Representation of synthetic biology in Dutch newspapers

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Abstract

The emerging field of Synthetic Biology (SB) is expected to bring many promising applications. However, there are also concerns for safety, security, and of ethical nature. It is widely acknowledged that to properly evaluate these issues, involving society in decision making regarding SB's potential applications, risks, and ethical issues is necessary. One of the public's major sources of scientific information are news media. However, it is largely unknown how SB is presented to the public by Dutch news media. In this study I applied quantitative and qualitative approaches to investigate how SB is represented in Dutch newspapers. A total of 261 Dutch newspaper articles (published between 2000 and November 2016) were analyzed for five aspects, i.e.: 1) publication data, 2) motives for publication, 3) normative impression, 4) mentioned applications, risks, and ethical issues, and 5) metaphor use. SB representation in The Netherlands showed many similarities to other countries, such as German-language, English-language, and Scandinavian countries. It was found that SB media representation was predominantly event-based, positive, future-oriented, relatively small, and science-led. Results suggest that the public debate on SB has not yet started in The Netherlands.

Introduction

Synthetic biology (SB) is a promising and innovative field of research on the cutting edge of biology and engineering. Synthetic biologists design new or alter naturally occurring DNA with the aim to design organisms with a specific, desired function, such as the production of medicine components or biofuels (de Vriend, van Est, & Walhout, 2007). At the moment SB research is still in an early phase, with few applications that are usable outside of the laboratory. An exception is artemisinin, an antimalarial drug of which a precursor is produced by yeast cells with a synthetically created pathway (Ro *et al.*, 2006). In the future, however, SB is expected to have a large influence on a variety of fields. Craig Venter, one of the most prominent SB researchers, has stated that synthetic organisms will become a major source of energy, antibiotic, and vaccine production (Craig Venter, 2008).

Although applications that are expected from SB are promising, certain risks and ethical issues are associated with it. Like genetic modification, SB raises questions about (human) safety, environmental consequences, applications in biological weapons, and intellectual property (Ancillotti, Rerimassie, Seitz, & Steurer, 2016; de Vriend *et al.*, 2007). Furthermore, developments in SB make it unavoidable to think about what we consider "life" to be and whether it is ethical to create artificial life and where to draw the line (de Vriend *et al.*, 2007).

Since SB research started (around the year 2000; Cameron, Bashor, & Collins, 2014) governmental and scientific organizations such as the European Commission, the InterAcademy Panel: The Global Network of Science Academies, and the Dutch Rathenau Institute[1], have been concerned with evaluating risks, societal and ethical issues of SB (Ancillotti *et al.*, 2016). However, it is widely acknowledged that for proper evaluation of these issues it is important to take societal concerns seriously and, moreover, to involve society in decision making. Therefore, the public should be involved in deciding if SB should be used, and if so, under which conditions and for what purposes (Ancillotti, Holmberg, Lindfelt, & Eriksson, 2015). Involving the public is especially useful because many (ethical) issues associated with SB are complex and ambiguous. They cannot be solved by

[1] The Rathenau Institute is an independent organization that stimulates societal and political opinion forming about science, by performing research and organizing debates (https://www.rathenau.nl/nl/overons/over-ons).

experts on their own, especially because they might have their own interests (de Vriend *et al.*, 2007).

Public involvement in science is high on the agenda of the European Union. The EU introduced the concept "Responsible Research and Innovation" (RRI), which aims to align research and developments with values, needs, and expectations of society (https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation). The RRI project SYNENERGENE focuses specifically on SB and aims to establish "(...) an open dialogue between stakeholders concerning SB's potential benefits and risks, and by exploring possibilities for its collaborative shaping on the basis of public participation" (https://www.synenergene.eu/information/what-synenergene). This study contributes to SYNENERGENE's aim by studying how SB is communicated to the public by news media, as explained below.

Since news media are the main source of health and scientific information for the public (Jarman & McClune, 2007; Sharpe, Di Pietro, & Illes, 2016), especially for science that impacts society (Jarman & McClune, 2007), they play an important role in presenting SB to the public. Therefore, media representation of SB is likely to influence public perceptions on applications, risks, and ethical issues.

Studying how SB is represented in news media will generate insight into the current public perception of the field and may indicate how the public debate will evolve (Ancillotti *et al.*, 2016). However, representation of SB in news media has only been studied in a few European countries, i.e. German-language countries (Gschmeidler & Seiringer, 2012), Scandinavian countries (Ancillotti *et al.*, 2015), and Sweden and Italy (Ancillotti & Eriksson, 2016). Also, SB press coverage has been studied in Europe and the United States in general (Pauwels & Ifrim, 2008) and in English-language countries (Hellsten & Nerlich, 2011). Furthermore, Hartman (2016) studied the framing of SB in Dutch media. It was found that media in The Netherlands mainly focus on future possibilities of SB and put little emphasis on risks and ethical issues. However, other aspects of SB media representation in The Netherlands, for example coverage data and language use, remain unknown. Therefore, this study will further map SB representation in Dutch news media, while using a different approach than Hartman (2016). This will also facilitate comparison with the previously mentioned SB media coverage studies performed in other countries.

The research question that will be addressed in this study is "How is synthetic biology represented in Dutch newspapers?". To answer this question a media analysis will be performed, taking into account quantitative as well as qualitative aspects. Publication data, motives for publication, tone of the articles, applications, risks, and ethical issues that are mentioned, and the use of metaphors will be studied apart from and in relation to each other. These aspects are further explained in the methods section of this thesis and are exemplified in **Appendices 2-6**.

Theoretical framework

Synthetic biology

SB is a discipline that arose around the year 2000 by applying engineering approaches to biology. This was possible due to advancements in DNA sequencing and synthesis made in the decades before (Cameron *et al.*, 2014; Pauwels, 2013). The goal of SB is to "create, control, and program cellular behavior" (Cameron *et al.*, 2014) by synthetically producing and recombining existing DNA sequences, or by designing completely new DNA sequences.

Two approaches for SB exist, i.e. top-down and bottom-up. Modifying existing biological systems is the top-down approach. Often, the goal is to create a "minimal genome": a system that contains only absolutely essential elements (Malinova, Nallani, Meier, & Sinner, 2012; de Vriend *et al.*, 2007). A minimal genome can serve as a chassis that can be extended with specific synthetic DNA sequences to perform a certain desired function (de Vriend *et al.*, 2007). In 2016, the J. Craig Venter Institute announced the first cell with a synthetically produced minimal genome containing just 473 genes (Hutchison *et al.*, 2016). This cell, called JCVI-syn3.0, was a minimalized version of the first cell with a complete synthetically produced genome (JCVI-syn1.0: Gibson *et al.*, 2008).

With the bottom-up approach, on the other hand, standard DNA sequences (BioBricks) are used to build biological systems from scratch. These building blocks have specific functions, for example the synthesis of useful materials such as bioplastics (http://parts.igem.org/Protein_coding_sequences). Combining several BioBricks makes it possible to create living systems with entirely new functions (de Vriend *et al.*, 2007), such as bacteria that change color at a certain temperature, which are useful to monitor industrial processes (Beintema, 2008). BioBricks are open-source, meaning that anyone can use them and add newly designed ones to the catalogue. Participants of the international Genetically Engineered Machine (iGEM) competition use and design BioBricks to build innovative biological systems that contribute to solving real-world challenges (http://www.igem.org).

Definition of SB

Because SB is a relatively new research field, there is no agreement about a definition yet (Ancillotti *et al.*, 2015; Gschmeidler & Seiringer, 2012; Koffijberg,

2015). A delaying factor in finding consensus seems to be that the distinction between SB and genetic modification is still unclear. Scientists disagree whether SB is a new discipline or an extension of existing biotechnologies (Gschmeidler & Seiringer, 2012). This is reflected in the public press, as will be further explained in the discussion section.

InterAcademy Panel: The Global Network of Science Academies (IAP), defined SB as "The deliberate design and construction of customized biological and biochemical systems to perform new or improved functions" (IAP, 2014). The words "deliberate design and construction" indicate a distinction from "classic" genetic modification. Thus, SB is framed as an independent discipline. The European Commission, on the other hand, adopted a definition that relates SB to other gene technologies: "The application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms" (Scientific Committee on Health and Environmental Risks [SCHER], Scientific Committee on Emerging and Newly Identified Health Risks [SCENIHR], Scientific Committee on Consumer Safety [SCCS], 2014). According to several scientific committees an important advantage of this last definition is that risk assessments and safety guidelines that already have been developed for genetic modification can still be applied to SB (see Ancillotti *et al.* (2015) for a more extensive discussion).

The definitions mentioned here will both be used to determine which newspaper articles are relevant for inclusion in this study. By using both definitions, articles that distinguish SB from other technologies *and* articles that approach SB as "another" biotechnology are both included, which is relevant due to the lack of consensus about this matter.

Risks and ethical issues associated with SB

Although developments in SB hold many promises for the future (Ancillotti *et al.*, 2015), certain risks and ethical issues are associated with it. These are comparable to questions that were previously raised about other gene technologies, such as genetic modification (Gschmeidler & Seiringer, 2012). However, with SB entirely new and thus unknown organisms may be created. This raises the question if we have enough knowledge to properly assess the risks and ethical issues that are associated with synthetic organisms (Rerimassi & Stemerding, 2013).

Concerns about *biosafety* include risks for humans and the environment. For example, laboratory staff might be infected with synthetic organisms, which could cause disease. Pathogenic synthetic organisms may even cause an epidemic. Also, it is unknown what effect synthetic organisms could have on the environment if they accidentally escape from the laboratory. They could mix with natural life forms or might disturb ecological balance (de Vriend *et al.*, 2007). Therefore, in 2012 several authors made a call in Nature for research on risks concerning ecological consequences of SB (Dana, Kuiken, Rejeski, & Snow, 2012). Other experts believed that regulations for genetically modified organisms are also sufficient for SB. However, in the future synthetic organisms might be so different from current life forms that new regulations would be desirable (Rerimassi & Stemerding, 2013).

Biosecurity risks refer to the design and use of synthetic organisms for terrorist purposes or biological warfare. The polio virus has already been synthetically recreated in laboratory conditions, indicating that it is possible to use SB to produce pathogens (de Vriend *et al.*, 2007). Since BioBricks are freely accessible to anyone, it might be possible that they are used by evil-minded individuals or terrorist regimes to create biological weapons (Rerimassi & Stemerding, 2013). However, it is unsure how realistic this risk is, since naturally occurring pathogenic organisms or genetically modified pathogenic organisms are easier to use and to produce (de Vriend *et al.*, 2007). Still, it is needed to have regulations to prevent misuse (as discussed in de Vriend *et al.*, 2007).

Ethical issues associated with SB relate to for example *naturalness*, which includes questions about what life is and where the borderline between natural and artificial lies. For example, should a cell containing a minimal genome be considered as life, or as a "machine"? (de Vriend *et al.*, 2007). SB might give the impression that life is equivalent to DNA, but this may be in conflict with the widespread believe that life is special and not just an interaction of chemical substances (Rerimassi & Stemerding, 2013). SB also raises ethical questions about whether it is moral to create unnatural life and how far we can and should take it (Ancilotti *et al.*, 2015). For example, are synthetic biologists "playing God?".

Furthermore, there is debate about whether it should be possible to hold intellectual property rights for synthetic gene sequences or organisms, or whether these should be open source (Ancillotti & Eriksson, 2016). Patenting is needed for

commercial purposes, but hinders further research on the other hand. It also has implications for *fairness*, because countries with limited financial resources might not be able to have access to beneficial SB applications (de Vriend *et al.*, 2007). The BioBricks foundation strives for free access to their parts. This is accomplished by stimulating producers of new BioBricks to promise that they will not patent their DNA sequence (https://biobricks.org/bpa/contributors/).

Public engagement in science

In the last decades attention for societal aspects of science has increased (de Vriend *et al.*, 2007). Initially, socioscientific issues were contemplated on by the scientific world itself. However, starting in the 1990s, calls have been made to involve the public in science in an active manner (Stilgoe, Lock, & Wilsdon, 2014; Verhoeff & Waarlo, 2013). For example, the Human Genome Project invested in studying the Ethical, Legal, and Social Aspects (ELSA) of their research (Verhoeff & Waarlo, 2013). Whereas ELSA mainly focuses on societal impacts of research, the later implemented RRI concept (as explained in the introduction) focuses on establishing a dialogue between scientists and societal stakeholders to foster collaborative shaping of research that meets the needs of society (Oftedal, 2014; Rerimassi & Stemerding, 2013).

Although the public has to rely on experts' knowledge to a certain extent (Ancillotti *et al.*, 2016), public engagement in SB can help to understand risks, ethical, and societal issues that may not be recognized from an experts' perspective only. Therefore, the public should contribute to scientific knowledge and consequently influence the course that science takes (Ancillotti *et al.*, 2016; Pauwels, 2013).

However, there are fears that the public will react to SB with major criticism and that a fierce and unsettled debate will arise (Ancillotti *et al.*, 2015), as has been the case for other biotechnologies (Ancillotti *et al.*, 2016; Boerwinkel, Swierstra, & Waarlo, 2014; Gschmeidler & Seiringer, 2012). When biotechnologies, such as genetic engineering, were applied in the 1990s there was much resistance from society. This might be explained by the fact that they were implemented before there was much public knowledge (Boerwinkel *et al.*, 2014).

Therefore, an important consideration needs to be made when involving the public in scientific developments, i.e. in which stage this should be accomplished. This was first recognized by Collingridge (1980), who stated that

> "the social consequences of a technology cannot be predicted early in the life of the technology. By the time undesirable consequences are discovered, however, the technology is often so much part of the whole economics and social fabric that its control is extremely difficult. This is the dilemma of control."

(Collingridge, 1980).

So, in later stages of research, assessments of societal impacts can be made based on expert knowledge, but adjustments are limited because a course has already been set. However, in an earlier research stage society can help to assess and consequently influence the course of scientific development, although it will be based on less knowledge (Ancillotti *et al.*, 2016).

For SB, many calls are made to involve the public in an early stage. For example, before the second international SB conference in 2006 several societal organizations unitedly wrote a letter to the organization in which they insisted on full involvement of society in setting up a dialogue about all aspects of SB. Moreover, they expressed the opinion that self-regulation of SB by scientists would be undemocratic (de Vriend *et al.*, 2007). Also, the Dutch Rathenau Institute concluded in their 2007 report on societal impacts of SB that involving the public is useful because of the ambiguity and complexity of ethical dilemmas associated with SB (de Vriend *et al.*, 2007). Furthermore, IAP stated in 2014 that in order for SB to become successful, society should decide on support and regulation of the field. Because previous biotechnology discussions have been intense, especially in Europe, early involvement with SB provides the opportunity for a more nuanced debate (Ancillotti *et al.*, 2016).

Public knowledge about SB

Several studies have shown that public knowledge about SB is limited. In three telephone surveys among more than 3000 US residents (Pauwels, 2013), most respondents had not heard about SB, although awareness increased from 9% in 2008 to 26% in 2010 (unfortunately, more recent data on public knowledge about SB is not available). When asked about the perceived risks and benefits of SB, about a third of the respondents was unsure if benefits would outweigh risks or vice versa. However, after being given a balanced description of SB that mentioned some potential risks and benefits, more respondents were able to

express their opinion. More participants believed that risks would outweigh benefits, whereas initially more respondents thought that benefits and risks would be equal.

Furthermore, providing balanced information about SB to participants of citizen focus groups (Pauwels, 2013) did not necessarily increase acceptance of SB, but did lead to a more nuanced discussion that reflected uncertainties, ambivalences, and complexities of SB. This shows that informing lay people about SB increases their ability to form an opinion. Moreover, focus group participants showed a great need for more information about SB and indicated that "more should be done to inform the American public" about SB.

In Europe, public knowledge about SB was also limited in 2010. In the most recent Barometer on Biotechnology and the Life Sciences, conducted by the European Commission (Gaskell *et al.*, 2010), 83% of the respondents indicated to never have heard about SB. 8% did hear of SB, but never sought information about it or discussed it. Furthermore, in Austrian citizen panels held in 2012 (as described in Ancillotti *et al.*, 2016) it was shown that although people were aware of the practice of SB, they were not familiar with the term "synthetic biology". Moreover, at first instance this term is perceived as something negative. Participants were skeptical and insecure about SB and their support was highly conditional. Also, people tended to relate SB to genetic modification, which has been under heavy debate in Europe (Ancillotti *et al.*, 2016; Boerwinkel *et al.*, 2014).

In the Netherlands, public involvement in SB is fostered by the Rathenau Institute, which published two reports on societal implications of SB (de Vriend *et al.*, 2007; Rerimassi & Stemerding, 2013). Also, they organized the Meeting of Young Minds in 2011, which was a debate between students participating in the iGEM competition and members of Dutch political youth organizations. Rerimassi and Stemerding (2013) concluded that the Dutch government mainly focuses on the progress and risks that SB might bring, but that the Meeting of Young Minds made clear that attention for societal and ethical questions related to SB is desired for political and public opinion forming.

The influence of news media on the public

News media are one of the public's major sources of scientific information (Jarman & McClune, 2007; Sharpe *et al.*, 2016). Although online news media have become

more and more important (Gschmeidler & Seiringer, 2012; van Dam *et al.*, 2014), newspapers have several benefits over internet news, for example the availability of specialized journalists and science sections (van Dam *et al.*, 2014). Furthermore, as concluded by the 2010 Eurobarometer (Gaskell *et al.*, 2010) 62% of the European citizens had confidence in newspapers and magazines reporting on biotechnology and genetic engineering. In the Netherlands, as well as in many other European countries, confidence in newspapers increased between 1999 and 2010. Moreover, despite the popularity of online news media, in 2013 60% of the Dutch population read a newspaper (van Dam *et al.*, 2014). Thus, studying the representation of SB in Dutch newspapers will provide a well-grounded image of the way SB is presented to the public in The Netherlands.

News media do not only provide the public with information about science; they also are an important factor in the attitude of their consumers towards the subjects that are reported on. According to the *agenda-setting theory*, media can influence what people think about by highlighting certain subjects and points of view. Thus, an issue that receives more attention in the media will be more salient to the consumer (Sharpe *et al.*, 2016; van Dam *et al.*, 2014). The agenda-setting theory may partly explain the limited public knowledge about SB, since media analyses in several European countries show that SB has not received much attention (for example Scandinavian (Ancillotti *et al.*, 2015) and German-language (Gschmeidler & Seiringer, 2012) countries).

Furthermore, media influences the way people think about a subject by *framing* news messages in a certain manner. Consumers' opinions are sensible to for example the risks and benefits that are emphasized or marginalized, the choice of metaphors, and the tone of the story (Ancillotti *et al.*, 2016; Gschmeidler & Seiringer, 2012; Sharpe *et al.*, 2016). Thus, media play a very powerful role in the formation of public opinion and investigating the way SB is represented in news media will provide insight into the public's state of knowledge and attitude.

Metaphors

The use of metaphors is very common in non-scientific communication about biotechnology. Journalists use metaphors for several reasons, such as simplification of complicated technological jargon, exaggerations, concretizations, and illustrations (Pauwels, 2013; van Dam *et al.*, 2014). The choice of metaphors has implications for the tone and the message of the article and thus may influence

the readers' perception of the subject (Ancillotti *et al.*, 2015; Boudry & Pigliucci, 2013; Gschmeidler & Seiringer, 2012; Hellsten & Nerlich, 2011). For example, an often used metaphor in SB makes an analogy to computers and software when describing designed organisms. However, this implies that we understand and can control biology like computers, which is misleading. Therefore, this metaphor may wrongly inform the public and consequently influence public debate about SB (Boudry & Pigliucci, 2013; Pauwels, 2013). The use of the computer metaphor will therefore be analyzed in this study, as well as other metaphors that may influence the readers' perception of the subject.

Related research

From 2003 to 2007 media coverage strongly increased in both Europe and the US (Pauwels & Ifrim, 2008). However, more recent studies concluded that SB did not receive extensive attention in German-language (Gschmeidler & Seiringer), Scandinavian (Ancillotti *et al.*, 2015), and Italian (Ancillotti & Eriksson, 2016) media. This might be because SB is not considered as special enough to publish about, since the distinction between SB and other biotechnologies is not completely clear and SB's risks and ethical issues are comparable to those of other biotechnologies, thereby limiting SB's newsworthiness (Gschmeidler & Seiringer, 2012; Kronberger, Holtz, Kerbe, Strasser, & Wagner, 2009).

In Scandinavian countries and Italy, the majority of SB articles was published after a certain, single event. Thus, in these countries SB is published about in an event-driven rather than a thematic manner (Ancillotti *et al.*, 2015; Ancillotti & Eriksson, 2016). Combined with the fact that many news articles about SB do not contain the term "synthetic biology" (Ancillotti *et al.*, 2015; Ancillotti & Eriksson, 2016 Gschmeidler & Seiringer, 2012), the low media coverage may explain the limited public knowledge about SB (Ancillotti *et al.*, 2016).

In all countries that were studied, including The Netherlands (Hartman, 2016), SB was portrayed in a positive way. Between 2003 and 2007 51% of the articles that appeared in American newspapers mentioned only potential benefits, against 28% in Europe. The majority of European news articles (59%) mentioned both potential benefits and risks. Merely 6% (Europe) or 5% (US) of the articles discussed only potential risks. The benefits that were mentioned most differed between the US (health) and Europe (energy). Also, biosecurity risks, such as bioterrorism, were more prominently present in US news (Pauwels & Ifrim, 2008).

In The Netherlands the focus of news media was on the progress that SB might bring, rather than on risks and ethical issues associated with it (Hartman, 2016). A possible reason for the positive portrayal of SB in the media is that until now, no scandals or large problems are associated with it (Ancillotti *et al.*, 2016).

In a recent Scandinavian study, SB was found to be described in a future-oriented way (Ancillotti *et al.*, 2015). Although risks were mentioned, the overall tone of the articles was positive or balanced (i.e. positive and negative aspects are given attention in an equal amount; Kohl *et al.*, 2016). The most prominent benefits that were mentioned were related to healthcare, biofuel production, and the environment. This was also the case for The Netherlands (Hartman, 2016), Italy (Ancillotti & Eriksson, 2016), and Germany (Gschmeidler & Seiringer, 2012).

Metaphors were abundantly used in news articles about SB. Notably, more metaphors were found in Italian than in Swedish newspaper articles (Ancillotti & Eriksson, 2016). In German-language media (Gschmeidler & Seiringer, 2012) the unclear position of SB in relation to other biotechnologies was reflected in the metaphors that were used, because many were comparable to the ones commonly used to describe other biotechnologies. However, engineering metaphors were more prominent for SB, which was also the case in Scandinavian media (Ancillotti *et al.*, 2015). This reflects the intentional aspect of SB, just like metaphors related to tailoring and designing (Ancillotti *et al.*, 2015) and the often-used expression "creation of artificial life" (Ancillotti & Eriksson, 2016).

An interesting difference between regions was found in metaphors relating to playfulness. In German-language articles playfulness was emphasized, for example by calling DNA strands "Lego blocks" or by referring to designing organisms as "playing" (Gschmeidler & Seiringer, 2012). However, these playfulness metaphors were not often used in Scandinavian countries (Ancillotti *et al.*, 2015). Furthermore, metaphors that might give a negative tone to SB, such as "Frankenstein cell" or "playing God", were not used often (Ancillotti *et al.*, 2015; Gschmeidler & Seiringer, 2012). When they were used, it was often to convince the reader that they were not true (Ancillotti *et al.*, 2015). Since metaphors may influence the message that a text conveys, it is important to study their use in newspaper articles. Therefore, metaphor use in Dutch newspapers will be analyzed in this study. This will also allow comparison of SB metaphors used in The Netherlands with those used in other studied countries.

Methods

To answer the research question "How is synthetic biology represented in Dutch newspapers?" a media analysis was performed. In this section I describe the five aspects - quantitative as well as qualitative – that were studied in newspaper articles covering SB:

1. publication data (i.e. publication date, newspaper, newspaper section, and whether the term "synthetic biology" was mentioned);
2. the motive for publication (*why*, or as a reaction to what event was the article published?);
3. the normative impression (the tone of the article);
4. which applications, risks, and ethical issues were addressed;
5. the use of metaphors.

These aspects are further explained in this section, and examples are provided in **Appendices 2-6**.

Collection of newspaper articles

Newspaper articles were obtained through the LexisNexis newspaper database, using Dutch search terms based on prior research on SB media coverage (Ancillotti *et al.*, 2015, Ancillotti & Eriksson, 2016; Gschmeidler & Seiringer, 2012; Hellsten & Nerlich, 2011; Pauwels & Ifrim, 2008) and own insights. All search terms used, in English equivalents, are listed below:

- Synthetic
    - Biology
    - Biologist
    - Cell
    - Bacterium
    - Virus
    - Organism
    - Genome
    - DNA
    - Genes
    - Chromosome(s)
- Minimal
    - Organism

    - Genome
- Artemisinin
- iGEM

Furthermore, the word "drugs" was excluded from the search term, since the Dutch word "drugs" does not refer to medical drugs, but to narcotics. The reason for this addition to the search query was that there were many newspaper articles about synthetic drugs, which were irrelevant for this study.

Newspaper articles that appeared in Dutch newspapers between 1 January 2000 and 24 November 2016 (the date of the search) were included in this study. This starting date was chosen because SB arose as a discipline around the year 2000 (Cameron *et al.*, 2014). Articles from all Dutch newspapers were included (see **Appendix 1**), i.e. nationwide as well as regional, membership-based as well as free, large as well as small circulation.

The relevance of the articles was established by screening the text of the articles. All articles containing the term "synthetic biology" were included, as well as articles that were about SB (according to the used definitions; see Theoretical Framework – Definition of SB) but did not explicitly mention the term. Also, all articles about iGEM were included in the analysis because iGEM is a competition specifically dedicated to SB. Articles that did not use the term "synthetic biology" *and* that were not related to SB were excluded from analysis.

Publication data

For all articles the publication date and the name of the newspaper in which it appeared were noted. It was also noted if an article contained the term "synthetic biology". Furthermore, the section of the newspaper in which the article appeared was categorized as "opinion", "science section", "special (i.e. irregular, extra, thematic) or weekend supplement", or "television and events". Articles from other sections, such as economic news or foreign affairs, were categorized as coming from a "news" section.

Text analysis

Coding

The text of the articles was analyzed according to pre-set coding schemes and manuals (see **Appendices 2-6**). Codes were based on previous SB media coverage studies (Ancillotti *et al.*, 2015, Ancillotti & Eriksson, 2016; Gschmeidler

& Seiringer, 2012; Hellsten & Nerlich, 2011; Pauwels & Ifrim, 2008) and own insights. New codes were added inductively during analysis, when unforeseen aspects were observed repeatedly. For example, a code for "television and event announcements" was added to the scheme for motive categories because multiple articles fell into this category.

All articles were read at least twice. At the first, global, reading all obvious aspects of the article were coded. During the second, and more thorough, reading less obvious aspects and metaphors were identified and coded. If in doubt or if some aspects were still uncoded, an article was read up to four times.

Motive for publication

The reason for publishing an article is referred to as "motive for publication". For example, the creation of a bacterium with a synthetic genome (by Craig Venter; Gibson *et al.*, 2010) was a motive for several newspaper articles.

Articles were divided over the categories as shown in **Table 1** regarding their motive for publication (see **Appendix 2** for examples). Articles without a specific motive were categorized as "background article". Articles that did not fit into an existing category were categorized as "other". After analysis, three new categories were created for motives initially categorized as "other", shown in italics in **Table 1**. A remainder of articles was left in the "other" category because they were too diverse to create substantial categories.

Normative impression

The tone of the articles was categorized as being primarily positive, primarily negative, neutral, balanced, or critical (see **Table 1**). See **Appendix 3** for exemplifying quotes. Positive articles had an overall enthusiastic tone or displayed an overall approving attitude towards SB, used positive words such as "milestone", "breakthrough", and "promising" and could highlight possible applications of SB. Articles that were categorized as negative displayed an overall rejecting attitude towards SB or (bio)technologies in general, focused on risks and ethical issues, or displayed the opinion that SB was a negative development. Balanced articles payed attention to both positive as well as negative elements in about an equal amount, whereas neutral articles presented the news objectively (i.e. without giving a value judgement). In critical articles critical or skeptical questions about SB were brought up, without a negative tone.

Table 1

Used categories for each aspect

Aspect	Categories
Motives for publication	Background
	Commercialization
	Discovery
	Governmental publication
	iGEM
	Scientific conference
	Statement about SB made by a scientist
	University-related
	Other (further divided into: art related to SB, book publications, and television broadcast or public event announcement)
Normative impression	Positive
	Negative
	Neutral
	Balanced
	Critical
Applications	Computers
	Environment
	Food
	Human enhancement
	Industrial
	Medical
	To improve research
	Other
Risks and ethical issues	Biosafety
	Biosecurity
	Ethical
	Patent-related
	Other
Metaphors	Books, reading and writing
	Computers and programming
	Creation and power
	Designing
	Do it yourself
	Engineering and building
	Industrial
	Tailoring
	Transplantation
	Other (further divided into: garage, minimalizing)

Applications, risks, and ethical issues

Because there was not enough prior insight into applications of SB that might be mentioned by news media, this aspect was categorized retrospectively. By making a grouped word cloud of all applications mentioned in the articles (see **Appendix 4** for examples), seven categories could be deduced, as shown in **Table 1**.

Risks and ethical issues were divided over four categories (see **Table 1**). If risks or ethical issues did not fit into these categories they were categorized as "other". See **Appendix 5** for exemplifying quotes.

Metaphors

Metaphors found in the articles were divided over categories shown in **Table 1** (see **Appendix 6** for examples). Metaphors that did not fit into one of these categories were categorized as "other". The "other" category was revised retrospectively as shown in italic in **Table 1**.

Each metaphor was coded only once per article, also if that metaphor was used multiple times within one article. Only metaphors referring to SB were taken into account; metaphors used to explain genetics in general or matters not related to SB were not coded.

Results

In this section I describe the results of the collection of articles, their publication data, and the quantitative text analysis. Qualitative interpretations of these results are found in the discussion section.

Publication data

The search in the LexisNexis database yielded 1155 newspaper articles, of which 261 were relevant for inclusion because they contained the term "synthetic biology", or because they were about SB without explicitly mentioning the term.

The articles were published in a variety of newspapers (see **Appendix 1**) and were primarily published in the last decade; only 16 articles were published before 2007. So, the amount of SB articles published did not rise gradually, but suddenly increased from 2007. Peak years were 2008 and 2015, with 34 articles in both years (**Figure 1**). In 2008 Craig Venter announced the creation of the first synthetic genome (Gibson *et al.*, 2008), whereas in The Netherlands two SB research centers were opened and two Dutch teams won prizes at the iGEM competition. These events together gained most attention in newspapers in that year. In the other peak year 2015 very diverse events took place and about each event four articles at most were published. So, the peak in media attention for SB in 2015 cannot be drawn back to one or several specific events.

The term "synthetic biology" was named explicitly in 55.2% of the articles, although articles that did not use the term often named for example "synthetic cells" or "synthetic DNA". However, the term "synthetic" was not found in all articles. The term "synthetic biology" was used for the first time in 2007.

Most articles appeared in a news section (37.5%) or the science section (33%) of the newspaper, whereas less articles were published in opinion sections (6.5%), special or weekend supplements (6.1%), or television and event sections (5%). For 11.9% of the articles the newspaper section could not be determined due to missing information from the LexisNexis database or unclear section names.

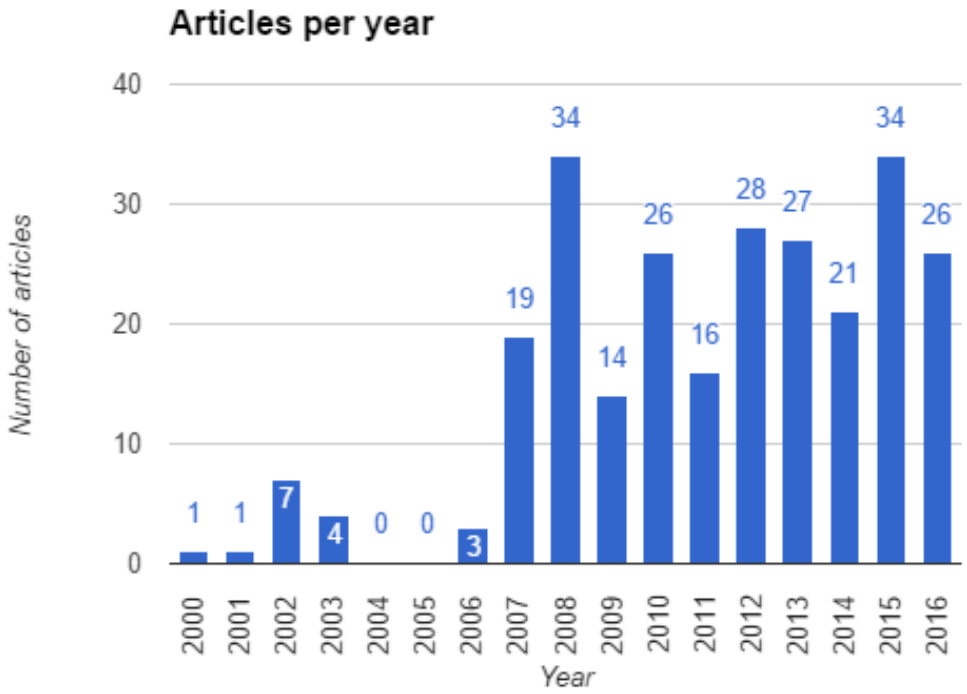

Figure 1. Coverage of newspaper articles about SB in Dutch newspapers. Note that the reported number of articles in 2016 is only up to and including 24 November - extrapolating this number suggests that 29 articles were published in 2016.

Text analysis

Motives for publication

The two most prominent motives (see **Table 2** for percentages, and see **Appendix 2** for examples for each code) for publishing an article about SB were discoveries (e.g. the production of artemisinin in yeast) and the iGEM competition. Most articles with the iGEM motive were about Dutch teams participating or winning a prize. The motives of the remaining articles varied greatly and were, in order from most mentioned to least mentioned, announcements for television or radio broadcasts or public events related to SB, university-related (e.g. the opening of an SB research center), book publications related to SB, scientific conferences about SB, statements made by scientists (e.g. Venter announcing he wants to make an organism with a minimal genome), governmental publications about SB, commercialization (e.g. Venter applying for a patent on synthetic genes), or art related to SB (e.g. an exposition containing SB-related objects). Articles with no specific motive were classified as background articles (e.g. an interview with synthetic biologist George Church). Some articles remained

classified as "other motive", because they could not be categorized in existing categories and no overarching category could be made.

Table 2

Percentages for motives for publication of articles

Motive	Percentage
Background	10%
Commercialization	1.9%
Discovery	26.4%
Governmental publication	2.3%
iGEM	18%
Scientific conference	4.6%
Statement about SB made by a scientist	3.8%
University-related	6.5%
Art related to SB	1.9%
Book publications	6.5%
Television broadcast or public event announcements	8%
Other	*10%*

Normative impression

Overall, the tone of the articles was neutral or positive. Some articles were critical, either about SB itself or about if SB is indeed as revolutionary as it is presented. Other articles were balanced and few articles had a negative tone. See **Table 2** for percentages, and appendix **3** for exemplifying quotes for each normative impression category.

A difference in normative impression was found in the 47 articles with the motive iGEM: these were predominantly positive or neutral. Articles were especially positive about Dutch participants, their prizes, and their applications, but not about SB per se. Only two iGEM articles were balanced and none of them were critical or negative.

A total of 32 articles about SB appeared in Christian newspapers (i.e. Reformatorisch Dagblad and Nederlands Dagblad). These were predominantly critical, mostly about the question if humans are allowed to "create life".

Table 3 summarizes results about normative impressions in general, in articles about iGEM and in articles from Christian newspapers.

Table 3

Frequencies and percentages of normative impressions found in all articles, in articles with the iGEM motive, and in articles from two Christian newspapers.

Normative impression	All articles (number (total number of articles) / %)	Articles with iGEM as motive (number (total number of articles) / %)	Articles from Christian newspapers (number (total number of articles) / %)
Positive	82 (261) / 31,4%	23 (47) / 48,9%	6 (32) / 18,8%
Negative	15 (261) / 5,7%	0 (47) / 0%	3 (32) / 9,4%
Neutral	94 (261) / 36%	22 (47) / 46,8%	6 (32) / 18,8%
Balanced	28 (261) / 10,7%	2 (47) / 4,3%	3 (32) / 9,4%
Critical	42 (261) / 16,1%	0 (47) / 0%	14 (32) / 43,8%

Applications, risks, and ethical issues

A total of 325 SB applications were mentioned, spread over 64,9% of the analyzed articles, i.e. on average 1,9 application per article that mentioned one or more applications. In **Table 4** percentages for each application category are mentioned, and **Appendix 4** provides examples of applications for each category.

Many applications that were mentioned were medical applications, such as biosensors or medicine production, including artemisinin. Environmental applications were also mentioned often especially biofuel production and breakdown of toxic substances in the environment.

Other applications, in order from most mentioned to least mentioned, were related to industry (e.g. production of bioplastic), food (e.g. production of additives), to improve (biology) research (e.g. fundamental knowledge), and computers (e.g. data storage in DNA). Using SB for human enhancement, such as designer babies or preventing aging, was mentioned only a few times. Some articles could not be categorized in existing categories and no overarching theme was found among them, so they were categorized as "other". Many of the applications in the "other" category were named in articles with the iGEM motive. This is not surprising, because one of iGEM's main dedications is to promote advancement of SB (http://igem.org/About).

A total of 112 risks and ethical issues were mentioned, spread over 24.5% of the analyzed articles, i.e. on average 1.7 risk or ethical issue per article that mentioned one or more risks or ethical issues. In **Table 5** percentages for each

risk/ethical issue category are mentioned, and **Appendix 5** provides examples of risks and ethical issues for each category.

Issues of biosafety, biosecurity, and ethics were mentioned approximately equally, whereas issues related to patents were mentioned less. Some risks or ethical issues did not fit into existing categories and no overarching category could be found, so these were categorized as "other".

Table 4

Percentages for applications mentioned in articles

Motive	Percentage
Computers	2.5%
Environment	32%
Food	8%
Human enhancement	1.8%
Industrial	8.9%
Medical	32.3%
To improve research	5.2%
Other	*9.2%*

**The percentages indicate which percentage of the 325 applications that were mentioned fell into a certain category.*

Table 5

Percentages for risks and ethical issues mentioned in articles

Motive	Percentage
Biosafety	24.1%
Biosecurity	28.6%
Ethical	29,5%
Patent-related	8.9%
Other	8.9%

**The percentages indicate which percentage of the 112 risks and ethical issues that were mentioned fell into a certain category.*

Metaphors

A total of 654 metaphors were used, spread over 63.3% of the analyzed articles, i.e. on average 3.9 metaphor per article that used one or more metaphors. In **Table 6** percentages for metaphor category are mentioned, and **Appendix 6** provides examples metaphors for each category.

Many metaphors referred to engineering or building, in particular "(re)building", building up, or "(re)constructing" a cell using "building blocks". The "Lego" metaphor was only used eleven times in total.

Creation and power metaphors were also used often. Especially the word "creating" (for example life, cells, or new life forms) was abundant, whereas "playing God" was used only a few times. Six articles used the term "Frankenstein cell" or "Frankenstein monster" to describe synthetic cells, although it was only used once in an article with a negative tone. When only considering the two

Christian newspapers creation and power metaphors were more abundant (8 out of 24; 33.3%) than overall.

Computer and programming metaphors, such as "DNA is the software of a cell" or "programming the genome" were also used often.

Other metaphors were used less. These were, in order from most mentioned to least mentioned, "designing" (e.g. "designing" or "designer of" a cell), "do it yourself" (e.g. "cutting and pasting with genes"), "industrial" (e.g. "the cell is a factory"), "books, reading and writing" (e.g. "writing the genome"), "garage" (e.g. "the cell is a car"), "transplanting" (referring to Craig Venter transferring a genome from one bacterium to another), "minimalizing" (e.g. "stripping the genome"), and "tailoring" (e.g. "stitching nucleotides together") metaphors. Some metaphors could not be categorized in the mentioned categories, and no overarching category could be created, so they were categorized as "other".

Table 6

Percentages for metaphors mentioned in articles

Motive	**Percentage**
Books, reading and writing	3.8%
Computers and programming	13.5%
Creation and power	14.7%
Designing	6.6%
Do it yourself	7.3%
Engineering and building	32.9%
Industrial	5.8%
Tailoring	1.2%
Transplantation	1.7%
Garage	3.2%
Minimalizing	1.2%
Other	*8.1%*

**The percentages indicate which percentage of the 654 metaphors that were mentioned fell into a certain category.*

Discussion

The results from this study indicate that the representation of SB in Dutch newspapers shows major similarities compared to SB press coverage in other countries, although some minor differences were found. Also, results from this study are in agreement with results from an earlier study of SB in Dutch news media (Hartman, 2016).

SB does not receive much attention in Dutch newspapers

The number of articles about SB published in Dutch newspapers cannot be compared precisely to data from other countries due to differences in for example search terms, selection of newspapers, and studied time periods. However, the number of articles published in The Netherlands is in the same order of magnitude as other countries. In 2009, for example, fourteen articles were published in Dutch newspapers, compared to 51 articles in Germany, Switzerland, and Austria combined (i.e. on average seventeen per country; Gschmeidler & Seiringer), six and sixteen articles in three major newspapers in Sweden and Italy, respectively (Ancilotti & Eriksson, 2016), three articles in Denmark's three major newspapers, and two articles in both Finland's and Norway's three major newspapers (Ancilotti *et al.*, 2015). Since these studies all concluded that SB did not receive much media attention, the same might be concluded for The Netherlands.

Furthermore, major events received remarkably little media attention. As an example, I take three events that are related to breakthroughs accomplished by Craig Venter, who is one of the most famous synthetic biologist and generally receives much attention in news media (Ancilotti *et al.*, 2016). After Venter's announcement of the first synthetic genome (JCVI-syn1.0: Gibson *et al.*, 2008) only nine articles addressing this breakthrough were published[2]. The event that raised the most media attention - fifteen articles - was the announcement of the first synthetic cell that could self-replicate (Gibson *et al.*, 2010), also by Venter. In other countries, but not in The Netherlands, this event resulted in a peak year considering the amount of SB articles published (Scandinavia: Ancillotti *et al.*, 2015; Sweden and Italy: Ancillotti & Eriksson, 2016; English-language: Hellsten & Nerlich, 2011). Moreover, Venter's announcement that he had made a cell

[2] The first synthetic genome was announced in February 2008. Since 34 articles were published in that year, which was a peak year considering the amount of articles published, this breakthrough may have been a stepping stone to more media attention for SB in general in 2008.

containing a minimal synthetic genome (Hutchison, 2016) in March 2016 yielded only two newspaper articles in the Dutch press.

Another noteworthy observation is that coverage suddenly increased from 2007; before only very few articles were published. In that year a genome was "transplanted" from one bacterium to another, which was an important step in SB research. This was again accomplished by Venter, who also applied for a patent on synthetic genes in 2007. Furthermore, the Dutch Rathenau Institute published its report "Constructing Life" ("Leven Maken") in 2007. These important international as well as national events may have stimulated SB coverage in Dutch newspapers and thus might explain the increased coverage from 2007.

SB is sometimes framed as an extension of biotechnology

A possible explanation for the low media attention might be that SB is not seen as a distinct discipline, but rather as an extension of existing biotechnologies (Ancillotti *et al.*, 2015). Since these are already familiar topics for news media, SB might be less newsworthy. Journalists tend to anchor SB in biotechnology in order to give the public a direction of how to relate it to more familiar science (Kronberger *et al.*, 2009). This is supported by the fact that the term "synthetic biology" was only mentioned in slightly more than half of the newspaper articles (55.2%). For example, *NRC Handelsblad* described SB described as "modern gene technology", without mentioning the term "synthetic biology":

> ""The power of *gene technology* has increased quickly", Goldsmith says through the telephone. "We can add many genes at the same time to a bacterium or yeast. We can *produce* and try new DNA sequences very fast." Before, you put one gene in bacteria or yeast, and let it produce the corresponding protein. But *modern gene technology* changes the whole metabolism of such a yeast or bacterium. Whoever has mastered that, cannot only let such an organism produce proteins, but all possible substances. The breakthrough came in 2013. Then, the malaria medicine artemisinin came into mass production - originally from a plant, now *biotech*."[3]

(van Santen, 2015; emphasis added).

[3] Quotes from newspaper articles are translated from Dutch.

In the scientific world there is also no consensus about whether SB is a self-contained discipline or that it is a more extreme form of genetic modification. Moreover, the risks and ethical issues associated with SB are very similar to those related to genetic modification (Gschmeidler & Seiringer, 2012). Hence, as Kronberger *et al.* (2009) stated: SB is "not perceived as different enough from biotechnology to merit special attention [by news media]".

SB is covered in an event-based manner

Considering results of motives for publication, it was observed that press coverage of SB was rather event-based. The majority of articles was published after something happened, especially a scientific discovery or something related to iGEM (see **Appendix 2** for specific examples). Other articles had very diverse publication motives but were also published as a reaction to an event, such as scientific conferences or television broadcasts. Only 10% of the articles was a background article, which means that there was no specific event leading up to publication of the article. The event-based coverage and the small amount of background articles imply that although certain events related to SB are newsworthy, background information on the topic is not (yet) newsworthy.

The event-based coverage of SB in The Netherlands is similar to patterns observed in other countries. In Scandinavian countries (Ancillotti *et al.*, 2015), Sweden and Italy (Ancillotti & Eriksson, 2016), German-language countries (Gschmeidler & Seiringer, 2012), and English-language countries (Hellsten & Nerlich, 2011) most articles were published as a reaction to a certain event as well. For example, the amount of articles published in English-language newspapers (Hellsten & Nerlich, 2011) increased majorly when Venter announced the first synthetic genome (Gibson *et al.*, 2008). In German-language press (Gschmeidler & Seiringer, 2012) and in American and European press in general (Pauwels & Ifrim, 2008) the first and third international SB meetings (SB1.0 in 2004 and SB3.0 in 2007) gained the most media attention, whereas in The Netherlands not a single article about these events was published. An explanation might be that SB3.0 was held in Zürich, Switzerland and was thus more relevant to publish about in that country.

Articles about iGEM focus on good student performances rather than on SB

In all countries where SB press coverage was studied iGEM was an important motive for articles, as it was in Dutch press. Pauwels and Ifrim (2008) attribute the increasing media attention for SB since 2006 to iGEM. However, the newsworthiness of the competition did not seem to be SB itself. Instead, almost all articles that reported on iGEM were mainly about how well Dutch students performed. For example the article title: "Relay race for bacteria - *TU team wins international prize synthetic biology*" (Wijnands, 2009; emphasis added) focuses on the performance of the students rather than on the application or SB.

Applications were also discussed in articles about iGEM, but it was rarely explained that these were established with synthetic biology. Moreover, the term "synthetic biology" was often not mentioned in these articles. Thus, SB was a side topic in articles about iGEM, whereas good performances of Dutch students were the main theme in such articles. This is supported by the fact that articles about iGEM had a positive or neutral tone and never a negative.

The Dutch press writes in a predominantly neutral or positive tone about SB, although Christian newspapers are mainly positive-critical

The majority of articles had a neutral or a positive tone. Neutral articles reported about SB with objective statements. For example, *Spits* wrote:

> "Researchers from the American J. Craig Venter Institute build the complete genome from the bacterium Mycoplasma genitalium in the laboratory. (..) This week it became clear that the names of the institute and some researchers were included in the synthetic genome as a "signature"."

(Kunstmatig DNA met handtekening, 2008).

Positive articles often used positive words such as "breakthrough" and often highlighted possible applications of SB. For example, *De Stentor/Zwolse Courant* wrote: "This finding might be a breakthrough in fighting several diseases that are at the moment still lethal." (Doorbraak met synthetisch virus, 2003).

Only very few articles wrote about SB in a negative way, for example by emphasizing risks associated with SB, as the *Reformatorisch Dagblad* did:

> "Meanwhile, progress in synthetic biology and other life science technologies makes it easier for amateur scientists outside of the secured institutions to make new biotechnological products. (...) This development does not make it easier for security services to avoid bioterrorism."

(Versterk verbod op biologische wapens, 2015)

(see **Appendix 3** for more exemplifying quotes). A small amount of articles was balanced, i.e. mentioning positive as well as negative aspects of SB. This is in line with findings in other European countries. For example, Ancillotti & Eriksson (2016) concluded that media portrayal of SB in Sweden and Italy was predominantly positive. This was also the case in the Scandinavian press (Ancillotti *et al.*, 2015). Other studies did not explicitly address the tone of articles.

Some articles had a critical tone, meaning that they put forward critical questions but did not have a negative attitude towards SB. These articles could be critical towards SB itself, asking questions about for example the desirability of synthetic life. For example, in an interview with the Dutch synthetic biologist Cees Dekker: "Isn't the cell a priori seen as work from a creator? (...) Do you see the building of an artificial cell as a form of creating life?" (van den Dikkenberg, 2015).

Critical articles could also be critical about whether SB was indeed as revolutionary and promising as it is presented by scientists. For example: "But it is nonsense to call JCVI-syn1.0 a new species, because the applied genetic changes are very limited. And we will have to wait for years for applications." (van Santen, 2010). Such questions were often brought up in Christian newspapers, whose readers probably consider this a relevant question regarding their religious view on life. Interestingly, these articles mostly expressed the opinion that SB was not in conflict with Christian values. This was often done through the words of the Dutch Christian nanoscientist Cees Dekker, for example:

> [Interviewer] "For Christians, another question is relevant: God is the only creator of life, right, shouldn't humans stay away from that?" [Cees Dekker] "I have the opinion that humans in a way even have the assignment to "play God". At the start of the Bible we read that God

> created humans as replica of himself. God gave those humans a cultural assignment, to manage the world and to have power over it. In this assignment we are commissioned to "play God"- we are called as his representatives to take care of this earth."

(Dekker, 2015)

So overall, Christian newspapers displayed a positive-critical rather than a negative attitude towards SB.

Newspaper articles focus on applications rather than risks and ethical issues

Similar to other countries (Ancillotti & Eriksson, 2016; Ancillotti *et al.*, 2015; Gschmeidler & Seiringer, 2012; Pauwels & Ifrim, 2008), and as found in a previous Dutch study (Hartman, 2016), Dutch newspaper articles focused more on applications than on risks and ethical issues related to SB. Applications were mentioned more times and in more articles than risks and ethical issues. Thus, risks and ethical issues associated with SB received less media attention. Also, they were often just mentioned without much elaboration, and, moreover, risks were often attenuated. For example:

> "And that terrorists have a new weapon in hands with this, seems very unlikely to me. Way more dangerous pathogens can be found in nature itself, for which you don't have to engineer anything. You can just isolate those and they pose a greater danger."

(Voormolen, 2015; quote from the Dutch microbiologist Oscar Kuiper)

However, some articles did consider biosafety or biosecurity as realistic risks, although there was no consensus among articles which risk is most realistic. Ethical issues were rarely discussed extensively. More exemplifying quotes for risks and ethical issues are provided in **Appendix 5**.

An explanation for the fact that risks and ethical issues received little attention might be that, as discussed before, they are very similar to risks and ethical issues associated with other biotechnologies (Gschmeidler & Seiringer, 2012; Kronberger *et al.*, 2009). Therefore, issues of for example human safety, bioterrorism, and the malleability of life are long-known patterns and thus not

interesting enough to mention again. This is consistent with the observation that SB is sometimes framed as an extension of biotechnology rather than as a new field of research.

Newspapers mainly mention future-oriented applications related to healthcare and the environment

SB applications related to healthcare (e.g. medicine production) and the environment (e.g. production of biological fuels) made up the majority of applications that were mentioned, as was also found by Hartman (2016). This is similar to other countries (Ancillotti & Eriksson, 2016; Ancillotti *et al.*, 2015; Gschmeidler & Seiringer, 2012; Pauwels & Ifrim, 2008). That these applications outnumbered other applications is not surprising, because synthetic biologists have pointed out the potential use of SB in these fields from the beginning. For example, Venter has often emphasized the important role that synthetic organisms might play in the production of biofuels (e.g. Craig Venter, 2008). Furthermore, topics that have more importance to the reader gain more media attention (van Dam *et al.*, 2014). Healthcare issues relating to SB might affect daily life in the future and are thus important for the public. Also, environmental consciousness has increased among the public in the last fifteen years (Schyns, 2016). Therefore, applications related to healthcare and environment are very newsworthy. Examples of these, and other, applications are provided in **Appendix 4**.

Kronberger *et al.* (2009) studied how journalists wrote articles based on SB press releases. It was found that journalists focus on concrete applications of SB and that they preferred press releases that focused on the implications of the research and less on scientific details. After all, knowing the implications for everyday life is more important for the reader than understanding the science behind them (Kronberger *et al.*, 2009). Given that until now very few SB applications are usable at large-scale, it is logical that most applications that were mentioned were future-oriented (an exception was artemisinin). However, by continuously focusing on implications of SB that might possibly be applicable in the future the reader might get the idea that SB already has a large impact. This may create a wrong image of SB among the public (Ancillotti *et al.*, 2015).

Interestingly, applications referring to human enhancement were mentioned only six times. In science, including other biotechnologies such as

genetic engineering, this is generally a more prominent issue (Lin & Alhoff, 2008), with discussions often leading up to questions about for example designer babies. This study does not provide an answer to why human enhancement is apparently not an issue for SB.

Metaphors used to describe SB suggest that "life is man-made" and controllable

As common for genetic topics (Hellsten & Nerlich, 2011) many metaphors were used to describe SB. The metaphors found in Dutch newspapers were similar to those used in other countries (Ancillotti & Eriksson, 2016, Ancillotti *et al.*, 2015; Gschmeidler & Seiringer, 2012; Hellsten & Nerlich, 2011), although some differences were present. Examples of metaphors per category are provided in **Appendix 6**.

Metaphors referring to engineering, such as "building a cell" were most prominent. This is not surprising, since experts often describe SB as "the engineering approach to biology" (Cserer & Seiringer, 2009). The metaphor "building blocks" is used very often for other genetic topics as well, to describe for example nucleotides. However, in SB this expression has an extra meaning because of the use of BioBricks. Therefore, building metaphors connect the metaphorical with the real (Hellsten & Nerlich, 2011).

Metaphors referring to computers and programming were also used often, for example "installing the software" when referring to putting synthetic DNA in a cell. Again, this may be explained by the fact that synthetic biologists use such metaphors to describe their work (Gschmeidler & Seiringer, 2012). For example, Craig Venter announced his bacterium with a synthetic genome as "the first cell whose parent is a computer" (Craig Venter, 2010).

The third most-used metaphor category contains metaphors referring to creation and power. Especially the word "creating" (of life, cells, or genomes) was abundant, whereas "playing God" and "Frankenstein cell" were used less. Creation metaphors were not used in a negative fashion: the words "creation" and "creating" were used neutrally, and if "playing God" or "Frankenstein cell" were used, it was often stated that these metaphors were not applicable to SB. Not surprisingly, creation metaphors were the most-used metaphors in Christian newspapers.

The abundant use of engineering, computer, and creation metaphors, and also the word "designing", might give the reader the suggestion that life is man-made and controllable (Hellsten & Nerlich, 2011). Other metaphors that were used less also contributed to this suggestion. For example, cells were described as "machines" and genomes could be "tinkered" with. The use of such metaphors implies that humans have the power to build, program, create, or design life. However, this holds wrong ideas about the malleability of life, because it suggests that life is simple. Therefore, the metaphors used in newspapers may establish a superficial image of SB and life itself (Boudry & Pigliucci, 2013). For the reader, this may result in a wrong image of SB and unrealistic expectations of its possibilities.

SB is described in a playful manner in articles addressing iGEM

Some differences between countries were found considering metaphor use. For example, tailoring metaphors (e.g. "stitching DNA together) were abundant in English-language press (Hellsten & Nerlich, 2011) but not in Dutch articles. This might be due to language differences. Also, in other countries the metaphor "Lego bricks" created a playful image of SB (Cserer & Seiringer, 2009; Gschmeidler & Seiringer, 2012; Hellsten & Nerlich, 2011). This metaphor was not so relevant in The Netherlands, similar to Scandinavia (Ancillotti *et al.*, 2015). This is interesting because BioBricks are often pictured and described as Lego bricks, also in educational publications about SB (for example governmental reports from the Dutch Rathenau Institute; de Vriend *et al.*, 2007; Rerimassi & Stemerding, 2013).

However, the suggestion of SB as a playful discipline was found in Dutch articles, but in a different manner, i.e. the description of iGEM applications. Many articles used language that presented iGEM applications as fun, often without mentioning their potential usefulness. For example, bacteria that change color at a certain temperature were called "disco bacteria" and the color changing was called a "funny effect". Also, many iGEM articles mentioned applications that are at first sight more entertaining than useful, such as bacteria that smell like bananas or that distinguish normal olive oil from extra vierge. This might distract the reader from more serious applications that are expected from SB. This playful, unserious representation of iGEM applications was also observed in German-language media (Gschmeidler & Seiringer, 2012). However, the majority of (non-iGEM) applications mentioned in newspapers were more serious.

Science determines the news about synthetic biology

Overall, several findings indicate that science rather than society determines when and how SB is represented in Dutch newspapers. For example, scientific events are often the motive for publication of newspaper articles about SB. Also, applications that are most put forward by the media relate to healthcare and the environment, which are the fields mentioned most by scientists. Furthermore, the language that is used in newspaper articles reflects the science-led press coverage of SB, given that many metaphors found in the press are also used by scientists. Moreover, scientists such as Craig Venter are often quoted or referred to, whereas Dutch scientists were asked to comment on events. In English-language press this phenomenon was observed as well (Hellsten & Nerlich, 2011).

A possible explanation for the science-led press coverage of SB might be that journalists in all countries rely on the same sources for their news, and that these sources are press releases from scientists. As proposed by Ancillotti *et al.* (2015) this would also explain the similarities found between countries. Furthermore, scientific press releases generally have a positive tone and they focus on applications of SB rather than on its risks and ethical issues. This is reflected in (Dutch) newspaper articles.

The public debate about synthetic biology has not yet started in The Netherlands

The way SB is represented in Dutch newspapers indicates that a public debate about the implications of SB has not yet started in The Netherlands. First of all, press coverage on SB was relatively low, with major events receiving little attention. Also, there was very little attention to risks and ethical issues. Moreover, only very few articles were published in opinion sections of newspapers, indicating that until now SB is not a controversial topic. This might be because so far, no "accidents" or scandals related to SB have happened (Gschmeidler & Seiringer, 2012).

However, SB experts and policy makers believe that more attention for risks and ethical issues of synthetic biology is desired in order to involve the public (Ancillotti *et al.*, 2015; de Vriend *et al.*, 2007; Hartman, 2016). The Rathenau Institute advocated that there should be political and societal opinion forming about SB, since it has barely started (Rerimassi & Stemerding, 2013). This idea is shared by the iGEM organization, since participants are obliged to consider "human

practices" of their work (i.e. "topics concerning ethical, legal, social, economic, biosafety, or biosecurity issues related to their work"; http://igem.org/Human_Practices). Furthermore, the need for public debate about SB for the Netherlands specifically was expressed in the Meeting of Young Minds, a debate between young scientists and young politicians organized by the Rathenau Institute in 2011 (Rerimassi & Stemerding, 2013).

So, although the need for more public involvement in SB is clearly expressed (for example by the Rathenau Institute; de Vriend *et al.*, 2007), the public is not involved yet. Besides little attention to risks and ethical issues in newspapers, this may also be because overall the public is not really aware of SB (Gaskel *et al.*, 2010; Pauwels 2013), as discussed in the theoretical framework of this thesis. Pauwels (2013) showed that after people had been informed about SB they wanted more information about positive as well as negative aspects. Moreover, providing balanced information led to a more nuanced discussion.

Conclusion

To answer the research question "How is synthetic biology represented in Dutch newspapers?" I conclude that SB is represented in a predominantly event-based, positive and future-oriented way in Dutch newspapers, although media coverage was relatively small and science-led. Therefore, the fear for major public resistance similar to other biotechnologies is not grounded for this emerging research field yet. However, the representation of SB in Dutch newspapers also shows that the public debate has not started yet, although this is considered desired by several (Dutch) experts (Hartman, 2016) and organizations (e.g. the Rathenau Institute: de Vriend *et al.*, 2007; Rerimassi & Stemerding, 2013).

More media attention for SB in general, and more balanced information between applications and risks and ethical issues specifically, could help to get the public debate about SB started in The Netherlands. More, and more balanced information, will foster opinion-forming of the public (Pauwels, 2013). Also, for SB it is still possible to involve the public in an early stage. This may prevent the public's rejecting attitude that was observed for other biotechnologies (Boerwinkel *et al.*, 2014) because society will still be able to assess and consequently influence the course of scientific development (Collingridge, 1980). So, more (balanced) media attention will support public engagement in SB, which is needed for responsible research and innovation (RRI). Then, SB can develop into a responsible discipline to meet the needs of society.

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Appendix 1

Newspapers in which the studied articles were published

Newspaper	Nationwide (N) / Regional (R)	Number of articles from this newspaper in this study
AD/Algemeen Dagblad	N	1
AD/De Dordtenaar	R	1
AD/Groene Hart	R	1
AD/Haagsche Courant	R	12
AD/Rotterdams Dagblad	R	1
Algemeen Dagblad	N	1
Boerderij Vandaag	N (*farmers' newspaper)	4
Brabants Dagblad	R	1
Cobouw	N (*construction workers' newspaper)	1
Dagblad De Limburger	R	1
Dagblad De Pers	N (*free daily newspaper)	4
Dagblad Tubantia/Twentsche Courant	R	1
Dagblad van het Noorden	R	13
De Gelderlander	R	7
sDe Stentor	R	1
De Stentor / Sallands Dagblad	R	2
De Stentor / Zwolse Courant	R	2

De Telegraaf	N	5
De Volkskrant	N	31
Delftse post	R	2
Eindhovens Dagblad	R	5
Groot Rijswijk	R	1
Het Financieele Dagblad	N	16
Het Parool	N	10
Leeuwarder Courant	R	4
Leidsch Dagblad	R	7
Limburgs Dagblad	R	1
Nederlands Dagblad	N (*Christian newspaper)	19
NRC Handelsblad	N	56
NRC.NEXT	N	16
Provinciale Zeeuwse Courant	R	1
Reformatorisch Dagblad	N (*Christian newspaper)	13
Rijn en Gouwe	R	1
Rotterdams Dagblad	R	2
Spits	N (*free daily newspaper)	3
Stadsblad Stad	R	1
Trouw	N	12
Utrechts Nieuwsblad	R	1

Appendix 2

Examples of motives for publication

Motive category	Code	Examples	Reference
Art related to SB	A	Exposition about the city of the future, filled with organisms created with SB.	Stelling, T. (2012, October 9). Enter de stad van de toekomst. *NRC.NEXT*, pp. [unknown]
		Artists make creative "maps" of a variety of things, including the first synthetic cell.	Stigter, B. (2014, August 30). Kijk, een nieuwe wereld; Stipje op een plattegrond. *NRC Handelsblad,* pp. [unknown]
Background	B	Interview with synthetic biologist George Church.	Pel. A. (2011, October 15). Hacker van het leven. *NRC Handelsblad*, pp. [unknown]
		Article describing SB on the basis of three possible applications and three risks.	Hazevoet, J. (2013, January 21). Algen melken voor brandstof. *Spits*, p. 8
Book publication	Bo	Journalist Arno Schrauwen and scientist Bert Poolman wrote a book called "Synthetic biology - mankind as Creator?".	*For example:* de Jaeger, P. (2012, July 28). Biologen met een schroevendraaier. *Het Parool*, p. 31
		A book called "New Animals", which also describes synthetic organisms, has been published.	Christus in labjas (2008, September 13). *NRC Handelsblad*, p. 13
Commercialization	C	Craig Venter applies for a patent on a synthetic gene.	Bacterie ombouwen tot levende machine (2007, June 19). *Het Financieele Dagblad*, p. 8

		The American Supreme Court judges that it is not possible to obtain a patent on human genes, but that patenting synthetic genetic material is possible.	Patent op menselijke genen niet mogelijk (2013, June 14). *Reformatorisch Dagblad*, p. 6
Discovery	D	Craig Venter announces the first self-replicating cell with a completely synthetic genome.	*For example:* van Santen, H. (2010, June 5). Geboren: JCVI-syn1.0. *NRC Handelsblad*, pp. [unknown].
		A virus with only synthetic genes has been made.	Ontdekking: bacteriedoder (2003, November 14). *Rotterdams Dagblad*, pp. [unknown]
		Synthetic Biologist Drew Endy makes a bacterium with logic gates.	van Calmthout, M. (2013, April 2). Biologen VS knutselen "transistor". *De Volkskrant*, p. 17
		Yeast with a synthetic pathway produces the anti-malarial drug artemisinin.	*For example:* Medicijn tegen malaria uit gist geproduceerd (2006, April 19). *NRC.NEXT*, p. 18
Governmental publication	GP	The Rathenau Institute publishes its report "Constructing Life" (Leven Maken).	*For example:* Hulshof, C. (2007, October 22). Toekomst Synthetische biologie - De mens gaat de schepping overdoen, maar dan beter. *Het Financieele Dagblad*, p. 7
		Stichting Biowetenschappen en Maatschappij publishes a report about synthetic biology.	Fransen, R. (2015, February 13). Wat als je zelf leven kunt "bouwen"?. *Nederlands Dagblad*, pp. [unknown]

iGEM	I	The Groningen iGEM team makes a bandage containing bacteria to support healing of burns and prevent wound infection.	Yoghurtverband tegen brandwonden (2014, September 26). *Dagblad van het Noorden*, p. 26
		The Delft iGEM team wins a prize with a bioprinter made from K'NEX, that prints bacteria that form biofilms.	*For example:* Bioprinter van TU in de prijzen (2015, September 30). *AD/Haagsche Courant*, p. 3
		The Delft iGEM team wins a prize for best weblog and a gold medal for making a "life thermometer": bacteria that change color at a certain temperature. The Groningen iGEM team wins a bronze medal.	[No title: short scientific news] (2008, November 20). *NRC Handelsblad*, p. 9
Other	O	High School students follow a workshop at the Technical University Eindhoven and present ideas that can be carried out with synthetic bacteria.	Kweekweek op Hoeksch Lyceum (2012, September 27). *AD/Rotterdams Dagblad*, p. 6
		Synthetic biologist Jay Keasling is proclaimed Scientist of the Year 2006 by the American scientific magazine Discover.	Heselmans, M. (2007, January 6). Lego van DNA; Synthetisch biologen ontwerpen bacterie alsof het machientje is. *NRC Handelsblad*, p. 37
		The Dutch Health Council, the Dutch	[Unknown title] (2008, September 30). *Dagblad De*

		Council for Health Research, and the Dutch Royal Academy for the Sciences (KNAW) advise Minister of Education, Culture and Science Ronald Plasterk to invest heavily in synthetic biology.	*Pers*, pp. [unknown]
Scientific conference	SC	Next week the (Christian) scientists Henk Jochemsen and Cees Dekker will be involved in a synthetic biology conference in Leiden.	Fransen, F. (2013, November 2). Onderzoek naar ontstaan van leven. *Nederlands Dagblad*, pp. [unknown]
		Synthetic biologist Drew Endy participated in the Life Science Conference in Delft.	van Raaij, B. (2012, May 19). We gaan leven programmeren. *De Volkskrant*, p. 5
Statement by scientist	SS	Craig Venter announces that he wants to make a microbe with a minimal genome.	Genetici willen leven bouwen (2002, November 23). *Het Parool*, pp. [unknown]
		In the journal PLOS Biology, scientists call for a dialogue between conservationists and synthetic biologists about risks and ethical issues related to SB.	Fransen, R. (2013, April 3). Mammoeten knutselen, mag dat?. *Nederlands Dagblad*, pp. [unknown]
Television, radio and events	TE	Announcement of a science cafe about synthetic biology in Nijmegen where the Dutch scientists Huib de Vriend and Bert	Debat over synthetische biologie (2008, October 8). *De Gelderlander*, pp. [unknown]

		Poolman will speak.	
		A documentary about synthetic biology will air on BBC 2 this evening.	[Television broadcasts] (2012, January 17). *NRC Handelsblad*, pp. [unknown]
University-related	U	Groningen University opens the Center for Synthetic Biology, led by Bert Poolman.	Milikowski, F. (2008, May 14). Leven maken volgens Gronings ontwerp; Onderzoek Synthetische biologie. *Dagblad de Pers*, p. 15
		Cees Dekker (scientist at Technical University Delft) is awarded a grant to study artificial cell division.	2,5 miljoen voor celdeling (2015, May 27). *AD/Haagsche Courant*, p. 5

Appendix 3

Exemplifying quotes for normative impression

Tone	Code	Description	Exemplifying quotes[4]	Reference
Positive	P	Overall enthusiastic tone, (almost) only positive aspects are mentioned	"Experts talk about a milestone in synthetic biology (...) Building synthetic chromosomes and genomes is important because you can let microorganisms carry out interesting tasks, such as producing new antibiotics or sustainable biofuels."	van Raaij, B. (2014, March 28). Kunstmatig chromosoom in gistcel. *De Volkskrant*, pp. [unknown]
			"This finding might be a breakthrough in fighting several diseases that are at the moment still lethal."	Doorbraak met synthetisch virus (2003, November 14). *De Stentor / Zwolse Courant*, pp. [unknown]
			"The students invented and applied the genetic modifications themselves. Last Monday, their project won the grand prize in the iGEM competition, an international student competition in the field of synthetic biology. (...) They had no idea if their experiment would work. "It was a bit of a guess", van Raaphorst admits. The guess	Brouwers, R. (2012, November 2012). Bewaren of weggooien?. *NRC Handelsblad*, pp. [unknown]

[4] Quotes are translated from Dutch.

			paid off: a handful of genes was activated only by rotten meat. "That was fantastic", van Raaphorst says, still enthusiastic. "One of the best moments in the lab.""	
Negative	Ne	Overall rejecting attitude towards SB or (bio)technologies in general, (almost) only negative aspects are mentioned, display SB as negative development	"Meanwhile, progress in synthetic biology and other life science technologies makes it easier for amateur scientists outside of the secured institutions to make new biotechnological products. (...) This development does not make it easier for security services to avoid bioterrorism."	Versterk verbod op biologische wapens (2015, December 22). *Reformatorisch Dagblad*, p. 6
			"Every chemically skilled person or bioterrorist now can make the [polio] virus himself (...) "Irresponsible", is how Craig Venter judged this initiative to show how you can make a disease-causing virus from simple building blocks. (...) The plan to [be able to] stop polio vaccination seems to be definitively canceled with Wimmer's demonstration project - paid by the Pentagon -, as is emphasized in comments in Science and the British Medical Journal.	Kohler, W. (2002, July 27). Virus op recept; Het poliovirus is nog niet uitgeroeid of de mens maakt het zelf. *NRC Handelsblad*, p. 31

			Now, no one can avoid that people who were educated for it learned to make the virus from simple chemical building blocks."	
Neutral	Neu	Neither negative nor positive: objective without justice value	"Researchers from the American J. Craig Venter Institute build the complete genome from the bacterium Mycoplasma genitalium in the laboratory. (..) This week it became clear that the names of the institute and some researchers were included in the synthetic genome as a "signature"."	Kunstmatig DNA met handtekening (2008, February 8). *Spits*, pp. 19
			"A first step towards a DNA computer has been made. American biologist rebuild a bacterium in such a way that it functions as a bit: a binary 0 or 1. They announced this yesterday in Proceedings of the National Academy of Sciences (PNAS). The work has been done by the group of professor Drew Endy of Stanford University, pioneer in synthetic biology."	Eerste stap naar levende computer is gezet (2012, May 22). *NRC Handelsblad*, p. 16
Balanced	B	Positive and negative aspects are both	"Venter and Smith say that they want to make a bacterium that contributes to alternative energy. That, for example,	Genetici willen leven bouwen (2002, November 23). *Het Parool*, pp. [unknown]

	mentioned approximately equally	releases hydrogen from seawater. Hydrogen is considered a future source of clean energy. (...) Already in 1999, Venter launched plans to build a bacterium in the lab. At the time, he did not get permission because of ethical objections en concerns about safety: bioterrorist might abuse the knowledge gained by him [Venter] to make deadly bacteria. Moreover, the bacteria - that are possibly dangerous for humans or the environment - could escape from the lab. Venter ensures that the organism will be made in a way that it cannot do harm to humans and that it will die as soon as it leaves the petri dish."	
		"Artificial bacteria that make new antibiotics to prevent resistance: it is an example of synthetic biology. Converted algae already produce sustainable energy. Which other possibilities are there and what are the risks? What would happen if a synthetic life form escaped? Students of the Free	[Events] (2015, December 12). *Het Financieele Dagblad*, pp. [unknown]

			University organize a freely accessible dialogue about "synbio" and look for answers.	
Critical	C	Neither positive nor negative, but critical questions are asked. Ethical / moral questions are raised.	"But it is nonsense to call JCVI-syn1.0 a new species, because the applied genetic changes are very limited. And we will have to wait for years for applications."	van Santen, H. (2010, June 5). Geboren: JCVI-syn1.0. *NRC Handelsblad*, pp. [unknown].
			"Isn't the cell a priori seen as work from a creator? (...) Do you see the building of an artificial cell as a form of creating life?"	van den Dikkenberg, B. (2015, May 13). Babystapjes om het leven te begrijpen. *Reformatorisch Dagblad*, pp. [unknown].
			"It is not hard to understand that ethical and political debates are needed, about the implications of genetics, cloning, synthetic biology, artificial intelligence, et cetera."	Etty, E. (2008, June 3). Krijg dan maar borstkanker. *NRC Handelsblad*, p. 7

Appendix 4

Examples of applications

Application category	Code	Examples, as mentioned in newspaper articles
Improve (biology) research	B	Fundamental knowledge
		Cloning extinct species
		Facilitating life on Mars
		Fostering communication between cells
Computers	C	Data storage in DNA
		Biological / DNA computers
Environment	E	Breaking down toxic substances in the environment (water, ground, and air)
		Taking up greenhouse gases
		Generating electricity
		Producing biofuels
Food	F	Producing foods and additives
		Detecting rotten meat
Human enhancement	H	Elongating life
		Preventing aging
		Regenerating limbs
Industrial	I	Producing biological plastic, glue, chemicals, proteins, etc.
		Measuring temperature to control industrial processes
Medical	M	Producing medicine (artemisinin, antibiotics, insulin, etc.) and vaccines
		Biosensors, for example to detect cancer

		Controlling drug release
Other	O	Preventing unwanted fouling on ships
		Warfare
		Biological lenses and lasers
		Producing biofilms
		Creating color-changing bacteria
		Creating bacteria that produce a certain smell

Appendix 5

Exemplifying quotes for risks and ethical issues

Risks/ethics category	Code	Exemplifying quotes[5]	Reference
Biosafety	BSa	"Critics directly point at the dangers. That a self-made bacterium à la Venter will escape from the lab."	van Santen, H. (2010, June 5). Geboren: JCVI-syn1.0. *NRC Handelsblad*, pp. [unknown].
		""Of course it is about genetically modified organisms and you can't just bring them into the environment", Kuipers says. (...) "Personally, I am not so afraid for bacteria gone crazy.""	Voormolen, S. (2015, March 28). Precisie antibiotica. *NRC Handelsblad*, pp. [unknown].
Biosecurity	BSe	"Critics directly point at the dangers. (...) Or that biohackers will build a self-invented disease-causing bacterium in their own garage - the destructive DNA ordered per mail."	van Santen, H. (2010, June 5). Geboren: JCVI-syn1.0. *NRC Handelsblad*, pp. [unknown].
		""And that terrorists have a new weapon in hands with this, seems very unlikely to me. Way more dangerous pathogens can be found in nature itself, for which you don't have to engineer anything. You can just isolate those and they pose a greater danger.""	Voormolen, S. (2015, March 28). Precisie antibiotica. *NRC Handelsblad*, pp. [unknown].

[5] Quotes are translated from Dutch.

		"To make matters worse, synthetic bacteria could be used as biological weapon. Jack Pronk, professor industrial microbiology at the Technical University Delft, has to laugh a bit about that last fear. "Let Al Qaeda invest in synthetic biology", he jokes, "Then at least we will not suffer from them in the coming years".	Becker, S. (2007, June 29). Gezocht: brandstofbacterie. *Trouw*, p. 5
Ethics	E	"Critics have ethical objections against what they see as creating artificial life in the test tube"	van Raaij, B. (2008, January 26). Genenkaart bacterie nagebouwd in lab. *De Volkskrant*, p. 5
		"Don't underestimate what is happening. The distinction between life and dead is disappearing. (...) In short, humans are developing into God the creator."	Hulshof, C. (2007, September 5). Ethiek Levenswetenschappen - Burgerverzet dreigt tegen nieuw leven makende onderzoekers. *Het Financieele Dagblad*, p. 9
		"For Christians, another question is relevant: God is the only creator of life, right, shouldn't humans stay away from that? (...) "I have the opinion that humans in a way even have the assignment to "play God". At the start of the Bible we read that God created humans as replica of himself. God gave those humans a cultural assignment, to manage the world and to have power over it. In this assignment we are commissioned to "play God"- we are	Dekker, C. (2015, July 31). Leven scheppen in het lab. Nederlands Dagblad, pp. [unknown]

		called as his representatives to take care of this earth.”‘	
Patent-related	P	“On 31 May he [Craig Venter] did receive an American patent on a set of genes that are necessary to keep a bacterium alive. The ETC Group makes a fuss about this. The activists demand that the patent is destroyed, because it would make Venter owner of all synthetic organisms that will ever be build based on that specific minimal gene set.”	Becker, S. (2007, June 29). Gezocht: brandstofbacterie. *Trouw*, p. 5
Other	O	“You are talking about safety, but are such experiments safe? Church: “Critics’ assumption that something that is unsafe now will always be unsafe, is wrong.”‘ [i.e. non-specified risks]	Voormolen, S. (2011, October 15). Hacker van het leven. *NRC Handelsblad*, pp. [unknown]

Appendix 6

Examples of metaphors

Category	**Code**	**Examples, as written in newspaper articles[6]**
Books, reading, writing	BRW	Reading the genome
		Writing the genome
Computers, programming	CP	DNA is the software of a cell
		The minimal cell is a printed circuit board on which gene modules can be plugged in
		The genome is an operating system
		Reprogramming yeast
		An empty cell is hardware
		An empty cell is a computer without software
Creation, power	C	Creating life
		Playing God
		God has competition
		Modern Frankenstein monster
Designing	ONT	(Re)designing a genome / a cell / a bacterium / DNA / life (from the drawing board)
		Designer
Do it yourself	DIY	Gluing together pieces of DNA
		Cutting and pasting of genes
		Crafting

[6] Metaphors are translated from Dutch. Due to language differences, metaphors in English may slightly differ from their originals in Dutch.

		Biohackers
		Biologists with screwdrivers
Engineering, building	EB	(Re)building (up) a genome / a cell / a bacterium / DNA / life
		Building blocks
		Lego bricks
		Engineer
		Reconstructing
		Building plan
Garage	G	The cell is a car
		The minimal genome can be used as a chassis
		Assembling a microbe
Minimalizing	M	Stripping the genome
		Undressing the genome
		Cutting genes away
		Mycoplasma light
Industrial	I	The synthetic cell is a factory
		The synthetic cell is a machine
Other	O	The synthetic bacterium is a creature
		Living robots
		Building a radio
Tailoring	T	Stringing / knotting together nucleotides
Transplantation	Tr	Transplanting the genome / DNA