How to Deal with Hybrids in the Anthropocene? Towards a Philosophy of Technology and Environmental Philosophy 2.0

MAGDALENA HOŁY-ŁUCZAJ

University of Information Technology and Management in Rzeszow
Budynek Główny
ul. Sucharskiego 2, pok. 209, 35-225 Rzeszów, Poland
Email: mholy@wsiz.rzeszow.pl
ORCID: 0000-0001-5860-3638

VINCENT BLOK

Wageningen University
Department of Social Sciences
Management Studies Group/Philosophy Group
Hollandseweg 1, 6706 KN, Wageningen, The Netherlands
Email: vincent.blok@wur.nl
ORCID: 0000-0002-9086-4544

ABSTRACT

The Anthropocene overthrows classical dichotomies like technology and nature and a new class of beings emerges: hybrids. The transitive status of hybrids – which establishes an extra, separate, 'third' ontological category, going beyond the dichotomy between nature and technology – constitutes a significant problem for environmental philosophy and philosophy of technology since they traditionally focus on either 'nature' (natural entities) or 'artefacts' (technological objects). In order to reflect on the ethical significance of hybrids, a classification of different types of hybrids is required. Such a classification is provided by this article, based on insights from both environmental philosophy and philosophy of technology. After explaining why a new class of beings emerges in the Anthropocene, and reflecting on the one-sidedness of philosophy of technology and environmental philosophy in their focus on either technology or nature, we propose a new classification of hybrids in this article that provides a new starting point for reflections on the moral significance of hybrids in environmental philosophy and philosophy of technology.

KEYWORDS

Hybrids, nature, technology, anthropocene, biomimicry

Environmental Values **28** (2019): 325–345.
 doi: 10.3197/096327119X15519764179818
Submitted 9 May 2018; accepted 11 July 2018

1. INTRODUCTION

In the Anthropocene – the epoch in which the geological human footprint on planet Earth is incomparable to past centuries – we find more and more objects which are neither purely natural nor purely technological. Alterations of the natural environment via humanly invented technological means, which is symptomatic for the period that started roughly with the industrial revolution, are so pertaining that they challenge this classical divide[1] in many cases. That is to say, the Anthropocene reverses our thinking about nature, which we are used to perceiving as always independent from human beings or free from our interventions. Nature becomes largely humanised and the human becomes naturalised in the Anthropocene. 'The Anthropocene represents a new phase in the history of both humankind and of the Earth, when natural forces and human forces became intertwined, so that the fate of one determines the fate of the other' (Zalasiewicz et al., 2010: 2231). Humanity experiences its dependency on the natural and technological environment while humanity's planetary population makes it impossible to conceptualise nature without human cultivation, preservation and development (cf. Blok, 2017). With this, the Anthropocene overthrows classical dichotomies like technology and nature to the extent that one of the founding fathers of the concept can argue that 'nature is us' nowadays as its theorists argue (Crutzen and Schwägerl, 2011). Such a view, however, has its contemporary critics, who argue that we should not give up on the idea that the nature is independent from us (Hailwood, 2015: 10–11). This means that there is no common agreement of how to think of nature in today's world.

Defining technology appears to be equally problematic in the Anthropocene. Treating it as a category of purely human activities which are oriented toward creating or adapting things to serve merely human purposes seems no longer possible in an era where technology does not any longer aim to destroy the environment, but on the contrary tries to serve nature and to work with nature, or at least in harmony with it. This ranges from climate smart technologies that mitigate and adapt to climate change, to biomimetic technologies that can claim to be natural technologies themselves (cf. Blok and Gremmen, 2016). These tendencies are in particular characteristic of the so-called third phase of the Anthropocene, in which human technology is called upon to ensure the carrying capacity of planet Earth as a life-support system for future human life on Earth.

1. We have to acknowledge that this divide is primarily at stake in Western philosophical traditions, while Eastern philosophies would traditionally challenge such a disconnection of humans and nature (see Pak-Hang Wong, 2015; Kam-por Yu, 2005). The further exploration of these Eastern philosophical traditions and their relevance for our main research question is beyond the scope of this article.

With this, traditional categories like nature and technology start to blend, while a new class of beings emerges in the Anthropocene, i.e., *hybrids*. Examples could be genetically modified food, synthetic biological inventions or technological implantations like chips in life stock farming. The transitive status of hybrids – as an extra, separate, 'third' ontological category, which goes beyond the dichotomy between nature and technology – constitutes a significant problem for environmental philosophy and philosophy of technology since they traditionally focus on either 'nature' (natural entities) or 'artefacts' (technological objects). An additional complicating factor is that these discourses seem to be largely disconnected from each other, while a dialogue between them may provide important insights into this new emerging class of beings. Philosophy of technology hardly ever discusses its concerns in the environmental context (Lemmens et al., 2017), and the vocabulary of environmental philosophy is concentrated on natural entities as opposed to technological entities, and is often even hostile to them (Hui, 2017: 320; Vogel, 2015; 2003). For this reason, neither environmental philosophy nor philosophy of technology are well equipped to encounter and reflect on this new class of beings in the context of the Anthropocene. If environmental philosophy and philosophy of technology want to contribute to the reflection of the philosophical and ethical issues at stake in this new emerging era, they need to abandon old binary oppositions like 'nature' and 'technology'. That is to say, they need to transform themselves towards a 2.0 version of environmental philosophy and philosophy of technology in order to exhibit a genuine interest in hybrids as a special class of entities. One could argue that in climate engineering, these philosophical and ethical issues are actually discussed (Heyward, Rayner and Savulescu, 2017: 105–107). However, although this literature explores nature-(human)technology assemblages in a progressive way, it often leaves the problem of hybrid entities aside. In fact, the researchers focus on how human technologies intensively change nature, i.e., how they (intentionally and unintentionally) harm or cure nature by managing it (Preston, 2015: 360–361; see also Clingerman, 2014: 10–11; Hamilton, 2014), rather than talk about the emergence of a completely new class of beings, which has to be located outside both nature and technology.

In order to contribute to the transition of environmental philosophy and philosophy of technology towards a 2.0 version, we have to move beyond the findings in the field of climate engineering and develop some characteristics which can help to classify hybrids in this article. With this, we do not aim to abandon categories like 'natural' and 'technological', but seek to revisit them. We shall not claim that there is no longer such a thing as nature in the Anthropocene (see Hailwood, 2015: 4–6) nor do we believe in the need to control and master nature by technological means in this new geological era (Rolston, 2017; Williston, 2017; Baskin, 2015; Blok, 2015). What we intend to do in this article is to reconsider the strong divide between natural and technological beings in the case of beings that we refer as to ‘hybrids’, to bring them into the scope of interest of both environmental philosophy and philosophy of technology. The baseline of our paper is then the question of how the new emerging class of objects in the Anthropocene can be defined and classified. We will try to answer this question by making use of insights from both environmental philosophy and philosophy of technology. Our starting point will be the way in which we normally think about things, namely in terms of ‘artefacts’. With a few exceptions, environmental philosophy is not interested in artefacts, as they represent not-purely-natural entities. Philosophy of technology, in turn, often overlooks the dependency of artefacts on the environment, be it as fuel or in the context of where to dump waste material and CO_2, and classifies its object of reflection as focused purely on the technological domain.

Although some philosophers of technology highlight the problematic division of beings into classes of natural and artificial objects and point to ‘the development of science and technology and their interconnections’ (Baker, 2009: 64; see Kroes and Vermaas, 2008: 30), these ‘interconnections’ seem to refer primarily to the creation of hybrids. The latter term occurs also in an article by Houkes and Vermaas, in the context of the normative aspects of the distinction between natural and artefactual beings (Houkes and Vermaas, 2009: 124, 133), but they do not question the status of hybrids in their article. Instead, they signal the need for such a categorisation (Houkes and Vermaas, 2009: 133).[2] In this respect, this article can be read as a response to this call.

The structure of our contribution is as follows. First, we provide an explanation as to why the Anthropocene is the epoch where hybrids emerge and challenge the old dichotomy between technology and nature. Second, we explore the tendency of the philosophy of technology and environmental philosophy to be one-sided in their focus on either technology or nature, which is no longer appropriate in the Anthropocene. Then, we critically compare the conceptualisation of artefacts in both sub-disciplines and show why their current orientation makes them unable to categorise hybrids. Based on our reflections, we propose a new classification of hybrids, draw our conclusion and propose a research agenda for future research.

2. There were some attempts to re-classify natural and artefactual beings (for example, it has been argued that biological organisms such as domesticated animals and cultivated plants, which are typically taken as natural objects, are artefacts as well (Sperber, 2007)), or that natural kinds in chemistry such as purified iron actually may be positioned somewhere at a continuum between artefacts and natural objects, a continuum at which there are no principled points for drawing metaphysical distinctions (Grandy, 2007)), but they did not embrace highly advanced creatures such as aforementioned ‘roborats’ or syntehic cells.

2. THE ANTHROPOCENE AND THE END OF CLASSICAL DICHOTOMIES

Much ink has been spilled to define what the Anthropocene is. We have no ambition to reexamine this term and we limit ourselves to a brief indication of the key ideas that are relevant to answering our research question.

It was suggested by the Nobel prize-winning atmospheric chemist and climate scientist Paul Crutzen (Crutzen and Stoermer, 2000; Crutzen, 2002) that we should refer to the current instable and unpredictable state of the Earth as 'the Anthropocene' (cf. Lemmens et al., 2017). Even though neither the International Commission on Stratigraphy nor the International Union of Geological Sciences has yet officially approved the term as an indication of a particular geological period, the idea of the Anthropocene became a great source of inspiration for scholars working in various fields, creating new frames for their investigations.

The concept of the Anthropocene consists basically in two assumptions. First, it is the fact that the human (*anthropos*) has gained geological agency and has become the most important geological factor on the planet, trumping all the natural factors. That is to say, the *anthropos* becomes a geological layer, just like ice before, in the sense that human agency determines the face of the Earth. Second, that as a result huge changes in the Earth's atmosphere and biosphere occurred, from which global warming and the collapse of vital ecosystems are the most pressing issues (Lemmens et al., 2017: 117; Blok, 2017: 128).

The period of the Anthropocene is generally assumed to start during the industrial revolution (first phase), accelerated after World War II (second phase) and ends in our current situation in which the Earth's existence is threatened due to climate change (third phase). Human impact on the Earth system – excessive use of natural resources and introducing new elements to the atmosphere and biosphere – is ruinous. Thus, some theorists believe that the return to the Holocene is impossible and that the Anthropocenic condition is irreversible (Rolston, 2017; Hailwood, 2015: 6). This, however, does not change the fact that there is a common agreement on the necessity to change the largely destructive and exploitative attitude toward our planet into a more constructive and care-taking attitude (Lemmens and Hui, 2017). This call is the hallmark of the third – current – phase of the Anthropocene, in which humanity is called to take responsibility for Earth's sustainability (Blok, 2017; Kolbert, 2011).

Although human agency can have two faces in the Anthropocene – both the continuation of the (destructive) exploitation of the planet or a new type of (caring) stewardship – in both cases, there is a significant role for technology, ranging from climate smart technologies to mitigate climate change (e.g., drip irrigation), to the development of new seeds and varieties that are better adapted to climate change. In many of these cases, nature and technology are blended and form hybrids. One can further think here of current developments in synthetic biology, as well as about biomimetic architecture, in which for instance the air-conditioning is inspired by a structure of the termite hill. Another example can be 'roborats' – rats with electrodes that direct the rats' movements. We can consider also 'a bacterial battery', which are biofuel cells that use microbes to convert organic matter into electricity (see Baker, 2009: 64).

In these examples, it is clear that the difference between natural objects and artefacts becomes blurred. It does not imply, however, that these 'technologies' move *beyond* the natural (see Rolston III, 2017) nor that we advocate mastering nature and assimilating it to become human artefact and technology (see Hailwood, 2015: 6). So although the ontological meaning of nature and technology is challenged in the Anthropocene and still awaits new definitions (Blok, 2016), we can already negatively conclude that the human interference in the ecosystem is so profound that existing demarcations between nature and (human) technology are no longer valid in many cases. What we also can no longer do is to ignore this entire new set of beings, which crosses previous borders of natural beings and technological artefacts. They are a threat to the natural world, but at the same time they are possible solutions to our current environmental problems. Because of this potential, environmental philosophy and philosophy of technology should ponder the question of the status of hybrids as new class of beings that can contribute to safeguard the carrying capacity of planet Earth for future generations in the AC. This requires a new vocabulary to discuss hybrids because the existing vocabulary is limited to either natural or technological objects, as we will see in the next section.

3. THE GAP BETWEEN PHILOSOPHY OF TECHNOLOGY AND ENVIRONMENTAL PHILOSOPHY

Environmental philosophy and philosophy of technology emerged as autonomous disciplines in a similar period – in the early 1970s – as the response to rapid changes in the natural and human environment (Kaplan, 2017: 1, see Gardiner and Thompson, 2017: 439). Yet, as David M. Kaplan noticed, environmental philosophy and philosophy of technology have taken divergent paths despite their common interest in examining the human modification of the natural world (Kaplan, 2017: 1). This is truly unfortunate since philosophers from each field have a lot to offer each other (Kaplan, 2017: 1).

There were, of course, significant exceptions – just to mention Andrew Light's efforts, who challenged strong rejections concerning ecological restoration as unhelpful (Light, 2006). That said, we cannot forget that the vast majority of both environmental philosophers and philosophers of technology were indifferent to research made in the other discipline. Today the situation has changed. A good example is the article 'Philosophy of technology and the environment' by Paul B. Thompson in *The Oxford Handbook of Environmental Ethics* (Thompson, 2017) or texts gathered in the volume edited by Kaplan (2017), which were written by both environmental philosophers and philosophers of technology. They discuss issues such as: possible intersections of the philosophy of technology and ecophilosophy; a nature–human relationship in the context of STS; assessing the risk which technology brings to the environment; geoengineering; *insidiousness* of technology; eco-friendly design, sustainability of animal agriculture, etc.

It seems that environmental philosophy is primarily making philosophers of technology aware of ecological issues and reorienting their purely anthropocentric paradigm, while philosophy of technology mainly contributes to environmental philosophy by showing exploitative tendencies of capitalist technological innovation, examining how technologies shape our perception and orientation to the world, and what implications it has for our attitude toward nature (Gardiner and Thompson, 2017).

What is missing in this analysis is the group of new beings that emerged in the Anthropocene, which we used to think about as artefacts – non-natural beings created by humans. Environmental philosophy is reluctant to take into its considerations artefacts otherwise than as a potential threat to natural beings, and at the same time, recognises them as inferior to the latter ones. The most significant exception in this regard is Steven Vogel's work on artefacts (Vogel, 2015; 2003). According to Vogel, environmental philosophers should concentrate on the environment, but without equating it with the *natural* environment (see Vogel, 2015: 2, 88). Vogel reminds us that the majority of us are surrounded on a daily basis by buildings and useful things that are ignored by environmental ethicists; in their pursuit of an expansion of moral considerations to include the entire realm of nature and not only humans, these environmental philosophers do not concern themselves with bridges or toasters (Vogel, 2015: 2). Vogel, on the contrary, calls for challenging the strong moral dichotomy between the natural and the artificial in environmental ethics. Even though he abstains from ascribing moral considerability to artefacts (Vogel, 2015: 164), he postulates to be more thoughtful, attentive and caring about them (Vogel, 2015: 163).

Inspired by such postulates, we aim to overcome the division between categories of 'natural' and 'artefactual' in our reflections on hybrids. Before we will offer a possible classification of hybrids, let us compare the ways in which environmental philosophy and philosophy of technology portrait artefacts.

4. DOUBLE PORTRAIT OF ARTEFACTS

Today's perception of artefacts to a large extent is defined by Aristotle's view on them and his theory of substance. According to it, substances were individual objects, which can be contrasted with everything else – predicables and attributes (Robinson and Dainton, 2014). However, in Aristotle not all particular individuals deserve this name. There is a significant difference in this regard between his *Categorie*s and *Metaphysics* (see Katayama, 1999: 13; Baker, 2004: 104–105). Aristotle declined the status of substances to artefacts, even though they are single, material beings. According to him, artefacts (which he defined as 'created things') are not genuine substances, because, in contrast to natural beings ('growing things'), they do not have the principle of origin in themselves, but this principle is located in man as their creator (Aristotle, *Physics* B). This is the reason why Aristotle recognised artefacts as ontologically flawed. Interestingly for us, environmental philosophers agree with the entirety of Aristotle's description of artefacts, while representatives of philosophy of technology dismiss the claim about their ontological inferiority (Houkes and Vermaas, 2009: 124; Baker, 2009: 50; Vermaas et al., 2011: 7–8; Verbeek, 2005: 29).

Based on the philosophy of technology, or more precisely, philosophy of artefacts, a reformulation of Aristotle's view that the essence of artefacts is inseparably connected to human being can be found in the assumption that artefacts are not only physical things, but also mind-dependent (intentional) objects (Franssen, 2008; Baker, 2009). That is to say, scholars representing this field argue that artefacts have two dimensions of identity. Technical artefacts remain physical objects that are subject to the laws of nature like any other material object in the universe, but additionally, unlike ordinary natural objects, their being created 'for a purpose' gives them an intentional 'side' (Franssen, 2008).

The intentionality of artefacts is actually identical to their functionality, which is seen as their primary characteristic (Houkes and Vermaas, 2009: 123; Vermaas, et al. 2009: 76). As Houkes and Vermaas point out, a large number of artefacts are even named in functional terms, such as 'screwdriver' (2009: 124; see Baker, 2009: 9). We have to remember, however, that this functionality (or intentionality) can be divided into two stages: the intentionality involved in design and in use of the artefact (Lawson, 2008). It is not a rare case that something is produced to serve a different purpose than it later actually has. Examples can be a tyre made into a garden swing, or dynamite that is later used for another purpose than was initially predicted. This divide between intentionality of design and use, however, does not change the fact that the functional/intentional aspect is something that is supposed to distinguish artefacts from the rest of the physical objects in the philosophy of technology.

Summing up, according to philosophers of technology, artefacts are different to natural beings, but this does not mean that they should be kept in low metaphysical regard. That is to say, their characteristics are: non-naturalness, intentionality/functionality and metaphysical equality (in relation to natural beings).

Environmental philosophy takes quite a different position on this issue. Environmental philosophers, it should be highlighted, rarely devote in-depth attention to artefacts. Technical artefacts appear in their considerations mainly in the context of the consumption of natural resources needed to produce them and waste after they are no longer used (see Hourdequin, 2015: 127), or as pollution and destruction of nature which is the result of their production and later use (e.g., car fumes) (see Gerber, 2002: 51; Devall, 1988: 15). But when environmental philosophy directly takes up the problem of the status of artefacts, it categorises them as ontologically inferior compared to natural beings – in accordance with Aristotle and contrary to philosophy of technology. The reasons for that are the following.

First, environmental philosophers highlight that artefacts have a determined function, which, moreover, is always related to human needs (Lee,[3] 1999: 73, see Katz, 2012, 1993), just like the philosophy of technology does. However, they evaluate such a characteristic negatively, arguing that due to this artefacts have a much poorer identity compared to natural beings (both biotic and abiotic, see Katz, 1993: 229; see Siipi, 2003: 414). The latter cannot be described by a single function or even by a limited amount of functions. Moreover, due to this characteristic, artefacts are not as ontologically independent as natural beings are (Lee, 1999: 178–179; Katz, 1993: 229). The dominant vision in environmental philosophy is that the essence of natural beings – in accordance with the thesis of non-instrumentality of nature – is not placed within the frame of human intentional/functional structures; natural beings do not exhibit human purposiveness and end-directedness as their foundations (Lee, 1999: 73; Katz, 2002: 1993). They have their own internal *tele* – as Keekok Lee underlines in reference to Aristotle (Lee, 1999: 37–39).

Furthermore, again unlike natural beings, artefacts are described as secondary to the material from which they were made (see Lee, 1999: 50). For example, a tree is not derivative of wood, but a wooden chair is. Of course, there are degrees of artefacticity in this regard. Material can be natural (e.g., wood), or derived from natural material (e.g., plastic as made from oil), or constructed *de novo* (e.g., diamondoid material) (see Lee, 1999: 49–52). However, it does not change the fact that all artefacts are dependent ontologically on the more or less natural materials and not the other way around. Such a gradation seems to be an implicit normative hierarchy – the more related to the natural material artefacts are, the more valuable they are.

The final claim of environmental philosophers is that artefacts are not as complex as natural beings are, since they lack the ability to self-repair or self-maintain. For example, plants are capable of tissue and cell renewal, and even self-defence (Lee, 1999: 170–172). This is the aspect that philosophy of

3. Keekok Lee is the author of the book *The Natural and the Artefactual. The Implcations of Deep Science and Deep Technology for the Environmental Philosophy* (1999), which is one of the most important works in environmental philosophy on the artefacts.

technology does not discuss. Environmental philosophy, on the other hand, emphasises that artefacts – unlike natural beings – do not strive to sustain their own functional integrity (Callicott, 2005: 189). So artefacts are portraited as if they do not have any interests of their own or, to put it bluntly, they do not care about their being. In this manner, as some environmental philosophers hold, artefacts are similar to abiotic nature (Lee, 1999: 172; see Cahen, 2002: 117; Goodpaster, 1980: 282; Hunt, 1980: 61). Yet, the latter belongs to the natural order and hence its ontological status is not as low as that of artefacts for the abovementioned reasons (see Naess, 1995; Birch, 1993: 331).

This brief overview makes clear that environmental philosophy does not treat artefacts as full-fledged beings – just like Aristotle did. This stipulation is clearly seen in environmental philosophy in the context of ecological restoration. Some theorists claim that we cannot ascribe equal worth to a tree which grows naturally and one planted by humans in order to replace a tree that had been cut down. Eric Katz compares the difference between the natural grown tree and the planted one to the difference between a work of art created by the original artist and a copy (Katz, 2012: 70–71[4]). Katz's intention is clear and understandable; he wants to prevent a too easy justification of the exploitation of nature by saying that we can always restore parts of natural systems that we have destroyed. This is the reason why Katz distinguishes the value of wild versus restored natural areas, and recognises the autonomy of origin as an important ontological value – natural beings have such an ontological value and artefacts do not (Katz, 2012: 72, Katz, 2002: 144; Ouderkirk and Hill, 2002: 126). According to environmental philosophy, therefore, artefacts' ontological dependence is twofold: on the one hand it is *anthropocentric* – in the sense of being oriented toward human ends, and second *anthropogenic* – as being created by humans. The latter means not only some modification of the particular being, but also deliberate bringing it into existence (Siipi, 2003: 415–418). Such a claim implicitly contains another characteristic of natural beings, which artefacts do not have: the first are able to *self-reproduce*, while the latter are not. This difference is so apparent and so obviously linked to the idea that the ontogenesis of natural beings is independent of human beings that it seems inappropriate to speak about it (and so environmental philosophy and philosophy of technology often do not). Yet, as we shall see later in the attempt to classify hybrids, it is worth making this difference explicit.

Because what *is* actually a restored tree? *Artificial being,* because it was human initiative to start its existence, or *natural* being, because it is not secondary to the material of which it is made, able to self-preserve etc.? Is such a

4. Thus, Lee highlights there are two meanings of 'artificial': one simply 'artefactual' (for naming human creations) and second 'ersatz', 'imitative' (Lee, 1999: 51). She argues that for example a silk rose is an artefact in both senses, whereas a black tulip only in the first sense, but it seems that for Eric Katz a black tulip (like a restored forest) would be an artefact in both senses.

description useful at all? And what about the synthetic (artificial or minimal) cell in synthetic biology? How can we classify such beings that are somewhat between natural and artificial? We attempt to answer these questions in the next section, offering a possible categorisation of hybrids.

Table 1. Characteristics of Artefacts

Philosophy of Technology	**Environmental Philosophy**
created by human beings (unable to self-reproduce)	created by human beings (unable to self-reproduce)
functional	functional
-	unable to self-preserve (self-maintain)
metaphysically equal to natural beings	metaphysically unequal to natural beings

5. THE HYBRIDS

We employ the term 'hybrids' to refer to beings that combine natural and artificial elements, which traditionally are seen as belonging to two binary categories.[5] In this sense, hybrids constitute a new class of beings, in which parts from different domains become inextricably linked and form a separate ontological class. The set of hybrids, however, seems to be too varied to include them to one category. Thus, we elaborate on the above definition and propose a classification of hybrids, diagnosing two basic tendencies, which we can observe in current advances in technology and innovation: technologising (artificialising) nature and naturalising technology. In our classification, however, we employ a new terminology, which attempts to go beyond the traditional divide of nature and technology. We suggest establishing two categories of hybrids, with three subcategories each: 1. bio-augmented projects (1a. fertile; 1b. sterile: with an 1bi. original function/1bii. new function) and 2. biomimetic projects (2a. bio-replacements; 2b. biomimetic beings: 2bi. weakly biomimetic/2bii. strongly biomimetic).

1. Bio-augmented projects. In our terminology concerning hybrids, we employ the term 'projects', because it refers to the human ability and willingness to design things, which can be seen as complementary to biological design. Another reason for doing so is that the 'pro-ject' is somewhere in between the 'subject'

5. There is a significant ambiguity in the use of the term 'hybrid' – it can refer to offspring resulting from cross-breeding (a mule), hybrid engine, socio-natural hybrids etc. What is common for all these meanings is that they indicate inherent dualism – combining elements which traditionally are classified as belonging to two different categories (see Driessen, 2017).

and 'object' – as neither fully ontologically autonomous nor totally dependent on its creator.

So, the first group of hybrids – bio-augmented projects – consists of organisms whose predecessors were regular natural beings, but they themselves become significantly different to past generations due to human intervention and design. The example can be a genetically modified cow, which produces human-like milk to feed allergic children. One can ask however whether such a statement does not apply to agriculture in general: human beings for ages have been developing numerous species by improving seeds, animals, and so on. And yet, the question is whether selective breeding and genetic modification (GM) – which is more widely adopted each year – can be actually recognised as the same kind of human intervention in nature as classical breeding for instance. Opponents of GMO like to stress how they are qualitatively and utterly different to anything that has gone before; their supporters argue that they are not that new or distinct, indeed, that 'humanity has always practiced genetic modification' (Kingsbury, 2009: 409). As Noel Kingsbury aptly comments, looking back on plant breeding history, we can appreciate that both standpoints involve a sleight of hand (2009: 409). Both traditional agriculture and genetic engineering aim to 'perfect' nature according to human needs, by altering wild species. Thus, supporters of GM technology maintain, there is no real, qualitative, difference between high-tech and traditional breeding methods (Van Acker, Rahman and Cici, 2017; Kingsbury, 2009). According to them, it's only a gradual difference – genetic engineering enables us to change animals and adapt them to human needs much faster and more efficiently compared to traditional breeding, which needed generations to implement desired changes. This seems however only half true: biotechnology's various techniques enabled breeders to perform crosses that had never been possible before and to propagate plants on a scale that could previously have only been considered possible in fairy tales (Kingsbury, 2009: 399). Thanks to GM technologies, human beings are able to import traits from any living being – breeders are no longer restricted to working with close relatives. Inheritance always used to be thought of in vertical terms, with genes being passed down breeding lines. Today it could be thought of as horizontal, with genes being transferred from one species to another, directly going from genome to genome. This is clearly a huge leap (Kingsbury, 2009: 399, 409), which poses a question whether GM organisms are still natural beings. We argue they are *not fully* natural beings anymore – they are hybrids in the sense that they can be classified as 'bio-augmented projects', that is augmented organisms. We wish to underline that in answering this question of the naturalness of GMO, we do not treat 'natural' as an evaluative term, trying to avoid any naturalistic fallacy – which identifies 'natural' with 'good' or 'positive' – but we are focused on assessing how far such beings are shifting toward the technological/artificial pole.

The very first trait, which assimilates them to artefacts, is that they are *designed* (which is typical to all projects), or to be more precise, they are designed for a particular human-invented purpose. At this point we need to make some reservation. The fact that human beings intentionally design – that is, *plan* to create – an entity which is supposed to serve some function does not mean that they always succeed in it. We can imagine a situation when GMOs accidentally leave the lab and survive in nature or turn out to have very different capacities than initially predicted. This, however, does not change the fact that they were intentionally designed for human-related purposes. Between designing and producing there is a solid gap. That is to say, being designed concerns an *intentional* design of a function, without implying anything about the actual use and functionality of this design. We have already discussed this chasm in the case of typical artefacts, when they have different functions than they later actually served (see section 'Double Portrait of Artefacts'). In this sense, we claim that GMOs' specific, 'artificial' feature is that they are designed for particularly human goals. Moreover, GMO technology gives breeders the precision that they have always wanted. New species have precise, specific capacities, which human beings needed from them: they are more resistant, more effective, giving particular types of foods and so on. That is to say, they are *more functional* than their predecessors, or they are more specialised in some functions. And functionality, as we remember, is one of the core characteristics of artefacts. GMOs then are more predictable than their natural counterparts and as such they lose much of their ontological autonomy. The functional aspect, however, is quite varied among augmented organisms, and therefore, we suggest dividing them into some subcategories, which we discuss below.

Human beings alter natural beings so that they are more resistant to various diseases, or can produce, for example, more milk or milk of a new, specific type (e.g., as already mentioned, human-like milk free from allergens). However, there are also augmented organisms, which due to human intervention gain completely new functions compared to their predecessors which were natural kinds. An example of this category could be bio-luminescent trees, which illuminate city-centre streets (Myers, 2012). Bio-luminescent trees seem to have a significantly different status than mere resistant GM crops regarding their hybridity, because such a tree becomes a 'natural' replacement of technological objects (bio-luminescent trees are designed to replace artificial street lamps or reduce their number). So, we could divide bio-augmented projects into two subcategories, namely one in which a *(strengthened) original function* is at stake (e.g., plants which are more resistant to certain diseases) and one in which a completely *new function* is at stake (bio-luminescent trees since trees do not normally emit light).

Such a classification, however, would not give us a broad enough picture of bio-augmented projects, and would incline us to too easily reduce GMO to artefacts due to their functional side. We should not forget that such hybrids are still organisms: they are able to *self-maintain*, that is to *grow, self-organise* and *self-regenerate* like natural beings. For instance, GM cows and trees self-develop (from egg cell or seed to a mature being) and are able to heal themselves in case of being hurt. These characteristics are clearly linked with natural beings. What is also of significant importance, is that some GMOs – under a few conditions – can *reproduce* themselves (e.g., some GM seeds) and/or fertilise their regular/natural counterparts (Van Acker, Rahman and Cici, 2017; Robaey, 2016[6]). This ability to self-reproduce can be a basis for a further divide of hybrids according to Aristotle's definition of artefacts – the latter are produced by an external agent such as an artist or engineer, whereas natural beings are produced by themselves (which is another indicator of their autonomy). So, translating it into more profane terms, we can divide bio-augmented projects into *sterile* and *fertile* projects. As a result, we receive the following subcategories of bio-augmented projects: *[1a] fertile and [1b] sterile: with a [1bi] (strengthened) original function/[1bii] new function*.

2. Biomimetic projects. The other category of hybrids – biomimetic projects – which we suggest establishing is linked to the second aforementioned tendency, namely naturalising technology. This category basically embraces artificial things, which try to follow natural solutions. Again, however, they are too varied to include them in one set. We propose to distinguish three subcategories: *[2a] bio-replacements; [2b] biomimetic entities: [2bi] weakly biomimetic/[2bii] strongly biomimetic*.

The first subcategory of biomimetic projects – [2a] bio-replacements – is actually the 'contraposition' of the subcategory of [1bii] bio-augmented projects with a new function: it includes 'technological' beings, which are designed to replace natural. That is to say, 1bii and 2a are 'complementary opposites' since they have equally high aspirations, but oriented in two different directions and originate from two different sides. Bio-augmented projects with completely new functions derive from nature and move toward the technological pole to serve typically artificial functions, while bio-replacements leave the purely technological domain to serve or sustain internal, natural functions of some organism. This 'bidirectional' development of hybrids – going beyond the 'natural order' (bio-augmented projects) or coming from the sphere external to nature (biomimetic projects) – which underlies the divide between two basic categories in our classification is probably the easiest to observe and investigate with regard to the subcategories 1bii and 2a which are 'next' to each other in our typology (if we assume some continuity within the set of hybrids), yet they are assigned to two different categories. An example of the subcategory 2a (bio-replacements) can be found in bionics, in which electronic devices and mechanical parts are integrated in the human body, or recently a synthetic cell. The latter is an *engineered particle*, which mimics one or many functions of a

6. For this reason Zoe Robaey refers to GM seeds as to 'living artefacts' (2016).

regular biological cell, and was designed to directly substitute it. The synthetic cell is yet not completely artificial, because it *consists of some natural components* and is in some cases *able to replicate*, which makes it quite 'natural'. On the other hand, it was designed by human beings and is under control to a much greater extent than natural cells (Xu, Hu and Chen, 2016).

Another category of biomimetic projects includes biomimetic entities. According to the proponents of biomimicry, it introduces a new and ecosystem-friendly approach to nature, which is no longer characterised by the domination and exploitation of nature, but by learning and exploration (Benyus, 2002). We can distinguish here, however, two approaches, which we can refer to as a 'weaker concept of biomimicry' and a 'stronger concept of biomimicry' (Blok and Gremmen, 2016: 205). They both provide a perfect ground for creating hybrids, yet the premium in each case is put differently: the first is more of being a natural *technology*, whereas the second attempts to be a *natural* technology.

The weaker concept sees mimicry not as the duplication of natural solutions, but primarily as a creative solution inspired by nature. For this reason some scholars refer to it as to 'bio-inspiration' (Rajeshwar, 2012: 3). According to this approach, some artefacts, which are inspired by nature, aim to be more 'perfect' (again – according to human needs) than nature itself. They keep what is valuable and try to reduce all weaknesses. An example of this subcategory can be found in a solar cell inspired by a leaf or a car design inspired by the way trees and bones optimise their strengths and materials. We can say that such devices perform *a secondary imitation of nature*. For instance, unlike a hammer or a shovel, whose creation is directly inspired by the first or the open hand and its possibilities, biomimetic car materials follow natural solutions which are not directly linked to the primary function of a car – motion – but refer to some other trait of an organism – being built from material which is resistant to various collisions. In this sense, the biomimetic car is something like a 2.0 model. Its 'upgrade' is linked to adding an innovation that adapts natural solutions that make it simply better – more resistant, safer – than its traditional, fully artificial counterpart (1.0 model).

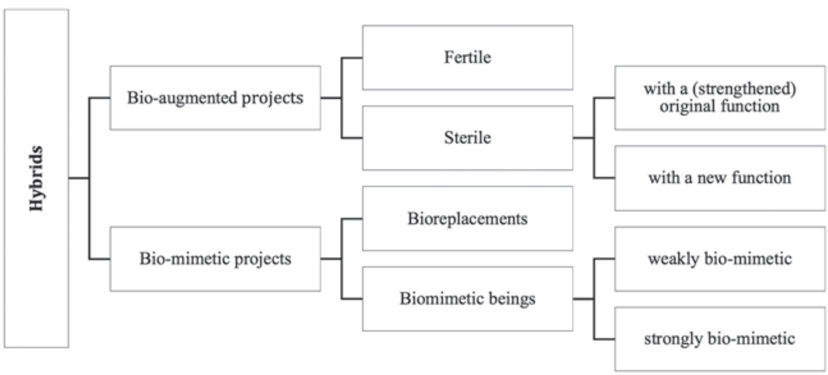
The stronger concept of biomimicry, on the other hand, studies the design of natural systems and then *imitates* these designs to solve human problems, recognising natural solutions as unequalled role models, which should not – and actually *cannot* – be improved (Dicks, 2017: 256; Benyus, 2002). The first example of hybrids belonging to the strong biomimetic category can be biodegradable materials made with natural components (such as starch for instance, see Avella et al., 2005). They can decompose into carbon dioxide, water, biomass and so on. In doing so, biodegradable materials are more advanced than traditional artificial materials such as non-recyclable plastic since they have capacities that the latter does not have.

Another example of a strong biomimetic hybrid could be innovations such as the air-conditioning inspired by the structure of a termite hill. They are compounds of technological facilities, natural agents and human beings, which are designed as and manage the entire complex. A good illustration of this type is a biorefinery in which bacteria, waste streams and humans are interconnected and form a hybrid entity (Blok and Gremmen, 2018).

It is worth underlining one more aspect of strong biomimetic hybrids: *'embeddedness'*. By 'doing it the natural way', such natural technologies can claim to be better embedded and in harmony with the natural ecosystems of planet Earth (Dicks, 2016: 231, 236; Blok, 2017; Benyus, 2002). Interestingly, this opposes the GMO hybrids, which tend to go beyond the internal limitation of nature. In designing them, human beings often disrespect the inherent character of nature, destroying naturally established species barriers and specific characteristics of the land (Peterson and Sandler, 2008). This is another difference which shows how internally varied the set of hybrids is.

The above analysis results in the following scheme of possible categories of hybrids, in which we distinguish 'bio-augmented projects', that is designed organisms which were augmented to serve modified (i.e., strengthened original or completely new) functions (which often result in a loss of fertility), and 'biomimetic projects', which are materials or devices that aim to replace natural parts or follow natural solutions (to a greater or lesser extent).

Table 2. Classification of Hybrids



CONCLUSIONS AND FURTHER QUESTIONS

Intensive human interventions in the natural environment, which define our epoch as the Anthropocene, call our attention to a new class of beings that are no longer purely natural or technological. 'Technologising nature' for instance introduces more and more traits into natural beings that were traditionally ascribed to artefacts, such as being designed or having precise functions. Such new entities cannot be clearly classified as belonging to the domain of nature or technology, which we are used to recognising as binary categories. They are rather hybrids, that is, entities in which characteristics from these two domains are inextricably mixed: nature becomes technologised. However, we can also observe the opposite tendency, which aims to reverse or correct the most destructive aspects of current human existence in the environment and implement the patterns of sustainable development. We can refer to this as 'naturalising technology'. It consists in following nature and its solutions in creating highly advanced devices and materials. They are hybrids as well, since they combine both technological and natural features.

This internal diversity of hybrids begs for some classification, which we have offered in the paper. We proposed a framework to distinguish two main categories of hybrids – 'bio-augmented projects' and 'biomimetic projects' – with further divisions in subcategories.

This classification of hybrids can be of help for philosophy of technology and environmental philosophy in their reflections of their adjusted 'object' of research in the Anthropocene, which for too long operated without mutual interactions. We aimed to provide a new vocabulary that should facilitate their dialogue, which is more urgent than ever before, concerning new types of beings – hybrids in particular – that seemed to be unseen by both branches of philosophy. It appears that they were excluded from their considerations, because in the case of hybrids *reality went ahead of ontology* – we did not have proper categories to analyse them and were sticking to the old dichotomy of nature and technology. In the paper, by offering new terminology, we attempted to take a preliminary step in clarifying the concept of both nature 2.0 and technology 2.0 regarding the problem of hybrids.

What is of significant importance for future research is the transgressive ontological character of hybrids in the Anthropocene, but also the ethical transgression it requires. In the domain of ethics the emergence of hybrids also causes a revolution. Namely, it challenges us to revisit the chasm of natural/artefactual and animate/inanimate categories regarding the problem of moral considerability. For instance, which entity deserves more moral respect: a fully natural stone, which is yet insentient and inanimate, or a GM animal, which is heavily modified, but able to self-maintain and feel pain? What about engineered particles? They play an increasingly important role in contemporary medicine. Should they be granted moral considerability? Such questions on the scope of moral considerability and the place of hybrids in it need to be taken by both philosophers of technology and environmental philosophers if they wish (and we believe they do) to keep up with changes that are emblematic for the Anthropocene.

REFERENCES

Avella, M. et al. 2005. 'Biodegradable starch/clay nanocomposite films for food packaging applications'. *Food Chemistry* **93** (3): 467–474. **Crossref**

Baker, L.R. 2004. 'The ontology of artefacts'. *Philosophical Explorations* **7** (2): 99–111. **Crossref**

Baker, L.R. 2009. *The Metaphysics of Everyday Life*. Cambridge: Cambridge University Press.

Baskin, J. 2015. 'Paradigm dressed as epoch: the ideology of the Anthropocene'. *Environmental Values* **24** (1): 9–29. **Crossref**

Benyus, J. 2002. *Biomimicry: Innovation Inspired by Nature*. New York. Harper Perennial.

Birch, T.H. 1993. 'Moral considerability and universal consideration'. *Environmental Ethics* **15** (4): 313–332. **Crossref**

Blok, V. 2015. 'The human glance, the experience of environmental distress and the "affordance" of nature: toward a phenomenology of the ecological crisis'. *Journal of Agricultural and Environmental Ethics* **28** (5): 925–938. **Crossref**

Blok, V. 2016. 'Biomimicry and the materiality of ecological technology and innovation'. *Environmental Philosophy* **13** (2): 195–214. **Crossref**

Blok, V. 2017. 'Earthing technology: towards an eco-centric concept of biomimetic technologies in the Anthropocene'. *Techné: Research in Philosophy and Technology* **21** (2–3): 127–149. **Crossref**

Blok, V. and B. Gremmen. 2018. 'Agricultural technologies as living machines: toward a biomimetic conceptualization of smart farming technologies'. *Ethics, Policy and Environment* **21** (2): 246–263. **Crossref**

Blok, V. and B. Gremmen. 2016. 'Ecological innovation: biomimicry as a new way of thinking and acting ecologically'. *Journal of Agricultural and Environmental Ethics* **29** (2): 203–217. **Crossref**

Cahen, H. 2002. 'Against the moral considerability of ecosystems'. In A. Light and H. Rolston III (eds), *Environmental Ethics: An Anthology*, pp. 114–128. Oxford: Blackwell.

Callicott, J.B. 2005. 'The pragmatic power and promise of theoretical environmental ethics: forging a new discourse'. In A.W. Galston and C.Z. Peppard (eds), *Expanding Horizons in Bioethics,* pp. 185–208. Dordrecht: Springer.

Clingerman, F. 2014. 'Geoengineering, theology, and the meaning of being human'. *Zygon* **49** (1): 6–21. **Crossref**

Crutzen, P.J. 2002. 'Geology of mankind'. *Nature* **415** (6867): 23. **Crossref**

Crutzen, P.J. and E.F. Stoermer. 2000. 'The "Anthropocene"'. *Global Change Newsletter* **41**: 17–18.

Crutzen, P. and C. Schwägerl. 2011. 'Living in the Anthropocene: toward a new global ethos'. *Yale Environment 360.* Accessed on 5 February 2019 at https://e360.yale.edu/features/living_in_the_anthropocene_toward_a_new_global_ethos

Devall, B. 1988. *Simple in Means, Rich in Ends. Practicing Deep Ecology*. Salt Lake City: Peregrine Smith Books.

Dicks, H. 2016. 'The philosophy of biomimicry'. *Philosophy and Technology* **29** (3): 223–243. **Crossref**

Dicks, H. 2017. 'Environmental ethics and biomimetic ethics: nature as object of ethics and nature as source of ethics'. *Journal of Agricultural and Environmental Ethics* **30** (2): 255–274. **Crossref**

Driessen, C. 2017. 'Hybridity'. In D. Richardson et al. (eds), *The International Encyclopedia of Geography: People, the Earth, Environment, and Technology*, pp. 1–10. Wiley/Association of American Geographers. **Crossref**

Franssen, M. 2008. 'Design, use, and the physical and intentional aspects of technical artefacts'. In P.E. Vermaas et al. (eds), *Philosophy and Design. From Engineering to Architecture*, pp. 21–35. Dordrecht: Springer. **Crossref**

Gardiner, S.M. and A. Thompson (eds),. 2017. *The Oxford Handbook of Environmental Ethics*. Oxford: Oxford University Press.

Gerber, L. 2002. 'What is so bad about misanthropy?'. *Environmental Ethics* **24** (1): 41–55. **Crossref**

Goodpaster, K.E. 1980. 'On stopping at everything: A reply to WM Hunt'. *Environmental Ethics* **2** (3): 281–284. **Crossref**

Grandy, R.E. 2007. 'Artefacts: parts and principles'. In E. Margolis and S. Laurence (eds), *Creations of the Mind: Theories of Artefacts and their Representation*, pp. 18–32. Oxford: Oxford University Press.

Hailwood, S. 2015, *Alienation and Nature in Environmental Philosophy*. Cambridge: Cambridge University Press.

Hamilton, C. 2014. *Earthmasters: The Dawn of the Age of Climate Engineering*. New Haven: Yale University Press.

Heyward, C., S. Rayner and J. Savulescu. 2017. 'Early geoengineering governance: the Oxford principles'. In D.M. Kaplan (ed.), *Philosophy, Technology, and the Environment* pp. 103–120. Cambridge (MA): MIT Press.

Houkes, W. and P.E. Vermaas. 2009. 'Produced to use: combining two key intuitions on the nature of artefacts'. *Techne: Research in Philosophy and Technology* **13** (2): 123–136. **Crossref**

Hourdequin, M. 2015. *Environmental Ethics: From Theory to Practice*. Noldon–New York: Bloomsbury Academic.

Hui, Y. 2017. 'On cosmotechnics'. *Techné: Research in Philosophy and Technology* **21** (2/3): 319–341. **Crossref**

Hunt, W.M. 1980. 'Are mere things morally considerable?'. *Environmental Ethics* **2** (1): 59–65. **Crossref**

Kam-por, Y. 2005. 'Moderating nature with responsibility and humility human genetics from a Confucian perspective'. *polylog: Forum for Intercultural Philosophy* **6**. Online: http://them.polylog.org/6/fyk-en.htm.

Kaplan, David M. (ed.) 2017. *Philosophy, Technology, and the Environment*. Cambridge MA: MIT Press.

Katayama, E.G. 1999. *Aristotle on Artefacts: a Metaphysical Puzzle*. Albany: SUNY.

Katz, E. 1993. 'Artefacts and functions: a note on the value of nature'. *Environmental Values* **2** (3): 223–232. **Crossref**

Katz, E. 2002. 'Understanding moral limits in the duality of artefacts and nature: a reply to critics'. *Ethics & the Environment* **7** (1): 138–146. **Crossref**

Katz, E. 2012. 'Further adventures in the case against restoration'. *Environmental Ethics* **34** (1): 67–97. **Crossref**

Kingsbury, N. 2009. *Hybrid. The History and Science of Plant Breeding*. Chicago/London: The Chicago University Press.

Kolbert, E. 2011. 'Enter the Anthropocene – the age of man'. *National Geographic*. Accessed 5 February 2019 at https://www.nationalgeographic.com/magazine/2011/03/age-of-man/

Kroes, P. and P.E. Vermaas. 2008. 'Interesting differences between artefacts and natural objects'. *APA Newsletter* **8** (1): 28–31.

Lawson, C. 2008. 'An ontology of technology: artefacts, relations and functions'. *Techne: Research in Philosophy and Technology* **12** (1): 48–64. **Crossref**

Lee, K. 1999. *The Natural and the Artefactual. The Implications of Deep Science and Deep Technology for Environmental Philosophy*. Lanham/Boulder/New York/Oxford: Lexington Books.

Lemmens, P. and Y. Hui. 2017. 'Reframing the technosphere: Peter Sloterdijk's and Bernard Stiegler's anthropotechnological diagnoses of the Anthropocene'. *Krisis: Journal for Contemporary Philosophy* **2017** (2): 26–41.

Lemmens, P., V. Blok and J. Zwier. 2017. 'Toward a terrestrial turn in philosophy of technology'. *Techné: Research in Philosophy and Technology* **21** (2–3): 114–126. **Crossref**

Light, A. 2006. 'Restoration ecology'. In A. Steffan (ed.), *World Changing: A User's Guide for the 21st Century,* pp. 484–485. New York: Abrams Publishers.

Myers, W. 2012. *Biodesign: Nature, Science, Creativity*. London: Thames & Hudson.

Naess, A. 1995. 'The deep ecological movement'. In G. Sessions (ed.), *Deep Ecology for the 21st Century: Readings on the Philosophy and Practice of the New Environmentalism,* pp. 64–84. Boston: Shambhala.

Ouderkirk, W. and J. Hill (eds). 2012. *Land, Value, Community: Callicott and Environmental Philosophy*. Albany: SUNY.

Peterson, M.J. and R. Sandler. 2008. 'Ethical evaluation of new technologies: genetically modified organisms and plants'. *International Dimensions of Ethics Education Case Study Series*, available at: https://scholarworks.umass.edu/edethicsinscience/36/.

Preston, C.J. 2015. 'Framing an ethics of climate management for the Anthropocene'. *Climatic Change* **130** (3): 359–369. **Crossref**

Rajeshwar, K. 2012. 'Biomimetic or bioinspired? Editor's note'. *The Interface*, available at https://www.electrochem.org/dl/interface/fal/fal12/fal_win12_p003.pdf

Robaey, Z. 2016. 'Transferring moral responsibility for technological hazards: the case of GMOs in agriculture'. *Journal of Agricultural and Environmental Ethics* **29** (5): 767–786. **Crossref**

Robinson, H. and B. Dainton (eds). 2014. *The Bloomsbury Companion to Analytical Philosophy*. London: Bloomsbury.

Rolston III, H. 2017. ‘The Anthropocene!: beyond the natural?’. In S.M. Gardiner and A. Thompson (eds), *The Oxford Handbook of Environmental Ethics,* pp. 62–76. Oxford: Oxford University Press. **Crossref**

Siipi, H. 2003. ‘Artefacts and living artefacts’. *Environmental Values* **12** (4): 413–430. **Crossref**

Sperber, D. 2007. ‘Seedless grapes: nature and culture’. In E. Margolis and S. Laurence (eds), *Creations of the Mind: Theories of Artefacts and their Representation*. Oxford: Oxford University Press.

Thompson, P.B. 2017. ‘Philosophy of technology and the environment’. In S.M. Gardiner and A. Thompson (eds), *The Oxford Handbook of Environmental Ethics,* pp. 62–76. Oxford: Oxford University Press. **Crossref**

Williston, B. 2017. ‘The question concerning geo-engineering’. *Techné: Research in Philosophy and Technology* **21** (2–3): 119–221. **Crossref**

Wong, P.H. 2015. ‘Confucian environmental ethics, climate engineering, and the “playing God” argument’. *Zygon*® **50** (1): 28–41. **Crossref**

Van Acker, R., M. Rahman and S. Cici. 2017. ‘Pros and cons of GMO crop farming’. *Oxford Research Encyclopedia of Environmental Science*, available at: http://environmentalscience.oxfordre.com/view/10.1093/acrefore/9780199389414.001.0001/acrefore-9780199389414-e-217. **Crossref**

Verbeek P-P. 2005. *What Things Do. Philosophical Reflections on Technology, Agency, and Design*. University Park: Penn State University Press.

Vermaas P.E. et al. (eds). *Philosophy and Design. From Engineering to Architecture*. Dordrecht: Springer.

Vermaas P., P. Kroes, I. van de Poel, M. Franssen and W. Houkes. 2011. *A Philosophy of Technology: From Technical Artefacts to Sociotechnical Systems*. Morgan & Claypool Publishers **Crossref**

Vogel, S. 2003. ‘The nature of artifacts’. *Environmental Ethics* **25** (2): 149–168. **Crossref**

Vogel, S. 2015. *Thinking like a Mall*. Cambridge: MIT Press. **Crossref**

Xu, C., S. Hu and X. Chen. 2016. ‘Artificial cells: from basic science to applications’. *Materials Today* **19** (9): 516–532. **Crossref**

Zalasiewicz, J., M. Williams, W. Steffen and P. Crutzen. 2010. ‘The new world of the Anthropocene’. *Environmental Science & Technology* **44** (7): 2228–2231. **Crossref**