

Cartoons on bacterial balloons: scientists' opinion on the popularization of synthetic biology

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Abstract How do scientists perceive the media coverage of synthetic biology (SB)? In this paper, we approach this question by studying a set of cartoons devoted to SB. Based on a categorization of the cartoons into five large thematic groups an international survey was carried out to assess the opinion of SB research groups on science communication with regard to the public image of their discipline. The 101 responses obtained indicate that in general, their perception of the communication is not negative, although many respondents raised concerns on the media's inclination to sensationalism and over-simplification. However, the results also suggest that (in the light of the unfortunate experiences with GMO communication) scientists should think twice before proposing metaphorical interpretations of their research.

Keywords Synthetic biology · Science communication · Science cartoons · Public understanding of science

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Introduction

In November 2005, *Nature* published a special issue on synthetic biology (SB hereon), in which researchers discussed the ethical issues raised by rewiring life (Nature 2005). It included a supplement, a comic book (*Adventures in Synthetic Biology*), written by Drew Endy and Isadora Deese and illustrated by Chuck Wadey (Endy et al. 2005). Its main aim was to portray the goals of the new field in a playful and amusing way: at the end of the story, after having built a bacterial balloon, one of the researchers, a nice young boy, happily claims: “We’re building stuff!!”

Undoubtedly, this comic may have helped the audience of *Nature*—mainly researchers and, to a lesser extent, the lay public—to understand the challenges of the new field, and may also have popularized its vocabulary (e.g. Biobrick parts, repressilator, inverter, genome engineering, xenobiology, etc.). Actually, the science comic genre has been proposed as an adequate tool for educational purposes (Tatalovic 2009) because it can help to explain concepts and promote reflection in students (Rota and Izquierdo 2003).

Nature's comic also invited readers to consider the implications of constructing life. Among them, it may have elicited the notion of risks posed by deliberately tinkering with nature, which is one of the most prevalent associations found in surveys and focus group work involving lay people (Dragojlovic and Einsiedel 2013a). It is arguable, though, whether this comic contributed to a positive perception of SB as obviously intended or, instead, to a notion of hazard and uncontrollability, and of the average SB scientist being a kind of doctor Frankenstein (Gschmeidler and Seiringer 2012).

Comics and, by extension, cartoons (understood as minimum units of comics, being independent entities) often function as gauges of the reception and acceptance of ideas

and positions on social realities (Bouvier 2001; Caswell 2004; Powell and Paton 1988). Analyzing cartoons to assess social reality is especially useful in the case of science (Bakker 1999; Giarelli 2006; Manzo 2012; Domínguez 2014; Domínguez and Mateu 2013), as it reduces the complexity of science communication to easily recognizable archetypes or metaphors. Cartoons respond to established social ideas, translated into a visual language (Domínguez and Mateu 2014). Due to their reductionist and satirical nature, science cartoons can reflect the lay public's reception and perceptions of a new scientific discovery more succinctly than any text-based journalistic genre.

Regarding SB, in principle, manifold images may be expected in public communication since scientists still use different definitions and have not yet developed a unanimous understanding of what SB essentially is (ter Meulen 2014). Although the term *Synthetic Biology* already appeared in the scientific literature a century ago (Leduc 1912), its modern use has only become established over the last decade, and much more so after 2008. A little later, in 2005, articles on SB appeared in the Internet, with a slow but steady increase in number as deduced from Google searches and Google Trends (<http://www.google.es/trends/explore#q=%22synthetic%20biology%22>). Interestingly, SB-related cartoons show wholly independent dynamics, with a sudden peak in 2009 and a slow decrease until today (Fig. 1).

Triggered by the field's rapid development, both synthetic biologists and social scientists showed an early interest in identifying challenges regarding the public's reception of SB (Schmidt et al. 2009). Since SB was considered prone to stir up debate on its risks and benefits (Schmidt et al. 2009), many scientists hoped that addressing potential concerns early on would minimize obstacles to public acceptance in the long run (Torgersen 2009). This has to be seen in the light of previous experience with

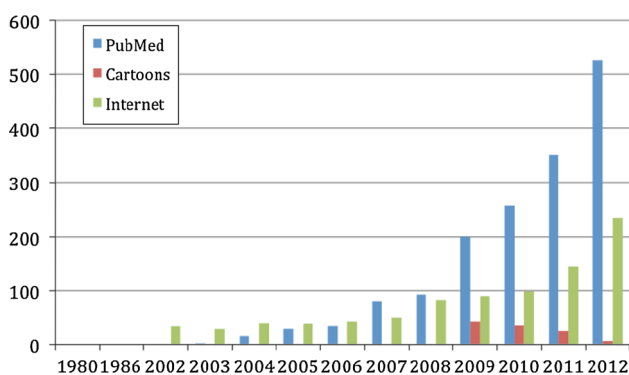


Fig. 1 Number of references including the term “synthetic biology” in PubMed, in graphic representations and cartoons in the mass media and in Internet searches (Google) in the last decade (data since 1980 are also shown for PubMed references)

GMOs and the problems with their public acceptance in many countries. Since SB produces GMOs, arguably public rejection of some applications at least would only be a matter of time. Indicatively, in the introduction to their report on SB EASAC (EASAC 2011) already identified “antagonistic questioning and pejorative comment” in the few media articles available then.

This said, several studies found that mass media coverage of SB was generally positive (Kaiser 2012; Schmidt 2009): “Media draw links to genetic engineering in general, but less so to GM crops, and public scapegoats such as multinational companies are largely absent” (Torgersen and Hampel 2012). However, SB’s public image may be more intricate: in a study on the German media, Gschmeidler and Seiringer (2012) found that representations of SB range between fascination and disgust. Matthias Kaiser (2012) attributed the positive image of SB in the media to the poor coverage of the field. In the same vein, Kronberger et al. (2012) noted that in homogenous focus groups, attitudes towards SB built up only after discussing the issue, but then closely mirrored those of the respective groups’ prior attitudes towards genetic engineering.

Thus, the lack of media attention may partly lie behind the somewhat positive reporting, and vice versa, more intensive future coverage might become less positive if closer links to, say, GMOs were forged. A more concise genre such as cartoons could provide early hints at such underlying perceptions of SB as they translate them into visual metaphors.

Some preliminary research has been carried out on the visual communication of SB (Cserer and Seiringer 2009) and comparative analyses with other fields such as GMOs (Kronberger et al. 2012). We think the results support the notion that cartoons and comics are powerful graphic indicators of public opinion and worthy of further investigation.

A pending question is how members of the SB scientific community consider the communication of their field. Even if it is unclear whether and how much they engage in popularization efforts, scientists often consider it both in their interest and remit—or societal duty, as some say—to contribute to a realistic picture of SB in the public eye (EASAC 2011). If cartoons can be taken as a concise reflection of public opinion, they may be used to assess scientists’ attitudes by asking them whether they consider the representations of SB suitable or not, and which kind of cartoons best match their own view on SB.

Accordingly, the survey was designed to address two questions:

1. What are the dominant ideas and metaphors applied in cartoons on SB, and do they convey a more positive or negative image?

2. What are scientists' views on the different categories of cartoons identified, and which category best matches their own perception of the field?

Methods

Selection of cartoons and definition of groups

A search in the main Internet search engines (Google and Yahoo, April 2013) using the keywords “cartoons + synthetic biology” rendered 165 hits. Cartoons were filtered in order to discard those not fitting synthetic biology. Topics chosen included: (1) artificial life forms; (2) creation of life; (3) explicit reference to SB reports. Related topics including the general GMO controversy, molecular biology or genome sequencing were not included. In the end, 57 cartoons could be properly attributed to SB. The rest, although associated with the keyword “synthetic biology”, referred to other fields. Five categories were defined, taking into account the different features of the cartoons (see Fig. 2):

1. Mystic/religious: These cartoons connect the idea of Divine Creation with the idea of creation of artificial

life in the laboratory. Mystic and religious cartoons refer to religious motives, e.g. to comparisons between SB and God's creation and/or apply metaphors related to God, creation, genesis, etc.

2. Monstrous: cartoons displaying monsters as products of SB, with key references to Mary Shelley's Frankenstein monster and the 'green amoeba', thus highlighting unexpected or uncontrolled side effects of SB. These cartoons emphasize the negative consequences of SB.
3. Engineering: cartoons alluding to the application of engineering principles to biotechnology in a static way. Metaphors of construction and building are thoroughly used in this group.
4. Descriptive: cartoons showing the dynamics of procedures or applications of SB with minor or no subjective positioning.
5. Comical: cartoons referring in a comical way to particular SB scientists, specially to John Craig Venter's personality and quotations from press conferences, such as his announcement in 2010 of having created an artificial cell.

After determining the classification of the cartoons, we tested its reliability with four independent researchers. The researchers assigned ten randomly selected cartoons (17 %

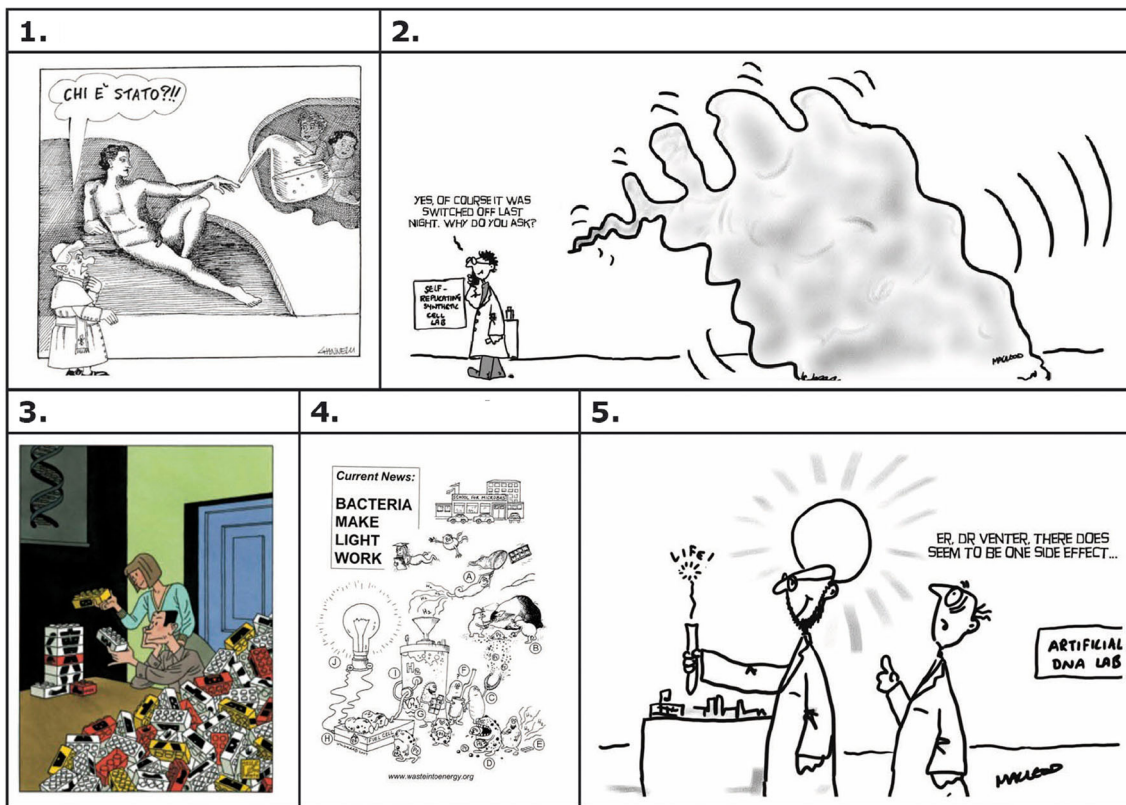


Fig. 2 Groups of Cartoons. 1 Mystic or religious. Cartoon by Emilio Giannelli (*Il Corriere della Sera*, May 10, 2010). 2 Monstrous. Cartoon by McLeod (Personal blog, May 27, 2010). 3 Engineering.

Cartoon by Joost Swarte (*The New Yorker*, September 28, 2009). 4 Descriptive. Cartoon by Geoff Gadd (*BBSRC*, June 17, 2009). 5 Comical. Cartoon by McLeod (Personal blog, May 26, 2010)

of the sample) to one of the five categories, which resulted a high level of consistency with our own attribution. The test also helped us to detect some ambiguity between categories and to define the groups more precisely. In the case of the cartoons in which there were elements of two or more groups, it was agreed that they should be ascribed according to the predominant elements to one of the groups only.

Survey design and sample selection

For the survey on researchers' opinion of the image of SB a questionnaire was drawn up and divided into four sections. The first retrieved personal information about education, gender, age and place of work. The second section, with four primary and three follow-up questions, focused on the researchers' assessment of their communication behavior within their field and with the wider public. The third section asked for the researchers' opinion on the set of cartoons presented, and the fourth section for their opinion on the *Nature* comic described above (Endy et al. 2005). The survey also included an optional open question on the overall subject.

We selected a sample of active SB researchers through PubMed by searching the Medline database for papers with the keyword "synthetic biology" published from January 1, 2011 to June 30, 2013. This rendered a total of 1,275 articles. A total of 1,106 email addresses of authors or co-authors were retrieved from them. The survey was sent out between July 26, 2013, and October 20, 2013. Approximately 10 % of the addresses turned out to be invalid. A total of 101 valid responses were received (see Table 1 for a profile of the respondents). Most respondents originated from the United States (26.7 %) and the UK (18.8 %).

Results

Visual communication of synthetic biology: typology of cartoons

Most of the selected cartoons were designed by professional cartoonists (44) and published in the media (11), blogs or the authors' web pages (20). Only five of the cartoons originated from cartoonists with scientific training and specialized in this type of visual divulgation of science. Below, there is a summary with the main features of the five groups analyzed.

Mystic or religious cartoons

Cartoons from this group (n = 7) connect the ideas of SB and Divine Creation, attributing the creation of life (as traditionally conceived in the catholic culture) to SB. In

Table 1 Profile of the respondents (n = 101): position, education, country of residence, age and gender

Position	
University professor:	47.5 %
Researcher:	19.8 %
Postdoctoral researcher:	15.8 %
PhD candidate:	10.9 %
Other:	6 %
Average age: 41.25 (SD 11.490 σ)	
Country of residence/work	
USA:	26.7 %
UK:	18.8 %
Germany:	5.9 %
France:	5.9 %
The Netherlands:	5 %
Others:	37.7 %
Gender	
Female:	22.8 %
Male:	77.2 %

fact, five of them apply Michelangelo Buonarroti's Sistine Chapel fresco 'Creation of Adam' as a metaphor. In some cartoons, God is replaced by metaphors of Science (a scientist, a piece of DNA or a test tube). In one of them, the creator is Man (Michelangelo's Adam) who, from a computer, gives life to a cell with his finger, referring to Venter's press release in 2010 on the creation of computer-generated artificial life. All seven cartoons thus refer to the expected controversy raised by the creation of artificial life in the laboratory, understanding creation as an exclusively divine act with religion always represented by Catholicism.

Monstrous cartoons

Within this relatively large (n = 17) group, the most common reference is Mary Shelley's fictional scientist, Dr. Frankenstein (n = 9), followed by the 'giant amoeba' (n = 6), an artificial creature of undefined, amoeba-like shape. Interestingly, the green amoeba also appears in the *Nature* cartoon, although here in the form of a victim rather than an autonomous (and evil) actor.

These cartoons emphasize the hazards of SB, portraying possible outcomes of the creation of artificial life rather than the mere fact. As Gschmeidler and Seiringer (2012) indicated, they evoke the negative consequences of tinkering with nature, and at the same time stress the ethical implications.

Engineering cartoons

In this group of cartoons (n = 6), SB is represented as a standardized engineering process. Therefore, metaphors of

construction, assembly, technology, etc. abound. The way this is depicted is predominantly static, with puns dwelling on combinations of tools, wires, building blocks and other elements, the result of which is often a DNA molecule.

This group of cartoons graphically depicts the various sub-fields of synthetic biology that made it the interdisciplinary discipline it is today: an interphase between biology and engineering (Kronberger et al. 2012).

Descriptive cartoons

Cartoons classified as descriptive ($n = 19$) were the most numerous. In the tradition of textbook illustrations, they mostly describe the dynamics of SB research and how its outcomes function, showing typical elements such as cells, bacteria, DNA strands, scientists in a laboratory, etc. in virtual motion.

They sported either the benefits of SB and its medical or energy applications, or ethical dilemmas arising from creating artificial life, or simply drew comparisons with day-to-day issues from politics or the economy.

Comical cartoons

This group of cartoons ($n = 8$) referred directly to particular people, either in the text or as a visual depiction, mainly to the researcher Craig Venter. The cartoons focused on his proclaimed ability to create life; some even compared him with God (in a way similar to the first group). For example, in a cartoon by Bart an angel explains to a newcomer at heaven's doors: "God had a prior engagement, but Craig Venter is available to see you."

Synthetic biology communication: the scientists' opinion

Based on the results of the survey, and in general terms, members of the international SB scientific community perceive the media coverage of SB to be fair rather than negative (40.6 % of respondents chose the "Fair" option in a 5-point scale: Very Good–Good–Fair–Poor–Very Poor). Nevertheless, respondents identify mistakes made by the media when communicating SB news, such as sensationalism (20.6 %) as well as over-simplification and a lack of understanding on the topic (18.8 %). Over-emphasizing risk and fear was less frequently criticized (8.5 %), as was a lack of coverage (6.1 %) (Table 2).

A large majority of synthetic biologists (89.1 %) stated that scientists should get more involved in the popularization of their field. This perceived deficiency is particularly striking if we consider that almost two thirds of the respondents claimed to be engaged in popularization activities. The reasons given why they should do better are:

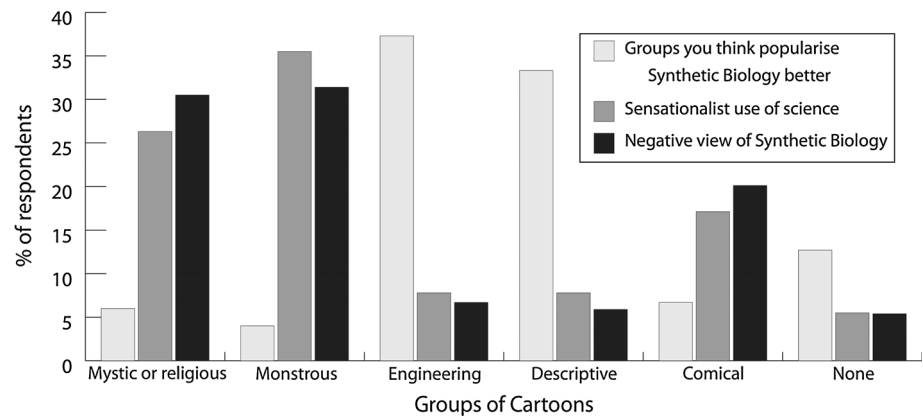
Table 2 Main faults of the media when informing about SB, according to respondents (multiple choice)

	Responses		Case percentage
	No.	Percentage	
Sensationalism	34	20.6	35.1
Oversimplification or lack of comprehension	31	18.8	32.0
Emphasis on risk/fear	14	8.5	14.4
Too little coverage	10	6.1	10.3
Polarization: focusing on the most positive or negative parts only	9	5.5	9.3
Mixing scientific breakthroughs with industrial progress and profit	8	4.8	8.2
Confusing SB and genetic engineering	8	4.8	8.2
Frankenstein myth	8	4.8	8.2
Focusing on individual stories	7	4.2	7.2
Focusing on religious aspects	5	3.0	5.2
Lack of journalist/scientist relations	4	2.4	4.1
Over-optimism (SB as a miracle worker)	4	2.4	4.1
Irrelevant ethical considerations	3	1.8	3.1
Little public exposure	3	1.8	3.1
Putting nature and science in opposition	2	1.2	2.1
Focusing on practical research	2	1.2	2.1
Other	13	7.9	13.4
Total	165	100.0	170.1

(1) scientists are the people best suited to communicate their results (21.4 %) ("scientists have specific correct information") and (2) they offer a positive perspective of SB and can thus foster the societal acceptance of the field (20.4 %). Some also argued that communication would promote the general understanding of SB and help prevent misunderstandings (14.3 %) such as mixing up SB and GMOs, or SB and pseudoscience. Again, it should be stressed, though, that the boundaries between SB and related fields like metabolic engineering are not always sharply defined (Porcar and Peretó 2012).

Up to 65.3 % of the respondents claimed to be involved in communicating their area of knowledge, mostly through conferences (27.7 %) and in the press (23.2 %). New digital media are used less: only 9 % claimed to have communicated through blogs, and barely 4 % through Twitter. Conversely, among those who indicated they do not popularize (34.7 %), 43.8 % claimed the reason was a lack of time and 22.9 % referred to a lack of academic recognition for communication efforts. Only 4.2 % claimed that public communication activities had a negative reputation among the scientific community.

Fig. 3 Opinion of the scientists on the five groups of cartoons. *X axis* indicates the groups of cartoons, whereas *Y axis* indicates the percentage of respondents having selected each particular group



Asked which group of cartoons conveyed an idea of what SB really is—and therefore constituted an adequate tool to popularize SB (see Fig. 3), respondents chose the “engineering” (37.3 %) and the “descriptive” group (33.3 %). Respondents also agreed that the “monstrous” group provided the most sensationalist image (35.5 %) of the field.

These results are somewhat contradictory to the opinion found regarding the *Nature* comic, which portrayed SB as a producer of monsters. In fact, 71.3 % found the comic useful to popularize SB and 68.3 % considered it to offer a positive vision of SB. In short, the scientists’ perception of the *Nature* comic was much more positive than their view of cartoons published in non-specialized media, even if they displayed similar metaphors. Nevertheless, in the final comments (28 were collected) some respondents gave a more thorough assessment of *Nature*’s comic, stressing its less fortunate aspects: “The tone is very frivolous, including a dangerous nonchalance about the potential for biological errors”; “the cartoon over-hypes things”; “it may exaggerate aspects of synthetic biology in an effort to make their work interesting or funny. This may lead to confusion or misconception in the public”. In addition, several respondents highlighted that *Nature*’s readers were a specialized audience and assumed that the comic would have little or no effect on the perception of SB among a general audience or on subsequent cartoons.

Discussion and conclusions

This is the first analysis of cartoons associated with the keyword “synthetic biology” and of their perception among the international SB scientific community. As such, it may shed a light on issues beyond those usually addressed in written journalistic texts. Two main observations could be made, which coincide with two waves of cartoons of very different contents.

Firstly, early cartoons point at a popular understanding of SB that seems to mix synthetic biology and a number of other fields of biotechnology. Although many of the cartoons labeled SB appeared in 2009, most of them in fact referred to human genome sequencing, organism cloning or the GMO controversy—issues that had already come of age then and had left their mark on public opinion. Hence, cartoonists took up what they expected the public would recognize as being associated with biotechnology instead of presenting SB as something entirely new. Linking new issues to familiar ones, however, is an established practice in communication and may be inevitable to problematize an issue. It should not be taken to indicate an intentional expression that the old and the new issue necessarily elicit similar concerns. It only indicates that the new issue will (initially) be discussed in terms that had already been introduced when debating the old issue, the outcome of such a debate still being open (Bogner and Torgersen 2014).

It may also point at a certain ambiguity of the term SB, often understood to overlap with GMOs. However, this is not unique to popular representations: even scientists seem to find it difficult to agree upon a definition for SB (ter Meulen 2014; Kronberger 2012), and even outstanding synthetic biologists such as Jay Keasling use the term ambiguously, for example as a platform for contributing tools to metabolic engineering (Keasling 2012). It would thus be naive to expect society to have a clear perception of SB from the outset.

Secondly, the publication of the first synthetic organism “whose parent is a computer” in 2010—as defined by Craig Venter during the press conference in which he announced the creation of artificial life (Wade 2010)—gave rise to a new wave of cartoons with more specific topics: the concept of playing God, Venter’s alleged supernatural power and religious metaphors on the creation of life. Hence, the subjects were somewhat different from the topics of the previous wave, although many cartoons on SB still shared topics such as biosafety, intellectual property issues or ethical

aspects with topics in (ordinary) biotechnology. Similarly, the risk of meddling with nature or the hubris of playing God is also found in the depiction of other disciplines such as genetics and biotechnology (Hansen 2006; Nisbet et al. 2003). However, our analysis shows that the overlap with other fields of biotechnology waned after Venter's announcement in 2010. In cartoons following Venter's statement, most cartoonists considered the distinctive property of SB to be the "creation of life" and consequently, this became the differential trait of SB cartoons.

The "creation" tag readily suggests mystic interpretations. In fact, cartoons tend to connect synthetic biology to religion, displaying them as somehow opposing forces. The survey shows that most scientists tend to reject such a juxtaposition of science and religion, and many consider such an association to be detrimental to the popularization of the field. Accordingly, perpetuating the perception that researchers "play God" would increase the odds of religious believers rejecting SB (Dragojlovic and Einsiedel 2013b).

The fact that the "playing God" and monstrous topics have emerged as some of the main *leitmotifs* of SB cartoons stands in contrast to the predominantly positive tenor in written media texts (Kaiser 2012; Schmidt 2009). The perception on SB displayed in cartoons other than the descriptive ones was mostly comical or even negative; arrogance and risks were common topics. This raises the question whether—and how—written texts and cartoons may display the same (SB) issue independently, and whether this is due to the different semiotic mode (visual vs. verbal) or the factual versus humoristic way of depiction (Tsakona 2009). Similarly, differences in reporting are also remarkable when it comes to frequency. The numbers of cartoons, of scientific reports on SB and of references to SB in the Internet were somewhat at odds over the years (Fig. 1). While the number of SB scientific reports showed a steady increase over the last decade, this was not the case for cartoons or for Internet references. A single SB report (on the "creation" of a synthetic cell) had crossed the boundary of public interest and been magnified through cartoons in a science-independent manner. Taken together, trends in the salience of synthetic biology (as a scientific field) and its social impact over time do not seem to go hand in hand.

Since the bias on ethically questionable or risky issues displayed in some of the more "political" cartoons does not correlate with the overall positive or factual description of the field in press articles, there is little wonder that the scientists who participated in the survey were more favorable towards the group of cartoons showing synthetic biology as a metaphor for construction as well as those providing descriptive illustrations of the field. They tended to display topics related to SB in a more positive light, and even if they raised ethical issues they did not emphasize hazards or juxtapose SB and religion.

In agreement with the generally positive tenor found in media reports so far, respondents assess SB communication in the media to be "fair", although they think scientists should be more deeply involved in communication practices. This raises the question as to which tools might be suitable to promote a better understanding of SB among the public. Although the way of depicting concepts and products of SB in visual metaphors usually was not criticized, cartoons of the "construction" or the "description" group clearly were considered better suited than the "monstrous" cartoon group, the latter being seen as a more negative way to communicate SB.

There was one remarkable exception: scientists tended to approve the somewhat questionable image of SB objectives and practices emerging from the *Nature* comic. In sharp contrast to their opinion on the often similarly amoeba-like metaphoric allusions found in SB cartoons in the general press, the *Nature* comic was even considered suitable for popularization purposes. Surely, *Nature* is a specialized journal with few readers among the general public, as some of the respondents stated. Nevertheless, it is recognized as an important source of scientific information for general-interest media. In fact, the comic was recommended by other publications with a large readership such as the American magazine *Wired* and *The New York Times* or *CNN*'s website. Therefore, the impact of the *Nature* cartoon may be larger than the restricted circulation of the source would suggest, be this fact better or worse for SB's public image.

Taken together, our analysis of the circular process (science—science communication—cartoons—science) strongly suggests the need for a more reflective attitude of scientists and, particularly, science communicators. Metaphors and comparisons are indispensable discursive elements when explaining science to a lay audience (Torgersen and Schmidt 2013)—but they must be chosen with care. By applying a certain metaphor or comparison, a particular frame is elicited. The ensuing societal debate may not only be transiently set but sometimes (as in the case of agricultural GMOs) shaped for good.

Synthetic life is one of the most delicate subjects in science communication today. If lessons have to be drawn from the case of communication on GMOs', scientists should think twice before proposing far-reaching metaphorical interpretations of their research and avoid a sensationalist approach or an extremely simplistic vision of their discipline. This would also include taking into account not only the context of the publication the piece is going to appear in but also of the wider repercussion this is expected to have if, for example, it is to appear in an important outlet such as *Nature*. Furthermore, the discrepancy between written text and pictures need to be acknowledged. Images (such as the figure of Frankenstein)

have a subtle but far-reaching power and often appeal to cultural stereotypes. Scientists should be very cautious actively emphasizing such metaphors even if they appear catchy and effective in popularizing the science at first glance.

Conflict of interest The authors declare no competing financial interests.

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