to protect and distribute benefits, one direction of investigation would be to assess whether this distribution is fair. However, from a moral point of view, the distribution of benefits cannot be considered without the distribution of risks. Indeed, one might expect some rectifications or adjustments that might be needed in order to strike a balance between risks and benefits.

Speaking of risks for approved GM seeds is, however, only the tip of the iceberg; GM seeds are complex because of their uncertainties. Uncertainties and risks, however, cannot be distributed in the same way that benefits are. Also, uncertainties are bound to a certain context, which might prove to have different kinds of vulnerabilities and ask for different measures given the GM seed and the place. What can be distributed, however, are the forward-looking moral responsibilities to the different actors involved in the social experiment. The distribution of risks should therefore in our case be rephrased as the distribution of forward-looking moral responsibilities for uncertainties.

Connecting the idea that benefits are distributed through ownership rights, to the idea that we should distribute forward-looking moral responsibilities for uncertainties is the main aim of this thesis.

In the literature, there are two proposals I have found making this relation, although not with the same aim. A recent proposal suggests using the iGEM competition as a testing ground for when to grant intellectual property rights and how this can foster responsible research and innovation (König et al. 2015). This proposal, however, gives no working definition of what responsibility means, and leaves a lot of questions to be answered empirically, instead of providing an ethical compass. Another, older, proposal from a legal scholar, appends a 'duty to do no harm' to a bundle of property rights (Honoré, 1961). This last notion will become a building block for the rest of this thesis.

This leads me to elucidate for the reader some differences in terminology. What is ownership, or property? What are ownership rights, or property rights? There are different schools of thought looking at ownership and depending on whom you talk you, you would get different answers. Let's begin with the most commonly used notion of ownership in the realm of GM seeds, meaning intellectual property rights. These are rights that grant exclusivity to the inventors setting the condition for how, by whom, and for how much, i.e. licensing, other agents may use the product of their labour. This is a very narrow understanding of what owning might mean that does not open doors for connecting the idea of owning to the idea of responsibility.

Busse and Strang (2011) report that the 1967 edition of *Notes and Queries on Anthropology* defined ownership as the "sum total of rights which various persons or groups of persons have over things; the things thus owned are property" (1967, 148-9). This coincides with a constructive notion of ownership as presented by legal scholar Honoré, with his description of the bundle of rights and his idea of split ownership. There is therefore a sense that when ownership is conceived of in a broader sense it allows two things: one being that several actors can own a thing, or copies of a thing, and that this ownership may differ in terms of the sum of their rights over the thing. In addition, anthropological accounts of ownership conceive of it as a relation between people and things. This is also found in psychological literature with regards to having a feeling of ownership over a thing (Pierce et al. 2003).

These definitions allow speaking of forward-looking moral responsibility for uncertainties of GM seeds, and relating it to the agents who decide to develop and/or use GM seeds for a perceived benefit. By exploring and defining this relation, my aim is to make a contribution to the field of ethics of technology and the literature on moral responsibility on the issue of moral responsibilities of owners for technologies with uncertainties. My research uses GM seeds as a ground for investigation.

1.5. Research questions and approach

Let us recapitulate the above depiction for the sake of clarity. GM seeds are technologies with uncertainties that are very controversial. Owners choose to develop and use them to because they expect benefits from them. We can understand these owners to be starting a social experiment with GM seeds since they spread in society, and they bring along uncertainties. It is important to keep in mind that the impetus of this research lies in the uncertainties of GM seeds. It is all the things we do not know about them that justify using the lens of the social experiment.

The main research question of my thesis is therefore: *what are the forward-looking moral responsibilities of owners in the social experiment with regards to uncertainties of GM seeds in order to deal with their uncertain risks?*

In order to answer this question, a few steps ought to be followed.

A first sub-question that guides this investigation is: *what is the relation between ownership and moral responsibility for uncertainties of GM seeds?*

In this introduction, hints of a relation between these two concepts were given but not elaborated upon. With the use of a conceptual analysis, 'Chapter 2: Looking for moral responsibility in ownership: a way to deal with hazards of GMOs' explores and specifies this relation. Here, clarifications on the bundle of rights and on the definition of moral responsibility are key to establishing this relation.

Once this relation is established, a second sub-question must be answered, namely, *what is the nature of the moral responsibility of owners for uncertainties of GM seeds in the social experiment?*

Indeed, it does not suffice to say that there is a relation between owning and being responsible. It is of utmost important to clarify what this responsibility exactly means in the social experiment. This is important because there are many definitions of moral responsibility, and they do not exclude each other, but in order to address the problem of uncertainties of GM seeds, we need a definition of moral responsibility that does that. To that end, 'Chapter 3 Gone with the Wind: conceiving of moral responsibility in the case of GMO contamination' explores what it is that makes owners responsible, how and why this responsibility may vary between different types of owners. In order to do so, I use the problematic case of GMO contamination that creates a tension with the ideas presented in that Chapter 2. Using a problematic case allows defining moral responsibility in a way that is useful to many cases for the uncertainties of GM seeds.

A further step is to ask if ownership can be transferred*, what does this entail for the transfer of moral responsibility for uncertainties of GM seeds*?

'Chapter 4: Transferring moral responsibility for genetically modified seeds' outlines when this transfer can be called a good transfer of moral responsibility. This conceptual analysis draws on the literature on use plans from the philosophy of design, and makes an adapted suggestion to the one of Pols (2010) on how to transfer moral responsibility through use plans. In addition, a case study on the Monsanto Technology Use Guide, and Technology/Stewardship Agreement allows underlining limits and opportunities of current practices in transferring moral responsibility.

Finally, looking at recent developments in the field of biotechnology where the idea of Safe-by-Design has gained popularity, I ask: *what does Safe-by-Design in SynBio mean for issues of uncertainties and moral responsibility*?

Having established a number of concepts with regards to moral responsibilities of owners for uncertainties of GM seeds, we study the hypothetical case of a synthetic biology application in food packaging, where principles of Safe-by-Design are put in practice. This case extends the idea of responsibility to design as well as use, as opposed to earlier chapters that focussed mostly on use. As mentioned in the beginning of this introduction in 'Chapter 4: The Food Warden: an Exploration of Issues in distributing Responsibilities for Safe-by-Design Synthetic Biology Applications' we reflect on the results of a Group Decision Room.

1.6. Overview of Chapters

Chapter 2: Looking for Moral Responsibility in Ownership: A Way to Deal with Hazards of GMOs

Until now, the debates around genetically modified seeds in agriculture have converged towards two main issues. The first is about hazards that this new technology brings about, and the second is about the ownership of seeds and the distribution of their economic benefits. In this paper, I explore an underdeveloped topic by linking these two issues: how ownership shapes the distribution of moral responsibility for the potential hazards of genetically modified seeds. Indeed, while ownership is debated in terms of economic rights and hazards in terms of “good” or “bad” science, no one has looked at whether or not we could and should ascribe and distribute moral responsibility for hazards based on ownership of genetically modified seeds. I argue that we should. Using the notion of ownership as a bundle of rights, I argue that from a moral perspective, the genetically modified seed has several owners at the same time. Although different owners may not have the same economic rights over the seed, they all have a moral responsibility, possibly to varying degrees, for the potential hazards brought about by the seed. Secondly, I argue that, as long as a seed carries the character trait that was intentionally modified, then it calls for moral responsibility. All in all, I formulate a way for linking issues of ownership and hazards of genetically modified seeds in agriculture through the concept of moral responsibility.

Chapter 3: Gone with the Wind: Conceiving of Moral Responsibility in the Case of GMO Contamination

Genetically modified organisms are a technology now used with increasing frequency in agriculture. Genetically modified seeds have the special characteristic of being living artefacts that can reproduce and spread; thus it is difficult to control where they end up. In addition, genetically modified seeds may also bring about uncertainties for environmental and human health. Where they will go and what effect they will have is therefore very hard to predict: this creates a puzzle for regulators. In this paper, I use the problem of contamination to complicate my ascription of forward-looking moral responsibility to owners of genetically modified organisms. Indeed, how can owners act responsibly if they cannot know that contamination has occurred? Also, because contamination creates new and unintended ownership, it challenges the ascription of forward-looking moral responsibility based on ownership. From a broader perspective, the question this paper aims to answer is as follows: how can we ascribe forward-looking moral responsibility when the effects of the technologies in question are difficult to know or unknown? To solve this problem, I look at the epistemic conditions for moral responsibility and connect them to the normative notion of the social experiment. Indeed, examining conditions for morally responsible experimentation helps to define a range of actions and to establish the related epistemic virtues that owners should develop in order to act responsibly where genetically modified organisms are concerned.

Chapter 4: Article title: Transferring moral responsibility for technological hazards: the case of GMOs in agriculture

The use of genetically modified organisms in agriculture makes great promises of better seeds, but also raises many controversies about ownership of seeds and about potential hazards. I suggest that owners of these seeds bear the responsibility to do no harm in using these seeds. After defining the nature of this responsibility, this paper asks, if ownership entails moral responsibility, and ownership can be transferred, then how is moral responsibility transferred? Building on the literature on use plans, I suggest five conditions for a good transfer of moral responsibility for genetically modified seeds. I also look at the Monsanto Technology Use Guide and Technology/Stewardship Agreement, as an examplar of a use plan, to explore the extent to which these conditions are present. I conclude that use plans can play a role in the distribution and transfer of moral responsibility for technologies with high benefits and potential harmful uncertainties.

Chapter 5: The Food Warden: an Exploration of Issues in distributing Responsibilities for Safe-by-Design Synthetic Biology Applications[6]

The safe-by-design approach in synthetic biology holds great promises. On the one hand, safe-by-design aims to design an artefact for the value of safety. On the other hand, synthetic biology aims to use building blocks of the genome to design biological machines that can fulfil a particular purpose. These two concepts combined seem to pave a new way for using biotechnologies. However, safe-by-design moves the bulk of the responsibility for safety to the actors in the research and development phase. Also, it assumes that safety can be clearly defined and understood similarly by all stakeholders. These assumptions are

[6] This paper was co-authored with Ibo van de Poel and Shannon L. Spruit. While the set-up of the research and collection of data was the result of a common effort as was the discussion about the findings, I took the lead in the write-up of the paper. All sections are written by myself besides the methodology section and the section on proximal vs distal causes.

problematic and actually undermine the achievement of safety. Our research explores these assumptions through the use of a Group Decision Room. In this set up, anonymous and non-anonymous deliberation methods are used to get different stakeholders debate issues and share their understandings. During the session, we investigate a potential synthetic biology application, the Food Warden, a biosensor contained in meat packaging that indicates freshness of meat. We discuss what potential issues might arise, how responsibilities should be distributed in a forward-looking way, who is to blame if something would go wrong and we take a broad view by looking at the journey of the bio-sensor and asking what safety and responsibility mean at different phases, and for different actors. The results of the session are not generalizable, but provide valuable insights. We find that issues of safety cannot all be taken care of in the design phase. Also, when things go wrong, there are proximal and distal causes to consider. We also see that capacities of actors play an important of instruction manuals and their role in achieving safety.

2 Looking for Moral Responsibility in Ownership: A Way to Deal with Hazards of GMOs[7]

2.1. A Constructive Proposal

The discussion about genetically modified organisms (GMOs) has been revolving around issues of risks and issues of ownership. The only way these two issues have been linked in law and policy are through the concept of liability for damages, i.e. people planting GMOs can be held liable for damages to organic farmers harvest in the European Union (EU) (c.f. Koch 2007) or internationally for any "possible damage caused by the imported GMOs" by the exporting party (Kuala Lumpur–Nagoya Supplementary Protocol 2011). In the case of the EU, the notion of damages is very specific; it applies to organic produce that would lose their certification in cases of contamination with GMOs. In the case of the Nagoya Protocol, the term possible damage is much more encompassing, but also loosing specifity by speaking of "adversely affect the conservation and sustainable use of biological diversity, taking also into account risks to human health." (ibid.). The underlying idea, in plain English, is that if one brings in something that has potential risks for other things, one must take measures to prevent those risks, or else one will be held liable for damages caused by one's property. While there may be a range of legal provisions for this in different countries, most of these provisions, as shown with the examples above, apply to liability. Liability is, however, only one application of moral responsibility, which is a backward-looking one (Van de Poel 2011b), i.e. an owner can be held responsible if the thing she owns has *already* caused harm. In this paper, I aim to expand the horizon of the link between moral responsibility, risk and ownership by exploring *why* and *how* ownership calls for forward-looking moral responsibility, i.e. a proactive moral responsibility for harms that have not *yet* happened.

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Van de Poel and Nihlén Fahlquist (2013) argue that the relation between risk and moral responsibility has been surprisingly understudied. An interesting observation they make with regards to forward-looking moral responsibility is that it is often linked to decisions and control, i.e. in the case of GMOs, the decisions of several actors to produce and use genetically modified seeds. Moreover, Nihlén Fahlquist (2006) argues that there are two values at stake in ascribing moral responsibility: effectiveness and fairness, which are respectively associated with consequentialist and non-consequentialist understandings of moral responsibility. She also argues that we need not choose one value over the other, but that ascribing moral responsibility is about striking a balance between these values.

In order to establish the link between ownership and moral responsibility for hazards of genetically modified seeds in agriculture, one sees that there is a decision involved, and that from the perspective of fairness, moral responsibility should be assigned to those who take these decisions. In other words, it is reasonable to expect an owner who will have benefits from its property to also have duties and responsibilities. For instance, a company developing and selling genetically modified seeds, and a farmer planting and harvesting them, all do so because they expect benefits from the seed. It is, therefore, reasonable to expect that these actors be given special duties or responsibilities in regards to their activities (or decisions). It is important to note that these observations could very well apply to other ways of creating new varieties of seeds, however, GMOs being considered novel organisms, in most countries, call for special measures, whereas conventionally bred seeds do not. I will not address the legitimacy of such differentiation here. What is important to observe, is that according to legislation in several countries, this novelty raises suspicions of risks. While the literature mostly speaks of risks, this paper seeks to extend the link between moral responsibility and risk to moral responsibility and uncertainties as well as ignorance. Uncertainties are known events with unknown probabilities, and ignorance describes things that simply cannot be predicted (c.f. Felt et al. 2007). In this paper, I focus on the value of fairness, i.e. why it is justified to ascribe owners of genetically modified seeds forward-looking moral responsibility. This is especially relevant in the case of genetically modified seeds where (1) there are several owners of the seed at the same time and (2) there are many uncertainties and ignorance linked to the use of genetically modified seeds. In this paper, I will show why this approach allows connecting debates, and defining a framework of shared moral responsibility that allows dealing with hazards of genetically modified seeds.

2.2. GMOs, Hazards and Ownership

There is not one, but several debates around GMOs, which, however, seem to converge towards two main issues: hazards and ownership. Both issues are also dependent on existing regulatory and legal institutions that do not seem to be able to keep up with the challenges GMOs bring. Also, I choose to speak of hazards, which include risks, uncertainties and ignorance.

2.2.1. GMOs and Hazards

Let us begin with hazards. GMOs, also nicknamed 'Frankenfoods' by certain critics (c.f. Van den Belt 2009 for a detailed overview of ethical issues in biotechnology), raise worries for environmental and human health as new organisms that are consumed by humans (or animals for eventual human consumption) and are planted alongside conventionally bred crops. To deal with these risks, different countries or regions have created ways to deal with them. Toft (2012) points out that, at the international level, governance of GMOs has two purposes: to set guidelines for safety and risk, and to facilitate free trade (p. 227). He outlines the guidelines that deal primarily with safety and risk, which are: (1) the Cartagena Protocol on Biosafety under the Convention on Biological Diversity, (2) the International Treaty on Plant Genetic Resources for Food and Agriculture by the Food and Agriculture Organization, (3) EU directives on deliberate release, labelling and traceability and (4) several national legislations. However, the ones that have as primary goal to facilitate free trade also contain measures regarding safety and risk. These are: (1) the World Trade Organization's (WTO) (a) Technical Barrier to Trade Agreement (TBT), (b) Sanitary and Phytosanitary Agreement (SPS), (c) the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and (d) Article XX of the General Agreement on Tariffs and Trade (GATT), and (2) The Food and Agriculture Organization's Codex Alimentarius. While Toft (2012) comes to the conclusion that these institutions allow for global justice claims to be made, he recognizes that they are attached to issues of risks and safety that are themselves more complicated. Indeed issues of hazards in GMOs remain very contested. In the EU, a de facto moratorium on GMOs was put in place between 1999 and

2004, while the EU was trying to agree on Directives to regulate them. No new GMO was approved during that period, which led to WTO disputes DS 291, 292, 293 initiated by the US, Canada and Argentina (WTO 2010). Through an historical analysis, Lynch and Vogel (2001) remark that

> While the EU has struggled to put into place a regulatory structure capable of adequately protecting the safety of food produced in fifteen Member States, each with their own regulatory institutions, and each Member State is attempting to upgrade its own regulatory institutions, the United States has in place a relatively well-established set of national regulatory bodies which appear to function reasonably well. In a sense, while the American regulatory structure underwent its baptism of fire, Europe's is only beginning to address the challenge of balancing scientific risk assessment with public confidence.

One could think that it is then just a matter of time until all regulatory bodies are up to speed and GMOs are safely regulated. However, the debates in the EU have raised serious questions on how to deal with the lack of full scientific knowledge. In addition, there are fervent opposing voices to GMOs, such as those from the ETC Group or the Third World Network. It is a struggle for policy makers to have to make decisions without having full information. Trying to elucidate this science/policy debate, Hansson (2008) distinguishes between theoretical and practical rationalities, i.e. what to believe and what to do, respectively. According to Hansson, the question of what to do is one that pertains to risk management for policy makers and "the task of scientists [is] to explain what science can and cannot do" (2008, p. 147). While this distinction is helpful to understand the limits of roles, Hansson also recognizes that this is not the case in reality. Indeed, Van Asselt and Vos coin this as the uncertainty paradox, "an umbrella term for situations in which uncertainty is present and acknowledged, but the role of science is framed as one of providing certainty" (2010, p. 282). Also, from a regulatory perspective, Levidow and Carr write, "These products have been put on trial also in the scientific-managerial sense, as regards what risks must be tested and managed, as well as what responsibilities should be assigned to agro-industrial operators." (2007, p. 409). There is still a lot to be debated with regards to the best way to deal with hazards. While Levidow and Carr describe the responsibility being shifted from the regulator to the agro-industry, Van Asselt and Vos describe the current way of dealing with uncertainty as one of organized irresponsibility. It seems that, even doing the best we can to responsibly tackle hazards of GMOs, there are limits to what we can do that are simply linked to limits in our knowledge. While institutions are set up to deal with risks, uncertainties and ignorance both remain unaddressed. This is where moral responsibility becomes important. Before going into more details on the role of moral responsibility, and in order to provide a constructive account of moral responsibility, I need to introduce the other pole of disagreeing opinions around GMOs that also lies within institutions—this time not regulatory ones, but legal ones.

2.2.2. GMOs and Ownership

The other problem with GMOs, discussed in the literature, is one of ownership, or property. A 2011 study by the ETC group on 'Who will control the Green Economy' reports that, "just three companies control more than half of the global commercial market for seed" (ETC 2011, p. 22). The concentration of ownership for genetically modified seeds has become more and more evident through a series of legal battles that have made the headlines since the late 1990s. These legal battles highlight the constant challenges that the current ownership system for genetically modified seeds is facing.

The first case to take prominence is the one of Percy Schmeiser, a Canadian farmer, who discovered that his field had been contaminated by RoundUp Ready Canola. He was found guilty of having seeds that he had not legally purchased (Monsanto Canada Inc v. Schmeiser 2001). Although this story does not end here, similar events have occurred elsewhere. For instance, farmers in Argentina have not been paying royalties to Monsanto after purchasing the first batch of RoundUp Ready Soybean, finding ways within national intellectual property laws to challenge Monsanto (Filomeno 2013), and now Monsanto is releasing a new version of its modified soy and putting a lot of efforts in writing up contracts that will uphold their economic rights. Recently, a US farmer, Hugh Bowman, lost a lawsuit against Monsanto in which he was defending the right of farmers to save seeds, including genetically modified seeds. The US Supreme Court upheld Monsanto's rights over the seeds as their property (Bowman v. Monsanto Co. et al. 2013).

In those cases, the problem is not that people are opposed to GMOs. To the contrary, they highlight how the institutions of property are changing agricultural practices. Seed saving, a very old practice, becomes illegal; contracts regulate which seeds may be harvested by whom and when. In the literature, these institutions are challenged but also often linked to the issue of bio-piracy, i.e. companies stealing traditional knowledge for applications in biotechnology. Challenging ownership structures is often seen in the context of opposing the use of biotechnology in agriculture. Risks, uncertainties and ignorance are then invoked. An interesting case that already links the issue of ownership to the issue of hazards is the pre-emptive lawsuit of Organic growers v. Monsanto. In this lawsuit, a coalition of 80 farmers sued Monsanto so that, in the event of contamination of their fields with GM crops, they would not be held responsible. The vocabulary in the lawsuit is very adamant that GMOs are bad and that these growers want to protect themselves, both from planting seeds they think are bad, and from having to pay royalties for using seeds they never wished to have in their fields (OSGATA 2011). This case suggests that those who choose to own, plant and harvest GM seeds expose others to hazards. Since GM seeds are perceived as bad by some, and good by others, and as we saw earlier, regulation does not seem to solve this issue, we can infer that there is a gap in dealing with hazards of GM seeds. Exploring the link between ownership and moral responsibility might provide for some answers concerning this gap. Indeed, instead of contesting ownership structures altogether, one may provide a more constructive account of how ownership could help dealing with hazards from GMOs.

As, Thompson writes

> In fact, owning property rights in such technologies may be instrumental to controlling and limiting their use. There may thus be legal grounds for recognizing a property right even when there are also compelling arguments to restrict a technology's use. Arguing that a technology is risky, harmful or downright evil is thus not in itself an argument against patents or other forms of intellectual property rights material to the technology. Nor is it clear that food and agricultural biotechnology would be stopped or even substantially slowed by an absence of such rights. (2007c, p. 254)

There is a link between the issues of ownership and hazards, but as Thompson writes, the presence or absence of property rights will not as such change the use and spread of GMOs, and will not change the lack of means to deal with uncertainties that might arise from GMOs. Also, GMOs in agriculture are a technology that has been around for the past 20 years and their use is only increasing; the problem of how to deal with their uncertainties remains. So far, a constructive discussion on how to deal with this problem from the perspective of moral responsibility is lacking. It is in this context that I formulate my proposal to link hazards and ownership through the notion of moral responsibility. While I will go in much more detail in the coming sections, I aim to refine the following formulation, which is the thesis I defend in this paper: *The owner of a genetically modified seed has moral responsibility for the hazards the seed might create.*

2.3. Ownership and Moral Responsibility

2.3.1. Conceptions of Ownership and the Bundles of Rights

I suggest that one can have moral responsibility for hazards potentially caused by a genetically modified seed that one owns. Before further expanding on this, it is important to position this argument within existing theories of ownership. The notion of ownership has existed for a very long time, and is linked to problems of justice, fairness, exploitation, etc. (for a brief yet comprehensive overview of property and ownership in philosophy, see Waldron 2012). In respect to biotechnologies, Thompson (2007c) summarizes these conceptions into two approaches: an instrumental one and an ontological one. In the instrumental one, property is a construct that allows the realization of ethical goals, and the ontological one questions whether or not something can be owned. While both of these approaches are relevant to discussing the link between ownership and moral responsibility, this paper focuses on the instrumental approaches of ownership because genetically seeds are currently owned. The instrumental approach is well known, for instance, with the use of patents to encourage innovation and create social value. The argument at hand takes a broader approach using the notion of "bundle of rights", which include patents that are essentially a certain type of rights over an idea and its derivatives.

When writing about bodily property, (Björkman and Hansson 2006) use the notion of the bundle of rights. They offer an extensive review of different bundles of rights in the literature to find Tony Honoré's to be the most comprehensive one. Honoré (1961) endorses a liberal notion of individual ownership, where ownership allows the "greatest interest in a thing". According to him, standard incidents of ownership include the rights to possess, to use, to manage, to income, to the capital, to security, as well as the incidents of transmissibility, absence of terms, the prohibition of harmful use, the liability to execution and its residuary character. All of these incidents provide insight into what ownership actually means. I would like to point out that, what Honoré calls the prohibition of harmful use, Björkman and Hansson call the duty to prevent harm. I will continue using that phrasing throughout the remainder of this paper, as it makes for a semantic counter balance to the terminology of rights. While Honoré does not phrase it as such, it is clear that he means it as a duty when he writes on the prohibition of harmful use, "These and similar limitations on the use of things are so familiar and so obviously essential to the existence of an orderly community that they are not often thought of as incidents of ownership; yet, without them 'ownership' would be a destructive force" (1961, p. 123). The two most interesting elements of Honoré's arguments on ownership for the purpose of this paper are (1) the prohibition of harmful use, which puts boundary conditions on many of the rights mentioned above, and (2) what Honoré calls 'split ownership', on which I will expand in the coming paragraphs.

2.3.2. Split Ownership and Shared Responsibility

Honoré speaks of split ownership, and also suggests that several people can be owners of the same thing at the same time, but with different bundles of rights. This observation is pivotal when thinking of the moral dimension of ownership for genetically modified seeds. It raises questions such as: if owners have different bundles of rights, do they all have a duty to prevent harm? Do varying degrees of economic rights mean varying degree of the duty to prevent harm? What does the duty to prevent harm mean practically? I will not answer all these questions here. Rather, I will focus on articulating part of the last one, i.e. the relationship between ownership and moral responsibility. It seems that there is a shared moral responsibility through the duty to prevent harm because there are several owners of a genetically modified seed at the same time.

Through the journey of the GM seed, from the scientist who invents it, to the farmer who sows it and reaps the harvest, to the company who markets the harvest, or even the retailer that sells its products; different actors are involved. All these actors may be conceived of as owners with different bundles of economic rights. This is not a new idea in itself. Indeed, Honoré already speaks of it as split ownership, and it echoes other scholarly work on property, such as the one of Schlager and Ostrom (1992). In that paper, the authors differentiate between an owner, a proprietor, a claimant and a user. Basically, all these different labels represent different bundles of economic rights over a good, i.e. they could also all be called owners with differing bundles of economic rights found in Honoré's list. Adopting such a broad definition of the word owner allows thinking more broadly of how moral responsibility is shared between owners. While economic rights can easily be bundled into different types of ownership, Honoré's duty to prevent harm remains left aside in other taxonomies such as the one presented in Ostrom and Schlager.

2.3.3. The Duty to Prevent Harm or the Responsibility to Do No Harm?

Let us now turn to the duty to prevent harm. Interestingly, if we put the ownership of a thing in its context, the duty to prevent harm might pose boundary conditions on economic rights. For instance, the duty to prevent harm might limit how the right to manage is implemented in agriculture, i.e. which pesticides are to be used, etc. Secondly, the duty to prevent harm presents a duty to the owner directly. Indeed, as discussed in the previous section, GMOs, when considered as novel organisms, raise fears of risks that require different owners (societal actors) to follow a number of guidelines on how to use these most safely, according to different legislations.

Then, what is the difference between a duty to prevent harm and a responsibility to prevent hazards? Goodin (1986, p. 50) argues that, "responsibilities are to consequentialist ethics what duties are to deontological ones". While both responsibilities and duties are prescriptions, these notions have different implications. For Goodin, while both responsibilities and duties aim at a certain state of affairs, the crucial difference is that a duty will have a reference to a specific agent and a specific action, or restriction of a specific action, whereas responsibilities will not "specify any particular actions which [an agent] must perform or refrain from performing" (p. 51). In other words, duties involve an agent that has to do a specific action, which implies that this duty hinges upon the realisation of those specific actions that, in turn, should result in the realisation of a certain state of affairs.

The problem with this notion is exactly this specificity. Under many regulatory systems, GMOs undergo extensive risk assessment and a certain number of actions are thereby defined. This becomes apparent when reading national legislation on GMOs, for instance in the UK, the Genetically Modified Food (England) Regulations of 2004, the emphasis on compliance requirements makes up an important part of the law, so speaking of duties, which agent has to do or not do certain things according to the law. Yet, responsibilities in the sense described by Goodin are absent. So, one can fulfill duties as described by the law but it might not lead to a desired state of affairs, and no one would be responsible if the agents involved fulfilled their duties and the desired state of affairs would not be met. This is exactly the moral conundrum that GMOs pose. While their risks can be researched, known and managed, the uncertainties and ignorance attached to their use cannot be predicted until they reveal themselves. In the case where we would only speak of duties, no agent bears the active forward moral responsibilities of achieving a desired state of affairs, so there is no range of action possible under duties besides the ones that are defined.

This is why the notion of responsibility to prevent harm becomes necessary to use when speaking of uncertainties and ignorance linked to a technology. Goodin himself writes that responsibilities "count as genuine responsibility rather than a duty, provided that injunction is understood merely to set [an agent] a goal and leave open the choice of actions to be taken pursuant to that goal" (p. 51). Goodin describes responsibilities as self-supervisory whereas duties "demand specific performance" (p. 52). Here, it is important to pause and expand on what "self-supervisory" implies if both duties and responsibilities relate to a moral agent who ought to see to it that a certain state of affairs applies. For Goodin, self-supervisory means that (1) a moral agent ought to monitor that a state of affairs is realised, and (2) a moral agent has discretionary powers. These two aspects combined give a moral agent the ability to improvise, or react to uncertainties as they reveal themselves. Responsibilities allow a choice of action in Goodin's own words. Using the notion of responsibility instead of duty thereby fills the lacuna in dealing with uncertainties and ignorance because it is not limiting and because it relies on judgement of the agent to choose how to act towards a certain desired state of affairs. Indeed, to simply speak of a duty to prevent any harm would limit action to dealing with known risks, and potential harm from GMOs can thus be prevented with adequate risk management. However, uncertainties and ignorance make it impossible for this duty to be fulfilled. It seems, therefore, that using a consequentialist notion of responsibility is better suited to the case of GMOs than the notion of duty. Indeed, preventing harm is far from qualifying as a specific performance, especially under uncertainty. Therefore, the duty to prevent harm needs to be reformulated into a responsibility. Since responsibilities focus on outcomes and are self-supervisory—i.e. involve monitoring to see to it that a certain state of affairs is realised, and giving discretionary powers to the moral agent—a possible translation of the duty to prevent harm is a moral responsibility for non-malevolence. So, in a way, translating the duty to prevent harm to a moral responsibility for non-malevolence might promise the best *possible* outcome. Here, the emphasis is on the word *possible* because of the self-supervisory nature of responsibility that allows a moral agent to explore all possible courses of action to be non-malevolent. For simplicity, I call this the responsibility to do no harm.

This responsibility to do no harm implies that a moral agent can act according to her own judgement, but it also does not exclude following laws. Without going into too much detail, it is easy to imagine how judgement may be formed through education, experience, etc. For instance, a farmer planting genetically modified seeds would have the responsibility to monitor, or to have someone monitor, certain important things for a particular goal, such as producing good crops. Upon unexpected observations, the farmer would then have the possibility to react, adjust, or even perhaps stop certain things. This opens a range of other questions that cannot be addressed in this paper but should be addressed, like how does a moral agent know what to monitor and where does this responsibility stop? However, the important point made here, is that a responsibility to do no harm is better suited to dealing with hazards than a duty to prevent harm, because it gives the moral agent more room for action.

So, to follow up on the previous sections, we can now state that: The owner of a genetically modified seed has moral responsibility to do no harm with that seed and there can be several owners of the said seed at the same time that will share moral responsibility.

2.4. When Does Moral Responsibility for Owners of Genetically Modified Seeds End?

2.4.1. Using the Type/Token Distinction

Now that we have an idea of what the moral dimension of ownership of genetically modified seeds means, it might be useful to reflect on what the moral dimension of ownership can be applied to. Indeed, the genetically modified seed is more than a seed. It contains the modified gene sequence, which is patented, and it will produce new, identical seeds that will most likely contain the modified traits. When we follow the journey of a GM seed, it becomes clear that the seed is an intentional artefact, that also happens to be a living artefact, and constitutes an innovation. For the purpose of clarity, I would like to apply the so-called type/token distinction to the genetically modified seed and all further deriving seeds. Coming from the philosophy of language, this distinction allows making a difference between the idea of a thing (the type), and the expression of that idea (the tokens). Indeed, the idea of a particular drought-resistant maize, how to create it, or even the gene sequence coding for this trait, is the type. The type, then, is what is patented and the seeds are tokens for which different bundles of economic rights are allocated. Patents are allocated differently in different countries, but they all represent a restriction on use and reproduction of the idea, with varying conditions. Koepsell (2009) argues that,

> We often own things in only limited ways. Some people lease cars and even though they might hold the title, their use of the car is restricted in a number of ways. The same is true for mortgaged properties. The books in their personal libraries are fully theirs, as are the DVDs and CDs they own, but their rights over those are also limited. They may not copy or otherwise reproduce them, and they may not perform or display them for profit without permission of the author. They own the tokens but not the types. The same is true for one fifth of our genes. We own the tokens but not the types. Yet there are clear differences between works of authorship and the complex polypeptide chains that exist in each of us and nearly every cell of our bodies. (p. 156)

Here, Koepsell points to two things. First, "owning things in limited ways" refers to having a different bundle of economic rights over that thing. Second, he points to the case where people have limited ownership of their own genes. This was written before the US Supreme Court decision on patenting human genes but Koepsell already makes the argument that the Supreme Court will later follow in regard to the moral inadequacy of such a practice. Indeed, patenting human genes restricted access of certain genes to medical research, or for the case of the lawsuit, certain screening tests for breast cancer. Altogether, this underlines that legal and institutional arrangements are also not always in line with morality. This might indicate why the lawsuits described at the beginning of this paper pointed at problematic situations with the use of genetically modified seeds in agriculture.

2.4.2. Placing the Locus of Responsibility in the Seed

Both the ownership of the type (patent) and the token (seed) have a moral dimension. However, most risks, uncertainties and ignorance, natural and social, arise through the use of the token and not the type. Of course, ownership of the type does have a moral dimension in the sense that owners of a patent that could be harmful have the duty to prevent harm, for instance. New patented inventions often need to undergo a risk assessment before they can be put onto the market, i.e. turned into types, following the regulations set out for the product in question. An example of this is the international agreement regarding nuclear proliferation, in which there is strict control of anyone who has access to the idea and means to build a nuclear bomb. This moral dimension of ownership becomes particularly important with tokens in the case of genetically modified seeds, because they are seeds.

Indeed, in the case of the genetically modified seed, the complexity of the token comes in that it carries that patented information from generations to generations by itself. A plant growing from a seed will produce new identical seeds. This self-replicating character, together with the ease with which seeds can spread, e.g. a gust of wind, an animal passing by, etc., both make for a difficult control over the tokens. Self-replication and dispersion of seeds pose a great challenge to monitoring and controlling the invention, which are primordial elements in preventing possible harm caused by a technology. I place the locus of the moral dimension of ownership in the token, and not of the type, because of the complexity of seeds. Nevertheless, while I place the locus of moral responsibility on the token, ownership begins with the type. Therefore, the modification also justifies owning the seed. This might be different for other technologies with different characteristics.

Tokens are, however, also not simply tokens. Usually, tokens are expression of a type, but, in the case of seeds, tokens become expressions of themselves. Let's call the first seeds produced as a result of the type the parent token, and all seeds coming from the parent tokens, children tokens. Children tokens, in turn, can bear more children tokens, and so on and so forth. I suggest that a genetically modified seed is no longer a token of a type, when it has lost the character trait that was intentionally brought about by the type as invention in the first place. Another argument supporting this statement is that the genetically modified seed is considered potentially dangerous because of the introduced trait.

It is important to follow the seed through generations for the moral dimension of ownership. Indeed, if the invention of a seed turns out to be harmful, the harm would not stop at the parent token. Ideally, the seed industry would like their seeds to be bought anew each year, and have the old one destroyed. Unfortunately for them, this is not the case. Many seeds are saved, intentionally, or unintentionally, legally or illegally. Many seeds disperse and contaminate other fields. And so the parent tokens will almost always have children tokens, and the children token as well in turn, etc.

Hence my suggestion of the following formulation: The owner of a genetically modified seed has moral responsibility to do no harm with that seed and there can be several owners of the said seed at the same time that will share moral responsibility for each seed that has the modified character trait and is currently owned.

2.5. Conclusion

In this paper, I set the stage for ascribing a moral responsibility to do no harm on the basis of ownership, in the case of genetically modified seeds in agriculture. Not only does my framework allow for a constructive discussion on the use of GMOs, but it also empowers and responsibilizes actors, or moral agents, who choose to use genetically modified seeds.

I argue that on the basis of fairness, owners should have moral responsibility because they decide to use GMOs and also because they will reap benefits from their use. Moreover, based on the bundle of rights, I use Honoré's claim of split ownership, i.e. that there can be several owners at the same time, to argue that responsibility is shared. Indeed, owners have a duty to prevent harm, which I translate in a responsibility to do no harm using Goodin's distinction of duty and responsibility. This translation gives room for owners to act responsibly and react to uncertainties as they reveal themselves, as opposed to a duty that is too specific and does not allow for improvisation. Last but not least, this responsibility extends for as long as the intentionally modified trait is to be found in the seeds. This is the case because the ownership of the seed depends on this modification and because it is the modification that raises suspicions of potential hazards.

Speaking of responsibility ascription in a forward-looking way allows for a more pro-active and constructive account of problems that have been impeding an ethically desirable use of genetically modified seeds. Nevertheless, many open questions remain: Do the differing bundles of rights have an impact on the extent of the moral responsibility of the owner? Indeed, do more economic rights increase one's moral responsibility to do no harm? Or are these independent and, as soon as one comes in some form of ownership, then full moral responsibility comes with it? Also, what does this responsibility entail? If owners have the responsibility not to do harm, then they must monitor and react. What exactly should be monitored, and by whom? Last, but not least, this paper focussed on the instrumental definition of ownership, but what do ontological considerations of ownership change with respect to the ascription of moral responsibility? Further work on these questions will continue my attempt at arguing that linking ownership and moral responsibility constitutes a positive way to deal with the hazards of genetically modified seeds. Maybe there is hope for the long-polarized GMO debate to become a constructive discussion on how our societies ought to act responsibly in securing the future of our food systems.

3 Gone with the Wind: Conceiving of Moral Responsibility in the Case of GMO Contamination[8]

3.1. Introduction

In ethics of technology and ethics of engineering, many scholars have asked how and why to ascribe moral responsibility to agents in forward- and backward-looking ways (see Vincent et al. 2011). However, new technologies bring new challenges to the field of engineering ethics. In this paper, I consider the case of genetically modified organism (GMO) contamination, which challenges the ascription of moral responsibility to agents based on the condition of knowledge. Indeed, how can we speak of the ascription of moral responsibility regarding a technology when its effects are very difficult to know or simply unknown? In this paper, I hope to contribute to the fields of engineering ethics and responsibility theory by exploring this question through the problem of GMO contamination.

There has been much discussion about the contamination that results from the use of GMOs in agriculture, which may create different types of harm. Firstly, there is economic harm to farmers who might lose organic certification because of the presence of GMOs in their fields; or, conversely, seed developers with certain rights over these seeds might lose out on expected profits when 'escaped' or 'duplicated' seeds are used without their permission. Many legal costs are involved in sorting these issues out. Secondly, there is environmental harm in the sense that agricultural biodiversity (and even biodiversity more generally) may be affected by the presence of new seeds or horizontal gene transfer in ways that are still unknown. Lastly, just as the effects of GMO contamination on the environment are currently unknown, unwanted and unknown GMOs in food may impact human health. This is highly speculative, as there is no uncontested evidence that points to such effects. However, past

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experiences with new technologies have shown that they should not simply be, so to speak, innocent until proven guilty and that we should show some precaution and humility when dealing with these new technologies (Stirling 2007). ISAAA (2015) reports that, “in 2014, a record 181.5 million hectares of biotech crops were grown globally—[...] more than 100-fold gain since 1.7 million hectares were planted in 1996.” Their increasing popularity make the question of responsibility ascription for technologies with unknown effects ever more important.

In answering this question, I first introduce some state of the art considerations with regard to knowledge and responsibility theory. I then present my proposal to deal with the hazards of GMOs by ascribing forward-looking moral responsibility to owners, and I explain how this proposal runs into problems when it comes to contamination. By drawing from experiences in the field of nuclear energy, as well as from the normative notion of social experimentation, I suggest practical solutions. I then return to the original problem of knowledge and responsibility to finalize my proposal about how owners are morally responsible for new technologies when their effects are unknown.

3.2. Knowledge, Ignorance and Responsibility

Scholars distinguish between forward- and backward-looking moral responsibility: the latter as a way to establish moral responsibility after the fact and the former as ‘prospective’ way. Backward-looking moral responsibility can usually be ascribed to an agent if the following conditions are fulfilled, at least to some extent: freedom of action, foreseeability, wrongdoing, causality, and capacity (Doorn 2012b; Nihlén Fahlquist et al. 2014). Freedom of action and capacity mean that an agent was not coerced into performing an action and that this agent has the means to perform that action. The three remaining conditions, foreseeability, wrongdoing, and causality, are linked to having knowledge about an action α and its results. Foreseeability implies the ability to anticipate things that will happen as a result of an action α. Wrongdoing also implies that there is knowledge that an action α might go against some norms. Causality means that after the fact, we are able to trace the causes of an action α and link them to the consequences of that action.

If an agent possesses only limited knowledge about an action y, we encounter the problem that foreseeability, wrong-doing, and causality become conditions that are difficult to judge when we assess her backward-looking moral responsibility, e.g. a farmer planting GMOs that are later found to be harmful. It would seem wrong to argue that if there are indeed limits to these conditions, then there is no moral responsibility on the part of the agent who has taken the action y.

These considerations are for backward-looking responsibility and knowledge, so what about the forward-looking variety? Van de Poel (2011b) argues that for at least two types of backward-looking moral responsibility, blameworthiness and accountability, there needs to be forward-looking moral responsibility ascription in the first place because moral responsibility is a relational concept. This does not include duties, as duties are specific actions for a specific individual and responsibilities are only concerned with a desired state of affairs, regardless of the individual who achieves it. The relational aspect of forward- and backward-looking moral responsibilities means that you cannot deem an agent blameworthy or accountable for an action that she did not have a forward-looking moral responsibility to perform before something went wrong and made her blameworthy or accountable. Therefore, a lack of (or limits in) knowledge will have an impact on the conditions for backward-looking moral responsibility, but it does not remove moral responsibility from an agent altogether.

This is quite a strong statement, because it does not remove responsibility from unknowing agents. Indeed, not knowing does not free someone from moral responsibility if she had a forward-looking moral responsibility in the first place. In terms of forward-looking responsibility, two types are identified in the literature: responsibility-as-virtue and responsibility-as-obligation (see Vincent et al. 2011). Although these distinctions can be challenged, this is not the purpose of my paper. Rather, I mention them here because the remainder of this paper will focus on responsibility-as-virtue. Van de Poel concludes his chapter on the link between forward- and backward-looking moral responsibility with a thought I would like to expand on. He writes, “Another direction in which the account can be extended is […] by incorporating the role of responsibility-as-virtue” (2011b, p. 51). Responsibility-as-virtue is defined as an agent having “the disposition (character trait) to act responsibly” (Van de Poel 2011b, p. 39). But what does having the disposition to act responsibly mean? Also, is there only one character trait that renders an agent morally responsible? This definition is very broad and therefore opens the door for exploring the concept of responsibility-as-virtue in the context of engineering ethics.

Being morally responsible with a lack of complete knowledge is another way of talking about culpable ignorance. Fitzpatrick's work (2008) is prominent in the ethical debate over whether there is culpable ignorance outside akrasia. The proponents of the akratic condition argue that there is only culpable ignorance if it can be traced back to an akratic action, i.e. if an agent, at some point, exhibited weakness of will. This thesis is highly debated in the field of ethics (for the latest refutation, see Robichaud 2014). Fitzpatrick opposes the akratic condition. He argues that this condition is too narrow, because it means that people can only be held responsible if an episode of akrasia can be identified at some point in the chain of action. Therefore, he brings in the notions of circumstantial and normative ignorance. Circumstantial ignorance refers to factual ignorance, or lack of knowledge, whereas normative ignorance refers to ignorance of right and wrong. For Fitzpatrick, culpable ignorance implies the exercise of epistemic vices. This will tie in nicely with the ideas developed above on moral responsibility-as-virtue. He writes,

> Culpable Ignorance: Ignorance, whether circumstantial or normative is culpable if the agent could reasonably have been expected to take measures that would have corrected or avoided it, given his or her capabilities and the opportunities provided by the social context, but failed to do so either due to akrasia or due to the culpable non-akratic exercise of such vices as over-confidence, arrogance, dismissiveness, laziness, dogmatism, incuriosity, self-indulgence, contempt, and so on. (2008, p. 609)

So culpable ignorance stems from epistemic vices. Therefore, in order to have responsibility-as-virtue for problems involving a lack of knowledge, we can specify responsibility-as-virtue as the responsibility to cultivate epistemic virtues in order to avoid the epistemic vices described above, given that those virtues would be the opposite of those vices. For our case, what is interesting in Fitzpatrick's definition is the importance of the social context, which makes his theory much more practical for real-life contexts.

Keeping these insights about knowledge and responsibility-as-(epistemic)-virtue in mind, let us now examine a proposal for ascribing forward-looking moral responsibility in the case of genetically modified seeds and consider how these insights can enhance that proposal.

3.3. Current Proposals to Ascribe Moral Responsibility for Contamination of GMOs

In previous work (Robaey 2015), I have suggested ascribing forward-looking moral responsibility to owners of a technology. This proposal was intended to address the hazards of GMOs, given the high level of uncertainty and ignorance with regard to their potential harms. I argue that "the owner of a genetically modified seed has the moral responsibility to do no harm with that seed and there can be several owners of the said seed at the same time that will share moral responsibility for each seed that has the modified character trait and is currently owned" (Robaey 2015, p. 53). In other words, a genetically modified seed has several owners at the same time, because each owner will have different sets (or "bundles") of economic rights over that seed at the same time. With ownership rights, however, comes the duty to prevent harm (Honoré 1961). In my work, I make a number of distinctions. First, I use Goodin's distinction between duties and responsibilities (1986); both notions are prescriptive, but they differ in that duties are a deontological notion, whereas responsibilities are a consequentialist notion. A second useful distinction is the one drawn among risks, uncertainties, and ignorance. Risks are known probabilities for known events, whereas uncertainties are unknown probabilities for known events, and ignorance involves wholly unanticipated factors (Felt et al. 2007). I argue that duties are better suited to dealing with risks, since duties can be formulated as "an agent X should do (or refrain from doing) α," where α is a specific action. However, it is very hard to define α in situations of uncertainty and ignorance—so an agent X should do something, but that something is not specified and thus requires the agent to have a degree of discretion in order to learn and improvise. Therefore, I argue that it is more useful to speak of responsibilities as a consequentialist notion when dealing with uncertainties and ignorance, i.e. "an agent X ought to see to it that φ" where φ is a desired state of affairs. I suggest transforming Honoré's 'duty to prevent harm' that comes with ownership into a 'responsibility to do no harm.' In that sense, ascribing forward-looking moral responsibility both requires and allows owners, i.e. agents who actively decide to use a given technology and have certain rights over it, to monitor and use discretionary powers to bring about a desired state of affairs φ.

The proposal was developed in light of current debates about genetically modified seeds in agriculture. Two main points of contention were identified: (1) about ownership and (2) about risks associated with genetically modified seeds.

There was no discussion of moral responsibility for using this technology—thus the proposal to ascribe forward-looking moral responsibility to owners in order to deal with risks. Nevertheless, genetically modified seeds, like other new technologies, pose new challenges. Seeds can self-replicate and spread, so genetically modified seeds can do the same, propagating the modified trait. But saying that owners have forward-looking moral responsibility does not actually solve the problem of contamination.

3.4. The Problem of Contamination

The issue of contamination arises because GMOs are a living technology. The seeds containing the modified gene can replicate and spread; the legal term for this is adventitious presence (AP). Also, the modified genes can be transferred to other plants of the same species or similar species that do not have the modified trait; this is called horizontal gene transfer (HGT). In the realm of GMOs, both these phenomena are commonly known as contamination. I would like to draw an initial distinction here. Recent studies have shown that the risks of HGT between plants are actually very small, and that transfer is more likely to occur with bacteria (Keese 2008). So although HGT has been observed in certain cases (for instance see Beckie et al. 2011), it raises worries only for unmanaged fields (Simard et al. 2002). Since HGT is so rare, we will leave it aside in this paper. Rather, we will focus our analysis on AP, as it has been the source of many lawsuits (cf. Monsanto Canada v. Schmeiser 2001 and OSGATA 2011) and the concern of much legislation, at least in the European Union (EU).

It is interesting to note that AP is commonly referred to as contamination. It is helpful to further investigate the meaning of contamination to understand how it has shaped current regulations of deliberate release and co-existence in the EU (see Regulation (EC) 1829/2003, Regulation (EC) 1830/2003 and special guidelines on co-existence). The focus will be on the EU since it has the most extensive body of regulation for the use of GMOs, which many countries either emulate or criticize for being too strict. It is, however, important to note that the notion of contamination in the food sector is a broad one that generally describes the unintentional presence of undesired and potentially dangerous substances, usually chemicals, bacteria, toxins, or metals, in food or feed. Contamination, which can occur during "production, processing or transport" (EFSA 2015), is therefore a term connected to food safety.

In the case of GMOs, contamination refers to the spread of GMOs to other fields, or to processed foods, which were not supposed to contain them. The European Commission's website for the Directorate General for Health and Consumers reads: "Conventional products, i.e. those produced without genetic modification, can be contaminated unintentionally by GMOs during harvesting, storage, transport or processing. However, conventional products 'contaminated' in this way will not be subject to traceability or labelling requirements if they contain GMO traces below a 0.9% threshold level, provided that the presence of genetically modified (GM) material is adventitious or technically unavoidable. This is the case where farmers can show the competent authorities that they have taken appropriate measures to avoid the presence of GM material" (DG Health and Consumers).

But where GMOs and food safety are concerned, the use of the term "contamination" is ambiguous. First of all, not all GMOs are the same. The health and/or environmental impacts potentially caused by a flood resistance gene, a pesticide resistance gene, and a gene that codes for vitamin A are unknown, and will most likely not be the same if they do exist. So the spread of GM seeds seems to pose another type of contamination problem, not one necessarily related to food safety. Rather, the spread of GM seeds threatens potential harm in the sense that their presence in other fields, or in other plants, will change the genetic make-up of a given field or plant. This could mean the loss of certain species, and thus loss in biodiversity, or loss in conserving certain species as they were. In the agricultural world, this can result in economic harm to farmers who do not wish to plant GMOs and find their own fields and seeds taken over by unwanted plants. It can lead to the loss of an organic certification, or simply to the loss of the farmer's or seed breeder's work in developing a certain crop. This, in turn, can generate problems in food security (rather than food safety) because it can lead to the loss of agricultural biodiversity; large monocultures are more susceptible to biotic shocks, which in the current changing climate could decrease the resilience of agricultural systems (Thrupp 2000, Timmermann and Robaey, 2016). Again, it is important to note that all seeds can travel, and spread, and transfer genes, so these problems are not restricted to GMOs. I address the problem via GMOs only because they are the subject of public fear and inquiry.

So there is a problem with GMOs, and it is commonly called contamination. This, as explained above, is a misleading term with regard to the effects of that contamination—but perhaps not when it comes to describing the unintentional and undesired spread of seeds, as well as the potentially harmful impacts of this spread.

In the European Union, the introduction of GMOs has stirred many fears and controversies (Levidow and Carr 2007), and the notion of co-existence was developed for farmers to be free to choose which kind of seeds they want to use. Plainly put, co-existence suggests that GMO fields and non-GMO fields can exist together, although adventitious presence is said to be technically unavoidable (Levidow and Boschert 2008). Introducing this definition may have created more problems than solutions. Levidow and Boschert argue that the concept of co-existence has in fact given rise to a battle of contradictions between agrarian paradigms (2008). So co-existence did not solve the problem of contamination, i.e. the self-replication and spread of seeds. This boils down to problems of knowledge and control. It is very difficult to predict where GMOs will go and how to trace them (Cardarelli et al. 2005).

There is a growing feeling of injustice regarding how courts deal with disputes over contamination. The case of Monsanto Canada against the Canadian farmer Percy Schmeiser, which was described as one of David versus Goliath, ended in victory for Monsanto. The case of OSGATA, an organic farmer coalition looking to pre-emptively sue Monsanto to prevent them from suing them in case of contamination, saw the same result.

The current system regulating GMOs therefore appears highly inefficient, in that it not only does not deal with potential hazards in a constructive way, but also creates new conflicts and apparent injustices. This puts GMOs, an application of biotechnology with potentially enormous benefits for society, at risk. The problem with contamination is also one of knowledge: who should know where these seeds go, and how should they know?

3.5. Contamination and Ownership

Now that we better understand the nature of the problem of contamination and its implications, let us return to our original problem, namely how the lack of knowledge challenges the ascription of moral responsibility. As mentioned earlier, ascribing forward-looking moral responsibility to owners does not actually solve the problem of contamination. If anything, contamination challenges the very idea of clearly-defined ownership. Indeed, due to the very nature of seeds, which can disperse and self-replicate, the link between ownership and forward-looking moral responsibility is challenged. How do we speak of moral responsibility for technologies that can literally be 'gone with the wind'? This also problematizes ownership because it would be nonsensical and counterproductive to expect owners to control all forces of nature. So do they still bear forward-looking moral responsibility for seeds that might have naturally spread and which they do not know about? There is also the case of farmers who might be cultivating those seeds as a result of contamination but also do not know of the seeds' presence in their fields; in a sense, they become de facto owners when they are using the seeds, but does this grant them forward-looking moral responsibility? Another case is one where the genetically modified seeds are in a no-man's land; then under whose forward-looking moral responsibility do they fall? These problems of ownership also imply problems of ascription of forward-looking moral responsibility for the hazards surrounding GMOs. One can either dismiss the role of ownership in ascribing moral responsibility or strive to further develop this framework. I will do the latter.

If moral responsibility is broadly defined as "an agent X ought to see to it that φ," where φ is a certain state of affairs in which contamination does not occur as far as reasonably possible, this is rendered difficult in situations of limited knowledge. It is difficult:

1. for original owners to prevent what they do not and sometimes cannot know, and
2. for de facto owners to further prevent what they also do not and perhaps cannot know.

At this point, it is important to recall that ownership is conceived of as a bundle of rights. In these cases, original owners have different bundles of rights depending on their role and relation to the genetically modified seed. For instance, a farmer may have purchased a seed and have a right to use and derive income from it, but not a right to transfer or a right to possess it (i.e. exclude others from using it). But the company selling the seed may very well have the right to possess it, the right to transfer it, the right to derive income from it, and the right to use it. This is what Honoré calls split ownership, where different agents have different bundles of rights over the same thing. So original owners may have different bundles of rights over the same genetically modified seeds. The de facto owners present an interesting case because they exercise a right to use without knowing that they do. They do not in fact have the right to use, but they unknowingly act as if they did by cultivating a field that might be contaminated. In the GMO case, de facto owners are by default always farmers who did not intend to cultivate GMOs but were cultivating them, like the Canadian farmer Percy Schmeiser.

As explained earlier, with the bundle of rights comes the responsibility to do no harm, which like ownership is also 'split' (or shared, or joint). So if the responsibility to do no harm involves preventing contamination, owners have a problem if they don't know about the contamination.

3.6. Solutions to Contamination: What GMOs can Learn from Nuclear Energy Technologies

GMOs have unique characteristics of self-replication and spread that are not found in other technologies. However, the problems of (1) contamination, (2) shifting ownership (with the de facto owners), and (3) lack of knowledge about effects are not unique to GMOs. Indeed, nuclear energy technologies present similar challenges.

3.6.1. Contamination

First, nuclear energy technologies have extensively dealt with problems of contamination because of the radioactive wastes they produce. The question of how to deal with nuclear wastes raises several questions relating to safe containment. Before I explain in detail how containment is done in nuclear energy technology, I would like to remind the reader that containment seems to be the most obvious answer to contamination; it is a way of controlling things that spread. This is also why the EU GMO regulations speak of deliberate release and containment.

In the case of nuclear waste, the main concern is how to stop remaining radiations from harming people. Nuclear radiations can spread and can cause harm. There are different kinds of nuclear wastes that require different kinds of storage, but this paper will consider only highly radiotoxic nuclear wastes. Amongst the solutions for dealing with these highly radiotoxic wastes, the most realistic and most commonly used method is deep underground disposal; geological repositories are believed to be the safest locations because they combine engineered and natural barriers. Creating multiple barriers for storage strongly reduces risks of leakage (see Taebi 2012).

While there are similarities to GMOs here, there are also differences. For instance, GMOs do not require that anything similar to nuclear wastes be moved around or stored. Also, in comparison to GMOs, nuclear radiations are generally easier to trace because there will be one point of measurable radioactive emission (unless they leak from the repository). GMOs are usually not easy to find, and tests need to be run on several seeds to establish AP (or contamination). These differences impact traceability, but methods of containment can still be implemented. An interesting lesson from the case of nuclear waste is the idea of multi-layered barriers. What kind of natural and engineered barriers could limit the spread of GMOs? Greenhouses and buffer zones are the ones currently used—especially when required by regulation, as in the European Union—but this is not universal. Maybe the idea of multi-layered barriers can be further implemented at different stages of GMO use in order to reduce the chances of contamination. Also, although there is no waste to be moved, perhaps thinking more strategically about sites of planting will prove helpful.

3.6.2. Shifting Ownership

Taebi (2012) speaks of inter- and intra-generational issues of justice with regard to the multinational disposal of nuclear wastes. This approach allows one to choose the most apt storage site. Multinational repositories are more just from an inter-generational perspective, because they permit access to the optimal geological repositories, although it is unjust from an intra-generational perspective for one country to take the nuclear wastes of another country. So as one generation makes decisions about the management of these wastes, a future generation will have to deal with these decisions. We can thus observe a shift in ownership of the nuclear wastes.

This is also the problem we see in GMOs. The difference is that the shifting ownership is a direct result of contamination, rather than being due to the longevity of the material in question, as with nuclear wastes. Some of the legal cases described at the beginning of this paper illustrate this shifting ownership. In the case of nuclear wastes, there are institutions and agreements around the idea of multinational waste disposal so that when ownership shifts, new owners have a means of dealing with the wastes. In the case of GMOs, only blame seems to be transferred with ownership; there is no constructive way to deal with them once ownership has shifted.

There are clearly-defined institutions responsible for dealing with nuclear wastes. Due to the different nature of GMOs, there is no such limited range of actors who have clear role responsibilities. Where we would have one nuclear plant and one waste disposal site, we have several farmers using GMOs in different places. This is not necessarily a bad thing. Indeed, Bergen (2016b) comments on the need for reversibility in institutional dealings with nuclear wastes. The lack of reversibility might create technological lock-ins where undesirable solutions prevail. In the case of GMOs, it is more the fluidity of technology, of institutions and of actors that prevails. Institutions differ from country to country—and hazards are also perceived differently from country to country, because they are less tangible than the past catastrophes associated with nuclear energy. GMOs have no Three Mile Island, Chernobyl, or Fukushima. This is a good thing. Having overly rigid institutions can create situations that are hard to adapt to, or that make it difficult to change the course of actions if agents find out these actions are wrong. With a more fluid situation, agents can react appropriately without being bound within a system that does not allow for unanticipated change. However, the question remains: if contamination is still such a pressing issue for GMOs, who bears the forward-looking moral responsibility for it, how is it shared, and what does it entail? Practically, this raises the following questions: Where will seeds go? Who will use or own them, intentionally or unintentionally? How will these actors deal with them responsibly?

3.6.3. Lack of Knowledge About the Effects

The third point of comparison is with regard to the effects of GMOs and radiation from nuclear wastes. There are many unknowns as to what will happen, and where and when it will happen, with nuclear wastes thousands of years down the line. Shrader-Frechette (1993) argues that the knowledge we have consists only of predictions stretching over 10,000 years, and that it is not reliable. In the same way, there are many unknowns as to the long-term effects of certain GMOs on the environment and on human health.

Pondering the case of nuclear energy brings us to a much-discussed notion: the social experiment. This concept has had many meanings in the past, both normative and policy-related (Robaey and Simons 2015). In the case of new technologies, it has had pejorative connotations. After Chernobyl, Krohn and Weingart (1987) wrote about the nuclear social experiment in a negative way. Indeed, society was experimenting, which also meant making mistakes at a scale where humans could be severely harmed. Similar analogies have been made in the realm of biotechnology, referring to GMOs as Frankenfoods (Van den Belt 2009) or as a “gigantic experiment” (BBC 2008). Beck (1992) describes new risks as unintentional, unseen, and compulsive; such risks create new societal problems. In the recent literature, non-pejorative descriptions of GMOs as experimental also appear, at least in terms of regulatory experiments (cf. Levidow and Carr 2007; Millo and Lezaun 2006). In the fields of ethics of risk and engineering ethics, Van de Poel (2011a) takes a stance on the nuclear catastrophe of Fukushima by arguing that we should experiment. Here, the notion of the social experiment is a normative one. Indeed, we should experiment in society because then we have to follow certain ethical conditions for responsible experimentation (Van de Poel 2011a). By experimenting, agents have to fulfill both higher and instrumental values. For instance, pursuing instrumental values such as learning and intervening will allow us to fulfill higher values such as justice, autonomy, benevolence, and non-maleficence to all members of society (Robaey and Simons 2015).

What is unusual about Van de Poel’s use of the term “social experiment” is that it emphasizes the unknowns that remain when we use new technologies. Unlike classical experiments, social experiments are not controlled and limited by one experimenter. Many agents are experimenting, and many may not be aware that they are experimenting. Being part of a social experiment gives rise to special responsibilities to fulfill certain conditions or values. Van de Poel’s proposal draws on literature in bioethics and environmental management. It does not define responsibility per se, but rather defines the aims of responsible introduction of new technologies into society: namely, minimizing negative and unwanted side effects to make the best of technologies that can greatly improve our lives.

In the next section, I ask how this notion of a normative social experiment relates to using ownership as a means of ascribing moral responsibility, and I explore the idea that owners must develop epistemic virtues in order to be responsible.

3.7. Owners as Social Experimenters: Some Practical Recommendations

Owners are social experimenters because they are the ones who actively decide to develop and/or use technologies, in this case GMOs. Who are the owners, and what should an owner do as a social experimenter?

First of all, not all owners will have the same interaction with the seeds, so they may have different means of pursuing the instrumental value of intervening. This also applies to learning, as well as to the other higher values of responsible experimentation. Indeed, those values will translate to different norms and requirements for different actors (Van de Poel 2013a). It is this complementarity and concerted action that will in the aggregate fulfill the goal of shared forward-looking moral responsibility for achieving a desired state of affairs φ, where contamination does not occur (or its chances of happening are greatly reduced).

The fluidity of institutions mentioned in the previous section might appear problematic; yet it can, under the right conditions, prove to be a very strong asset. If they are to bear forward-looking moral responsibility, owners should have self-supervisory and discretionary power, following Goodin's consequentialist definition of responsibility. Therefore, they are responsible for learning about the technology they develop and use in order to be able to react to unexpected events. As explained at the beginning of this paper, we choose to speak of responsibilities because duties are too limiting in terms of the instrumental values of learning and intervening (to use the language of the social experiment).

Also, if we formulate forward-looking moral responsibility as "an agent X ought to see to it that φ," φ takes on a new meaning in the social experiment. Under uncertainty, φ seems more likely to be achieved if the experiment is carried out responsibly. In addition, lacking knowledge about the presence of seeds does not absolve owners of their responsibilities but instead further defines these responsibilities. Since owners can carry out the social experiment responsibly regardless of the outcome and regardless of their lack of knowledge, the problem of contamination no longer challenges the allocation of responsibilities according to ownership. It is then a collective, or joint, imperative to act responsibly to limit or avoid contamination.

Table 3.1 Possible conditions for socially responsible experimentation (Van de Poel 2011a) – emphasis added to the conditions under study

1. Absence of other reasonable means for gaining knowledge about hazards.
2. Monitoring.
3. Possibility to stop the experiment.
4. Consciously scaling up.

5. **Flexible set-up.**
6. Avoid experiments that undermine resilience of receiving 'system'.
7. **Containment of hazards as far as reasonably possible.**
8. Reasonable to expect social benefits from the experiment.
9. Experimental subjects are informed.
10. Approved by democratically legitimized bodies.
11. Experimental subjects can influence the set-up, carrying out and stopping of the experiment.
12. Vulnerable experimental subjects are either not subject to the experiment or are additionally protected.
13. A fair distribution of potential hazards and benefits.

To refine the notion of the social experiment, Van de Poel (2011a) suggests initial conditions for responsible experimentation (see Table 3.1). As mentioned, these conditions can be linked back to a set of instrumental and higher values. In a way, these conditions refer to a range of actions that actors, or in this case owners, may take in order to fulfill their forward-looking moral responsibility. In this paper, we are concerned specifically with the problem of contamination and with the role of owners—in other words, with how forward-looking moral responsibility works for a technology that spreads in an unexpected way. Therefore, we will focus on asking what the conditions of monitoring, scaling-up and flexible set up, and containment of hazards as far as reasonably possible can mean as a range of actions for the different types of owners involved. There are several other conditions presented by Van de Poel that will not be elaborated on in this paper due to space constraints. In the following paragraphs, I explore what these conditions imply for owners' range of actions. And I will later link these findings to owners' epistemic virtues. It is important to distinguish among the different types of owners in order to establish what they can do, or what their capacities are.

Owners are not only the ones who decide to use a given technology, but also the ones who have certain rights over it. Moreover, it is important to think about which of these conditions apply to owners, as some (such as approval by democratically legitimized bodies) are clearly meant for other social actors. Indeed, owners are not the only experimenters. Citizens, governments, agencies, and NGOs all participate in the social experiment; they are affected by and involved with the technology in society.

If we consider scientists or bio-engineers to be the primary developers of GMOs, for them the condition of monitoring could mean providing guidance about what to monitor. Also, they could integrate markers that would make finding GMOs easier. In the past, fluorescence genes have been suggested, but other ideas could be developed as well. For the conditions of the set-up and the scaling-up, developers are not in the field, so their range of actions is limited. Finally, with regard to containment of hazards, developers can think in terms of design requirements—this time not for the seeds themselves but for their management in the field.

In many ways, farmers have the same responsibilities as scientists. For instance, they must provide local knowledge for identifying what to monitor and must consider design requirements for using field management to contain hazards, which goes hand-in-hand with the idea of the flexible set-up and scaling-up. Farmers have first-hand knowledge and experience of their fields, and they should be given discretionary power to set these up in the way they feel is safest. By learning from factors such as wind patterns and migration habits of local species, they can integrate new knowledge into the management of their fields. Their position at the front line, so to speak, gives them increased burdens. However, there should be support structures to prevent them from becoming over-burdened as they seek to carry out their forward-looking moral responsibility.

If a farmer becomes an unintentional de facto user by harvesting seeds without knowing that they are GMOs, it is a bit trickier to define her range of actions. However, if these farmers are aware of the proximity of other seeds and aware that they could become de facto owners, then they can support the GMO farmers in providing information and constructing barriers. Coordination among different actors will help to resolve the issue of contamination. The burdens of potential de facto owners should not be greater than the ones of original owners. However, in the current system, these de facto owners are unfairly over-burdened with backward-looking responsibility. Unfortunately, their cooperation is necessary to head off contamination and to react to it quickly if it does occur.

This is where companies, universities, and research institutes who are promoting and benefitting from the applications of GMOs have a special role. As institutions, they are not necessarily "on the ground" as scientists and farmers can be, so their role is a supportive one that involves facilitating and aiding proper implementation. Currently, companies like Monsanto spend a lot of resources searching for their seeds in others' fields, as several lawsuits have demonstrated. They could spend the same resources to help create multi-layered barriers, as we have learned from the case of nuclear wastes.

I have mentioned design requirements for GMOs. One goal is to address contamination, but this should not hinder achieving values of benevolence; in the case of seeds, benevolence is about creating agricultural systems that are sustainable and can feed the world. So design requirements should not produce more problems, as with the concept of the Terminator gene (Van den Belt 2009). Companies, universities and research institutes can play a role in providing a good (i.e. benevolent) direction for the people who work for them in developing GM seeds.

Retailers and seed distributors have a different kind of role in that they help to spread seeds. However, like the institutions mentioned above, they are not directly in the field. Their role can instead be supportive. They can make sure that purchasers of GM seeds, like farmers and consumers, are well aware of how to deal with them in terms of limiting contamination. This might, for instance, involve training and appropriate labelling.

These practical recommendations, derived from the concept of the social experiment, are strengthened by the notion of forward-looking moral responsibility as epistemic virtue. The next section shows exactly how.

3.8. Taking Responsibility Under Uncertainty

This paper began by posing the following question: if we cannot know of contamination, how can we ascribe forward- and backward-looking responsibility for it to owners? Now that we have seen in more practical detail what an owner can do as a responsible experimenter, I would like to return to the notion of responsibility as virtue. Indeed, the three conditions for morally responsible experimentation that we translated into different ranges of action for each actor all relate to the development of epistemic virtues, regardless of the type of owner involved. Be it through new design requirements to enhance traceability, or be it through new ways to learn about dispersion in order to better anticipate and limit it, these actions are the result of developing epistemic virtues.

Earlier, we listed what FitzPatrick calls epistemic vices, but we did not go into further detail once we established that virtues are the opposite of vices. Early discussions of epistemic virtues were linked to belief formation and finding the truth. While these are relevant questions, they are outside the scope of this paper, which focuses on practical applications. For now, it is sufficient to mention what Montmarquet (1987) identifies as possible epistemic virtues: impartiality, intellectual courage, and community. He also warns that epistemic virtues should be regulated, because otherwise they might turn into dogma; hence the need for community. In other words, an agent who develops and uses a new technology is responsible for finding out more about it in a sound way and for sharing that knowledge. To use the vocabulary of the social experiment, epistemic virtues allow an owner to fulfill the instrumental values of learning and intervening—and thus possibly other higher values.

Yet this might seem like a lot to demand of certain agents. In the previous section, we distinguished among various roles. For instance, one can hope that scientists who have the role of developers will possess epistemic virtue, given that they work in the field of research. In this case, the key is to expand their scope of inquiry, which we suggested via the notion of social experiments. Similar considerations apply to actors who can be considered sponsors or spreaders; their curiosity should not stop at the development and deployment of the product, but should also apply to the use of the product, to see whether it actually helps to bring about their goals. As for farmers, it seems that they are on the front line of the experiment and can observe more. They might therefore bear greater burdens when it comes to developing epistemic virtues. Epistemic demands might be too much for certain agents to carry out, which would create a responsibility gap.

This is where Fitzpatrick's definition is especially important. He writes that ignorance is culpable if an agent fails to do what he or she could "given his or her capabilities and the opportunities provided by the social context" (2008, p. 609). Similarly, in the context of backward-looking moral responsibility, David Miller proposes the capacity principle: "remedial responsibilities ought to be assigned according to the capacity of each agent to discharge them. [...] If we want bad situations put right, we should give the responsibility to those who are best placed to do the remedying" (2001, pp. 460–461). These distributive ideas are very clear from the standpoint of backward-looking moral responsibility. Can we translate them to a forward-looking allocation of responsibility? Of course being culpable for a wrong, or being responsible for remedying a wrong, is not the same as having forward-looking moral responsibility for something that didn't happen. However, the contexts and circumstances surrounding the use of

GM seeds are not unknown. If each actor's range of actions and responsibilities as epistemic virtues are at the level of that actor's capacity to carry them out—in a manner that their epistemic virtues will help them define—then they are able to take responsibility for the technology they are developing or using. How owners' responsibilities relate to each other is beyond the scope of this paper, but it is certainly a topic for future investigation.

3.9. Conclusion

GMOs promise improved agricultural yields in both quantity and quality. However, their use has proven to be highly contested and problematic. In this paper, I examined the proposal that we should allocate forward-looking moral responsibility to owners of GMOs, as well as the limits of this proposal in the case of contamination. Contamination highlights the problems stemming from limited or non-extant knowledge about the spread of GMOs, and therefore challenges the ascription of moral responsibility. I established that incomplete knowledge does not remove forward-looking moral responsibility from owners. GMOs are a technology that can self-replicate and easily spread because of the nature of seeds. I focused on two problematic cases: (1) the responsibility of original owners with regard to potential contamination, and (2) the responsibility of de facto owners. Looking at nuclear wastes led to two observations: (1) GMOs could benefit from multi-layered barriers, and (2) the normative notion of the social experiment provides owners with a range of actions. Through this reasoning, a range of action was defined for different types of owners. This provides a solution to case (1), as the responsibility of owners to avoid contamination is further defined by shared values relating to responsible experimentation. Therefore, owners are responsible for developing epistemic virtues and defining a range of actions to deal with potential problems, such as contamination. Lack of knowledge does not pose a problem for the ascription of moral responsibility, because owners are experimenters who should take responsibility.

This paper focused on forward-looking moral responsibility; this does not, however, mean that backward-looking responsibility is not important. Indeed, mechanisms of backward-looking moral responsibility can influence agents' forward-looking responsibility (cf. Van de Poel 2011b). In the case of GM seeds, several lawsuits have transferred backward-looking responsibility to unintended owners. But if conditions of forward-looking moral responsibility had been fulfilled by the original owners, we would be left with cases that are straightforwardly morally wrong, such as theft of seeds, rather than unintentional cases. This framework does not change the rights of owners, but instead suggests forward-looking responsibilities that provide a fair and efficient paradigm where stealing (rather than unintentional use) is punished. Owners developing epistemic virtues and defining their range of actions will allow for more responsible use of GMOs, despite incomplete knowledge. Seeds will then not simply be gone with the wind, because owners will take responsibility and do everything they can to avoid contamination.

4 Transferring Moral Responsibility for Technological Hazards: The Case of GMOs in Agriculture[9]

4.1. Seeds of Discontent

More and more, genetically modified organisms (GMOs) are being used in agriculture for a variety of purposes. Some seed modifications involve improvements for agricultural practices (e.g. MON 810 for decreased pesticide use), while others augment nutritional content (e.g. Golden Rice with increased vitamin A). There are many ways of speaking of these seeds; I choose to refer to them as genetically modified (GM) seeds in this paper. In the past 20 years, "the annual global hectarage of biotech crops [reached] 179.7 million hectares" (ISAAA 2015). During that same period, they have also raised many controversies; including a de facto ban on importing and developing them in the European Union between 1998 and 2004, as well as permanent bans in Switzerland and other countries. The two main points of controversy that GMOs raise are hazards and ownership.

Where hazards are concerned, there are human and environmental health concerns. Much of the research purporting to show that GM seeds have negative effects on human health has been discredited. For example, the famous Séralini study was originally published in *Food and Chemical Toxicology*, retracted by the editors on the grounds that the data did not support the conclusions, and controversially re-published in *Environmental Sciences Europe*. Yet, one should note that while GM seeds may not harm human health, it is likely that they may not improve and even possibly harm environmental health. For instance, there is increasing evidence to discredit the notion that they allow farmers to use fewer pesticides (Bonny 2011). Also, they might affect non-target organisms more than previously thought (Bøhn et al. 2016).

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On the question of ownership, GM seeds often travel to fields where they do not belong, transferred by natural agents such as animals or the wind. The unlucky farmers who own those fields have been accused of stealing GM seeds and have had to pay royalties to the companies in question (cf. Monsanto Canada Inc. v. Schmeiser 2001). Other farmers have been prohibited from using the age-old method of seed saving since GM seeds are, like other patented seeds, protected by intellectual property laws (cf. Bowman v. Monsanto Co et al. 2013). These problems are especially acute because GM seeds are living organisms that can replicate and spread with or without human intervention once they are out in the world. Even though government regulations demand buffer zones to prevent the unauthorized spread of GM seeds, these regulations vary from country to country and do not guarantee that seeds will not spread. All in all, the use of biotechnology in seeds turns out to be problematic because the institutional mechanisms of regulation, risk management, and ownership of GM seeds are changing the face of agriculture.

These changes to agriculture over the past decades call for an urgent need for social and legal innovation in the way we deal with seeds. In this paper, I connect the above-mentioned controversial issues by arguing that one effective way to address the question of hazards is through the question of ownership and the moral responsibilities that come with it. GM seeds are owned and owners reap great benefits off of these seeds, and so they should bear responsibilities, to varying degrees (Robaey 2015, 2016a). In the next sections of this paper, we will see in more detail what this statement entails. The main question in this paper is that if ownership can be transferred, and if ownership comes with responsibilities, then how is moral responsibility transferred? And how should it be transferred? We investigate the issue of transferring moral responsibility for hazards of GM seeds, by drawing from the literature on moral responsibility and the ethics of technology.

4.2. Ownership Entails Moral Responsibility

Ownership can materialize in many different ways, social, psychological, technological, anthropological, and legal. In this paper, the focus is on the legal rights that owners receive. Indeed, ownership can be conceived of as legal rights, which give owners authority and benefits. This is an instrumental way of conceiving of ownership (cf. Thompson 2007c), that allows putting in question the way we organize ownership of genetically modified seeds.

Conceiving of ownership as a bundle of rights (Honoré 1961) allows conceptualizing the moral responsibilities that come with these rights. In this paper, and in previous papers, I underline the importance of speaking of the responsibilities that come with ownership rights (Robaey 2015, 2016a). This means, however, that when we speak of rights, they have legal import, and when we speak of responsibilities, they have moral import and may—but need not—have legal import. On the one hand, claims about ownership refer to the legal realms, i.e. different actors have different kinds of ownership rights by law. Different scholars define these rights to different extents (see Björkman and Hansson 2006), but these are, amongst others, the right to use, the right to income, the right to transfer, the right to manage, etc. On the other hand, claims about moral responsibility belong to the moral realm and have no direct legal import. All in all, a legal right might imply legal responsibilities, or duties, but they also imply moral responsibilities. It is important to stress moral responsibilities because of the uncertain, and somewhat experimental context of agriculture. The legal realm defines what we should do about what we know, but defining moral responsibilities empowers agents to act beyond what is prescribed, with the goal of not doing harm. In this paper, I assess whether the current ways of transferring ownership allow the transfer of moral responsibility, i.e. corresponds to what would be a good transfer of moral responsibility.

Indeed, ownership entails both rights and responsibilities. Since owners derive benefits from GM seeds they own, they also bear a special forward-looking moral responsibility to avoid harm. This is a so-called active responsibility, which applies *before* something harmful happens. It is aimed at reaching a good outcome (or avoiding a bad one), and the actions that lead to this good outcome are not prescribed but instead rely on the experience and judgment of the owner, or in other words, her discretionary powers. More precisely, in this paper, responsibilities are understood through a consequentialist lens. Goodin understands duties as being the deontological pendant of responsibilities (Goodin 1986). I add to this distinction, in the context of the ethics of risks, by suggesting that duties can be allocated to deal with known risks, but responsibilities are better allocated to deal with unknown risks, or uncertainties, given that they focus on desired outcomes, and grant discretionary powers to agents (Robaey 2015). This is important because it means owners, or agents, when responsible, must continuously learn about their technology, so that they can use their discretionary powers. In other words, so that they can improvise based on experience, judgement, and newly acquired knowledge, as soon as unknown risks may materialize. These discretionary powers, or experience and judgment of agents, or different owners are further defined as epistemic virtues. Indeed, it is not enough to have discretionary powers, but it is also about how to use them well, and for good ends.

So, while owners may have different bundles of rights on the GM seed and all of its copies, they also have the responsibility to do no harm with these seeds. This responsibility will be expressed differently for the different owners according to their capacities and rights over the seeds. In order to achieve this, they should all strive to learn more about these seeds and thereby develop their epistemic virtues. These epistemic virtues can give owners a disposition to a range of actions. This range of action would however also depend on an owner's capacities. For instance, take the case of GM crops contaminating other fields: a biotechnologist could think about how to enhance the seeds' traceability, an agro-biotech company could provide financial support for this (provided that both the scientist and the company are on the patent), and a farmer with a license to use the GM seeds could experiment with different ways of using them that would diminish contamination in specific contexts (Robaey 2016a). These actions might or might not be governed by legal regulations, but could in any case be seen as part of active or forward-looking moral responsibility. In other words, each owner should do what she can do to learn more about (in this case) the behaviour of the GM seeds in the field.

Owners exercising their epistemic virtues, i.e. learning, and acting according to their capacities would allow for an equitable situation in terms of efficiently and fairly sharing moral responsibility. Indeed, giving people responsibilities for which they do not have the legal rights and/or the capacities to fulfill them, would be counter-productive. The other way around, people who would have rights and/or capacities to take actions to avoid harm but would not try to avoid harm simply because it was never laid out to them as their responsibility to bear would also be counter-productive.

Ownership therefore involves not only benefitting from seeds but also being responsible for them. Of course, this argument might take a different shape if we were to establish that seeds could not be owned through ownership rights. It is, however, not the object of this paper to debate whether seeds, GM or non-GM can or should be owned. Here, we take a pragmatic approach, looking at the status quo and broadening the current notion of seed ownership.

4.3. The Materialization of Ownership

In the legal realm, ownership can be established through various ways that describe which rights and under which conditions these are granted to specific agents. In agriculture, ownership comes with legal innovations that have been developing since the beginning of the twentieth century along with the formalization of agriculture. It started with the Plant Patent Act of 1930, which was a first form of intellectual property rights (IPRs) on plant varieties (Fowler 2000). Throughout the last century, IPRs for plants have expanded throughout patent institutions all over the world and are granted depending on the type of innovation and the governing IPRs institution.

These developments accompany the move of breeding, or developing varieties from the field to the lab. IPRs grant exclusivity to one agent because they are seen as a way to protect investments on the R&D for new seeds (see Timmermann 2015 for an ethical discussion of IPRs). For the attribution of IPRs, the systems differ in different countries, but the results are the same, there are IPRs on GM seeds[10] by virtue of having patents on an inventive step, or a new process in their development. Also, the patents may be on a process, or a technology, but it will apply to all copies of a seed, giving the owners of the patent the right to license the GM seed as they want. Jefferson et al. (2015) investigate the issue of patent on genetically edited (i.e. modified) plant genome sequences in the US and find that a few companies hold most of the patents.

As a counter-reaction to these legal innovations, the International Treaty on Plant and Genetic Resources for Food and Agriculture lays out Farmers Rights, which try to preserve rights that farmers are progressively loosing with the advent of breeders, seed developers and biotech companies claiming rights over these seeds. More generally speaking, scholarship on the matter debates whether the reasons for setting up IPRs in such a way make sense given that it also excludes other actors from contributing to the pool of knowledge, as Jefferson et al. (2015) underline with their empirical study, and as Timmermann (2013) argues with respect to the human right to benefit and contribute to scientific knowledge.

However, in this paper, we take a look at the status quo with regards to how patents and treaties manage the attribution of ownership rights and contracts

10 It is important to note here that patents are also given to varieties of plants that are bred through conventional methods.

manage the transfer of these rights. Some rights might be transferred and not others, depending on what the original owner, or the full owner may want. Also contracts explain what duties come with the transfer, often formulated as “do A”, or “do not A”. Earlier, we examined how duties differed from moral responsibilities in the context of potential risks. Just to remind the reader, as mentioned earlier, the goal of this paper is not to question whether and how seeds should be owned, but rather to look at the transfer of ownership and how it comes to transfer moral responsibility.

So, if ownership rights can be materialized and transferred through contracts, then how is moral responsibility transferred? Are there existing social or legal instruments to do so in the case of GM seeds? If so, do they shift moral responsibility from one owner to another in a fair and effective way? It is important to think of the transfer in terms of fairness and efficiency. Nihlén Falhquist (2006) argues, in the case of public health, that moral responsibility ascriptions should follow these values. With regard to efficiency, the goal of responsibility ascription is to achieve a good outcome overall with the use of GM seeds. This implies that agents who cannot realistically fulfill certain responsibilities should not be overburdened. With regard to fairness, it is important to ascribe moral responsibility to those who make a deliberate choice. For instance, a company may choose to sell GM seeds and some farmers may choose to buy them, so they bear responsibility because of their freedom of choice. If the values of fairness and efficiency are essential for ascribing moral responsibility, they should also be found in the ascriptions resulting from the transfer of moral responsibility.

As we have seen, ownership of GM seeds is protected by IPRs, so when GM seeds are purchased, they typically come with a contract.[11] For example, the Monsanto Technology/Stewardship Agreement (MTSA) grants a license to the buyer and comes with a detailed Technology Use Guide (TUG). Both these documents lay out the details of the transfer of ownership rights in terms of the right to use the GM seeds, and in terms of how those seeds should be used. One could argue that this latter topic brings about a transfer of responsibility. Indeed, issuing instructions about the proper use of a technology presupposes that using

11 There is a growing movement looking for alternatives to the current IPR system adapted to agriculture. For instance, the BiOS licensing system (see www.bios.net)

it incorrectly would have negative consequences, but we will come back to this in more detail in the next section.

Monsanto, a prominent actor on the agro-biotech stage, provides for a perfect case study that allows us to ask whether responsibilities are indeed transferred with a contract, what these responsibilities entail, and how they are embodied in the MTSA and the TUG. In the previous section, we briefly saw what an owner's responsibilities could entail in theory. Before we evaluate how specific documents present moral responsibility, it will be useful to reflect on what a good, i.e. desirable and effective, transfer of responsibility might entail. Building on the literature in ethics of technology and design studies and more specifically, the notion of use plans, we can seek not only to transfer forward-looking moral responsibility but also to do so in a way that will help avoiding potential harms. Figure 4.1 depicts the relations between the different concepts presented so far. In the pages that follow, I suggest a framework for assessing current practices in dealing with agro-biotechnological innovations.

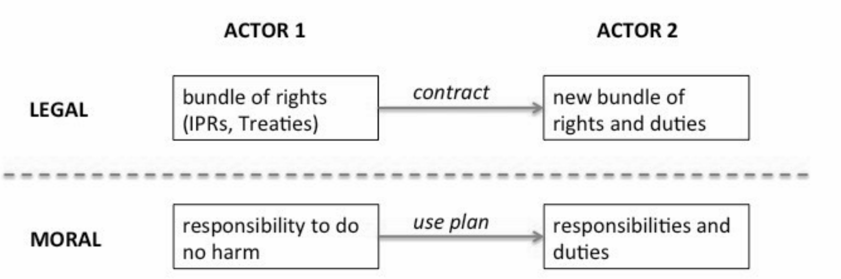

Figure 4.1 Sketch of concepts. The arrow indicates a transfer to another agent, in the legal realm this is realized through contracts, and in the moral realm, this can be realized through use plans (that can be instruction manuals).

4.4. Transferring Moral Responsibility for Technology

4.4.1. Transferring Moral Responsibility for an Artefact

Scholarship on the ethics of technology allows us to take a step back from the legal realm and look at what contracts and instruction manuals actually do, using the concept of *use plans* (Houkes and Vermaas 2004). Artefacts can be described by their physical properties but also by the intentions that are put in their design. The latter can be understood either as the function of an artifact, or its use (as described in a use plan). While these are inextricably connected, we focus on describing use in this paper. Indeed, since the objects of our investigation are contracts and instruction manuals, and these describe rights and duties of an owner, they therefore also describe the desired use of the artefact. Moreover, one can assume that an undesired use of an artifact might lead to undesirable outcomes. In order to think in more specific terms about whether and how contracts and instruction manuals can provide a platform for transferring moral responsibility requires looking at how we can conceive of a good transfer of moral responsibility. The scholarship on the matter is not vast. Pols (2010) makes a suggestion on how to transfer moral responsibility through use plans but before we can look into it, we need to take a closer look at what use plans actually are.

Houkes and Vermaas (2004) challenge the functional approach to artefacts and suggest an actionable account of artefacts through the idea of a *use plan*. A use plan is any rational sequence of actions with an artefact that will lead to the realization of a goal. If a use plan is appropriate, it will lead to a specific desired outcome. Use plans can vary according to the agent's skills and capacity for using the technology. Among many ways, use plans can be communicated through instruction manuals. However, these manuals provide only one possible sequence of actions that will realize one goal, whereas, in fact, several goals could be achieved with an artifact. Reversely, several use plans may achieve the same goal.

To describe this phenomenon, Houkes and Vermaas speak of a standard and non-standard use of an artifact, and the distinction between these uses is gradual. A standard use of an artifact implies a rational sequence of action that will lead each time to one specific goal following more or less the same sequence of action. A standard use is more or less obvious and repeatable. It implies that the design will lend itself to the standard use, and that the standard use can be communicated. A non-standard use of an artifact will evolve from a sequence of action and a goal that will differ to the one of the standard use. A user may come up with a non-standard use herself. An example for non standard-use are these famous life hacks suggestions on how to use a hair pin as a means to squeeze out the remnant toothpaste out of a tube instead of holding hair.

In addition, Houkes and Vermaas describe that a standard and a non-standard use can be either rational or irrational. So non-standard use by itself does not imply bad outcomes, indeed, a non-standard use might lead to a use that was not intended but that could be good, as in the example of the hair pin above. However, Houkes and Vermaas emphasize that irrational non-standard use have a higher chance of leading to no realization of any goal. One other important distinction would be an irrational but standard use. In this case, for instance, the standard use would not fit a given context, so it would be irrational.[12] Moving from a non-standard to a standard use is a dynamic and gradual process, which involves "autonomous, context-sensitive deliberation by users" (Houkes and Vermaas 2004, p. 61) and communication.

All in all, the reader might get the idea how this actionable account of artefacts underlines how narrow both a contract and an instruction manual might be in terms of communicating use.

But to return to our original problem, which was how to transfer moral responsibility, which, as we saw is connected to how we use an artifact, the idea of the use plan alone does not provide a solution. Indeed, Radder (2009) comments that the *use plan* approach does not allow for a normative assessment of use. There is an idea about achieving a goal or not achieving it and in that sense a use plan is good or bad. However, if we put it in a normative context and in the context of the ethics of risk, we can add that the outcome of the use plan should have good consequences, so be morally desirable for society. This is where the idea of defining moral responsibility for owners as a consequentialist notion re-joins the idea of the use plan. We use technologies because we want to achieve good ends, and we want to minimize unwanted negative side effects.

We had to make a detour to explain the notion of use plans, so let us now return to Pols' idea of how to transfer responsibility through use plans. In the context of risk, Pols (2010) proposes five conditions for a transfer of responsibility through use plans from the engineer to the user. These conditions are as follows:

(1) An engineer is morally responsible for a technology.
(2) An engineer can successfully communicate at least one rational use plan for the technology to a user.
(3) This use plan can (under normal conditions) physically be executed with the technology.
(4) The user is able to execute the use plan.
(5) The user has access to the technology.

[12] This corresponds to the critique that Akrich (1992) voices through what she calls the script of a technology, i.e. how its design presupposes a certain use. She describes how inappropriate assumptions about users influence the design of a technology and thereby limit users.

These conditions specify how the use plan can also have a normative dimension by transferring responsibility. It is important to underline Pols' definition of responsibility and how it differs from the definition provided in this paper. Indeed, Pols provides an account based on control, so if a use plan allows to transfer the control of an artifact, it also transfers responsibility. By control, Pols means control of the artifact, i.e. a series of actions leading to certain outcomes with the artefact, but also, what he calls regulative control, i.e. actions that will react to the artefact's momentum in order to control it. He gives the example of putting chains on the tire of a car in icy road condition as an example of the first type of control, which allows the user to have regulative control over the car.

Transfer of control therefore implies transfer of moral responsibility. What is responsibility in Pols' view? Pols does not present one definition of moral responsibility. To the contrary, there are several notions to be found in his account. Pols underlines that some degree of responsibility always remains with the engineer. This is because Pols understands the responsibility of the engineer as a 'role responsibility', which could, in this context, also be understood as a professional responsibility. It seems that the user in Pols framework does not receive a role responsibility from the transfer, but rather, the user's responsibility is defined in terms of ability to execute the use plan, and access to the artifact. Moreover, Pols' notion of responsibility seems to encompass forward and backward looking moral responsibility without very clear distinctions on who bears what kind of moral responsibility, at what point, and why.

This approach to responsibility differs from the one suggested in this paper. Indeed, in the current proposal, we focus on one definition, or aspect, of moral responsibility. Here, we understand moral responsibility for hazards as a forward-looking moral responsibility to do no harm. This is then further specified in the context of uncertainty as the cultivation of epistemic virtues that allow an agent to take actions, to learn about the artifact, and react accordingly when unexpected and undesired impacts start materializing. This is the responsibility that should be transferred when transferring ownership rights over a GM seed. So how does Pols' proposal fair in the case of GM seeds and with this more precise definition of moral responsibility?

4.4.2. Problems with the Framework in the Context of GM Seeds

GM seeds are not just any artefacts like a car, or a hairpin. GM seeds are first of all seeds; so they can grow if planted, create more seeds, spread beyond the place where they were intended to grow, they might even change without human intervention. Also, being seeds, many of them have the purpose of feeding humans and other animals, so their success is linked to our survival. Because of their characteristics and because of what is at stake in their use, they should not be treated like any artefacts.

There are three types of problems with Pols proposal: (a) about the underspecification of the conditions, (b) about the simplification of the conditions that is not helpful in the case of GMOs and (c) a problem at a more fundamental level.

Underspecification

First of all, it is important to point where the underspecification of the conditions are because they can lead to problem in the application of the conditions. In the formulation of conditions themselves, it is not a problem to underspecify as it allows them to be applicable to a broad array of cases.

A first underspecification can be found in condition (2) 'An engineer can successfully communicate at least one rational use plan for the technology to a user'. This condition assumes that a successful communication can be easily identified and evaluated. How can we know if the communication was successful? Also the communicated use plans makes certain assumptions about the user when in reality there is a variety of users. When applying this to the case of GM seeds, some adjustments should be made regarding what a successful communication might entail and this implies identifying who is communicating to whom.

Another underspecification is found in condition (5) 'The user has access to the technology'. This condition assumes access without defining what access means. In the example that Pols provides he explains that it is about the car and all that goes with it. If the user has the car and all that allows driving it, then the user is responsible, according to Pols. In the case of GM seeds, farmers have access to the GM seed, but not to the 'contents' of the seed, i.e. they cannot save the GM seed and use it for breeding.

Simplification

Simplification is necessary when developing a general framework. However, when thinking about the transfer of moral responsibility and the uncertainties surrounding GMOs, some conditions seem to not quite apply.

One first such simplification is found in condition (1) 'An engineer is morally responsible for a technology'. This condition assumes a direct relationship between the engineer and the technology. In the case of GM seeds, the agro-industrial complex is much more convoluted. It involves many actors including lawyers applying for patents and drafting contracts, as well as different bio-engineers for the development and the use of the seeds, regulatory bodies, seed distributors, farmers, and retailers. The assumption of linearity in transfer, i.e. that responsibility moves from one agent onto the next is problematic. There is always a degree of responsibility that remains with the agent who has done the transfer, although that agent might no longer be a user. Pols does argue that some responsibilities cannot be transferred and that engineers "remain responsible for the complete lifecycle of the artifact" (p. 191, 2010). Pols, however, does not expand on this point beyond the examples of recalling defect artefacts or providing opportunities for recycling obsolete artefacts.

Another simplification is found in condition (3) 'This use plan can (under normal conditions) physically be executed with the technology'. What are normal conditions when dealing with uncertainties? We could encounter cases of use where there are no identifiable normal conditions. For example, in a hypothetical scenario, a certain GM seed might have unexpected interactions with another species and this unexpected interaction might change the normal conditions. There are a lot of empirical uncertainties as to how the use of GM seeds impacts environmental and human health in the long run, and furthermore, these impacts might differ depending on the type of genetic modification and the use entailed by the modification. For instance, a pesticide resistance gene entails the use of a specific pesticide with the plant. Taking into account potential hazards and uncertainties that surround the use of GM crops, the definition of transfer provided above seems insufficient because the realization of condition (2) and (3) would be challenged. Indeed, the successfully communicated use plan might no longer apply (2), and the conditions would not be normal anymore so that might have implications for its execution (3).

Last but not least, another simplification is found in condition (4) 'The user is able to execute the use plan'. This condition demands the ability to execute the use plan, which recalls what Houkes and Vermaas refer to as skills and capacity.

First, these might be context-specific. Second, who decides when this ability is sufficient? When a farmer orders a bag of GM seeds, how is she supposed to know that she will have the ability to execute the use plan? How does the seller know that the farmer will have this ability? This might create false incentives to diminish the level of ability required in order to sell more. Or the other way around, it might exclude the access to potentially better seeds because of a lack of ability. Not all farmers operate in the same context or have the same capacity for carrying out instructions. Some might be very wealthy and able to fulfill requirements, while others might be over-burdened with other responsibilities. Still others might be subsistence farmers who happen to have GM crops without even knowing about it.

Shortcomings of Framework

The main problem in the suggested framework is with the definition of moral responsibility. Indeed, in the previous paragraphs, we notice many problems.

If the responsibility of the engineer is a role responsibility (or a professional responsibility), then how can this be transferred to other agents who do not have this role? It cannot. Also, in the suggested framework, the user's responsibility is defined by having a use plan and being able to follow it. If this use plan is for some reason irrational, or non-standard, then the user is not exercising a forward-looking moral responsibility. And if something goes wrong, the user would also have a limited backward moral responsibility because she was executing a use plan.

With the lack of a definition of moral responsibility to be transferred, we also cannot specifying what responsibilities remain with an agent, and what responsibilities are transferred. Also, if we consider the owners again for a moment, when an artifact is transferred, only certain specific rights are transferred over this artifact. Contracts specifically lay out what these rights are that are transferred and remain. So if we assume that different actors have different bundles of rights, we must recognize what Honoré (1961) calls split ownership; responsibility should therefore also be split in the transfer. There are no mentions of this in Pols conditions.

In order to transfer moral responsibility in a good way for GM seeds, we need to address the problems mentioned above. The next section makes a proposal to that end.

4.4.3. Conditions for a Good Transfer of Responsibility for GM Seeds

In this paper, we look at agents with a bundle of ownership rights over the GM seed that we call owners. An engineer has some ownership rights over a technology she develops, be it for instance by having her name on the patent. A user also has some ownership rights, simply put, the right to use. So we can read Pols' proposal by replacing *engineer* and *user* to *owner i* and *owner j*. Also, in reality, things are more complicated and an artifact will have many owners with varying rights through its life, so we can call an owner with any bundle of right at any point of that chain, an owner *i*.

In the previous section we have established the many shortcoming of the current framework for transferring moral responsibility through use plans. We have also examined what the responsibility of owner *i* entailed, namely the forward-looking moral responsibility to do no harm with the GM seed. We explained how in order to fulfill their forward-looking moral responsibility to do no harm, owner *i* would need to cultivate her epistemic virtues in order to learn about the GM seed and be able to define a range of actions that would facilitate her learning and intervening in case some undesirable effects would manifest. These actions would differ from owner to owner given their capacities and contexts.

What, then, would constitute a satisfactory account of the transfer of moral responsibility for GM seeds? Let us revisit the suggested conditions.

(1) An engineer is morally responsible for a technology

Adding a more precise definition of moral responsibility, as explained above and moving away from the engineer and her role responsibility by speaking of the owner instead allows us to formulate the following condition as follows:

(1') An owner i is morally responsible for a GM seed in a forward-looking way to do no harm with the technology.

(2) An engineer can successfully communicate at least one rational use plan for the technology to a user

For this condition, we need to address the specificity of our case, namely include some context-sensitivity. This reformulation allows avoiding high burdens that might lead to inefficient and unfair distribution of moral responsibility, as described in (1') and thereby failing to achieve the goal to do no harm. The condition can therefore be reformulated and specified as:

(2') An owner i can communicate this rational use plan x to another owner j. This use plan x is context-sensitive, i.e. ensures that the new owner j need not change the seed's

intended context dramatically to be able to start using it. This allows avoiding high demands on capacities from owners who might not have them.

(3) This use plan can (under normal conditions) physically be executed with the technology and *(4) the user is able to execute the use plan.*
We merge these two conditions in order to account for a transfer of moral responsibility where normal conditions might not be met. The fact that the use plan can be physically executed and that the user is able to execute it should not be separated because the use plan should be context specific as described in (2’). Also, the use plan should allow for a transfer of responsibility that corresponds to the capacities of the new owner, and if these use plan cannot be fully performed by the new owner, then the previous owners in the chain of transfer should make sure they can support the new owner in the execution of the use plan. So we can formulate this new condition as such:
(3’) The new owner j has the capacity to execute the use plan and where j's capacity might be lacking, the original owner i that has executed the transfer should ensure that she helps the realization of the use plan, whether on their own or through the recruitment of more actors.

(5) The user has access to the technology.
As we saw, the definition of access was very narrow. In order to realize their forward-looking moral responsibilities as defined in this paper, owners need to cultivate their epistemic virtues in order to learn about the potential hazards that might arise and take the necessary actions to prevent and/or limit their impacts. This implies a broader notion of access, as in having epistemic access to the technology, and not only having access to use the technology in a black-boxed manner. Thus, we can rephrase this condition as:
(4’) The new owner j has epistemic access to the technology. This means that the technology does not remain a black box for j; instead, owner j should have the possibility to change and manage the technology in a context-sensitive manner. This, in turn, ensures that the new owner j has the opportunity to learn about the seed (e.g. through training).

Now that we have revised the existing conditions, it is important to add two more considerations for this framework, updating one condition and adding another one in order to fully address the issues mentioned above.

Since we removed the notion of role responsibility for the engineer in these new conditions, it is important to make explicit that the rational use plan should have for a goal as itself to do no harm with the technology. So it is not only that the owner has a responsibility to do no harm, it is also that the use plan communicates this. We can complement condition (1') as such,

(1') An owner i is morally responsible for a GM seed in a forward-looking way to do no harm with the technology. This implies that there should be at least one rational use plan x that does not result in unacceptable harm from the use of the technology.

Connecting this condition to the notion of moral responsibility as epistemic virtues, as well as the problem of uncertainties, the reader is reminded of the distinction between duties and responsibilities drawn earlier in this paper. Duties demand specific performances and are well fitted for managing known risks. In contrast, responsibilities are self-supervisory and demand of the agent to cultivate her epistemic virtues in order to learn and intervene when uncertainties materialize.

A use plan will and may contain duties, but if the use plan is to address the problem of uncertainty, we need to formulate another condition that will allow for adaptability in the use plan. Moreover, this will make the communication chain less linear, and more dynamic between owners. Thus, we add the following condition:

(5') The new owner j has the possibility to create and communicate adapted rational use plans y to other owners k, when and where it is relevant to preventing harm with the use of technology.

Table 4.1 Conditions for a good transfer of moral responsibility for GM seeds

(1') An owner i is morally responsible for a GM seed in a forward-looking way to do no harm with the technology. This implies that there should be at least one rational use plan x that does not result in unacceptable harm from the use of the technology.
(2') The owner i can communicate this rational use plan x to another owner j. This use plan x is context-sensitive, i.e. x ensures that the new owner j need not change the seed's intended context dramatically to be able to start using it. This allows avoiding high demands on capacities from owners who might not have them.
(3') The new owner j has the capacity to execute the use plan x and where j's capacity might be lacking, the original owner i that has executed the transfer should ensure that she helps the realization of the use plan, whether on their own or through the recruitment of more actors.
(4') The new owner j has epistemic access to the technology. This means that the technology does not remain a black box for j; instead, owner j should have the possibility to change and manage the technology in a context-sensitive manner. This, in turn, ensures that the new owner j has the opportunity to learn about the seed (e.g. through training).
(5') The new owner j has the possibility to create and communicate adapted rational use plans y to yet other owners k, when and where it is relevant to preventing harm with the use of technology.

4.5. Insights from an Existing Case

The Monsanto Technology Use Guide and Technology/Stewardship Agreement

With these insights, we can now make an ethical assessment of the transfer of moral responsibility in the 2015 Monsanto Technology Use Guide (TUG) and Technology/Stewardship Agreement (MTSA) (Monsanto 2015).[13] It is important to underline that Monsanto is not the only company producing such documents to accompany the sale of its seeds, indeed Syngenta, Bayer, BASF, Dow, and

[13] At the time of this analysis, the 2015 TUG was used. A new version, 2016, has now been released but was not the subject of analysis of this paper, mostly because the updates concerned more the products included, rather than how things are dealt with, which is the point of interest for this analysis.

Dupont[14] do so as well. In this article, we take a look at only one of these companies because the goal of this investigation is not to compare their practices. Rather, the goal of this paper is to reflect on the conditions for a good transfer of moral responsibility. All the passage cited in this section are from the TUG and the MTSA.

These two documents, the TUG and the MTSA are contained in one document. In addition, their goals seem to differ but nonetheless, they have a common aim. On the one hand, the TUG primarily instructs on proper use for different crops such as corn, or cotton, but more generally for issues of insect resistance management, integrated pest management, weed management, etc. What these instructions also create, as a side effect, is to deflect liability from Monsanto in case of improper use by the Grower. On the other hand, the MTSA defines which rights and duties are passed on from the company to the grower, and thereby protect the company's ownership over the seeds. The MTSA is however not only about rights; an important function of the contract is also to define conditions that would remove liability from the company (paragraphs 11 and 12).

Liability is one type of responsibility, but these documents also see stewardship as a form of responsibility 'for proper management of these products' (p. 4). Also, these documents address more the management than the product as such, with a very heavy emphasis on connected technologies, i.e. pesticides. So we will analyze whether the conditions for a good transfer of moral responsibility are met. Here, the transfer is from Monsanto to the Grower or, in the language of our framework above, owner i to owner j. In other words, I ask, do the TUG and MTSA fulfill the conditions for a good transfer of responsibility? It is important to note here that the TUG communicates on the use of the seed and the technologies accompanying them, namely pesticides. Since they go hand in hand in the case of Bt technologies, they can be considered as one technology.

With regards to condition (1'), there are two main elements to consider: first that there is moral responsibility in a forward-looking way and second that at least one rational use plan x does not result in unacceptable harm from the use of the technology. Before we can answer this question for condition (1'), we need

14 Also called the Big 6, by some critical observers like the ETC group, but corroborating that the largest part of patent ownership in agrobiotech is with these companies.

to first underline how harm is defined in these documents. There is no encompassing notion of harm, instead there are several interpretations to be found that are case specific. For instance, in the context of pest management where the need to be managed, "in a manner that is least impactful to people, property and the environment" (p. 7). Another example is in the case of corn, "sustainability of corn agricultural systems is enhanced when growers follow recommended IPM practices, including cultural and biological control tactics, pest sampling and appropriate use of pest thresholds for management practices." (p. 14). Another type of possible harm mentioned is the decreased effectiveness[15] of Bt corn technologies (p. 15) on the label itself that comes with a bag of Genuity® SmartStax® Corn. It seems that the TUG is communicating at least one rational use plan that avoids some specific harms described in the TUG. In a way, each general section in the TUG could be rephrased as places where specific types of harm might happen, with regard to resistance, pest, coexistence, etc. It also seems that it is about forward-looking moral responsibility, in the sense of avoiding certain undesirable outcomes. All in all, it seems condition (1') is more or less fulfilled although a more encompassing notion of harm, and formulated more prominently in the goals of the TUG would be more desirable. For now, it seems like avoiding harm is a side topic to the TUG.

Looking at condition (2'), the important things to pay attention to are context-sensitivity and avoiding high demands on those who do not have the capacity to carry out responsibilities. When it comes to context-sensitivity, we need to further discern between context sensitivity for the technology, and context sensitivity for the owner, or here, the Grower. There is ample attention to the context sensitivity of the technology, for instance Growers must "use seed products, seeding rates and planting technologies appropriate for each specific crop and geographical area. As much as possible, manage the crop to avoid plant stress." (p. 7). Also, there is context-specificity for rules and regulations for the technology, like with "refuge requirements [that] vary by the type of product being planted and the location of planting. Growers must plant the amount of refuge acres for a product that is required for their growing region." (p. 6). Last but not least, there is attention to the surroundings in which Growers are using

15 In agrobiotech, including pesticides, there is a big problem with how innovations are protected as their efficiency, and effectiveness diminish over time (Timmerman 2015)

the technology, "each grower needs to be aware of the planting intentions of his or her neighbour in order to gauge the need for appropriate best management practices." (p. 10). There is, however, a lack of attention to the capacities of the Grower, which may be affected by their context, i.e. the country, the type of farming, their socio-economical background.

This is why condition (3') is extremely important. The focus of condition (3') is the capacity of the owner and how these will be compensated for if the demands on the new owner are too high. This is a point where the TUG and the MTSA have clear defects. In a generous reading, we find several places where attention to capacity and support can be found, such as through the "Take Action effort [...] an industry-wide partnership between university weed scientists, major herbicide providers and organizations representing corn, cotton, sorghum, soybean and wheat growers to help them manage herbicide-resistant weeds" (p. 8), or growers having access to, "a free Insect Resistance Management (IRM) corn refuge calculator" (p. 19). While an online calculator might be a useful tool, it is unclear, however, how Growers can tap into the Take Action effort. The TUG also claims, "Monsanto works to develop and implement IRM programs that strike a balance between available knowledge and practicality, with grower acceptance and implementation of the plan as critical components." (p. 6). However, practicality and acceptance neither mean that capacities are there, nor how the balance is being struck. In contrast to this, the TUG and the MTSA contain many formulations where the Grower must read and follow, must comply, must cooperate, should scout, should consult, should monitor, should be aware, etc. With the lack of clear emphasis on capacities, or how they could be compensated for via other actors, and the clear number of requirements on growers, it is difficult to assert that condition (3') is fulfilled in the current form of these documents. This could create inefficiencies and imbalances in being morally responsible in a forward-looking way since not fulfilling condition (3') impedes a good transfer of moral responsibility.

In addition, we can observe further imbalances that also impede a good transfer of moral responsibility. Condition (4') on the epistemic access to the technology allows us to underline another imbalance on who has what kind of epistemic access. It seems that Growers are mostly transferred epistemic access in terms of monitoring and reporting to the company or appropriate authorities. Through this monitoring and reporting, appropriate decisions should be made, e.g. for pest management. There are also hotlines, websites, training centers available to fulfill these responsibilities. I would, however, qualify this as a limited epistemic access since the technology, i.e. the seed, remains black-boxed. Indeed, seed-saving is strictly prohibited (paragraph 4 g of the MTSA). The company, however, has full epistemic access, and receives on the field information from the monitoring and reporting, allowing a continuous development of new seeds. Earlier, we saw that epistemic access was important for owners to react appropriately in the context of uncertainty. Here, the access is limited, and the stakes are high, namely the future of our food systems. In a constantly changing environment, in order for all agents to be responsible in a forward-looking way, they should have an equivalent amount of access to the technology, and not only to the management of the technology. The argument becomes broader here, because of the goal of these types of technology, which is to feed the world, hence, the more agents, or owners, can learn about them to improve them and diversify them, the better off we would be.[16]

This leads us to condition (5'), about the possibility to create and communicate new rational use plans where it is relevant to preventing harm.

It seems in the TUG and the MTSA that only Monsanto has that responsibility, given the limited epistemic access of other owners. It is necessary that at least one agent has this possibility, "Monsanto is committed to the proper use and long-term effectiveness of its proprietary herbicide brands through a four-part stewardship program: developing appropriate weed control recommendations, continuing research to refine and update recommendations, education on the importance of effective weed management and responding to repeated weed control inquiries through a product performance evaluation process" (p. 8). This is, however, not sufficient to fulfill a good transfer of moral responsibility under conditions of uncertainty. Condition (5') underlines the need for adaptability in changing circumstances, which goes hand in hand with the idea of being actively responsible to achieve good outcomes, and acting as soon as possible.

There is more to condition (5'); not only is Monsanto the only agent with the rights to create new use plans where new harms might arise, but also the TUG and MSTA is only *use plan* that actively and legally excludes any other possible use plans and thereby makes illegal other potential good use of the GM seeds. So

16 More could be said about how we innovate and what kind of innovation models would be more desirable in the agriculture, especially where it concerns basic goods, such as food.

the current set-up of the use plan actively prohibits new owners from being responsible, and limits them to fulfilling a set of duties.

There are other points we did not touch upon because we were looking at the conditions for a good transfer of moral responsibility but the TUG and MTSA have a punitive nature, so if an agent X fails to do an action, then access to the technology will be denied. As mentioned above, the grower is bestowed with a lot of duties, or obligations, phrased as an agent X must do A and yet very little rights. These documents present the rationale as such, “These new technologies bring enhanced value and benefits to growers, and growers assume responsibilities for proper management of these products.” (p. 4). Except these are not responsibilities as we understand them in this paper, rather, they are duties.

All in all, it seems like the TUG and MTSA have the potential for transferring forward-looking moral responsibility to do no harm but in the end do not. Also, the transfer may not be partial, either moral responsibility is transferred or it is not. There are other kinds of responsibilities that are transferred here, like duties, or obligations. These are also forward-looking, but they do not correspond to the definition we provided, namely as cultivating epistemic virtues in order to define a range of actions that will help react in the context of uncertain use and effects of new technologies. This is because they do not take into account the capacities of the new owner and they do not grant a real epistemic access to the technology. This will also have an impact on backward-looking moral responsibility and who can be held blameworthy in cases where things would go wrong.

4.6. Conclusion

If we now return to the main questions of this paper, namely, if ownership can be transferred, and if ownership comes with responsibilities, then how is moral responsibility transferred? And how should it be transferred?

To remind the reader, we connected the issues of ownership and moral responsibility in order to address the problem of hazards. Indeed, in conditions of uncertainty with the use of a technology, those who reap benefits off of it should also bear moral responsibility. There are different definitions of moral responsibility. The one suggested in this paper is forward-looking and aims at avoiding harm. It is further specified as being the cultivation of epistemic virtues that allow owners that chose to use GM seeds to define a range of actions that will allow them to learn and react when uncertain hazards materialize. If this responsibility is transferred properly, then, it is more likely that owners will be able to react on time.

A good transfer should be set up so that this type of moral responsibility can be transferred, especially when dealing with technologies such as GM seeds which have high potential benefits for society but also unknown hazards. After reviewing the existing proposal for transferring responsibility through use plans, I suggested a new set of conditions that would allow the transfer of responsibility. These are listed in Table 4.1. What is important to note about these conditions is that the transfer does not imply a linear transfer where responsibility leaves one agent to go to the next. To the contrary, a good transfer of moral responsibility will grant new responsibilities to new owners, but it will not remove responsibility from the original owner, as long as this one retains ownership rights because these entail moral responsibility. Further research would be to look into what happens to moral responsibility when ownership is removed. So as ownership is split, so is moral responsibility. Here, the notions of capacity and context become very important. Indeed, the conditions do not want to overburden one owner because it could lead to negative outcomes.

With the help of this framework, we looked at a case, which is a practical implementation of a use plan, namely the MTSA and the TUG. We find that while these do transfer rights and legal duties, and obligations, it is still too little to claim that it is a good transfer of forward-looking moral responsibility for hazards. Such documents have, however, the potential to do so. Or perhaps new platforms should be created for the communication of desirable use plans with GM seeds.

If anything, one thing this investigation underlines is that with technological innovations, social and legal innovations are needed. The current way of transferring moral responsibility when we deal with uncertainties is insufficient from an ethical standpoint. Further steps for this research line would be to think about practical means of meeting the conditions for a good transfer of forward-looking moral responsibilities for hazards of GM seeds. Also we should reflect on possible exceptions such as the expiry of ownership. Reflections in the field of ethics can help finding the directions for using GM seeds in a responsible way.

5 The Food Warden: an Exploration of Issues in distributing Responsibilities for Safe-by-Design Synthetic Biology Applications[17]

5.1. Introduction

Synthetic biology (synbio) is an emerging field that combines principles of the life sciences together with principles of engineering disciplines. The hybrid and new character of this field present great opportunities for beneficial applications but also potentially great challenges in terms of risks and uncertainties. One of the great promises of synbio applications is that they can be designed for safety by using only the necessary elements of a genome to achieve a goal. In this paper, we investigate some of the challenges of safe-by-design in synbio and the implications for the distribution of moral responsibility. This, in turn, allows us to test some of the assumptions in the safe-by-design approach about distributing responsibility for dealing with risks.

The safe-by-design approach, as a way to deal with the potential risks of synbio applications, seems to come with specific assumptions about which actors are responsible for properly addressing the risks of these technologies. In particular, it seems to assume that the actors in the research and development (R&D) phase bear special responsibilities for safety. This raises a number of issues. First, it raises the issue of whether all the safety issues can be taken up in the design phase. Second, we can also ask whether other stakeholders are also inclined to allocate the responsibility for dealing with safety to the R&D phase. Third, one might also wonder what happens when something goes wrong, are

[17] This paper is currently under review for the Journal of Risk Research. It was co-authored with Ibo van de Poel and Shannon L. Spruit. While the set-up of the research and collection of data was the result of a common effort as was the discussion about the findings, I took the lead in the write-up of the paper. All sections are written by myself besides the methodology section and the section on proximal vs distal causes.

then also the actors in the R&D phase blamed or does blame primarily apply to other actors in the chain from product to consumer? Last but not least, is safety an issue that can and should be left to the actors in the R&D phase?

In order to explore these questions, we conducted a Group Decision Room on a synbio application, the Food Warden, a biosensor contained in meat packaging that indicates freshness of meat. This application is an innovation to the commonly used expiry date. Expiry dates on food products are often conservative for safety reasons and might be inaccurate in cases, for instance when meat is not stored properly. In this paper, we give a brief introduction in risk and safety issues in synbio and the scholarship on the relationship between technological design and moral responsibility. We then present the Food Warden case, the method we used – the Group Decision Room – and the main results of this exploratory session. Finally, we discuss our findings with respect to four main points of discussion: the types of safety issues raised by participants, the concentration of forward-looking moral responsibilities in the R&D phase, the relation between forward and backward-looking moral responsibility, the forward-looking moral responsibilities of owners, and the importance of responsible transfer of the biosensor.

5.2. Risk and Safety in Synthetic Biology Applications

In this paper, we investigate a synbio application that is, as we will see, safe-by-design. The claim that we can design technologies to be safe-by-design is not unique to synthetic biology. It can, in fact, also be found in more traditional fields of engineering.

In engineering, the notion of safety has been developed in relation to the notion of risk. Safety is often defined as the absence of risk. Doorn and Hansson (2011) argue, however, that the notion of risk itself is not that clear. There are several definitions of this concept, most of which based on a capacity to assign probabilities to certain hazards. However, in practice most hazards are not completely predictable, there are also uncertainties to take into account. Following this observation, they argue that to design for safety does not only imply taking into account known risks but also designing for uncertainties and hazards that are not yet known (for example by using safety factors that can also deal with uncertainties). When it comes to risk and uncertainties in synbio, the paradigms are different than traditional biotechnology. Indeed, through synbio, a number of engineering principles are translated from other engineering disciplines to synthetic biology. For instance many parallels are drawn with computer systems engineering or IT systems in general (Andrianantoandro et al. 2006). To put it simply, synbio allows the creation of biological machines. The promise of synbio is that these machines can do whatever the designer wants them to do. In other words, synbio simplifies the bacteria's genome in order to keep only preferably coding parts that matter for the expression of a purpose. This, in itself, is already a design principle particular to synthetic biology as opposed to traditional biotechnologies. In this line of thinking, the simplification of the genetic material could play a role in increasing safety of synthetic biology applications.

In addition, switches can be introduced in the coding of the cell so that they can be turned on and off depending on the substrate. The possibility of having a kill switch that will disintegrate the cell membrane is also seen as an advantage in designing for safety. These are not technological innovations limited to the field of synbio. However, in the synbio world, there is a quest to create standardized bio bricks that could easily be assembled in any order to create whatever biological machine you would want. When thinking about safety in sybio, Schmidt writes that there are different levels to consider: the individual parts, the circuits and the chassis (2008). Andrianantoandro and colleagues (2006) point to the fact that the behaviour of even very simple engineered cells will be difficult to predict. Indeed, as opposed to computer systems, reliability and predictability in synbio are problematic because single cells might behave differently than groups of cells, hence the need to consider the different levels.

We started by questioning whether safety could simply be understood as the absence of risk. We see that it is difficult to speak about the risks of synthetic biology in general, as every application will have different implications, and the risks of a single application might not be as well understood as we might think. Generally speaking, the risks would be that a synbio application doesn't do what it's supposed to do and instead does something else that negatively affects other things. All the promises of safe biological machines that synbio brings, warrant an investigation on the understanding of safety for these applications.

5.3. Design and Moral Responsibility

In engineering ethics, discussions on the relation between humans and technological artefacts are central. There is one seminal argument made by Winner (1980) underlining that the design of artefacts contains choices that humans make. Therefore, they will mirror our values, intentions and decisions. Van de

Poel and Kroes (2014) argue that if artefacts can embody values it also means that we can design them for values, so we can design for safety. In addition, values can be translated to norms, which in turn can be translated into design requirements (Van de Poel 2013a).

However, there are fields where safe-by-design is more advanced and defined such as civil engineering. The field of synbio is still in its infancy and so is its understanding of safety. There are possibilities to have safety mechanisms in the design, but it is not clear who has the responsibility to decide what safety means and how it should be implemented. This is why some clarifications are needed on both the definition of safety and on the distribution of moral responsibilities.

When looking at moral responsibility, there are two important distinctions: forward-looking and backward looking moral responsibility (e.g. Van de Poel et al. 2015). Forward-looking moral responsibility is also called active moral responsibility and the idea that people are responsible to see to it that a certain state of affair is realized. So it's a proactive notion of responsibility. Backward-looking moral responsibility refers to responsibility after the fact. Typically in engineering ethics, there are five conditions stated to establish whether there is backward-looking moral responsibility: freedom of action, wrong-doing, foreseeability (knowledge), capacity, and causality. Examples of backward-looking responsibility are accountability (the obligation to account for an action or outcome), blameworthiness (being blamed for an action or outcome) and liability (the obligation to repair or compensate for an undesirable outcome). In case of desirable outcomes, backward-looking responsibility may also include praiseworthiness.

When we think of distributing and allocating moral responsibility we have to keep in mind why we allocate moral responsibilities. Given that we allocate responsibility with the goal of achieving safety, we should allocate forward-looking moral responsibilities in a fair and efficient way (Nihlén Fahlquist 2006). Otherwise, some actors may be overburdened and some responsibility gaps may appear, which could lead to not fulfilling the value at hand, in our case safety. It is also important to address how responsibilities are distributed, since actors may understand their own responsibilities and the responsibilities of others differently (Shelley-Egan and Bowman 2015).

Allocating forward-looking moral responsibilities is therefore particularly crucial when thinking of safe-by-design. Indeed, the idea of safe-by-design builds on the forward-looking moral responsibilities of designers. In that framework, designers think about safety issues and think about how their design can prevent them. However, there is uncertainty about the real use, and impact of new technologies on our societies and environment. In addition, safe-by-design doesn't inform the discussion on backward-looking moral responsibility. This doesn't mean that the whole endeavour is pointless. To the contrary, it means that these issues of allocation and distribution expand beyond one type of actor and can involve several actors.

This is what the concept of the social experiment articulates. On the one hand, it deals with all the actors involved with the introduction of new technologies in societies and on the other hand, it deals specifically with uncertainties and how to deal with them in an ethical way (Van de Poel 2010, 2011b, 2012; Doorn et al. 2016). Indeed, the introduction of new technologies can bring great benefits but also potential hazards, and can be understood as a social experiment. This proposal encompasses questions of distribution and allocation of moral responsibilities, forward, and backward, as well as strategies to deal with the introduction of new technologies, like for instance through learning. In the social experiment, all actors can be considered experimenters; it provides a new dimension to the governance of risks and uncertainties.

Building on the notion of the social experiment, another recent proposal suggests allocating forward-looking moral responsibilities to owners of technologies. The reasoning behind this proposal is that since owners reap benefits, they also bear special forward-looking responsibilities for the technologies they own. These responsibilities could include learning about these technologies in order to be able to act when unknown risks would start materializing (Robaey 2015, 2016a).

In a nutshell, these concepts can provide a useful analytical lens to study the distribution of moral responsibilities in safe-by-design for synbio applications. Asking whether all safety issues can be taken up in the design phase, and whether other actors agree with this, are questions of allocation and distribution of forward-looking moral responsibilities. Looking at backward looking moral responsibility addresses questions of who's to blame when things go wrong. Taking a broader view at safety beyond safe-by-design, like through the lens of the social experiment, allows thinking about what safety and responsibility mean at different steps of the journey of the biosensor.

5.4. Case: the Food Warden

There are a few synbio applications currently being used, the most prominent ones being for the production of artemisin by Amyris®, of vanillin by Evolva®, and of algal oil by Ecover® (cf. Asveld and Stemerding 2016). These cases have the advantage that these synbio applications are used in the context of industrial production and are thereby contained. We wanted to look at a case where the applications themselves would have the potential to be in places where they shouldn't be in order to broaden the scope of stakeholders. So we decided to look into the case of a potential synbio application that could exist but doesn't exist yet. The advantage was that we were not constrained by the reality of an existing case, and the disadvantage was that it was more difficult to motivate stakeholders around a case that does not yet have a clearly defined community.

For our case, we chose an application -- developed by the 2012 team from the University of Groningen for the International Genetically Engineered Machine Competition (iGEM) -- the Food Warden, a concept for a biosensor. The biosensor is to be placed in a resistant pocket as part of the packaging and would replace the expiry date by detecting, or "smelling" when meat goes rotten. The team argues that using this technology would be safer and more accurate than the currently used expiry date system. Also, using this technology would address a major societal problem of food waste by providing more accurate information on the freshness of meat.

In terms of Safe-by-Design, there are several elements that make the biosensor safe (iGEM Groningen 2012). The bio-sensor is 1) made from a soil bacteria that is harmless to humans, it is 2) contained in a very solid packaging that is not supposed to break, and it has 3) a limited nutritional substrate, which is also the only substrate in which it can survive.

While there is no implementation of the concept, the team had gone far in the developments of the prototype, and won the Grand Prize of the iGEM competition that year. For the purpose of our research, we assume a future where the Food Warden is being used in the market.

5.5. Methods

5.5.1. The Group Decision Room

In order to explore the questions on moral responsibility and safe-by-design, we use the format of a Group Decision Room (GDR). The goal of a GDR session is to solve complex issues in a collaborative manner using virtual communication tools (cf. Kolfschoten and de Vreede 2009).

The use of virtual tools helps preserving the anonymity of participants. During a GDR session participants each take place behind their own laptop in a room. Individual questions are interchanged with plenary presentations and discussion. Our GDR session, that took place on September 30, 2015, included anonymous discussions via *Meeting Sphere*, opinion survey via *Lime Survey* and open discussions that were observed and recorded by means of notes by the researchers. The facilitation was the result of collaboration between the researchers and a professional facilitator.

These tools help organise an anonymous but lively written discussion, presenting and organizing the information in an almost real-time fashion, and giving and receiving feedback on the discussion. In the GDR, we do not only collect people's opinions on different issues but we also challenge their assumptions and reasoning by going over an issue in different ways and by providing input, or new perspectives that help participants form an opinion. The general method for this GDR is inspired by Doorn (2010, 2012a).

5.5.2. Structure of the Session

In order to gain insights on the relation of safe-by-design and moral responsibility in the Food Warden case, we divided the session in five main steps (see Table 5.1). After the introduction on the case, we brainstormed with the participants to identify issues of concern. Then, we used these issues to investigate the distribution of forward-looking moral responsibility and a scenario for distribution of backward-looking moral responsibility (see Table 5.5). As a last and somewhat apart exercise, we examined the distribution of ownership rights. Before starting the introduction participants were assigned an anonymized alter ego for the GDR software. Each step had presentations, online and offline discussions, as well as votes on different issues. This programme had been tested out and adjusted based on the experience of a group of civil servants, before running the GDR session on which this paper is based.

Table 5.1 Protocole

Programme part	**Time (approx.)**	**What**
Pre-workshop		-Allocation of alter-ego for the session by observer
Introduction	15 min	-Introductory round participants and facilitators -Explanation goals GDR Session -Explanation software -Informed Consent form reading and signing
Identification issues of concern	45 min	-Presentation developer on Foodwarden -Presentation facilitator on Safe-by-Design -Brainstorming safety issues via Meeting Sphere -Individual voting on two most import and one 'new' safety issues via Meeting Sphere -Plenary ordering of safety issues based on voting
BREAK	10 min	
Distribution of forward-looking moral responsibility	1 hr	-Explanation phases by facilitator (see next subsection for explanation phases) -Participants are asked to individually connect issues to one or more phases and explain their choices via LimeSurvey -Voting results are shown, followed by a plenary discussion on the results -Second round of voting on the same topic via LimeSurvey -Participants are asked to allocate themselves to a phase and explain why
BREAK	10 min	
Distribution of backward-looking moral responsibility	1 hr 10 min	-Presentation on the catastrophe scenario developed by the Dutch Institute for Health and the Environment -Discussion in *Meetsphere* where participants are asked to indicate who would blame whom (a blame game) -Participants vote in *LimeSurvey* who is responsible in catastrophy scenario, and explain their choice -Presentation by facilitator on the relation between knowledge and moral responsibility -Participants individually vote in *LimeSurvey* on the level of knowledge stakeholders in each phase should have had.

BREAK	10 min	
Distribution of ownership rights	10 min	-Presentation on ownership rights -Individual vote on the distribution of ownership rights to stakeholders via LimeSurvey
Round up	15 min	-Plenary evaluation

5.5.3. Distinction of Phases

As part of the preparatory work for the GDR (used for part 3 of the programme), we divided the development and use of the Food Warden into six phases (see Table 5.2). These phases are identified in the tradition of science and technology studies that suggest following the object (cf. Latour 1987). So these phases trace the journey of the biosensor from the moment it is being developed to the moment it is disposed of. These phases were important in the GDR session because they allowed creating a proxy to talk about in which phase responsibilities are located instead of pointing to stakeholders who would tend to have these responsibilities. Defining the phases prior to the session also allowed mapping the relevant stakeholders.

Table 5.2 Phases and their main actors

Phases / Stakeholders	**Research & Development**	**Market approval**	**Use in Industry**	**Retailer**	**With the consumer**	**Waste disposal**
	Scientists (universities, companies); Companies in material, packaging, synbio	I&M; RIVM; Ministry of Health; Ministry of Economic Affairs	Meat industry; packaging industry	Different supermarkets; restaurants	Consumers; consumer watchdog	Waste removal companies; municipality; health inspection

5.5.4. Participants

Participants relevant to each phase were invited. In the end, 11 participants from industry, government and science, were present at the session (see Table 5.3 for an overview). Unfortunately, none of the civil society invitees participated in the workshop, which may result in the position of consumers less well defended. The number of participants underlines the exploratory nature of this research and we want to stress that the results we will present are only relevant to this case and might provide avenues of inquiry, as we examine in the discussion.

Table 5.3 Participants' sectors

Code	Sector
Q45	National government
H11	National government
A12	National government
S73	National government
C31	Regulatory organisation
W19	Research organisation
F06	Research organisation
A08	Developer
R36	Meat industry
K55	Packaging industry
Z04	Packaging industry

5.6. Results

Before being able to speak of the distribution of moral responsibilities, the most important part of the session was to identify the issues of concern. After presentation of the Food Warden participants were asked to identify potential safety issues of this product by answering the question, "what could go wrong with the biosensor?" Table 5.4 gives an overview of the issues that were selected for further discussion because they were (1-8) deemed important by the group, and (9-11) considered surprising.

A striking observation is that even though participants were asked about the biosensor, some of their answers seem to go beyond purely safety issues of the product. Fraud (issue 6) and problems of misuse (issue 2 and 9) don't have to do with some inherent feature of the biosensor itself, but rather identify negligence or malicious intent as causes for unsafe practices. Issues 3 and 7 seem to hint at how the introduction of a technology such as Food Warden influences our perception of safety, and show that a conflict between our perception of safety and actual safety in itself poses a safety risk.

Table 5.4 Issues of concern for the biosensor*

Issues
(1) The bacteria will adapt in an undesirable way
(2) Misuse
(3) Illusion of safety (perception of the consumer)
(4) The bacteria survives outside the packaging
(5) Sensitivity is not appropriate
(6) Fraud
(7) The sensor is unreliable
(8) The bacteria comes in contact with meat
(9) The sensor is ingested by a child
(10) Transfer of genetic traits to nature
(11) The instructions for usage are unclear

* (These issues were originally listed in Dutch and translated to English by ZR)

Once these issues were listed, we carried three rounds of voting for participants to allocate these issues to phases. The multiple rounds of voting allowed the participants to become more familiar with the issues and clarify differences in interpretations along the way. In the first round, participants were able to allocate issues to several phases. In the second round, they could allocate issues to only one phase. The second round was followed by a discussion of the results of that vote (an excerpts is included in the discussion section), and it was followed by a third and last round of voting, where again, each issue could only be allocated to one phase.

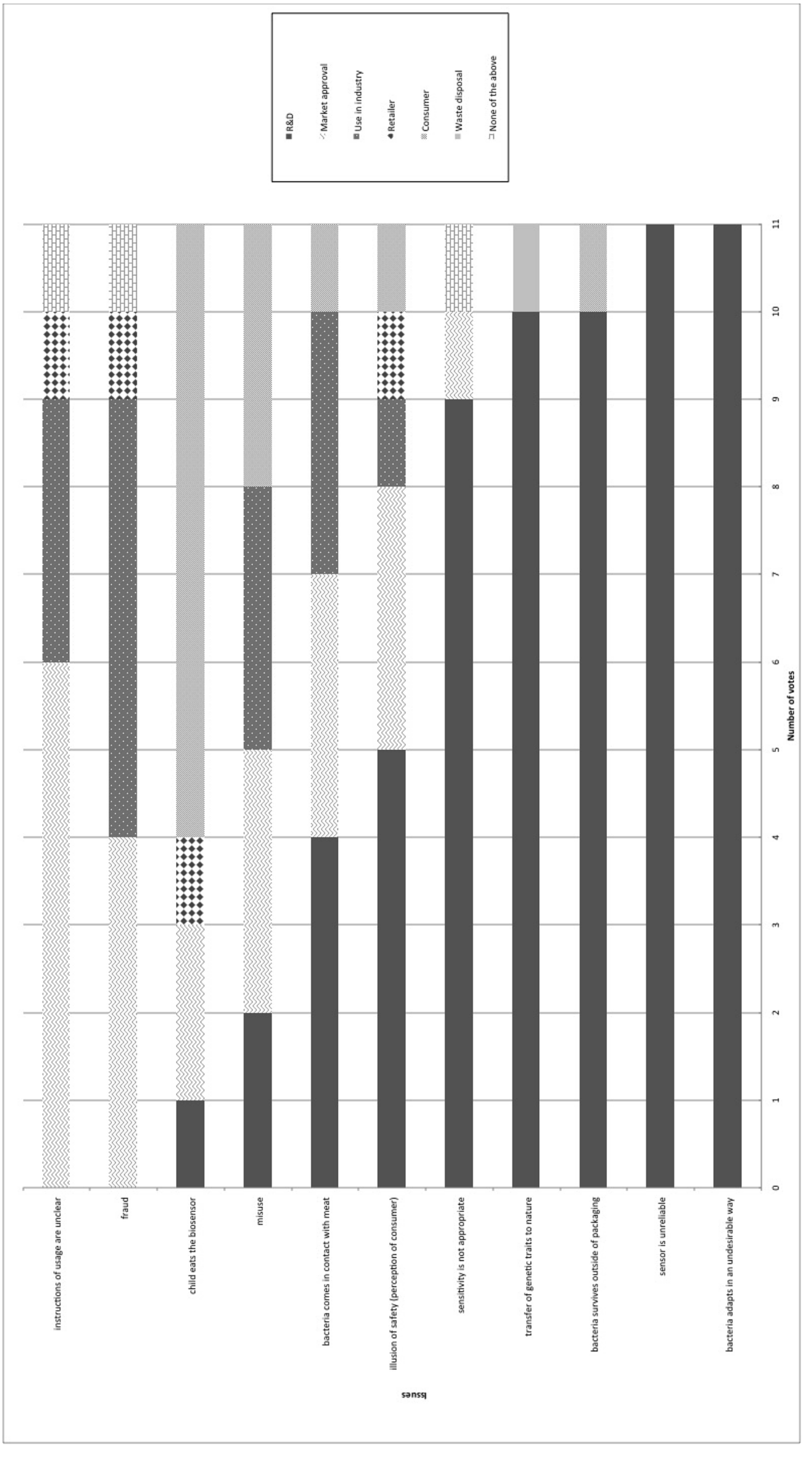

Figure 5.1 Results of Vote 3: Participants allocate each issue to only one phase

After these votes, we presented a problem scenario, developed by the National Institute for Public Health and the Environment, where many children got ill at a party after eating meat that was packaged using the biosensor and used by a snack bar for burgers, i.e. the retailer (see Table 5.5).

Table 5.5 The catastrophe scenario

During a children's party, all kids got ill after eating hamburgers from a snack bar. After angry phone calls from worried parents, the snack bar owner realizes that some of the Food Warden pockets are ripped open. The hamburgers were purchased at a retailer that uses the Food Warden as an indicator of freshness. It is unclear when those pockets containing the Food Warden might have broken open. Fortunately, all the children recover very quickly. However, the parents refuse to go eat at establishments that make use of the biosensor and they share their outrage on social media.

Participants had to vote for those they thought would be to blame for the children getting sick. In Figure 5.2, we compare these results with the "amount" (i.e. the average number of issues that were allocated to phases in vote 3) of forward-looking responsibilities that were allocated to the same phases.

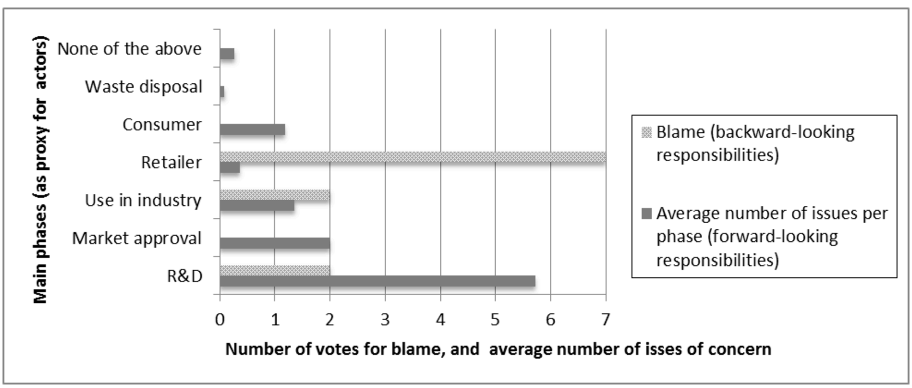

Figure 5.2 Comparison of backward-looking responsibility versus forward-looking responsibilities

After this vote, we asked participants to reflect on the knowledge condition of backward-looking moral responsibility. We will expand on this in the discussion, but for now Figure 5.3 depicts is what participants answered.

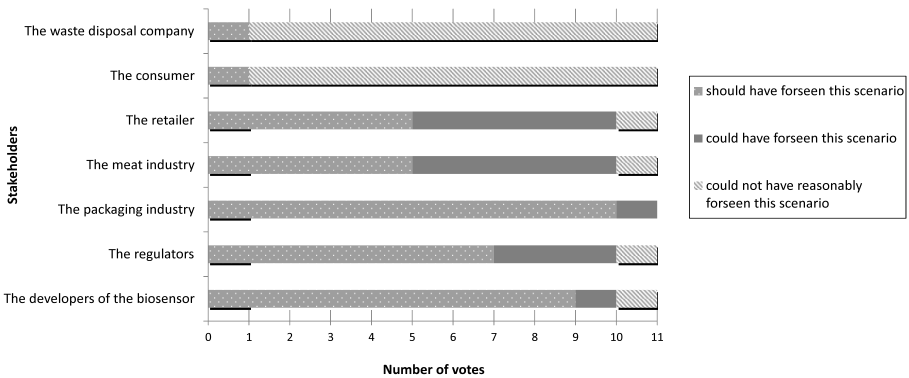

Figure 5.3 Votes on which stakeholder and foreseeability in the problem scenario

The issue of backward-looking moral responsibility was further discussed offline, and online through an anonymous discussion where participants had to put themselves in the shoes of other stakeholders. We do not include these results here as they were not the most salient for the issues we are considering but we do come back to some observations by participants in the discussion.

As a last step, we explored the participants' perceptions on ownership rights. We asked participants to ascribe to the different stakeholder with ownership rights they thought these stakeholders should have. Table 5.6 shows their votes compared with the number of issues per phases at vote 3. We use the result of the third vote, as we understand them as the most stable agreement.

Table 5.6 Votes for ownership rights allocated to actors in phases compared to number of issues per phase from Vote 3 (in italic)

Stakeholder / Rights	R&D	Market approval	Use in packaging industry	Use in the meat industry	Retailer	Con-sumer	Waste dis-posal
Right to Use	7	2	6	9	7	8	2
Right to manage	6	5	5	3	0	0	0
Right to transfer	11	0	3	3	2	1	1
Right to income	11	1	8	5	4	0	2
Number of Issues (vote 3)	*9*	*7*	*5*	*5 **	*4*	*5*	*1*

*idem for both industries

5.7. Discussion

In the introduction, we presented the concept of safe-by-design, as one that shifted most of the burdens of moral responsibility to the actors in the R&D phase. In the case of the Food Warden, can the actors in the R&D phase take up this responsibility? Who bears what forward-looking moral and backward-looking moral responsibilities? Should and can safety of the Food Warden be left to the actors in the R&D phase alone? Our exploration of the case does not provide generalizable evidence for all synbio applications, but we do observe a number of interesting things.

5.7.1. On the Concentration of Moral Responsibility in the R&D Phase

First, Table 5.1 shows that at the 3rd round of voting, and after discussions, participants felt that five of 11 issues were in the hands of the R&D phase (all participants or a clear majority of participants). These five issues of sensitivity and reliability, the possibility of the bacteria adapting in an undesirable way and surviving outside the packaging, or even transferring genetic traits to other organisms in nature. In other words, participants identified these issues and then decided that the actors who had the capacity to prevent those issues were in the R&D phase. This is far from surprising as all these issues concern the design of the biosensor.

However, some participants allocated other issues to the R&D phase, albeit not by a majority. These issues are that the bacteria comes in contact with meat, that a child eats the sensor, the possibility of misuse and the illusion of safety. This could be interpreted as that although actors in the R&D phase do not necessarily have these forward-looking moral responsibilities, some of the participants believed that they might have the possibility to influence the likeliness of these issues.

All in all, actors in the R&D phase do seem to be bear most forward-looking responsibilities according to our participants, supporting what one would expect with the use of a safe-by-design approach. It should be noted, however, that participants from the R&D phase were under-represented in our GDR session. Further research might want to focus on whether these actors are willing and able to undertake these responsibilities. Moreover, although the participant in the R&D phase allocated a lot of the issues to the R&D phase, she also allocated several issues to the waste disposal phase, a phase that was not very much paid attention to by other participants, also in the discussions. Also, with the experience of responsibility ascription with nano-materials (cf Shelley-Egan and Bowman), it is important to bear in mind that different stakeholders might understand their own, as well as others' responsibilities differently.

5.7.2. On the Relation between Forward and Backward-looking Moral Responsibility

Now that we've established that in our GDR session, many of the forward-looking responsibilities are allocated to the R&D phase, it is time to look at whether this is the case for backward-looking moral responsibility. Before investigating whether there was any relation between how the participants allocated forward-looking and backward-looking responsibility, let us first explain why, at least philosophically, one might expect such a relation to exist.

According to most philosophical theories of responsibility, the appropriate apportioning of backward-looking responsibility (like accountability, blameworthiness and liability) depends on a number of conditions. One of the conditions that is regularly mentioned in the philosophical literature for backward-looking responsibility is wrong-doing. One cannot be blameworthy for an action or outcome if one did nothing wrong. Elsewhere, we have argued that wrong-doing might either involve not living by a forward-looking responsibility might either involve not living by a forward-looking responsibility or the breaking of a duty (Van de Poel 2011a). Both can be seen as the breaking of a moral obligation.

One might expect that for most non-philosophers, like the participants in our session, the distinction between breaking a duty and not living by a forward-looking responsibility is too fine-grained to make a real distinction in their reasoning. Therefore, we expected that our participants would see all moral obligations as forward-looking responsibilities and that there would be a certain relation between how they attributed the forward-looking responsibility and how they attributed backward-looking responsibility. However, Figure 5.2 suggests that such a relation was absent. It should be noted that the retailer in Figure 5.2 corresponds to the snack bar in the scenario, as was explained to the session participants.

One possible reason why Figure 5.2 does not show a relation between forward-looking and backward-looking responsibility is that the attribution of backward-looking responsibility is based on the scenario presented above, while the forward-looking responsibilities relate to a range of possible risks. The scenario was deliberately formulated broadly and somewhat ambiguous so that it would not point at one cause but at a range of possible causes for the sickness of the children. When we look at the various safety issues that were inventoried (see Table 5.4), it would seem to us that all of these except for one could be among the causes of the sickness of the children in the scenario. The only risk that would seem impossible as cause in the specific scenario is the risk of gene transfer to the environment. Nevertheless, it is conceivable that the participants when interpreting the scenario ruled out possible safety issues as causes. This seems indeed the case as some participants in part 4 of the GDR gave as explanations for attributing the responsibility to the retailer that the sensor has been tested and therefore had no influence on the meat.

It should be noted that the above highlights a more general difference between attributing forward-looking and backward-looking responsibility. In attributing backward-looking responsibility, we usually consider one specific event that has already occurred, while in the case of forward-looking responsibilities we typically consider a much larger range of possible scenarios that could occur but need not to have occurred yet.

Another possible reason why Figure 5.2 does not show a relation between forward-looking and backward-looking responsibility is that wrong-doing is only one of the conditions for backward-looking responsibility. Another condition is knowledge, or more precisely the ability to foresee certain scenarios or consequences. We therefore also asked the participants whether according to them the various actors should have foreseen this specific scenario (see Figure 5.3).

However, it would seem that the results as presented in Figure 5.3 do not explain why most participants attributed responsibility to the retailer as the participants apparently did not believe the retailer to be in the best position to foresee this scenario. Moreover, it also does not explain why they attributed quite a lot of forward-looking responsibility to the actors in the R&D phase but much less backward-looking responsibility to these actors as 9 out of 11 of the participants voted that the actors in the R&D phase should have foreseen this scenario.

To understand why most of the participants attributed backward-looking responsibility to the retailer, it is worthwhile looking at the justifications they gave for this attribution in part 4. Two things catch the eye. First, some participants state that the retailer is blame-responsible until it can be proven that a mistake has been made elsewhere in the causal chain. A second remarkable argument is that it is the first in the causal chain that should have the blame from the viewpoint of the consumer.

The first argument is interesting because it suggests a heuristics in attributing blame-responsibility ('blameworthy until proven innocent') that seems to be the opposite of the legal adagio that someone is innocent until proven guilty. This heuristics is perhaps less amazing as it seems because also in many real-world cases of disasters or scandals people feel that somebody should be blameworthy, even if we have reason to believe that there might be situations in which we cannot reasonably blame anybody (so called cases of the problem of many hands, see for example Van de Poel et al. 2012)).

This heuristic may also be related to the so-called Knobe-effect. Knobe (2003) found experimentally that in cases of undesirable outcomes, we are more likely to attribute intentionality or blameworthiness to the agents causing the undesirable outcomes than in cases of good or desirable outcomes. This may possibly explain why the retailer is only attributed with limited forward-looking responsibility but much more backward-looking responsibility after the unfolding of a scenario with an undesirable outcome.

However, this would not seem to explain why the participants in majority hold the retailer blame-responsible rather than for example the developers of the sensor. One possible explanation here is the distinction between proximate and distal causes. If something undesirable happens it typically does not have one but many causes (Del Frate et al. 2011; Bhaumik 2009). The proximate causes are the causes that are most direct and attract initial attention. In this specific case, the quality of meat that was delivered by the retailer is likely to be a proximate cause of the illness of the children. In contrast to proximate causes, distal causes or so-called root cause lie earlier in the causal chain, but often are considered more important or fundamental for avoiding certain scenarios. One might hypothesize that in attributing forward-looking responsibility, people tend to focus on distal causes as they are often more important in avoiding certain scenarios. While once something undesirable has happened, people may well focus on more proximate causes, especially if there is limited information available about the scenario that has unfolded or if the scenario is ambiguous (as is often the cases in real-life situations and also in the scenario that we presented). Such a hypothesis would explain our observations, in particular the disconnection between the attribution of forward-looking and backward-looking responsibility.

5.7.3. On the Forward-looking Moral Responsibilities of Owners

In the introduction, we asked whether safe-by-design means that only actors in the R&D phases would bear moral responsibilities for safety issues of the Food Warden. We also briefly presented the proposal of allocating forward-looking moral responsibility to owners of that technology.

The idea behind this type of forward-looking moral responsibility ascription is that if owners reap benefits off of a technology, then they should also have forward-looking moral responsibilities to do no harm with that said technology (Robaey 2015). This concerns new technologies with potentially great benefits but that also entail uncertainties and unknowns, when the introduction of a new technology in society can be considered a social experiment (Van de Poel 2011a).

How can owners avoid harm, if there are many uncertainties and unknowns that come with the use of a technology? Ignorance does not absolve of responsibilities, so if owners do not know possible hazards of their technology, they ought to learn about it. The way owners learn, i.e. what they will learn about and how, will depend on the cultivation of their epistemic virtues and their capacities. Owners have to act as responsible experimenters, or in other words, to learn about these technologies, in case that they might have unintended side effects, so they can react (Robaey 2016a).

Ownership is here conceived of as a bundle of rights and responsibilities (Honoré 1961). With regard to rights, different owners can have varying amounts of rights over a technology, what Honoré calls split ownership e.g. only the right to use and the right to income, or only the right to manage. But every owner of a technology, or its tokens, have the responsibility to do no harm. In turn, this responsibility is translated for each owner into a *range of actions*, that are themselves defined by capacities and contexts.

In the GDR session, we started by identifying potential issues of the biosensor. These issues can also be understood as the basis of defining a range of actions that stakeholders (possibly some of them owners) can take in order to avoid undesirable outcomes.

Indeed, the issues listed are all connected to the responsibility to do no harm, and also, in a more or less direct manner, to learning about potential effects, or rather learning how to deal with these potential issues. Also, for the purpose of this exercise, we focussed on the ownership rights that were most relevant to the case at hand: the right to use, the right to manage, the right to transfer, and the right to income. These were most relevant because of the type of issues we could expect with the biosensor that would have to do with containment, potential malfunctions and issues in use.

An initial assessment of the relationship between ownership rights and moral responsibility could make for the following hypothesis: the more rights owners have over a technology, the more they should have responsibilities. However, as Robaey (2016a) points out, the important criteria for responsibility is owners' capacities rather than their rights (although more rights might provide for more capacities). In this explorative set-up, the question of ownership was not at the centre of investigation. Also, explanations were kept to a minimum regarding the rights; this might have led to a varying range of interpretations by the participants. However, we gathered some initial results that can provide a base for discussing the insights above.

In Table 5.6, for the actors involved in the R&D phase, it seems that participants generally ascribed them all of the rights with a majority of the votes. Also, most of the issues are allocated to the R&D phase. It corresponds to the idea that the more ownership rights actors may have, the more forward-looking responsibilities they would have. A similar but less pronounced pattern is observed in the industry phases.

There are two phases that stand out particularly when considering the relationship between rights and responsibilities: the market approval one, and the consumer one. In both these phases, we see that the hypothesis that more rights entail more responsibilities does not hold. Indeed, for both phases there are overall lesser rights, but a high proportion of forward-looking moral responsibilities. For instance, the right to manage received many votes at the market approval phase (i.e. the regulators), but not the other rights. Likewise, the right to use for the consumers received many votes, but not the other rights. These two groups of actors are responsible for a large number of issues overall but have less rights overall.

During the GDR session, there might have been a misunderstanding on the meaning of ownership rights. It is very well possible that participants interpreted the "right to" of an actor, as an actor "can do/have X". This interpretation would support the idea that the actual allocation of forward-looking moral responsibility is more strongly connected to the idea of capacity, i.e. what actors can do. Therefore, there does not seem to be straightforward relation between the allocation of forward-looking moral responsibilities and the amount of ownership rights.

When looking at the issues that participants listed, that are not strictly linked to the design of the bio-sensor, we observe that these tend to be split between different phases (Figure 5.1), like with misuse, fraud, unclear instructions, a child eating the biosensor, and the illusion of safety. This could indicate that participants focussed on different capacities of actors in each phases to do something about the issues[18].

Ascribing forward-looking moral responsibilities to owners should allow them to define their range of actions to do no harm when acquiring the biosensor. These actions depend on their capacities, and also do not exclude other actors from taking responsibility; it only puts the emphasis on forward-looking responsibilities of owners that have been left unexplored. Making these explicit can only enhance the chances of a good use of new technologies, such as the biosensor. So safe-by-design does also involve other actors than the ones in the R&D phase. In the next section, we share an unexpected observation that goes on to specify our claim to broaden the scope of actors.

[18] We did not present the results of vote 1, because what they showed what that all issues could be allocated to all phases, so in other words, following this reasoning, it would mean that everyone is responsible for everything. This could also be interpreted, as there are always capacities at some level to do something about an issue.

5.7.4. On the Importance of Responsibility Transfer

As presented in the results, the issues that were raised did not all pertain strictly to the idea of safe-by-design. Indeed, several of the issues raised are linked to the use and social context of the biosensor. In this section, we pay special attention to the transfer of responsibility through instruction manuals, which appeared in the session as an issue (issue 11, 'instructions for usage are unclear') and around the discussion on misuse.

Before we asked participants to allocate issues to one phase, there was a plenary discussion on the answers collected until then. The following is an excerpt of the discussion that followed after the facilitator asked why participants had allocated the issue of misuse to a specific phase[19]. A participant from the national government (Q45) starts of by explaining why he chose to allocate the issue misuse to the phase of market approval.

> Q45: Misuse should be listed in the manual, this should be checked during market approval.
> F06: But you often see that people don't do this.
> Q45: That's why you have to inform the consumer, for instance through the Voedingcentrum[20]
> [Unidentified participant]: Maybe the consumer should do this herself.
> A12: explains that irrespective of the manual the responsibility for misuse is with the consumer.
> R36: But this does not absolve producers from their duty to put a good product on the market.

The discussion concerning the creation of a false sense of security links up to this topic as well:

> Q45: This is analogous to our earlier discussion on the manual. This [Food Warden] is a way to indicate the shelf life[21] of meat. But it includes uncertainties as well, so you should indicate under what circumstances it can be used; 'No not in such and such cases' and ' Yes, if...'.
> W19: 'when in doubt...'
> R36: You could also make a claim based on science.

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19 GDR observation notes (from 15:12 onwards), translated from Dutch to English by SLS

20 Official translation : Netherlands Nutrition Centre Foundation

21 The original word was *houdbaarheid* in Dutch , it would mean in literal way 'keepability'.

> K55: What kind of manuals do you expect? I wouldn't expect more than one sentence.
> Facilitator: That's a good question.
> F06: You should indicate the circumstances under which it works.
> [Unidentified participant]: That would be a reason to go back to the R&D phase, to ensure it always works. To make a foolproof product.
> A12: The use of the sensor would be determined to a great extent. Including [the risk of] breaking it and what he sensor indicates.
> Z04: and that [information] fits on the sensor? ...

These observations allow raising an important question on the role of instruction manuals as a way to negotiate responsibilities. If instruction manuals are meant to prevent misuse, and thereby foster a responsible use of the biosensor, then who should be responsible for what they contain and how should they be written?

According to our participants, votes casted after the above-discussion shed a divided outlook on the distribution of forward-looking responsibilities. Around half of participants allocated the issues of 'the instructions are unclear' to the market approval phase, about a quarter of participants to the use in industry, with the remaining votes split between the retailer and R&D phases. The majority of votes, slightly more than half for the issue of 'misuse', are split between the use in industry and the consumer phases, with the rest of the votes placed towards the R&D and market approval phases.

These results are confusing because it seems that the same actors (for the most part) are involved in defining the instructions, and misusing the biosensor. But it is this very confusion that allows shedding light on the potential that instruction manuals have in achieving the value of safety.

Instruction manuals act as a way for producers to deflect liability. They present one way of using an object and if this is not followed and something bad happens, then the producers are not liable. This is, however, a backward-looking understanding of moral responsibility. Looking at the role of instruction manuals through the lens of forward-looking moral responsibility can open new avenues for achieving safety.

In the design literature, instruction manuals can be understood as a use plan (Houkes and Vermaas 2004). A use plan is a rational sequence of action that leads to the realization of a goal, as intended by the designer; it is therefore prescriptive. In reality, there could be more than one use plan, but there is one prescribed set of instructions, that might be transmitted via sentences or graphics. As a participant points out, instructions are usually quite succinct, and could be as short as one sentence.

Instructions can differ greatly amongst technologies such as drugs, which have very long instructions inside the packaging and clear intake instructions from the physician and the pharmacist. Or cars, which are black-boxed to a certain extent, leaving exposed some basic component for the user to be responsible for and leaving the rest to the car mechanic. As mentioned earlier, the way instructions are formulated and presented are to prescribe use, and deflect liability.

Instructions are written to prescribe a good use of a technology and avoid undesired events designer and developers think might happen. This process of formulation leaves out two important components: what users actually do, and all the potential unknown events that might happen (Robaey, 2016b). It is a lot to ask of instructions to make for all eventualities imaginable and unimaginable. Also, as mentioned in the introduction, different synbio applications may warrant different types of concerns regarding uncertainties. Dealing with a technology is therefore a dynamic process (in terms of users, and effects), and currently instruction manuals may not be the best reflection of this. But what does this mean for the transfer of moral responsibility?

In our GDR session, regulators, industry, R&D and retailers are all involved in the issue of 'unclear instructions' according to different participants. The construction of instruction manuals can therefore become a locus of negotiation between the different stakeholders. In theory, one could argue that designers have the obligation to produce good instructions with a product. However, participants of our GDR session seem to think that not all the responsibility can remain there. Also, it is inevitable to transfer some amount of responsibility with the transfer of an object (Pols 2010), the question is therefore: how to transfer responsibility in a good way.

This leads us to re-think the formulation of an instruction manual as a place of negotiation for the distribution of moral responsibility. This negotiation should entail the awareness that there could be more than one way to use the biosensor and that these might also lead to good use. Moreover, using the notion of social experiment as a frame to deal with the negotiation of moral responsibility broadens the scope of actors that will be involved earlier in the process, and allows actively sharing the forward-looking moral responsibilities with actors beyond the R&D phase. In a way, all actors involved in the use of the biosensor are experimenters, and there are responsible ways to experiment. Perhaps the locus of negotiation of an instruction manual could be where various actors and stakeholders come together to define how they will experiment with the biosensor, instead of following a linear journey of product development, approval, market placement and use.

5.8. Conclusion

While the results of our GDR session are exploratory, they have allowed reflecting on a number of issues on the theme of safe-by-design in synbio. First and foremost, we see that when presented with a safe-by-design synbio application, our participants do tend to put many possible safety issues with the R&D phase. Safe-by-design does seem to place most of the forward-looking moral responsibilities in the R&D phase for the Food Warden case. Does this also mean that backward-looking moral responsibility is also mostly in the R&D phases?

We found, somewhat surprisingly, no relation between the attribution of forward-looking and backward-looking responsibility. A possible reason for this may be that in attributing backward-looking responsibility people tend to focus on the proximate causes of the specific scenario that unfolded and on the actors connected to these proximate causes while in the case of forward-looking responsibility people tend to focus on distal (or root) causes.

We also see that not all safety issues listed by our participants are strictly connected to design and this broadens the horizons of what safety means when safe-by-design principles are used. From the very beginning, our investigation points to a salient fact: safe-by-design doesn't solve all safety issues. Safe-by-design only goes so far in terms of safety, because safety is not only established in design but also in use and misuse.

So there are forward-looking moral responsibilities to be allocated to actors in other phases. Looking at owners of technologies and their special responsibilities to learn about the technologies of which they reap benefits underlined the importance of capacities rather than ownership rights. Further research could look into whether actors' capacities can be understood as responsibilities to take actions that could prevent harm. This could have implications on how responsibilities are distributed.

We also looked at our exploratory results through the lens of the social experiment, and we found that the negotiation of distributing and allocating moral responsibilities could be done at the moment where instructions for use are defined by the different stakeholders.

In a nutshell, despite the promises of safe-by-design, safety cannot be achieved with safe-by-design only. However, looking at the journey of the biosensor, we find interesting places where further research could be carried out, namely proximal and distal causes, non-regulatory and non-R&D actors and their capacities, and instruction manuals as a locus of negotiation for the responsibilities of different actors in a social experiment with synbio applications.

6 Conclusion

In the following pages, I summarize the main findings of this thesis (section 6.1), I present some possible objections and complications (section 6.2), I suggest some generalisations (section 6.3) and I ask some of the questions that remain unanswered while providing suggestions for avenues of enquiry (section 6.4).

6.1. Main findings

This book begun with the depiction of the scene in which the use of GM seeds takes place and the problems that they raise. This led to the following question: what are the forward-looking moral responsibilities of owners in the social experiment with GM seeds?

The first step to answer this question was to look at the nature of the relation between ownership and moral responsibility for uncertain harms from GM seeds. An important finding in Chapter 2, is that using Goodin's distinction of duties and responsibilities, I argue that since duties require specific actions, they are a concept that can address how we ought to deal with known risks. I also argue that since responsibilities, are defined as requiring self-supervision from the agent, and has discretionary powers, i.e. the capacity to improvise, they are better suited to deal with uncertain risk. This is why this thesis investigates the responsibility to do no harm. Another important finding in Chapter 2 is that the owner of a genetically modified seed has moral responsibility to do no harm with that seed, and there can be several owners of the said seed at the same time who will share moral responsibility for each seed that is owned and has the modified character trait.

The second step was to define the responsibility to do no harm. By looking at the difficult case of contamination, I found that the moral responsibility to do no harm of owners implies that owners should do everything they can to try to find out about effects of GM seeds. This is where the lens of the social experiment (Van de Poel 2016) adds an useful analytical component.

Indeed, using GM seeds in agriculture can be conceived of as a social experiment, since it can bring great benefits to society while also bringing harmful unexpected side effect. It is then these unexpected side effects that owners need to try finding out. One way to achieve this is through an owner's possession and cultivation of epistemic virtues. These epistemic virtues can lead to different types of learning for different types of owners. For instance, a biotechnologist will not have the same knowledge as a farmer, but both are owners and can possess and/or develop epistemic virtues. Thus, when confronted with the uncertainties of GM seeds, owners must try, to the extent of their capacities, to learn about the effects of GM seeds, and act as soon as it appears necessary to avoid harm. In that way, we can define the forward-looking moral responsibility to do no harm as the development of epistemic virtues that allow the owner to define a range of action to do no harm with the use of GM seeds. This range of action will differ from owner to owner given that each owner has different capacities. This creates opportunities for a variety of actions all aimed at preventing harm, and this, at different moments of the journey of the GM seeds.

The third step was to answer the question: how is responsibility transferred when ownership is transferred? We can understand that ownership can be transferred, and split, with owners having different bundles of rights. How is moral responsibility then transferred? Or in other words, how can we insure that new owners can have the forward-looking moral responsibility to do no harm? In Chapter 4, I find that the current way of transferring ownership through contracts does not imply transferring moral responsibility, and that use guides, or instructions provide for an insufficient transfer of moral responsibility when it comes to avoiding harm. What would constitute a good transfer of moral responsibility? I suggest the following five conditions for transferring the forward-looking moral responsibility to do no harm:

(1) An owner i is morally responsible for a GM seed in a forward-looking way to do no harm with the technology. This implies that there should be at least one rational use plan x that does not result in unacceptable harm from the use of the technology.

(2) The owner i can communicate this rational use plan x to another owner j. This use plan x is context-sensitive, i.e. x ensures that the new owner j need not change the seed's intended context dramatically to be able to start using it. This allows avoiding high demands on capacities from owners who might not have them.

(3) The new owner j has the capacity to execute the use plan x and where j's capacity might be lacking, the original owner i that has executed the transfer should ensure that she helps the realization of the use plan, whether on their own or through the recruitment of more actors.

(4) The new owner j has epistemic access to the technology. This means that the technology does not remain a black box for j; instead, owner j should have the possibility to change and manage the technology in a context-sensitive manner. This, in turn, ensures that the new owner j has the opportunity to learn about the seed (e.g. through training).
(5) The new owner j has the possibility to create and communicate adapted rational use plans y to yet other owners k, when and where it is relevant to preventing harm with the use of technology.

With the responsibility to do no harm with GM seeds (Chapter 2 and 3), and conditions that allow a good transfer of this responsibility (Chapter 4), owners are now conceptually equipped to deal with hazards and avoid harm. The field of biotechnology is, however, rapidly evolving and there are suggestions that some issues of responsibilities may be replaced by technological solutions. For instance, the rise of Safe-by-Design in synthetic biology might provide for technological answers to safety concerns by suggesting that safety can be designed in. In Chapter 5, I explore what such technological approaches to safety imply for moral responsibility. I underline that if safety is defined as the absence of risks, then it does not account for the uncertainties that might arise from the use of GM seeds. I explore issues of moral responsibility and safety in an empirical exploration using a hypothetical synthetic biology application (also a GM artefact). Several findings come to light with regard to the moral responsibility to do no harm. First, Safe-by-Design places a lot of the responsibility to do no harm on the actors in the research and development (R&D) phase. However, not all safety issues can be addressed in the R&D phase. Indeed, many uncertainties can arise in other phases of the lifecycle. So it seems worthwhile considering other actors who use the technologies and who have capacities to realize safety. In addition, I suggest that what safety means and who should realise it can be defined and negotiated in the formulation of instructions. Attention to actors who use the technology, or in other words, owners, and what safety means and how they can help realize it link back to defining a range of actions for owners and moral responsibility being transferred in a desirable manner. All in all, I find that the moral responsibility to do no harm cannot be replaced by technological means, as might be suggested by the approach of Safe-by-Design.

In a nutshell, these findings allow answering my original research question: what are the forward-looking moral responsibilities of owners in the social experiment with regards to uncertainties of GM seeds in order to deal with their uncertain risks?

I'd like to start answering my main research question by contrasting two popular GM seeds, the Roundup Ready soybeans and the Golden Rice. These seeds differ in their modifications and in their ownership structure. Roundup Ready soybeans have a built in herbicide tolerance, that allows using a herbicides that will not harm the desired crop. It is a technology owned by Monsanto. The Golden Rice is a vitamin A enriched GM rice that aims to solve malnutrition issues in developing countries. It is a project supported by the International Rice Research Institute, that aims at doing rice research for reducing poverty, and promoting sustainability. The Golden Rice has a humanitarian license, so it can be used for free in areas in need. These two examples of GMOs therefore seem very different in their technology and set up, but they are not so different in their dynamics, as social experiments. First, both the Golden Rice and Roundup Ready soybeans raise criticism: the Golden Rice for being a band aid on poverty instead of solving structural issues that lead to poverty, and the Roundup Ready soybeans for making farmers dependent on a given seed and a given pesticide. Moreover, there are uncertainties as to long term effect linked to the use of both GM seeds. Regardless of their goal, or set up, they both can be considered social experiments, require special consideration and call for their owners to fulfil their moral responsibility to do no harm.

So we are doing a social experiment in agriculture with a variety of GM seeds. If the experiment is to be responsible, there needs to be more than a set of conditions but also a way for how to be responsible. We assume certain seeds will be better for certain reasons but we don't really know beforehand how their use will impact our environments, and our societies. So what are the forward-looking moral responsibilities of owners in the social experiment with GM seeds?

In the social experiment, owners have the forward-looking moral responsibility to do no harm with the GM seeds they use and develop (Chapter 2). However what causes harm is not fully known beforehand. Therefore, this moral responsibility implies dealing with uncertainties and ignorance, so it implies dealing with more than known risks that can be addressed by duties (Chapter 2). In order to fulfil this forward-looking moral responsibility to do no harm for uncertain risks, owners need to learn about the GM seed. Learning in a responsible way about uncertainties is possible if and when owners possess and/or can develop epistemic virtues. Also, different owners will have different capacities which will allow them to define a range of actions in order to learn (i.e. be self-supervisory) and this will facilitate intervening if something goes wrong (i.e. employing discretionary powers). These actions of learning and intervening will take different forms for different types of owners (Chapter 3). While owners can transfer ownership, they also have the forward-looking moral responsibility to transfer moral responsibility in an acceptable way! This implies that the means to learn and intervene, i.e. epistemic access through self-supervision, and intervention through discretionary powers, also should be transferred in order to fulfil the moral responsibility to do no harm. Use plans can provide for a way to transfer moral responsibility (Chapter 4). If technological means are available to owners to fulfil their moral responsibility to do no harm, they should be used. However, they should also not be seen as a panacea for the forward-looking moral responsibility of owners in the social experiment. Such advances in biotechnology can also provide an opportunity for involving different owners in the discussion of what safety is, how it can be achieved, and who can contribute to it. As such, all owners can contribute their responsibility to do no harm with GMOs (Chapter 5).

6.2. Possible objections and complications of the research

While I have answered my main research question, I realise that my claims raise many questions that challenge the validity of my findings. In this section, I would like to present a few of these objections.

6.2.1. What if ownership ends?

The suggestion in this thesis is that agents with ownerships rights have the responsibility to do no harm with GMOs. Most of the focus has been on what this responsibility entails rather than discussing what happens if ownership rights ends. There are a variety of situations that can come to mind (e.g. theft, bankruptcy, or even hacking) and I will explore one: patent expiry, as it is closest to the topics discussed in this thesis. What could this situation mean for the moral responsibility to do no harm?

Let's begin by considering patent expiry. It is important to elucidate what the implications are. On the one hand, it means that the owner of the patent can no longer make restrictions on the use of its invention. In other words, it means that the use of the invention falls within the public domain. This implies that farmers who have purchased GM seeds can save them and distribute them within the legal limits of seed saving and trading. On the other hand, it does not mean that these seeds will be simply out there, as they bear a modified trait and their use still has to go through an approval process.

The most prominent example of patent expiry is Roundup Ready soybeans by Monsanto whose patent expired in 2015. On their website, they explain that, "Monsanto expects to maintain full global regulatory support for the Roundup Ready soybean trait through 2021. This enables farmers to continue to market their soybeans around the world for the next 8 years and, perhaps beyond, if a third party is interested in taking responsibility for the relevant regulatory packages beyond that time" (Monsanto). This is because, according to the American Soybean Association, periodic renewal of the GM seeds regulatory approval might be demanded by regulation in some countries (ASA 2010). However, it also means that beyond that period a "third party", i.e. someone else than Monsanto, will have to take responsibility to go through regulatory approval in order for these seeds to be legal. At the same time, this third party will most likely not have patent-like ownership rights but will nonetheless bear responsibility.

So the expiry of patents does not mean the absence of responsibility or regulation for that matter. However, there are several problems one could anticipate. Would the harvest from royalty-free GM seeds be considered of lower value than those of the 2.0 versions of these seeds? How will this be evaluated and decided upon? How will farmers relying on those patent-less GM seeds cope once these seeds become illegal if no one takes responsibility to renew their regulatory approval? How and who will keep track of tracing where the modified trait might go (in the case for instance where a GM seed would be used in breeding with a conventional seed)? I realise that asking these questions does not answer the question initially set out in this section. One could even think of several more questions but for now, I leave the reader to ponder and suggest that further research is needed to address this problematic situation.

6.2.2. What if seeds are not privately owned?

One could also question the findings of this thesis in relation to different types of ownership models. For instance, some argue that agricultural seeds belong to the commons (see Timmermann and Robaey 2016 for a discussion on agrobiodiversity and property regimes). Would this mean that seeds resulting from biotechnological interventions also belong to the commons and not be under private rights? Currently, many seeds, conventional or GM, have patents (see de Schutter 2009), thus are under private property models. If we were to decide as a society that all seeds, including GM seeds, were to be under a different property model, what would happen to the framework presented in this thesis?

Timmerman and Robaey (2016) reflect on different property regimes with regards to agrobiodiversity conservation and the types of incentives they create and for whom. We differentiate between the following cases: no property, private property, commons, state sovereignty and common heritage. The first observation we make with regards to GM seeds is that property regimes might influence incentives to innovate.

If there were no property on GM seeds, one can imagine that people might not try to develop seeds due to the large type of investment they require. Also, it is important to understand that giving no property does not equate a humanitarian license, like the Golden Rice has, or an open access. So if there are no ownership rights that can be claimed, how can we give the responsibility to do no harm to owners?

Now, if GM seeds were part of the commons, one might expect similar problems as to the case of no ownership in terms of incentives to innovate. But if there were incentive structures that would stimulate innovation for GM seeds as commons, one could imagine that by virtue of being a common good, GM seeds would be cared for in a more responsible way. This would happen by means of cooperation within a clearly defined group with rules on how to maintain the GM seed, as suggested by Ostrom (1990, p.90). One point where further research could be done is with regards to the creation of new commons such as new seeds and the possible hazards that they might bring about. Most of the time, commons are naturally occurring and finite resources. Nowadays, with the advent of the bio-economy, natural resources are being exploited in innovative ways. New technologies allow the creation of natural resources, and these new technology bring about uncertainties as to their social and physical impacts (cf. Asveld et al 2015).

Another interesting case to consider is the one of state sovereignty. This could greatly change the way GM seeds are developed, as one could imagine a state defining agricultural needs for GM seeds, and it being framed as a societal project, rather than a private enterprise. One of the problems with this would be that it would probably move all the responsibility to the state as a multitude of actors. This could create a situation where all the information and power would be controlled by a selected few, as we see with large infrastructures such as nuclear energy facilities (Bergen 2016a). How would such a structure influence the allocation of the responsibility to do no harm? Different actors will still have some degree of ownership. The main difference would be that the full bundle will belong to the state instead of a company in the private sector. Perhaps this would impact the processes through which responsibility is defined and transferred, but it would not necessarily change the suggested framework, i.e. the conceptual connection between ownership and moral responsibility.

Last but not least, the concept of common heritage of humankind provides an interesting avenue for distributing moral responsibility for uncertain risks of GM seeds. Five principles define this concept: "common management, no unilateral appropriation without worldwide sharing of benefits, swift sharing of knowledge gathered by scientific research, prohibition of harmful uses, and preservation for future generations'' (in Timmermann and Robaey 2016). The salient elements of these principles link to coordination between actors, sharing of knowledge, and preventing harm. All these ideas are present in this thesis but presented differently. In a way, one could imagine these principles as a layer over the current scheme of private property that could help deciding on what basis the allocation of rights and responsibilities should occur.

6.2.3. Can we allocate forward-looking moral responsibility without ownership?

My thesis argues that owners should be allocated the forward-looking moral responsibility to do no harm with GM seeds. The two previous sub-sections consider different cases where ownership is not as defined in this thesis and reflect on implications for the responsibility to do no harm. Can we allocate this forward-looking moral responsibility without linking it to ownership? My answer is yes, absolutely. There are many arguments that one can give to allocate forward-looking moral responsibility to an agent. These arguments can be based on similar rationales as presented in this thesis, relating to capacity, to knowledge, etc., without having to be connected to ownership. For instance, regulatory actors and civil society do not have ownership rights over GM seeds, which does not mean they cannot be allocated forward-looking moral responsibility.

In this thesis, I attempted to explore whether and how owners could be responsible. My intention was to broaden the notion of ownership beyond the discussion of intellectual property rights because it has been stiffening and polarizing the debate. I wanted to contribute an account that could complement current approaches and bridge discourses of risk and ownership.

6.3. Generalisations

6.3.1. Are ownership regimes coupled to specific technology?

Does the type of ownership regime matter for the type of technology? In this thesis, the departure point of all investigation is observing what happens with GM seeds and what kind of suggestions can be made to ameliorate the status quo when it comes to dealing with uncertain risks by looking at ownership in a certain regime. Is the relationship between ownership and moral responsibility described in this book then only applicable to technologies like GM seeds? It should be noted that there is no necessary relation between the ownership regime and the technology. Therefore it would seem that my thesis that ownership entails moral responsibility would also apply to other technologies. As the previous section points out, we could very well think of other ownership regimes in which responsibility could be allocated differently, and we could very well think of moral responsibility without ownership. An empirical question could be to observe what would happen to the management of a technology if the ownership regime where to change. Empirically, these investigations might reveal that some ways of managing certain technologies might be better than others in certain contexts, and with regards to dealing with risks. However, there is nothing that indicates that the type of ownership regime and the type of technology should matter for owners having the responsibility to do no harm.

6.3.2. What about the known risks?

This thesis focusses on uncertain risks of GM seeds, but could its finding apply to known risks? In Chapter 2, I make the distinction between duties that are well suited to deal with known risks and responsibilities that are well suited to deal with unknown risks. However, I would like to suggest that the findings of this thesis also apply to known risks. It would come as an addition to duties requiring specific actions, and not as a replacement. Indeed, in order to deal with risk

X, an agent has the duty to do A. In addition, this agent might also have the responsibility to learn about X in order to suggest new ways of doing A that might be better for her or for others. The agent would then also have the responsibility to transfer doing A, or new ways of doing A in an acceptable manner. All in all, the findings of this thesis might also lead to suggesting new ways of dealing with known risks.

6.4. Further Investigations and Practical Implications

6.4.1. Balancing rights and responsibilities

One area of further investigation concerns the balance of rights and responsibilities. In this thesis, I show that owners have the responsibility to do no harm, what this responsibility means, and how it can be transferred. However, this raises a number of questions: do more rights mean more responsibilities? In other words, should it be the case that the higher the expected utility (deriving from having rights) one has over a GM seed, the more responsibility should that agent have? What if agents with more rights do not have the capacity to be responsible, should we only give rights to those who have the capacity to be responsible? Or is it the case that having more rights ultimately allow agents to have more capacity to be responsible?

These questions suggest that there should be some sort of way to balance rights and responsibilities, but should there be a balance between rights and responsibilities in the first place? My preliminary answer is yes. Indeed, it would seem unfair and inefficient to burden an agent with many responsibilities and little rights, or the other way around, give an agent many rights and little responsibilities. This argument was made a several places in this thesis. However, the only parameter I have provided to rely on is the capacity of agents to do fulfil this responsibility.

There is still much to be investigated with regard to the idea of balancing rights and responsibilities. One could also ask what other values (other than fairness and efficiency) could be at stake when thinking of balancing rights and responsibilities. One suggestion from the Nuffield council with regard to important values to consider when developing new biotechnologies are equity, solidarity and sustainability (2012). The Nuffield council also suggests a number of procedural and institutional values for the governance of modern biotechnologies: openness and inclusion, accountability, public reasoning, candour, enablement, and caution. These values recall principles suggested by the concept of the common heritage of humankind. An avenue of investigation could be to see what the implementation of such values could have as a positive impact in balancing rights and responsibilities of owners.

6.4.2. Intellectual Property Rights

Another area of further investigation is intellectual property rights (IPRs). This thesis made a distinction in Chapter 2 between the type and the token of the GM seed. Indeed, I argued that the bundle of ownership rights that we considered was over the tokens, i.e. the copies of the GM seed, whereas IPRs were for the type, i.e. the idea of the GM seed. In Chapter 4, we see however, how important the access to knowledge about the GM seed is for dealing with uncertainties and varying contexts. IPRs create restrictions on the access to knowledge about GM seeds. In the context of dealing with uncertainties, and food safety and security, the findings of this thesis might suggest that we should revisit the basis on which IPRs are attributed. Further research could look into a more normative framework for granting IPRs, this could also connect to the previous avenue of investigation on balancing rights and responsibilities. Suggestions in this direction should bear in mind that they should not deter innovators or users from developing or adopting the new seeds. The current situation creates a lot of resistance towards a technology that might be beneficial under the right conditions, so if we were to update the way IPRs work, we should do so as to anticipate future problems they might bring about, in the case of seeds. Some suggestions exist, such as the BiOS license (Cukier, 2006) that is around for the past decade but still has not gained wide support.

6.4.3. Beyond individual responsibility

In this thesis, I define an owner's individual moral responsibility to do no harm. However, at every step of my argument, it is primordial that owners are not alone in their individual moral responsibility. In Chapter 2, I argue that owners, as individuals, have a shared responsibility to do no harm. In Chapter 3, I argue that owners ought to develop their epistemic virtues in order to act as responsible experimenters and that different owners have different capacities. In Chapter 4, I define an acceptable way to transfer this moral responsibility to other owners. In Chapter 5, I show how an artefact changes hands through its lifecycle and the different issues that might arise and related responsibilities for different actors. In this section, I would like to think of this responsibility beyond the individual.

Of the possible avenues of investigation, I would like to mention Miller's joint moral responsibility (2015), and Spruit and colleagues' idea of the duty to collectivize (2016). Miller describes how joint actions can be performed by members of a team, or as a series of joint actions. His description of a series of joint actions as multi-layered structures of joint epistemic actions corresponds to the type of coordination required to fulfil moral responsibility as described in this thesis. Another possible avenue of investigation is Spruit et al.'s idea of the duty to collectivize. They develop this argument in the context of fields that fall under the nanotechnology umbrella but are actually disconnected from each other. Considering the case of GM seeds, and their split ownership, speaking of the duty to collectivize could be an avenue for increasing coordination amongst owners. In addition it could feed into the next point of further research, which is the one of professional ethics through codes of ethics.

6.4.4. Code of ethics

There's an inherent tension when speaking of professional ethics and the field of food production as analysed in this thesis. Indeed, in order to produce food with GM seeds, several professions come into play. Some may not even be defined as professions by an order or an institution. The findings above nonetheless may suggest a need for some sort of code for all actors involved in the development and production of food, even if they do not form one profession. Indeed, since food production is a private endeavour for the public good, there should be some sort of shared vision or guidelines as to what consists of a good food production chain. Such calls for institutionalizing a professional ethics in agriculture have been made in the past but there still does not seem to be a universally accepted. In 2001, the FAO defined a set of actions with respect to ethical issues in food and agriculture, one of which being: "Developing codes of ethical conduct where they do not currently exist". In 2005, Burkhardt and colleagues write, "Ultimately, though, the issue of institutionalizing ethics in the food system comes down to the responsibility of each of us involved in this system to accept the fact that if ethical issues are going to be understood, and if ethical conflicts are going to be resolved, it is our responsibility, within the limits of our place in the system, to understand and contribute." (p.10)

There are two problems with codifying a professional ethics for food production. First, when people talk of agricultural ethics, a long list of concerns is presented (for instance cf. Chrispeels & Mandoli 2003), and each of these concerns might be of relevance to different actors. Second, if we were to dig deeper, we could probably find codes of ethics linked to various biotechnological associations, but there seems to be no code uniting the variety of actors involved in food production. So a code might not actually be the best way to institutionalize professional ethics for food production.

However, Harris Jr. draws a distinction between preventive and aspirational professional ethics (2008, 2013). According to Harris Jr. preventive ethics aims to prevent harm with rules, and is mandatory. Aspirational ethics allows for more self-supervision and discretion as to how to act with the focus of promoting well-being. Self-supervision and discretion are the basis of defining moral responsibility in this thesis (Chapter 2). This distinction is therefore interesting because the ideas presented in this book could lead to an aspirational code ethics to prevent harm in the food sector, and maybe even actively promoting well-being. This code could be shared by all people involved in food production.

These observations provide for practical implications of the research, as well as a venue of further investigation.

6.4.5. A moral responsibility to do good?

This last observation ties in nicely with the last question of this book. I defended owner's responsibility to do no harm with GM seeds, but should they, in addition, have the responsibility to do good with GM seeds? This would be a very strong claim to defend, and I will not do so in this paragraph. I will just underline why we should talk about this. So far, the framework of the social experiment was presented as somewhat neutral lens that allows increasing moral responsibility for new technologies with high potential social benefits but also potentially dangerous uncertainties. However, we should also think about why we undertake a certain social experiment with a new technology. To what end do we do what we do? Should this end be doing good? If so, how could we define what doing good means? Also, good compared to what? Here speaking of alternatives becomes paramount to deciding what doing good might mean. Perhaps there is a forward-looking moral responsibility to do good with technology, and what this moral responsibility might entail is still to be defined.

Epilogue

After having presented all these considerations, I would like to conclude my thesis with a few words on what I find the most important normative message that emerges from my work. In the end, it is about how we use and share knowledge, who uses it, to what ends, and how. Knowledge and property are locked-in through intellectual property rights. In my work, I tried to disentangle knowledge from intellectual property right and link it to moral responsibility through to a constructive understanding of ownership. The concentration of ownership as IPRs, brings many problems. The ideas in this thesis suggest a future where all owners can be responsible, develop and share knowledge in order to work together towards a better use of GM seeds.

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Summary

The use of modern biotechnology in agriculture has made great promises of better yields. Thanks to a range of techniques, modifications can be made to seeds in a much faster way than through conventional breeding techniques. Genetically modified seeds (GM seeds) can range from being pesticide resistant to having an increased nutritional content. However, the extent of social and political contention in using these seeds is, in some parts of the world, as great as their promises. There are indeed many unknowns that remain around the use of biotechnology in agriculture. Different modifications could have different types of hazards or long-term impacts on human and/or environmental health, or even on the practice of farming itself. To some extent, we can anticipate potential problems with GM seeds, but deliberately releasing a living technology that can easily spread strongly suggests that not everything is predictable and controllable. No major accidents have resulted from the use of GM seeds in agriculture. Nonetheless, cases of unpredicted contamination have occurred, and so have many legal disputes since their introduction on the market.

Indeed, GM seeds are protected by intellectual property rights, which makes every copy of these seeds subject to ownership claims. This in itself is a type of legal and social innovation in the agricultural world making practices such as seed saving illegal. Also, the development of seeds has increasingly moved from the farmer to seed breeders and the agrobiotechnology industry. In this thesis, I take a constructive approach to the notion of ownership, as a bundle of rights. This allows to disentangle issues of intellectual property on the idea or the process through which a GM seed is developed from issues of use of the GM seeds.

Technologically, and socially, the introduction of GM seeds has taken the shape of an experiment in society. This is not only a figure of speech, but also a conceptual framework in the ethics of technology (Martin and Schinzinger 1983; Van de Poel 2011, 2016)that I explore and build upon. In this thesis, I present new insights from the ethics of technology to shed light on new avenues for responsible development and use of GM seeds, or in other words, responsible innovation. Particularly, I look at the role of agents who directly reap benefits

from this technology, i.e. owners. My research question is therefore, what are the forward-looking moral responsibilities of owners in the social experiment with regards to uncertainties of GM seeds?

In order to answer my research question, I begin to establish the link between ownership and moral responsibility in Chapter 1. A constructive understanding of ownership sees ownership as a bundle of rights. In this scholarship, Honoré (1961) also attributes the duty to prevent harm to the bundle. However, it is unclear whether owners with different bundle of rights all have the duty to prevent harm. Before I elucidate this question, I suggest a translation of the duty to prevent harm to a responsibility to do no harm, following Goodin's (1986) distinction of duty and responsibility, and I argue that responsibility is a more fitting notion to deal with the uncertainties that come with GM seeds. I then proceed to argue that the responsibility to do no harm is shared by all owners. This implies that a GM seeds and its copies can have several owners with different bundles of rights and that they all share the responsibility to do no harm.

Sharing the responsibility to do no harm is too broad a concept to be operationalized. In Chapter 3, I therefore take the problem case of GM seeds contamination and ask: how can owners be responsible for what they do not know? I suggest that there are two elements that come to form the description of their forward-looking moral responsibility. Drawing from the literature on culpable ignorance and from the literature on responsible social experimentation, I argue that different owners might have different capacities but will all have the responsibility to cultivate their epistemic virtues to learn about the GM seeds they develop, use and spread. This will allow defining each owner's range of action, which is how the shared forward-looking moral responsibility to do no harm is operationalized. Owning GM seeds therefore does not stop at possessing and reaping benefits, it bestows a special kind of responsibility to all owners to be responsible experimenters. This does not take away responsibility from regulating bodies or other agents; it opens new horizons on how to better deal with GM seeds and thereby engage the variety of owners in the social experiment.

So owners have a moral responsibility to do no harm with GM seeds, and I explain what this moral responsibility means, but if ownership of GM seeds can be transferred, how can moral responsibility for GM seeds be transferred? In

Chapter 4, I answer this question by drawing from the literature on design and ethics, and applying it to a case study of the Monsanto Technology Use Guide. There is a thin line to be drawn between the legal and moral realms of ownership, and they are intricately connected. In the legal realm, duties are normally laid out in contracts, or in instruction manuals. Contracts also transfer certain rights to new owners and maintain other rights to the original owners. So how can we know if these legal document transfer moral responsibilities in a good way? I define five conditions that suggest how the transfer of moral responsibility for uncertain risks can take place in a desirable manner.

Modern biotechnology is about more than GM seeds, there are many methods and fields of application. With these new methods, the idea that we can not only read DNA but also write it also lead to the suggestion that we can write safety in the design of modern biotechnology, or in other words, safe-by-design. In Chapter 5, I explore a synthetic biology application and the notion of safety. I underline that defining safety as the absence of risk leaves out dealing with uncertainties. What does designing for safety imply for the distribution responsibilities? I present some main lines of future investigation with regard to the distribution of moral responsibility in the case of safe-by-design. These are that issues of safety cannot be confined to the design phase, that capacities of actor along the life cycle of a technology matter for responsibility, and more deliberation can take place in defining instructions on use in order to achieve safety.

To conclude, the insights of this thesis in the ethics of technology suggest new horizons for the governance of GM seeds and modern biotechnology. This has implications for property regimes, granting of intellectual property rights, balancing the distribution of risks and responsibilities, and shared moral responsibility and even perhaps a code of ethics for the food domain. Through the lens of the social experiments, perhaps we can move from a culture that seeks have certainty to a culture that seeks openness and inclusiveness, to really live the agenda of responsible research and innovation.

Samenvatting

Het gebruik van moderne biotechnologie in de landbouw belooft hogere opbrengsten. Dankzij een scala van technieken kan de modificatie van zaden veel sneller verlopen dan met meer conventionele kweektechnieken. Genetisch-gemodificeerde zaden (GM-zaden) zijn gevarieerd, sommige zijn resistent tegen bestrijdingsmiddelen, andere hebben weer een hogere voedingswaarde. In sommige delen van de wereld, echter, is het gebruik van deze zaden even veelbelovend als sociaal en politiek omstreden. En inderdaad zijn er nog veel onzekere factoren rond het gebruik van biotechnologie in de landbouw. De modificaties zouden uiteenlopende soorten gevaar kunnen opleveren of lange-termijngevolgen kunnen hebben voor de gezondheid van mens en milieu, en zelfs voor de landbouw als zodanig. We kunnen tot op zekere hoogte anticiperen op mogelijke problemen met GM-zaden, maar opzettelijk een levende technologie introduceren die zich gemakkelijk kan verspreiden, maakt duidelijk dat niet alles voorspelbaar of controleerbaar is. Totnogtoe zijn er geen grote ongelukken gebeurd vanwege het gebruik van GM-zaden in de landbouw; desalniettemin, gevallen van onvoorziene besmetting zijn er, evenals vele juridische geschillen, sinds ze op de markt werden geïntroduceerd.

GM-zaden worden namelijk beschermd door intellectuele-eigendomsrechten, zodat elke kopie van deze zaden onderworpen is aan eigendomsclaims. Dat is op zichzelf al een juridische en sociale innovatie in de landbouwwereld, die een praktijk als het opslaan van zaden illegaal maakt. Ook is de ontwikkeling van zaden meer en meer overgegaan van de boer naar de zaadkwekers en de industriële agro- en biotechnologie. In dit proefschrift benader ik het idee van eigendom op constructieve wijze, als een ‘pakket van rechten’ (‘bundle of rights’). Hierdoor kunnen de problemen rond het gebruik van GM-zaden worden losgekoppeld van de problemen rond het intellectuele-eigendomsrecht op het idee of het ontwikkelproces van GM-zaden.

De introductie van de GM-zadentechnologie heeft de vorm aangenomen van een sociaal experiment. Dit is niet alleen maar beeldspraak, maar ook een conceptueel kader in de ethiek van de technologie (Martin en Schinzinger 1983; Van de Poel 2011, 2016) dat ik onderzoek en waarop ik voortbouw. In dit proefschrift presenteer ik nieuwe inzichten uit de ethiek van de technologie die een licht kunnen werpen op nieuwe manieren waarop we de ontwikkeling en het gebruik van GM-zaden in verantwoordelijke banen kunnen leiden, anders gezegd: verantwoordelijke innovatie. Ik kijk in het bijzonder naar actoren die direct voordeel hebben bij deze technologie, namelijk eigenaren. Mijn onderzoeksvraag is dus: wat zijn de toekomstgerichte morele verantwoordelijkheden van eigenaren in dit sociale experiment wat betreft de onzekere factoren rond GM-zaden?

Om mijn onderzoeksvraag te kunnen beantwoorden, leg ik in Hoofdstuk 1 allereerst het verband tussen eigendom en morele verantwoordelijkheid. Het meest constructieve begrip van eigendom beschouwt het als een pakket van rechten. De wetenschap (Honoré 1961) voegt hier ook de verplichting aan toe om schade aan het pakket te voorkomen. Echter, het is onduidelijk of eigenaren met een ander pakket van rechten allemaal de verplichting hebben schade te voorkomen. Voordat ik deze vraag verder toelicht, stel ik voor om de 'verplichting geen schade te berokkenen' te vertalen als 'een verantwoordelijkheid geen schade te berokkenen', waarin ik Goodin (1986) volg, diens onderscheid tussen plicht en verantwoordelijkheid, en betoog ik dat de verantwoordelijkheid om geen schade te berokkenen een geschikter idee is voor de omgang met de onzekere factoren rond GM-zaden. Ik vervolg met te stellen dat de verantwoordelijkheid om geen schade te berokkenen wordt gedeeld door alle eigenaren. Dit houdt in dat een GM-zaad en zijn kopieën verschillende eigenaren kunnen hebben met verschillende pakketten van rechten en dat ze allen de verantwoordelijkheid delen om geen schade te berokkenen.

De gedeelde verantwoordelijkheid om geen schade te berokkenen is als concept te breed om te kunnen worden geïmplementeerd. Vandaar dat ik in Hoofdstuk 3 het probleemgeval neem van GM-zaadbesmetting en vraag: hoe kunnen eigenaren verantwoordelijk worden gesteld voor wat zij niet weten? Ik stel voor dat er twee elementen zijn die samen invulling moeten geven aan hun toekomstgerichte morele verantwoordelijkheid. Met behulp van de literatuur over verwijtbare onwetendheid en verantwoorde sociale experimentatie, betoog ik dat ook al mogen verschillende eigenaren verschillende capaciteiten hebben, zij toch allemaal de verantwoordelijkheid hebben hun kennisdeugden ('epistemic virtues') te ontplooien om weet te hebben van de GM-zaden die zij ontwikkelen, gebruiken en verspreiden. Zo kunnen wij de handelingsruimte van elke eigenaar definiëren, waarmee de gedeelde toekomstgerichte morele verantwoordelijkheid kan worden geïmplementeerd. Het bezit van GM-zaden houdt dus niet op bij voordelen hebben en ontvangen, het legt aan alle eigenaren een bijzondere verantwoordelijkheid op om verantwoordelijke experimenteerders te zijn. Dit ontslaat de regelgevende instanties en andere actoren niet van hun verantwoordelijkheid; het opent wel nieuwe vergezichten op een betere omgang met GM-zaden en vergroot de betrokkenheid van uiteenlopende eigenaren bij het sociale experiment.

Eigenaren hebben dus een morele verantwoordelijkheid om met GM-zaden geen schade te berokkenen, en ik leg uit wat deze morele verantwoordelijkheid inhoudt; maar als eigendom van GM-zaden overdraagbaar is, hoe kan dan morele verantwoordelijkheid worden overgedragen? Ik beantwoord deze vraag in Hoofdstuk 4 met behulp van de literatuur over ontwerp en ethiek, en pas haar toe op een case-study van Monsanto's *Technology Use Guide*. De scheidslijn tussen het juridische en morele domein van eigendom is smal, en beide zijn nauw verbonden. In het juridische domein worden plichten normaliter vastgelegd in contracten, of handleidingen. Contracten dragen ook zekere rechten over aan de nieuwe eigenaren, terwijl andere rechten bij de oorspronkelijke eigenaren blijven. Hoe kunnen wij dus weten of deze juridische documenten de morele verantwoordelijkheid overdragen op een goede manier? Ik definieer vijf voorwaarden, die schetsen hoe de overdracht van morele verantwoordelijkheid voor onzekere risico's op een wenselijke manier kan plaatsvinden.

Bij moderne biotechnologie gaat het om meer dan GM-zaden, er zijn veel meer methodes en toepassingsgebieden. Met deze nieuwe methodes leidt het idee dat we niet alleen DNA kunnen lezen maar ook schrijven tot de gedachte dat we veiligheid in het ontwerp van de moderne biotechnologie zélf kunnen opnemen, ofwel: 'safe-by-design'. In Hoofdstuk 5 onderzoek ik een synthetische biologie-toepassing en het idee van veiligheid. Ik benadruk dat wanneer we veiligheid definiëren als de afwezigheid van risico, we het omgaan met onzekerheden weglaten. Wat betekent het ontwerpen voor veiligheid voor de verdeling van verantwoordelijkheden? Ik presenteer enkele hoofdlijnen van toekomstig onderzoek met betrekking tot de verdeling van morele verantwoordelijkheid in het geval van safe-by-design. Deze hoofdlijnen zijn: veiligheidskwesties kunnen niet beperkt blijven tot het ontwerpstadium, de capaciteiten van de individuele actor gedurende de levenscyclus van een technologie tellen mee bij de verantwoordelijkheid, en instructies voor gebruik kunnen met meer overleg worden gedefinieerd ten behoeve van de veiligheid.

De inzichten van dit proefschrift in de ethiek van de technologie, ten slotte, openen nieuwe vergezichten op het beheer van GM-zaden en moderne biotechnologie. Dit heeft implicaties voor vermogensstelsels, het toekennen van intellectuele eigendomsrechten, de evenwichtige verdeling van risico's en verantwoordelijkheden, de gedeelde morele verantwoordelijkheid en zelfs misschien een ethische code voor voedsel. Door de lens van de sociale experimenten, kunnen we misschien evolueren van een cultuur die de zekerheid zoekt naar een cultuur die openheid en inclusiviteit omhelst, om de agenda van verantwoordelijk onderzoek en innovatie ook daadwerkelijk te leven.

Curriculum Vitae

Zoë Robaey is currently a researcher at the Rathenau Instituut since June 2016. She completed her PhD in Ethics of Technology at Delft University of Technology between April 2012 and January 2017. Her work, in the most idealist sense, is about building bridges between societal actors around problems they might have, in order to make the world a better place.

Zoë's background is truly interdisciplinary. She holds a B.Sc in Biology (University of Ottawa), an M.A in European Studies for Society, Science and Technology (Maastricht University), and an M.P.P (Hertie School of Governance). She has worked in environmental policy consulting at the Ecologic Institute in Berlin from 2008-2011, and at the Center for International Governance Innovation (Waterloo, Canada) for their annual event on climate negotiations in 2010.

Besides being a researcher, Zoë is a passionate educator and communicator. During her PhD, Zoë was actively involved in engineering ethics education. In 2015, she co-developed and organized the Impact! Competition, a project aiming to teach ethics to engineering students through art. That same year, Zoë also organized the Meal of Ignorance, an interactive dinner with dilemmas for participants in order to raise awareness on food inequality, in the context of a campaign for Food Guerilla and World Food Day. Last but not least, Zoë participated in the competition 'Dance your PhD' and made it to the front page of Science Magazine during the voting process, despite not winning anything. Besides learning and teaching lindy hop in Rotterdam, Zoë also enjoys making silly cover songs with her ukulele and doodling dog comics.

List of Publications

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Simon Stevin (1548-1620)

'Wonder en is gheen Wonder'

This series in the philosophy and ethics of technology is named after the Dutch / Flemish natural philosopher, scientist and engineer Simon Stevin. He was an extraordinary versatile person. He published, among other things, on arithmetic, accounting, geometry, mechanics, hydrostatics, astronomy, theory of measurement, civil engineering, the theory of music, and civil citizenship. He wrote the very first treatise on logic in Dutch, which he considered to be a superior language for scientific purposes. The relation between theory and practice is a main topic in his work. In addition to his theoretical publications, he held a large number of patents, and was actively involved as an engineer in the building of windmills, harbours, and fortifications for the Dutch prince Maurits. He is famous for having constructed large sailing carriages.

Little is known about his personal life. He was probably born in 1548 in Bruges (Flanders) and went to Leiden in 1581, where he took up his studies at the university two years later. His work was published between 1581 and 1617. He was an early defender of the Copernican worldview, which did not make him popular in religious circles. He died in 1620, but the exact date and the place of his burial are unknown. Philosophically he was a pragmatic rationalist for whom every phenomenon, however mysterious, ultimately had a scientific explanation. Hence his dictum 'Wonder is no Wonder', which he used on the cover of several of his own books.