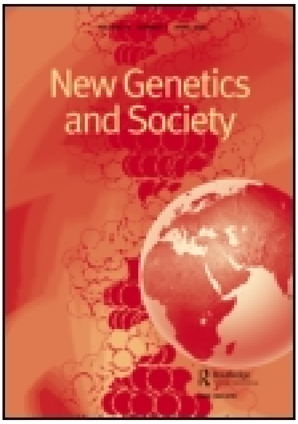

New Genetics and Society
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cngs20

Synthetic biology: building the language for a new science brick by metaphorical brick

Iina Hellsten [a] & Brigitte Nerlich [b]

[a] Department of Organization Sciences, VU University Amsterdam, Amsterdam, The Netherlands

[b] School of Sociology and Social Policy, Institute for Science and Society, University of Nottingham, Nottingham, UK

Available online: 01 Nov 2011

To cite this article: Iina Hellsten & Brigitte Nerlich (2011): Synthetic biology: building the language for a new science brick by metaphorical brick, New Genetics and Society, 30:4, 375-397

To link to this article: http://dx.doi.org/10.1080/14636778.2011.592009

New Genetics and Society
Vol. 30, No. 4, December 2011, 375–397

Synthetic biology: building the language for a new science brick by metaphorical brick

Iina Hellsten[a]* and Brigitte Nerlich[b]

[a]*Department of Organization Sciences, VU University Amsterdam, Amsterdam, The Netherlands;* [b]*School of Sociology and Social Policy, Institute for Science and Society, University of Nottingham, Nottingham, UK*

Changes in the biosciences and their relations to society over the last decades provide a unique opportunity to examine whether or not such changes leave traces in the language we use to talk about them. In this article we examine metaphors used in English-speaking press coverage to conceptualize a new type of (interdisciplinary) bioscience: synthetic biology. Findings show that three central metaphors were used between 2008 and May 2010. They exploit social and cultural knowledge about books, computers and engines and are linked to knowledge of three revolutions in science and society (the printing, information and industrial revolutions). These three central metaphors are connected to each other through the concepts of reading/writing, designing and mass production and they focus on science as a revolutionary process rather than on the end results or products of science. Overall, we observed the use of a complex bricolage of mixed metaphors and chains of metaphors that root synthetic biology in historical events and achievements, while at the same time extolling its promises for the future.

Keywords: metaphor; media debate; synthetic biology

> How much do we need to worry about a few arguable metaphors? Here, more than usually, because it is these ideas of complete control and the reduction of biology to the digital domain that are so central in investing the visions of synthetic biology with such power. (Jones 2010)

Introduction

In the year 2000, the first draft of the human genome was announced in a flurry of publicity, a publicity that involved Craig Venter as one of the lead scientists

*Corresponding author. Email: i.r.hellsten@vu.nl

ISSN 1463-6778 print/ISSN 1469-9915 online

http://dx.doi.org/10.1080/14636778.2011.592009
http://www.tandfonline.com

working on the sequencing of the human genome. Scientists and politicians spoke of the discovery of a magnificent map and of unraveling the book of life (e.g. Drenthen *et al.* 2009). About a decade later scientists announced the creation of artificial or synthetic cells, such as the synthetic bacteria *Mycoplasma genitalium* in 2008 and *Mycoplasma mycoides* in 2010, with much less political fanfare, but with Venter, again, being one of the lead scientists in this field and one of the most publicly visible ones. Between 2000 and 2010 there have been many changes in the biosciences and associated sciences. Research has shown that metaphors used to discuss genomics and its subsequent developments have, however, not substantially changed since the beginning of the human genome project in October 1990 (Nerlich and Hellsten 2004). The questions we wanted to ask in this article are: Did this situation change with the advent of synthetic biology? Did metaphors and with them conceptualizations of life, humans and nature begin to shift or not?

In May 2010 Venter published an article in *Science Express* announcing that his research group at the J. Craig Venter Institute (jcvi.org) had created the first self-replicating "artificial cell" (Gibson *et al.* 2010). This was heralded in many mainstream media articles as the creation of life (Sample 2010, p. 9). The search for "artificial life" has gone on for centuries, if not millennia, a search that, since the nineteenth century, has been framed in terms of recurring metaphors, myths and images, in particular of *Frankenstein* and *Brave new world*, but also, reaching back into Greek mythology of *Pandora*, *Icarus* or *Prometheus*, all three trying, in one way or another to "play God" (Ball 2011). It is therefore not surprising to find that the announcement of the creation of the first, viable, synthetic cell was covered by headlines such as "Scientists create Frankenstein bacteria" (*Wetenschappers maken Frankenstein-bacterie*) in a Dutch newspaper (*Volkskrant*, 21 May 2010, section Science), for example, indicating a continuity in the language used around the creation of "artificial life."

Here the focus is obviously on the end product of science, a metaphorical focus that is quite common in media coverage of biological breakthroughs. This end product can be seen as a scary monster, such as Frankenstein, or a positive achievement, such as deciphering the book of life for example. We will show that in the press coverage devoted to synthetic biology the focus is shifted by scientists and journalists from the end product towards the process of science itself, or rather the processes or work of the main sciences that feed into synthetic biology.

Synthetic biology is a new field of study which has its roots in a wide range of disciplines, approaches and traditions, each using quite different (but also overlapping) metaphors to frame what they are doing. The questions we want to ask in this article are: Did the collaboration and integration of many different disciplines within synthetic biology, which is hailed by some as the next industrial revolution, contribute to a revolution in the use of metaphors or lead to the construction of new metaphors? How did scientists frame what they were doing? And how did the media (in our case traditional newspapers) respond to these framings? Did journalists use old metaphors inherited from genetics and genomics (such as blueprint, map/journey, book, recipe, music and so on) or did they use new ones? Or, did they take a pick and mix approach to metaphors alongside an elaboration and transformation of conventional metaphors? Did scientists and journalists in fact engage in what one may call metaphorical bricolage? And finally: What are the ethical implications of this metaphorical framing? Answers to these questions may allow us to gain insights into whether a new language is emerging with relation to the "life" sciences, in the sense of sciences contributing and collaborating in the creation of (artificial) "life," and with it a new way of science communication.

Context: what is synthetic biology?

Synthetic biology is old and new at the same time (see de Lorenzo and Danchin 2008), that is, the methods and techniques used in synthetic biology are quite old, but the field itself only really emerged over the last five years or so. Historically, synthetic biology has its roots in many fields, but is mainly based on a convergence of engineering, computing and modeling with molecular biology, evolutionary genomics, and biotechnology on the one hand and research into the origin of life, artificial life and orthogonal (parallel) life on the other (on the history of synthetic biology see Luisi 2006, Peretó and Català 2007, Campos 2009).

The first to use the term "synthetic biology" was, it seems, the French biophysicist Stéphane-Armand Nicolas Leduc in 1912. This was a time when the search for artificial life was the height of biological fashion and when scientists such as Jacques Loeb announced its creation (see Keller 2009, Morange 2010). Around 2005 scientists at MIT, especially around Drew Endy, started talking about a new discipline, which they called synthetic biology (Endy 2005, Andrianantoandro *et al.* 2006). Other leading figures shaping the field were George Church at Harvard and Jay Keasling at the University of California for example.

Modern synthetic biology consists of three broad approaches of DNA-based device construction, genome-driven cell engineering and protocell creation (O'Malley *et al.* 2007). It "aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems" (Royal Academy of Engineering 2009, p. 6). The applications of the new technology are wide and potentially immense: "These methods are based on the advances in gene technology, in particular the technical feasibility of increasingly rapidly decoding genetic information and re-synthesising it. In the medium term, the potential applications of synthetic biology range from medicine and environmental technology right through to biotechnology" (Deutsche Forschungsgemeinschaft 2009). Most importantly, those working within synthetic biology use genes, or rather standard DNA parts that encode basic biological functions, not only metaphorically but almost literally as "the building blocks of life," sometimes called "BioBricks" (Endy 2005; see http://bbf.openwetware.org/). This increased blending between the metaphorical and the real is one of the features of synthetic biology that will be explored further in this article.

One of the most high-profile scientists working in synthetic biology in the new millennium was the genomics entrepreneur Craig Venter. He declared in October 2007 that he was creating "artificial life" (for a media analysis of this announcement, see Balmer and Herreman 2009). On 24 January 2008 the J. Craig Venter Institute announced that it had created the first synthetic bacterial genome of *Mycoplasma genitalium*. The results were published in the online version of *Science* the very same day under the headline "Complete chemical synthesis, assembly, and cloning of a mycoplasma genitalium genome" (Gibson *et al.* 2008). When talking about their "creation," Nobel-prize winning biologist Hamilton Smith described it as installing the software, and having to boot up the genome, get it operating. "We're simply rewriting the operating software for cells" (quoted in Blakemore 2008). In this context Colin Blakemore, a renowned British neuroscientist, wrote a comment piece for the UK broadsheet *The Observer* in which he pointed out that:

> The idea that life is just genetic information – just a sequence of DNA bases that remains the same information whether it is written in a book, displayed on the internet or sent by email – is sobering. I can remember Francis Crick ridiculing the notion of some kind of "life force" – a concept he said still appeared in print in the pages of scientific journals, long after his discovery, with James Watson, of the structure of DNA. But is life really just a chemical cookery book? (Blakemore 2008)

There are others who fear that doing synthetic biology will not only be restricted to elite laboratories or institutions, such as the J. Craig Venter Institute or the Massachusetts Institute of Technology, but that it can be done by anybody in a DIY fashion ordering biological parts over the Internet and assembling them in a garage (see e.g. Sample 2009, p. 5), according to a "cookery book" and by using various "ingredients."

Whereas during the time of the Human Genome Project scientists only spoke of the genome as a recipe or cookery book, a new generation of scientists is now taking this book out into the literal kitchen (and/or garage). This view of, what one might call, a more democratic approach to assembling life is reinforced by yearly competitions in which teams of young researchers from all over the world compete to create a self-replicating cell. The International Genetically Engineered Machine (iGEM) competition is a worldwide synthetic biology competition whose logo mixes two images into a striking visual metaphor, namely that of a cell overlaid on to a cogwheel. This "garage biology" stands in contrast to Venter's research using extremely costly equipment.

So we not only have a new science, constructed out of various components of older sciences, we also have a new way of doing science, framed, as we shall see, through a bricolage of metaphors. Does this mean we are seeing the emergence of a new language in this context? As the quote by Blakemore highlights, there is some continuity in framing between metaphors used to promote or report on previous advances in genetics and genomics and the synthetic biology project, a continuity which is not that surprising given the "continuity" in people promoting both projects, most importantly Venter himself.

However, there are discontinuities too in the language and framing, between for example the Human Genome Project, billed as enabling us to read the book of life and synthetic biology which, at least according to Venter, should enable us to move "from reading the genetic code to writing it" (Venter as quoted in Regaldo, 2005). Apart from this reversal in metaphorical direction, there are other differences, relating, not entirely surprisingly, to the aims and the methods used in synthetic biology, of which many are rooted in mechanical and computer engineering. Another, more important, difference emerges in the promises that are made around this new field. Instead of promising to cure all human ills, as was implicit in promoting the Human Genome Project, the focus here is more on curing the ills of the planet. In addition to biomedicine and biopharmaceuticals, synthetic biology promises applications such as the environmentally friendly production of chemicals, bioremediation, production of energy, production of smart materials and biomaterials and counter-terrorism (Pleiss 2006).

While many social scientists and bioethicists are beginning to immerse themselves in synthetic biology and issues related to ethics and public engagement (e.g. van Est *et al.* 2007, Balmer and Martin 2008, Calvert 2008, Lentzos *et al.* 2008, Lentzos 2009, van den Belt 2009), no one has as yet studied the emergence of a new language (or the transformation of an old one) alongside the emergence of the field and what this might mean for science and society. Keeping an eye on language is important, as synthetic biology is an offspring of genetic engineering where the metaphor of Frankenfood was effectively and lastingly used to oppose the creation of genetically modified foods and crops.

So far synthetic biologists have tamed this monster, so to speak, by, on the one hand, focusing promises they make about synthetic biology on saving the planet and making it greener, that is, by what one may call the "greening" of genetic engineering, and, on the other hand, by using a rather playful language of cutting and pasting, building blocks and Lego, tinkering, stitching and sewing, focusing attention on the rather benign sounding process of production rather than any scary end product. After surveying and analyzing the emergence of these and other metaphors between 2008 and 2010, we shall go on to ask what the societal implications are for framing (artificial) life in this way.

Metaphor clusters and chains

Recently, several authors have called for more research into complex, mixed metaphors rather than studying single metaphors in isolation (Lee and Barnden 2001, Ceccarelli 2004, Kimmel 2010). In authentic texts, metaphors often appear in clusters which might seem to consist of conflicting metaphors. Condit (1999), working on genetic discourses, was the first to point out that publics can flexibly understand a set of seemingly conflicting metaphors as part of an underlying narrative. Kimmel

(2010) argues that the selection of metaphors and the binding of these metaphors together into a discursive whole are two, separate, issues – and that mixing of metaphors does not necessarily lead to confusion. Ceccarelli (2004), for example studied the conflicting and complementary interaction between mixed metaphors, in particular those of the genome as a map, a blueprint and a text. In fact, these metaphors were used to complement each other, as parts of the wider theme of an expedition to a new frontier. Mixed metaphors can be used skillfully to strengthen an argument (see Kimmel 2010, p. 98), to attract attention (Corts and Pollio 1999, Koller 2003), to make discourse more effective (Kyratzis 1997) and to shed light on complex and unfamiliar subject matters (Corts 2006). This is especially important when communicating about a new type of science, and, in particular, where this new science is based on mixing and matching approaches from many other sciences, as in the case of synthetic biology.

We will also examine whether any chaining of metaphors occurred in the press coverage alongside the mixing of metaphors. By chains of metaphors we mean for example the metaphorical chaining that links the embodied, physical cutting and pasting involved in, say, cutting out a newspaper article, the cutting and pasting used in word processing and computing, which is actually just "cutting" and "inserting" (no pasting is involved), and the cutting and pasting, emailing and so on of actual biological entities, such as so-called "BioBricks," which returns the metaphor to some sort of "biological" origin and involves actual pasting rather than mere virtual inserting. This chain links three metaphorical source domains together, namely those related to books, to computing and to design/engineering and uses them to create knowledge of a new target domain, namely synthetic biology. The same is true for the word "reading" which is used by synthetic biologists mainly with respect to computing (where computers rather than humans read), but has its roots in our experience of book reading, and the previous metaphors of genetics and genomics on reading the amino acids in the DNA molecule.

In the next section, we first discuss our datasets and their limitations as well as provide more details about our methodological approach. Thereafter, we will summarize and discuss our findings.

Datasets and methods

In order to trace the metaphorical framing of synthetic biology, we collected data from all English-language newspapers with the exact search phrase "synthetic biology" indexed in the LexisNexis newspaper database. LexisNexis Academic (www.lexisnexis.com) contains full-text access to more than 350 newspapers from the US and around the world, more than 300 magazines and journals and over 600 newsletters, and broadcast transcripts from the major television and radio networks (http://academic.lexisnexis.com/online-services/academic-content-news.aspx). We focused only on newspapers in order to make this research more comparable with past research into the metaphorical framing of genetics and genomics.

Using this particular search term instead of several search terms, such as “synthetic life” or “artificial life” limits our dataset only to those news items that mention the new field (synthetic biology) by its name – instead of company names in the field, for example.[1] We restricted our analysis to newspaper items closely related to the scientific field in order to focus on texts that can be expected to deal with the core of the new emerging techno-science.

We manually removed duplicates of the same article, if it was published in the same newspaper on the same date – and was hence a technical error in the database[2] (see Figure 1). We read through the newspaper items, and manually coded the main themes of each news item and the metaphors used in the articles, at the level of metaphoric expressions, coding each specific expression only once per newspaper item because the same users tend to use the same metaphorical expressions repeatedly.

Results

Although newspaper coverage exploded in May 2010 (Figure 1), when Venter announced the successful creation of a synthetic cell, the amount of items published per month remained relatively small, as compared to earlier biosciences debates. So far synthetic biology seems not to have captured the public imagination, as much as genetic engineering did or as much as, at least initially, nanotechnology did.

We will first discuss the main themes of the news items and the main metaphors used in the debate, before engaging in a qualitative analysis of the metaphor chains and mixed metaphors. We restricted our metaphor analysis to the period of January 2008 to May 2010 to cover the main developments of the debate.

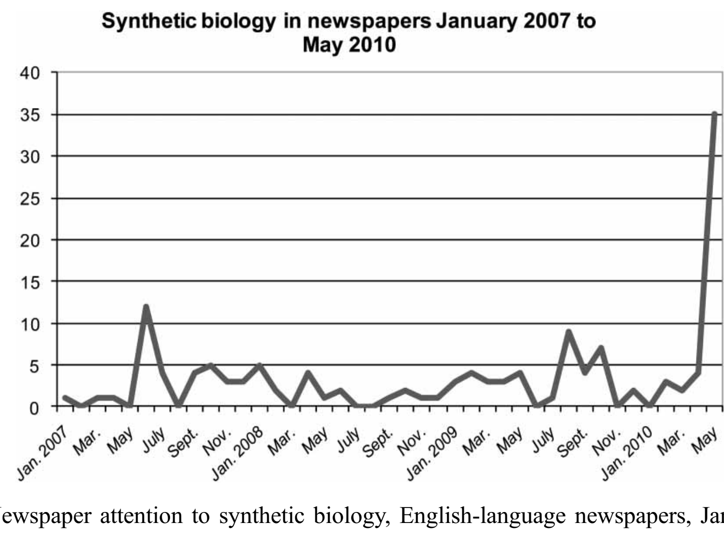

Figure 1. Newspaper attention to synthetic biology, English-language newspapers, January 2007–May 2010.

Main themes and metaphors

As a context to our metaphor analysis, we first conducted an analysis of the main themes in the media debate, from 1 January 2008 to 31 May 2010. For example, newspaper items about do-it-yourself, DYI synthetic biology are expected to be loaded with metaphors of building blocks and "BioBricks," while items about the various press briefings by Venter's group were expected to reflect the team's talk about competition and computing.

The main themes of the debate emerged around publications and press briefings staged by Venter, especially and obviously in May 2010 (Figure 2). The publications, press briefings and conferences by other scientists in the field gained far less attention in the newspapers. Other popular themes were news items about the state-of-the-art in synthetic biology, providing reflections and summaries about the field, for instance on "Life & genetics: the actual and the possible" special supplement of *The Observer* (Leroi 2008) and news about student competitions to create synthetic life, and the possibilities of DIY synthetic biology or so-called garage synthetic biology.

In 2009, synthetic biology was also mentioned in the news items in a TV guide, in a list of the world's most pressing problems (e.g. Henderson 2009), green energy sources (Weitzman 2009) and in *The Guardian* education pages as a Master's program at Imperial College London (Tobin 2009).

The main sources interviewed for the newspaper items had university or research institute affiliations, but there were also representatives of NGOs, in particular Friends of the Earth and the Action Group on Erosion, Technology and Concentration (ETC).

The main metaphors, counted separately to give an overview, were those of computers and computing; journey; reading and writing and book; building and engineering; sewing and mapping (Figure 3). The metaphor of blueprint was almost non-existent.

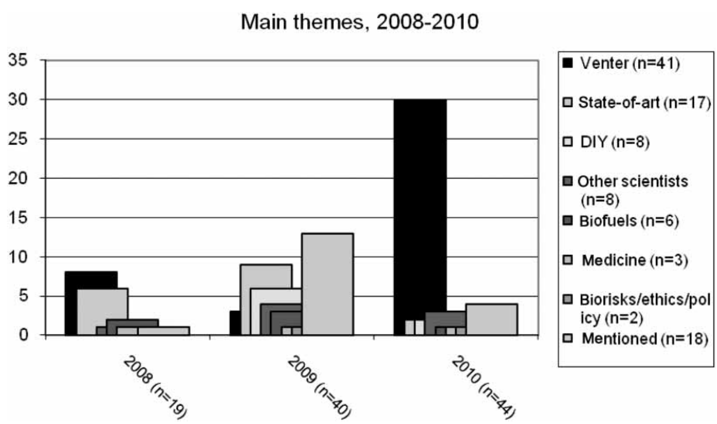

Figure 2. Main themes in the newspapers.

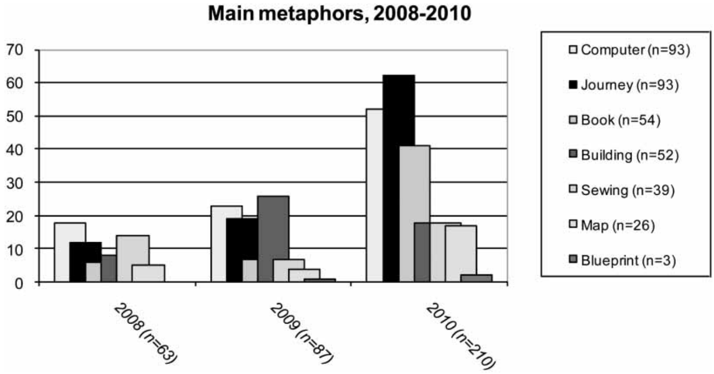

Figure 3. Types of metaphors, counted separately.

The metaphors of *computers* and computing were very popular in the debate on synthetic biology, especially in quotes from scientists; the language was rich in codes, booting up, software, hardware, programming, executing and tagging.

> Venter says "it's pretty stunning" to replace the DNA software in a cell. "The cell instantly starts reading that new software, starts making a whole different set of proteins, and within a short while all the characteristics of the first species disappear and a new species emerges from the software that controls that cell going forward." (Munro 2010)

Previously, "reading" was done by researchers or computers, while now it seems that cells do the reading and function as software, a chaining of metaphors that is quite novel in a media context. While in the debate about the human genome the only parts of the computer/computing metaphor were those of codes and software (Nerlich and Hellsten 2004), in the debate on synthetic biology the metaphor was extended to cover booting up, tagging and executing, all new uses of the metaphor.

Interestingly, the metaphors of *books*, letters of life (mostly referred to as the DNA nucleotides), reading and writing, instruction books, language and phrases gained in popularity in 2010 while the metaphors of buildings and building bricks and Lego were more popular in 2009.

The metaphors of *sewing*, stitching and tailoring life were used to claim, for example, that "Venter's project was more ambitious. The scientists knew the order of the 1,089,202 DNA letters ('nucleotides') of Mycoplasma mycoides's genome. They built it in pieces, nucleotide-by-nucleotide. Then they stitched the pieces together" (Brown 2010) and "manufacturing life forms from scratch and eventually of creating tailor-made creatures" (Harris 2008). One should say that although the stitching metaphor may be relatively new to the media representation of synthetic biology, it has been around much longer in the discipline itself (Trost and Ball 2004).

Alongside these more science-specific metaphors ran a metaphor that is ubiquitous in all science reporting, namely the very traditional framing of science as a *journey* or progress, such as steps, breakthroughs, leaps and speed of the progress as well as crossing borders, pushing boundaries and paving the way to new eras, continues to be used.

Compared to previous bioscience press coverage, the synthetic biology coverage contained two types of "new" metaphors. First, those derived from sewing and stitching, and, second, extending the metaphors of computers and computing. In the next section, we will take a look at how the metaphors were mixed in the newspapers. We will discuss first how traditional book and writing metaphors have been mixed with other metaphors, second how computers and programming provided inspiration for metaphorical framing and lastly how design/engineering and tinkering were mixed into the picture painted about synthetic biology.

Mixing metaphors and mixing the literal and metaphorical

In this section we focus on the chaining and mixing of metaphors around the three main source domains (including a network of associated common-places) from which metaphorical expressions are derived: books, computers and building/engineering (see Figures 4 to 6).

Books: reading and writing

Language, book and information metaphors have been endemic in genetic and genomic discourse since the beginning of the twentieth century (see Figure 4) and were still used within the emerging discourse of synthetic biology, but mostly referring back to Venter's genomic past:

> Venter, a former school drop-out with an IQ of 142, was vilified by the scientific establishment for taking them on in a race to sequence the human genome – the biochemical instruction manual for homo sapiens. (Anon. 2007)

The older ideas of reading and writing life using a genetic alphabet were however also flexibly connected to the newer metaphors of stitching chemical letters together (a rather mixed metaphor), for example in describing the creation of the artificial *Mycoplasma mycoides* bacterium:

> Synthetic biology makes the transition from "reading" DNA [. . .] to the much harder job of "writing" genetic code. The Venter scientists built up the synthetic genome of a bacterium called *Mycoplasma mycoides* in steps. They started with relatively short stretches of DNA, each about 1,080 chemical letters in length. These were *s*titched together in three stages, producing DNA assemblies of first 10,000 and then 100,000 letters, before the final combination produced the full bacterial genome of 1m chemical letters. (Cookson 2010)

The underlying idea is (mass) production of life by stitching together standardized pieces of DNA. The writing metaphor was also extended (rather than mixed)

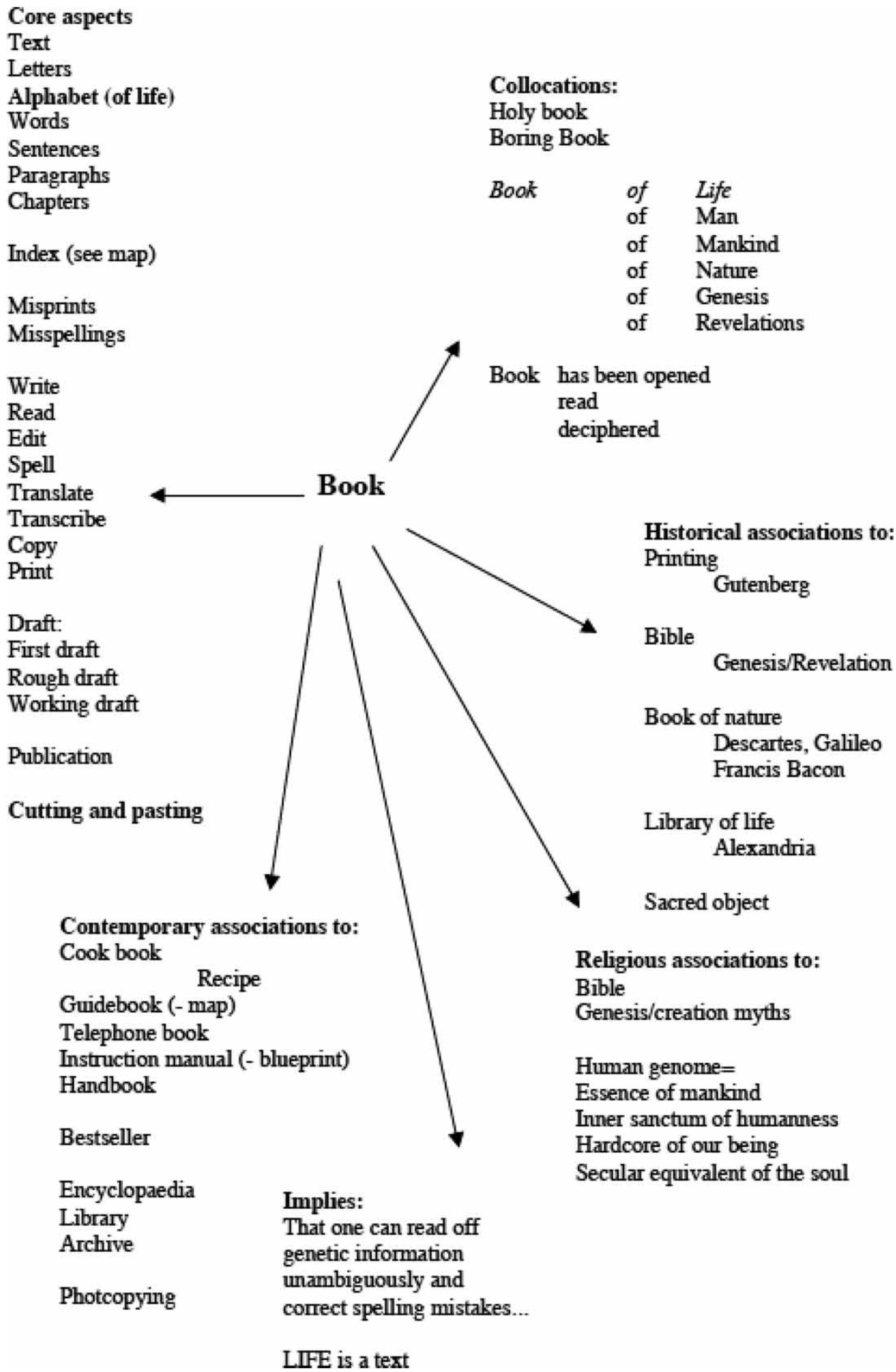

Figure 4. Mapping associations around "book."

throughout the following text in terms of code, letters, characters, punctuation marks, spelling out, message, and so on:

> Messages can be "written" into a genetic code because the DNA sequence is made up of four "letters", which scientists call G, C, T and A. But as well as making their organism identifiable, Venter's team added a knotty challenge for other scientists. They developed a code that used the four characters to spell out the 26 letters of the alphabet, the numbers 0 to 9 and several punctuation marks. They then wrote into the sequence one message that gives the key to the code. A second spelt out the names of the scientists, a third listed three philosophical quotes, and the fourth gave details of a website where people can write to the authors once they crack the code. (Sample 2010)

In both examples, book and writing metaphors have been connected to newer ones, such as stitching. At the same time the metaphor itself has been extended, as new parts, such as punctuation marks were added and secret codes were not only deciphered but written into synthetic life. Sometimes, also more general metaphors of language were used: "The iGEM competition began in 2004 with five teams and a few dozen students. This year, organizers said they expect about 1,050 students, nearly all of whom are fluent in the language of plasmids and protein-coding sequence" (Brown 2009)

Metaphors of codes and computing, which we shall discuss in the next section, are effortlessly used in the mix:

> Dr Venter, who has been working on synthetic life for a decade, told *The Times*: "It is our final triumph. This is the first synthetic cell. It's the first time we have started with information in a computer, used four bottles of chemicals to *write up a million letters of DNA software*, and actually got it to *boot up* in a living organism." (Henderson 2010, emphasis added)

Computers and programming

Computer and computing metaphors consist of discussing DNA and cells in terms of software or hardware, and synthetic biology as designing life on a computer, or booting up the cell. Computer metaphors are not entirely new (see Figure 5), but what we have here is a real "fusion" between authentic computing or engineering and metaphorical computing or engineering. "Synthetic biologists envision being able to design an organism on a computer, press the 'print' button to have the necessary DNA made and then put that DNA into a cell to produce a custom-made creature" (Pollack 2008) or "The human cells as machine hardware, and genetic code as the software required to make them run: that is how a new branch of science, synthetic biology, sees them" (Matsudaira 2009).

Venter promoted the computer metaphor quite regularly:

> Here is what Venter's institute has delivered this time around: "We started with a genetic code in the computer, wrote the software, put it into the cell and transformed it biologically into a new species." The key factors are a) the DNA assemblies were stitched together in a computer and b) when these were transferred into the host cell, they replaced its biological machinery completely. (Anon. 2010)

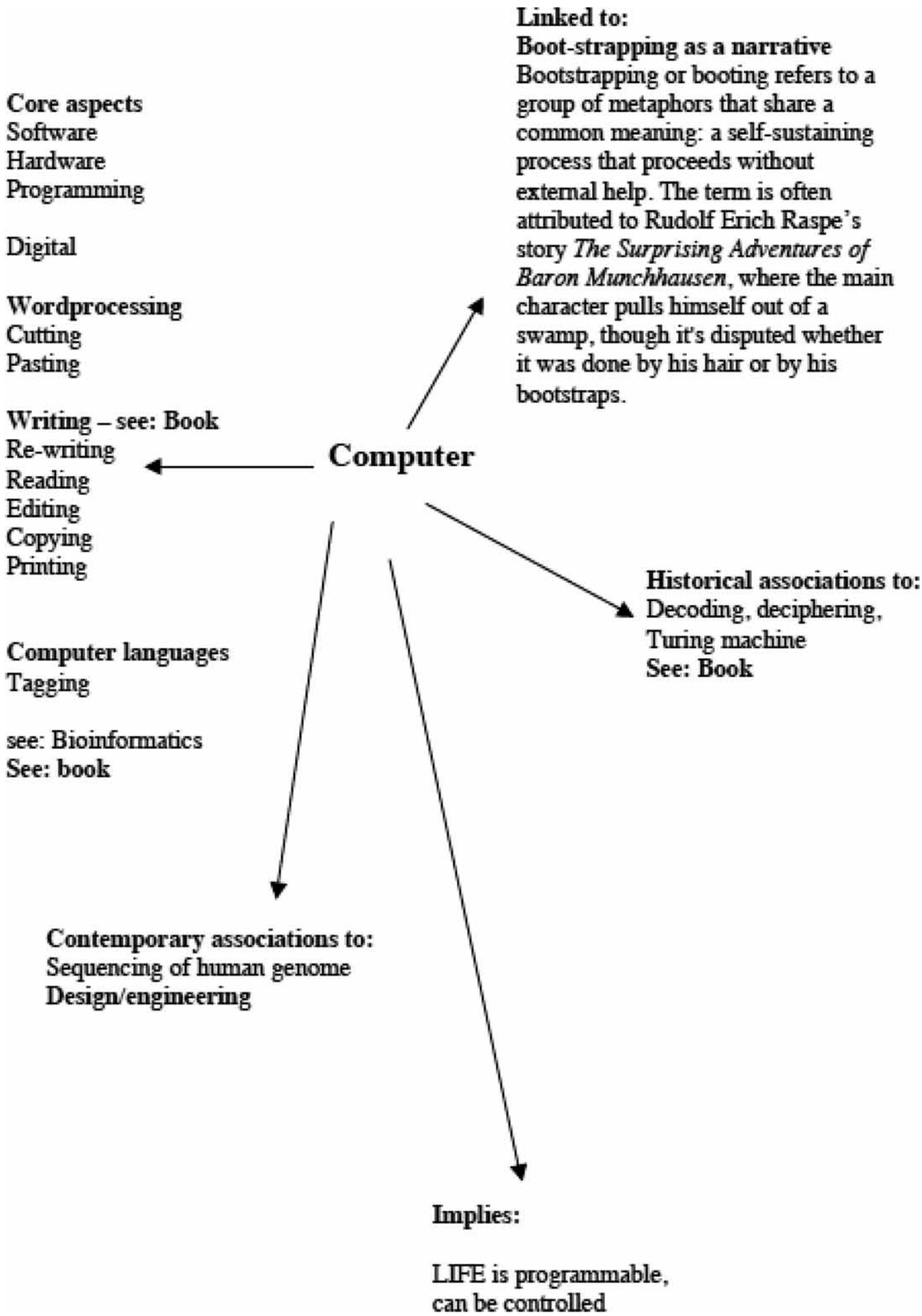

Figure 5. Mapping associations around "computer."
Note: On bootstrapping, see Wikipedia entry, accessed 13 September 2010.

In these examples, the physical and virtual are intertwined via the use of the computer metaphor as life is designed on a computer, semi-literally. Computer and computing metaphors were used systematically to describe synthetic biology, and sometimes to criticize the metaphor:

> Building a new organism from scratch is possible. In January this year a US team reported in *Science* magazine how it built the entire DNA code of a common bacterium in the laboratory using blocks of genetic material. The team synthesised small blocks of DNA before knitting them together into bigger "cassettes" of genes. Large chunks of genes were joined together to make the circular genome of a synthetic version of a mycoplasma bacterium.
>
> Altering genes isn't like editing a document in Word. DNA is an invisibly thin molecule coiled upon itself with the millions of letters that we can't see – trying to alter just three letters without damaging anything else is a truly daunting task. These dangers mean that designer babies are not possible now and may never be. (Parry 2008)

Here the metaphors of computer (Word program), books (DNA letters), and building blocks (see next section) are mixed with those of DNA as a code that can be "knitted" together into cassettes – into a coherent whole, to discuss (as yet impossible) products of science, in this case designer babies. The underlying idea is that of designing new life.

The metaphors of computing were also flexibly connected to more conventional views on science as a process, for example:

> The researchers then placed this synthetic chromosome into the cell of another species of bacterium, *M. capricolum*, which had had its own chromosome removed. After months of trial and error – when one mistake in the million letters led to a three-month delay – the scientists managed to "boot up" these empty cells so that the M. capricolum cells replicated normally, but without any of its own genes or proteins and only with those of *M. mycoides.* (Connor 2010)

In some instances the metaphors of journey and computer form a coherent narrative of what synthetic biology is about, and where it may lead us:

> For the layman, he [Venter] compared his work with building a computer. His breakthrough was the equivalent of creating the software for a computer's operating system. Now what he had to do was insert it into the computer – the empty cell – and boot it up. What's more, he was already working on the next stage of his great project. He would build an entirely synthetic organism, which he would use to save the world from global warming. (Leake 2008)

However, the view of synthetic biology as writing a computer code and booting up cells was also criticized in some newspapers:

> "IGEM is effectively an attempt to build a workforce for … a very disruptive industry," said Jim Thomas, a researcher with the Ottawa-based ETC Group, a nonprofit group that opposes genetic engineering in agriculture. "It's sold as it's light, it's

> fun, it's hip, it's green. It's not being sold as risky, as untested. One of the big concerns is that kids are being taught that DNA is a computer code, and you can program biological organisms the same way you can program a computer. I think that's going to prove to be a bad analogy." (Brown 2009)

In summary, computers are part of cultural commonsense knowledge that readers are expected to have and which enables them to understand what synthetic biology can achieve. The chains of (sometimes mixed) metaphors "knitted" around that common core seem to build a bridge between the biological and physical, cells and computers, but also the literal and the metaphorical. At the core of these metaphors lies a view that life can be controlled, just as we can control a computer or word processor. We will next take a look at building and engineering metaphors to see how they function in the debate.

Engineering, building and bricolage

Besides metaphorizing synthetic biology as writing DNA codes on a computer, synthetic biology was also framed as building or designing life, sometimes discussed in terms of using building blocks. Again the term "building blocks" is an old genetic metaphor (see Figure 6) but it took on a new meaning in the context of synthetic biology, when metaphorical building blocks became real BioBricks.

Knowledge of building blocks and Lego bricks are, again, expected to be shared by most readers:

> At the heart of the competition is MIT's Registry of Standard Biological Parts, founded in 2003 as a physical repository and online catalogue of DNA pieces whose function and behavior have been defined. Called BioBricks, these are the building blocks that students use, Lego-like, to build new organisms. Students are constantly designing new BioBricks, such as the DNA that arrived at U-Va.'s lab last month, a tweaked version of a gene that occurs naturally in plants. (Brown 2009)

Similar to computing metaphors, building blocks, and in particular so-called BioBricks, build a connection between the physical and the virtual, the literal and the metaphorical, the mundane and the revolutionary, as well as the past and the present. The metaphor of building blocks was also used in a more general way, describing the aim of synthetic biology as building up new organisms – according to a specific design, which, again, is under the control, this time, of the master builder or DIY builder, rather than the computer programmer.

The metaphors of building blocks and computer programs complement each other and are also sometimes mixed with journey metaphors, in this case building blocks are mixed with the removal of roadblocks:

> Researchers led by George Church [. . .], have copied the part of a living cell that makes proteins, the building blocks of life. The finding overcomes a major roadblock

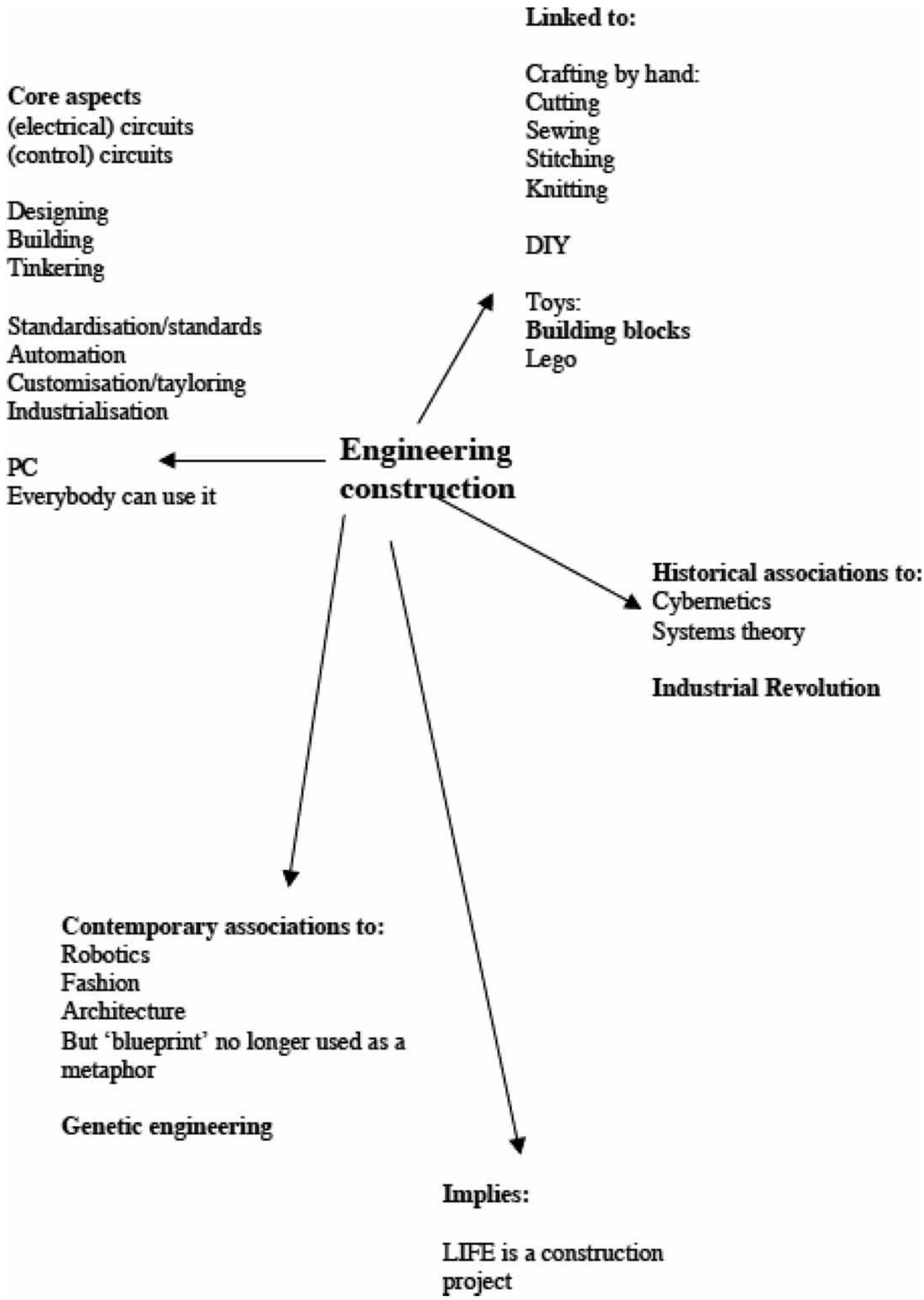

Figure 6. Mapping associations around "engineering."

> in making synthetic self-replicating organisms, Church said Saturday in a lecture at Harvard in Cambridge, Mass. (Lauerman 2009)

The metaphor of building blocks has also been connected to the idea of knitting, sewing and cooking – metaphors that were only rarely used in the discussion of other genetic or genomic advances. Surprisingly, it appears that in German media coverage of synthetic biology the cooking metaphor was almost absent (Cserer and Seiringer 2009). All these metaphors highlight the playful side of synthetic biology as "bricolage," diluting somewhat the theme of "control" or "mastery." Cooking in the household sense, souping up in the garage sense and sewing are metaphors that are mixed together in the following passage:

> Welcome to the curious and quite possibly alarming world of DIY Biology (usually shortened to DIYbio), a fledgeling community of people who want to do science for themselves. Their agenda is part curiosity, part democratisation of science: they relish bouncing around their kitchens tinkering with the genes that make jellyfish glow (one goal is to make glow-in-the-dark tattoos) but they also want a stake in the next big scientific revolution, which is synthetic biology. The field fuses engineering with biology: it entails souping up life forms by inserting off-the-shelf DNA into their genomes to make them, say, deliver a vaccine, or even cooking new organisms up from scratch. Last year, Craig Venter [...] announced that he had sewn together, using purely synthetic DNA, the genome of a small bacterium. (Ahuja 2009)

Both computers and computing metaphors on one hand, and those of building and building blocks on the other hand, created a language of semi-metaphors, linking the biological and the physical, real and virtual. The underlying idea is that of potential mass production of synthetic organisms which are compared to very old-fashioned mechanical devices that work using nuts and bolts and pulleys:

> Drew Endy, an assistant professor in the biological engineering department at the Massachusetts Institute of Technology, and his colleagues are putting together a registry of standardized biological parts, which they call BioBrick parts. The registry consists of the DNA code for different biological modules, interchangeable protein parts that they hope may someday be pieced together into a wide variety of biological devices to perform any task a bioengineer may have in mind, rather like the way nuts, bolts, gears, pulleys, circuits and the like are assembled into the machines of our civilization. (Angier 2008)

Whereas the human genome was deciphered by people adept at revealing the "book of life," even the cookery or recipe book of life, a new generation of scientists is portrayed as taking this cookery book out into the kitchen or garage in order to cook up new biological entities in more literal than metaphorical sense. Constructing or designing life is here framed by a mixture of metaphors taken on the one hand from cooking and on the other hand from tinkering with cars, with some metaphors, such as "souped" up (in the sense of modified for higher performance, applied by extension to other items), linking the discourses of so-called garage biology to what one might call kitchen-sink biology.

The negative connotations of science playing God and creating monsters in private laboratories were used rarely, probably because of our more scientific search term. In summary, all the three (mixed) metaphor chains discussed above are rich extensions of existing and well-known metaphors, and creative combinations of more conventional and novel metaphors. All three contribute to a new overarching (conceptual) metaphor: LIFE IS A CONSTRUCTION PROCESS. This new way of creating life was seen as "revolutionary" and this in more than one sense.

Revolution metaphors

Despite the discourse of tinkering, toying and bricolage, the consequences of synthetic biology, its great promises, have been compared to the industrial or computer revolution, a comparison made by Venter himself in an interview with the BBC (Gill 2010). In our corpus reference to the industrial revolution wavered between the hyperbolic and metaphorical and the literal:

> "Synthetic biology represents a new approach to engineering," said Professor Richard Kitney of Imperial College London [. . .]. "It has brought us to the cusp of a new industrial revolution in which new fuels, drugs, medical treatments and sensors can be created from biological materials." (McKie 2008)

> "We're not modest. We all believe that in these next 50 years, synthetic biology is going to be the Industrial Revolution of our time," said Randy Rettberg, director of the competition. [. . .] there's the idea that life, like cars or computers, can be designed and built from standardized parts that behave predictably. (Brown 2009)

> To circumvent some of these hurdles, synthetic biologists have looked to the Industrial Revolution of the 19th century for one important lesson about engineering nature. "Standards, standards, standards" became the mantra that enabled a machine to be assembled from interchangeable parts made in separate factories. Before the 1800s, parts were custom-made with hand tools. By early 1800, machine tools were invented and a part like the common screw was manufactured to a common specification for the thread. Without standardised parts, the automated assembly line in factories worldwide would not exist today. (Matsudaira 2009)

"Revolution" and even the "industrial revolution" metaphors are, again, old workhorses of metaphorical framing whenever a new advance in science is made. However, the second quote switches the use of this metaphor as pure hyperbole to historical "reality," namely the standardization of parts for the manufacturing industry, and indeed car and computer industries, and the possible future of synthetic biology. As Calvert (2010, p. 97) has recently pointed out:

> [. . .] the "BioBricks" school, which is the dominant approach to synthetic biology, draws on the engineering principles of standardization, decoupling and abstraction with the objective of developing biological components which are interchangeable,

> functionally discrete and capable of being combined in a modular fashion, along the lines of "plug and play" [...].

The industrial revolution metaphor also has a rather concrete forward-looking component, as synthetic biology is envisioned to revolutionize industrial production itself or to be the next green revolution. This means that what looks like a simple metaphor can pack in a lot of aspirations and visions for a more prosperous, greener and healthier future controlled by (nice) humans.

The wider narrative of synthetic biology as a yet another great revolution provides the background against which the separate metaphors as well as chains of mixed metaphors make sense. While in the genetics and genomics debates the main narrative was conquering the unknown, i.e. gaining access to the map of DNA, or the book of life, in the debate on synthetic biology, the main narrative not only covers the position of synthetic biology as a particular type of revolutionary science, but positions it within a historical context of standardization, automation, assembly and control. The metaphors exploit knowledge of past technologies and technological revolutions to familiarize audiences with what is hoped to be a future revolution.

In summary, the three metaphors that frame synthetic biology (books, engines and computers) are linked to three historical revolutions. While books were the result of the printing revolution initiated by Gutenberg in the 1400s, the construction of engines, engineering and building skills led to the industrial revolution in the 1800s, and finally, computers have led to an information revolution in the late 1900s (Figure 7). Synthetic biology, we are told, partakes of all three revolutionary processes and revolutionizes these in turn.

The concepts that mediate between these three metaphors of books, engines and computers are all highly visible in the debate on synthetic biology, and moreover all of them, reading/writing, designing/engineering and mass production, emphasize processes instead of products.

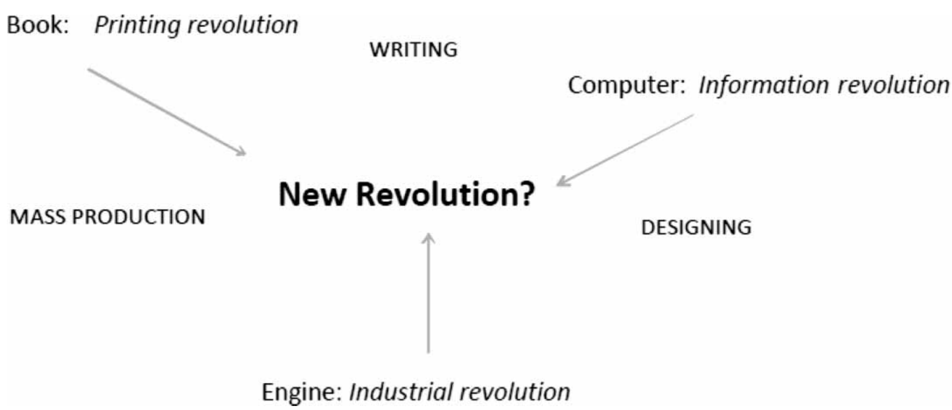

Figure 7. Summary.

Discussion

Reflecting on the language we use in the context of synthetic biology is important for science and society: for science, as what was once merely metaphorical is becoming almost literal, but in complex ways; for society, as how we talk about life reflects back on how we live it. We have seen that the majority of (chained and mixed) metaphors used by scientists and journalists tend to portray nature and life in a new light when compared to older frames. Older genetic and genomic projects, especially the human genome project, focused on gaining new insights through mapping, deciphering and reading, whereas now the focus is on turning natural processes and the process of life itself into construction processes designed and controlled by humans. The focus shifts from deciphering the blueprint of life to building life according to scientists' own blueprint, brick by BioBrick. Whereas in the past the metaphor "building blocks" of life was just a metaphor, it is becoming increasingly real and whereas in the past these blocks were, in a sense, made and put together by "nature," they are now designed and assembled (and controlled) by humans.

This also distinguishes synthetic biology from another older genetic project to which it is related, namely genetic engineering. While metaphors around genetic engineering, especially of food and crops and the cloning of animals, focused on the end products of this engineering process, such as "Frankenfood" or "Terminator seeds," the metaphorical framing of synthetic biology focuses on the process of production itself, which is framed in terms of control over operations.

Those communicating about synthetic biology readily employ the language of very benign sounding processes of constructing life in terms of sewing, stitching and tinkering. This focuses attention away from the (ethically more dubious) conceptualization of life within the synthetic biology project as just another part of the process of industrialization begun in the nineteenth century, a period of history that has left a lasting impression on collective memory and the collective imagination, including metaphorical framing (Hellsten 2008). Mass production of life as portrayed for example in the 1932 novel *Brave new world* by Aldous Huxley shaped some of the debates about cloning in the 1990s (Hellsten 2000).

It is therefore not astonishing that people participating in a public engagement activity about synthetic biology in the UK in 2009 "found the idea of treating nature as parts to be assembled as problematic" (see BBSRC/EPSRC 2010), as also indicated in our opening quote by Richard Jones (2010). So, while synthetic biology promises to revolutionize life on earth to some extent, framing it in terms of the industrial revolution might cause problems. Given public disquiet about seeing life as an assemblage and an assembly line, as mass production outside their control, the real and metaphorical processes of writing, designing and manufacturing life will need continuous ethical and linguistic scrutiny by social scientists and those monitoring science communication, in the media. The use and misuse of "BioBricks" in labs and garages needs to be monitored just as much as the use and misuse of the metaphorical bricks that have contributed to constructing synthetic biology in the public sphere.

Notes

1. It is interesting to note that Venter, for example, prefers to use the term "Synthetic Genomics" as the name of his entrepreneurship instead of the more generic term of the field.
2. LexisNexis sometimes returns exactly the same article several times, perhaps because the newspaper has published several editions that day, and that article has been included in all editions. If the same article had been published in different newspapers (and came, for example via news agencies) we would have counted these as separate news items, but this was not the case in our dataset.

References

Ahuja, A., 2009. Can all of us be DIY biologists? Science Citizen scientists are shaking up biology, which is fine – until something escapes, says Anjana Ahuja. *The Times*, 9 May, p. 4.

Andrianantoandro, E., Basu, S., Karig, D.K., and Weiss, R., 2006. Synthetic biology: new engineering rules for and emerging discipline. *Molecular Systems Biology*, 16 May. Available from: http://www.ncbi.nlm.nih.gov./pubmed/16738572 [Accessed 18 June 2011].

Angier, N., 2008. Pursuing synthetic life, dazzled by reality. *The New York Times*, 5 February, p. 1.

Anon, 2007. National: Scientists compete to build best living machine: building blocks of life turned into technology: critics warn of terrorist risk over deadly viruses. *The Sunday Times*, 1 July 2007, p. 21.

Ball, P., 2011. *Unnatural: the heretical idea of making people*. London: The Bodley Head Ltd.

Balmer, A. and Herreman, C., 2009. Craig Venter and the re-programming of life: how metaphors shape and perform ethical discourses in the media presentation of synthetic biology. *In*: B. Nerlich, R. Elliott and B. Larson, eds. *Communicating biological sciences: ethical and metaphorical dimensions*. Aldershot: Ashgate, 219–234.

Balmer, A.S. and Martin, P.M., 2008. *Synthetic biology: life, but not as we know it?* Report commissioned by the BBSRC [online]. Available from: http://www.synbioproject.org/topics/synbio101/selected_synbio_readings/ [Accessed 18 June 2011].

BBSRC/EPSRC, 2010. *Synthetic biology dialogue report* [online]. Available from: http://www.bbsrc.ac.uk/web/FILES/Reviews/1006-synthetic-biology-dialogue.pdf [Accessed 18 June 2011].

Blakemore, C., 2008. And man recreated life. But now the problems begin. *The Observer*, 27 January [online]. Available from: http://www.guardian.co.uk/commentisfree/2008/jan/27/comment.controversiesinscience [Accessed 18 June 2011].

Brown, D., 2010. Creating a cell from scratch: "important advance" scientists transplant genome into bacterium. *The Washington Post*, 21 May, p. A03.

Brown, E., 2009. New works of science nonfiction: U-Va. students are using "BioBricks" to try to build an original life form. *The Washington Post*, 23 October, p. B01.

Bsht, R. 2010. DNA of the future. *Financial Express*, 24 May.

Calvert, J., 2008. The commodification of emergence: systems biology, synthetic biology and intellectual property. *BioSocieties*, 3, 383–398.

Calvert, J. 2010. Synthetic biology: constructing nature? *The Sociological Review* 58, 95–112.

Campos, L., 2009. That was the synthetic biology that was. *In*: M. Schmidt, *et al.*, eds. *Synthetic biology: the technoscience and its societal consequences*. London: Springer, 5–21. Also online. Available from: http://www.springerlink.com/content/978-90-481-2677-4 [Accessed 1 November 2009].

Ceccarelli, L., 2004. Neither confusing cacophony nor culinary complements: a case study of mixed metaphors for genomic science. *Written Communication*, 21 (1), 92–105.
Condit, C., 1999. How the public understands genetics: non-deterministic and non-discriminatory interpretations of the "blueprint" metaphor. *Public Understanding of Science*, 8, 169–180.
Connor, S., 2010. Synthetic cell is a giant leap for science, and could be bigger still for mankind. *The Independent*, 21 May, p. 2.
Cookson, C., 2010. Let there be life. *Financial Times*, 21 May, p. 6.
Corts, D.P., 2006. Factors characterizing bursts of figurative language and gesture in college lectures. *Discourse Studies*, 8 (2), 211–233.
Corts, D.P. and Pollio, H.R., 1999. Spontaneous production of figurative language and gesture in college lectures. *Metaphor and Symbol*, 14, 81–100.
Cserer, A. and Seiringer, A., 2009. Pictures of synthetic biology: a reflective discussion of the representation of synthetic biology (SB) in the German-language media and by SB experts. *Systems and Synthetic Biology*, 3 (1–4), 27–35.
de Lorenzo, V. and Danchin, A., 2008. Synthetic biology: discovering new worlds and new words. *European Molecular Biology Organization, EMBO Reports*, 9 (9), 822–827.
Deutsche Forschungsgemeinschaft, 2009. *Synthetische Biologie*. Available from: http://www.dfg.de/dfg_magazin/forschungspolitik_standpunkte_perspektiven/synthetische_biologie/index.html [Accessed 18 June 2011].
Drenthen, M., Keulartz, J. and Proctor, J., eds., 2009. *New visions of nature: complexity and authenticity*. Dordrecht: Springer.
Endy, D., 2005. Foundations for engineering biology. *Nature*, 438, 449–453.
Gibson, D.G., *et al.*, 2008. Complete chemical synthesis, assembly, and cloning of a mycoplasma genitalium genome. *Science*, 319 (5867), 1215–1220.
Gibson, D.G., *et al.*, 2010. Creation of a bacterial cell controlled by a chemically synthesized genome. *Science Express* (20 May 2010) and *Science*, 329 (5987), 52–56.
Gill, V., 2010. "Artificial life" breakthrough announced by scientists. BBC News, 20 May [online]. Available from: http://www.bbc.co.uk/news/10132762 [Accessed 18 June 2011].
Harris, J., 2008. Who's afraid of a synthetic human? *The Times*, 17 May, p. 21.
Hellsten, I., 2000. Dolly: scientific breakthrough or Frankenstein's monster? Journalistic and scientific metaphors of cloning. *Metaphor and Symbol* 15 (4), 213–221.
Hellsten, I., 2008. Popular metaphors of biosciences: bridges over time? *Configurations* 16 (1), 11–32.
Henderson, M., 2009. We see problems, they see solutions. Fifteen scientists are tackling the world's most pressing problems. So what are their answers? *The Times*, 8 October, pp. 16, 17, 18, 19, 20, 21, 23, 24, 25, 26.
Henderson, M., 2010. Genome scientist creates first synthetic life: potential for good is real but the risks are unparalleled, says ethics expert. *The Times*, 21 May, p. 3.
Jones, R., 2010. Digital vitalism [online]. Available from: http://www.softmachines.org/wordpress/?cat=11 [Accessed 18 June 2011].
Kimmel, M., 2010. Why we mix metaphors (and mix them well): discourse coherence, conceptual metaphor, and beyond. *Journal of Pragmatics*, 42 (1), 97–115.
Koller, V., 2003. Metaphor clusters, metaphor chains: analyzing the multifunctionality of metaphor in text. *metaphorik.de*, 5, 115–134.
Kyratzis, A., 1997. *Metaphorically speaking sex, politics and the Greeks*. Thesis (PhD). Lancaster University, UK.
Lauerman, J., 2009. Discovery opens door to synthetic life. *Chicago Daily Herald*, 8 March, p. 2.
Leake, J., 2008. Maverick scientist Craig Venter claims he can create artificial life in the lab. Is this the dawn of a new era for mankind? *The Sunday Times*, 27 January, p. 16.
Lee, M.G. and Barnden, J.A., 2001. Reasoning about mixed metaphors with an implemented AI system. *Metaphor and Symbol*, 16 (1&2), 29–42.

Lentzos, F., 2009. Synthetic biology in the social context: the UK debate to date. *BioSocieties*, 4 (2–3), 303–315.

Lentzos, F., *et al.*, 2008. Visions and challenges in redesigning life. *BioSocieties*, 3 (3), 311–323.

Leroi, A., 2008. The actual and the possible. *The Observer*, 27 April, p. 3.

Luisi, P.L., 2006. *The emergence of life: from chemical origins to synthetic biology*. Cambridge: Cambridge University Press.

Matsudaira, P., 2009. Seeing human cells through engineers' eyes. *The Straits Times* (Singapore), 11 October, [p. missing].

McKie, R., 2008. Biologists join the race to create synthetic life. *The Observer*, 20 April, p. 15.

Morange, M., 2010. Synthetic biology: a bridge between functional and evolutionary biology. *Biological Theory*, 494, 368–377.

Munro, M., 2010. First synthetic cells brought to life in lab: "technological feat" by US geneticists evokes awe, angst. *The Calgary Herald*, 21 May, p. A3.

Nerlich, B. and Hellsten, I., 2004. Genomics: shifts in metaphorical landscape between 2001 and 2003. *New Genetics and Society*, 23 (3), 255–268.

O'Malley, M.A., *et al.*, 2007. Knowledge-making distinctions in synthetic biology. *BioEssays*, 30, 57–65.

Parry, V., 2008. Can we create life? Our knowledge of, and ability to, alter DNA remains rudimentary, in spite of notable scientific advances and the persistent dream of genetic perfection. *The Observer*, 27 April, p. 22.

Peretó, J. and Català, J., 2007. The renaissance of synthetic biology. *Biological Theory*, 2, 128–130.

Pleiss, J., 2006. The promise of synthetic biology. *Applied Microbiology and Biotechnology*, 73 (4), 735–739.

Pollack, A., 2008. Researchers announce a step toward synthetic life. *The New York Times*, 25 January, p. 17.

Regaldo, A., 2005. Next dream for Venter: create entire set of genes from scratch. *The Wall Street Journal*, 29 June, 2005, p. A1.

Royal Academy of Engineering, 2009. *Synthetic biology: scope, applications and implications*. London: The Royal Academy of Engineering.

Sample, I., 2009. National: Scientists compete to build best living machine: building blocks of life turned into technology: Critics warn of terrorist risk over deadly viruses. *The Guardian*, 15 April, 2009, p. 5.

Sample, I., 2010. Genetics: man who played God? Artificial life raises scientific hopes – and fears: US geneticist believes breakthrough could earn him trillions of dollars. *The Guardian*, 21 May, p. 9.

Tobin, L., 2009. "I'm hoping the economy will have recovered by the time I finish.". *The Guardian*. Education: Higher, 17 February, p. 10.

Trost, B.M. and Ball, Z.T., 2004. Synthetic stitching with silicon: geminal alkylation – hydoxylation of alkanyl carbonyl compounds. *Journal of American Chemical Society*, 126, 13942–13944.

van den Belt, H., 2009. Playing God in Frankenstein's footsteps: synthetic biology and the meaning of life. *Nanoethics*, 3, 257–268.

van Est, R., de Vriend, H., and Walhout, B., 2007. *Constructing life: the world of synthetic biology*. The Hague: Rathenau Institute.

Weitzman, H., 2009. Wind of change sparks US renewables revival. *Financial Times*, 23 September, p. 1.