Philos. Technol. (2012) 25:525–541
DOI 10.1007/s13347-012-0075-6

SPECIAL ISSUE

Biological Interests, Normative Functions, and Synthetic Biology

Sune Holm

Received: 1 February 2012 / Accepted: 12 April 2012 / Published online: 3 May 2012

Abstract In this paper, I discuss the aetiological account of biological interests, developed by Varner (1998), in the context of artefactual organisms envisioned by current research in synthetic biology. In "Sections 2–5", I present Varner's theory and criticise it for being incapable of ascribing non-derivative interests to artefactual organisms due to their lack of a history of natural selection. In "Sections 6–7", I develop a new alternative to Varner's account, building on the organisational theory of biological teleology and function. I argue that the organisational account of biological interest is superior to Varner's aetiological account because it (i) can accommodate both artefactual and naturally evolved organisms, (ii) provides a non-arbitrary and practical way of determining biological interests, (iii) supports the claim that organisms have interests in a sense in which artefacts do not, and (iv) avoids the possibility of there being a conflict between what an organismic part is supposed to do and what is in the interest of the organism.

Keywords Functions · Biocentrism · Synthetic biology · Artefactual organism · Artificial life · Moral considerability · Organism · Artefact · Teleology

1 Introduction

This paper was prompted by a growing interest in the moral considerability of the non-sentient artefactual organisms envisioned by prominent research programmes in synthetic biology.[1] At the core of biocentrist theories is the claim that non-sentient organisms have non-derivative interests by virtue of having certain goals, such as survival and reproduction, which may be facilitated or frustrated by specific things.

[1]For informative overviews of synthetic biology research programmes, see, e.g., O'Malley et al. (2008) and Deplazes (2009).

S. Holm (✉)
Department of Media, Cognition, and Communication, Philosophy Section,
University of Copenhagen, Njalsgade 76, 2300 Copenhagen S, Denmark
e-mail: suneh@hum.ku.dk

However, defining the interests of organisms by reference to their goal-directedness presents biocentrists with a significant and well-known challenge: If we ascribe interests to organisms on the basis of the fact that they are goal-directed systems with ends that may be promoted, then the fact that technical artefacts such as telephones and thermostats also have ends seems to entail that technical artefacts have interests too. In order to avoid this allegedly absurd consequence, biocentrists must show that the sense in which non-sentient organisms have interests is different from the sense in which interests are ascribed to artefacts.

Varner (1998) puts forward a philosophically sophisticated theory to meet this challenge. Unlike artefacts, living organisms have *biological* interests, and it is by virtue of having biological interests that living beings are directly morally considerable. In this paper, I show that the kind of artefactual organisms expected to result from current research in synthetic biology, according to Varner's account, will not have non-derivative biological interests. Furthermore, the possibility of artefactual organisms reveals a problematic feature of theories of biological interest that are grounded in aetiological accounts of biological function. I will argue that Varner's aetiological account of biological interest should be rejected in favour of an organisational theory of normative function that enables the biocentrist to ascribe biological interests to artefactual as well as naturally evolved organisms.

I begin by presenting the biocentrist's task of developing a notion of non-derivative interests that can be ascribed to non-sentient organisms but which does not apply equally to technical artefacts. In "Section 3", I present Varner's biological interest theory, and in "Section 4", I consider in more detail why the biocentrist is tempted to appeal to the aetiological theory of normative function rather than to dispositional alternatives. In "Section 5", I characterise the notion of an artefactual organism and present my criticism of Varner's account in the context of current research in synthetic biology. Then, in "Section 6", I review the organisational theory of normative function, and in 'Section 7", I use it to define a notion of biological interest that is superior to Varner's when it comes to grounding the non-derivative interests of non-sentient organisms.

2 Biocentrism and Non-Derivative Interests

Biocentrists claim that all living beings, including non-sentient organisms such as oak trees and yeast cells, are morally considerable. To say that an individual is morally considerable is to say that it has interests of its own and that these interests should be taken into account for their own sake, when moral agents deliberate about what to do (see Goodpaster 1978, p. 309). I will refer to such interests as *non-derivative interests*.

To illustrate the idea that moral agents are morally obliged to take the interests of non-sentient organisms into account, consider a case in which I want to build a big garden shed next to a cherry tree and that the shed will reduce the tree's access to sunlight considerably. The idea is that I ought to take the cherry tree's interest regarding access to sunshine into account when I contemplate building the shed. Importantly, the claim is not (though it might be strengthened to be) that the interests of the cherry tree should carry the same weight as my interest in a garden shed in my deliberations. The claim is that the cherry tree's interests ought to be taken into account.[2]

The claim that non-sentient organisms are morally considerable in virtue of having non-derivative interests has been met with criticism from different quarters. Sentientists such as Singer have argued that it only makes sense to ascribe interests to beings capable of experiencing pleasure and pain (1975, p. 8). Others recognise that water and sunlight can be in the interest of non-sentient organisms but deny that this is to be understood in a morally important non-derivative sense. In particular, two claims yield an important objection to biocentrism. First, it has been claimed that in so far as non-sentient organisms have interests, it is in the same sense as technical artefacts, namely in relation to interests that humans take in them. Second, this means that if non-sentient organisms merit moral considerability in virtue of having interests, then telephones and thermostats are morally considerable too, which is absurd.[3]

This line of argument has been pushed by Feinberg (1974).[4] Feinberg acknowledges that we often say that something is good for non-sentient organisms: e.g., we commonly say that plants need sunlight and water to grow and develop. He points out, however, that when we say something is good for plants, we should *not* take this to mean that they have a good of their own towards which the satisfaction of their needs contributes. The sense in which plants need sunshine and water, according to Feinberg, is no different than the sense in which a car needs gas. The car cannot drive without gas; the plant cannot grow without water. However, in both cases, the satisfaction of needs does not serve the good of the car or the plant itself. In so far as something is good for non-sentient organisms, it is in relation to the interest an agent takes in them: “Plants may need things in order to discharge their functions, but their functions are assigned by human interests, not their own” (Feinberg 1974, p. 54).

In short, the challenge that faces the biocentrist is that she must provide an account of non-derivative interests that (1) applies to non-sentient organisms and (2) does not entail that artefacts are morally considerable.[5] In the next section, I discuss Varner's attempt to provide an account of non-derivative interests that meets the first part of this double challenge.

[2] Thus, Goodpaster distinguishes between moral considerability and moral significance (1978, p. 313).

[3] In this paper, I will assume that it is a *reductio* of the biocentrist position if it entails that technical artefacts also have interests, since this seems to be Varner's conclusion, which is the focus of the present discussion: “(…) if identifying some of the interests of human beings with their biologically based needs implies that can openers and cars have interests, then surely we should abandon the biological portion of the psycho-biological theory of welfare” (Varner 1998, p. 62).

[4] In his influential article on moral considerability, Goodpaster (1978, p. 319) discusses Feinberg's argument, and so does Varner (1990, 1998, p. 63). Singer (1979) has a similar criticism: all we mean when we say it is in the interests of a tree to be watered is that the tree needs water if it is to continue to live and grow normally; if we regard this as evidence that the tree has interests, we may as well say that it is in the interests of a car to be lubricated regularly because the car needs lubrication if it is to run properly.

[5] My focus in this paper is on whether biocentrists have provided a sound argument in favour of an account of non-derivative interests that applies to non-sentient organisms. Whether such interests are morally considerable is a further question that I will not discuss here.

3 Varner's Account of Biological Interest

Varner (1990, 1998) develops a sophisticated version of biocentrism, the core of which is the notion of *biological interest*. The aim is to establish a basis for the claim that non-sentient organisms have interests and that it is possible to specify what those interests are in a way that does not rely on human interests.

To begin with, Varner presents Regan's conceptual distinction between *having* an interest in X and consciously *taking* an interest in X.[6] Regan (1976) points out that there are logically independent ways in which we can understand the claim that X is in A's interest. According to one interpretation, "X is in A's interest" means that A is interested in X; in another interpretation, it means that X is good for A, even if A is not interested in X. It is worth noting that X may be in A's interest in the first sense and not in the second, and vice versa. Thus, beings may have an interest in something even if they are incapable of taking an interest in the thing in question due to a lack of conscious awareness. To illustrate, consider the following example used by Varner:

> Human beings with a cognitive apparatus (and the relevant knowledge) can consciously *take* an interest in something, e.g., in consuming vitamin C. If Jane reads an article that tells her that vitamin C is good for her health, she may form a belief that she should take vitamin C tablets and set out to find a shop where she can buy such tablets. However, even if Jane, due to some brain damage, were to lose any ability to be aware of the existence of vitamin C and its effect on her health, it seems reasonable to claim that she would still *have* an interest in vitamin C.

With the distinction between having and taking an interest in hand, we can now move on to consider Varner's definition of biological interest:

> Non-sentient organisms have a biological interest in X if and only if X contributes to the fulfilment of some biological function (Varner 1998, p. 68).[7]

Given this definition of biological interest, all and only entities whose parts and processes have biological functions can have biological interests. To explicate his definition of biological interest, Varner turns to a version of the popular aetiological theory of biological function, which assigns functions to parts and processes of organisms on a non-intentional basis (1998, p. 68):

[6] Varner (1998, pp. 57–62) invokes the distinction between having and taking an interest in something in connection with his argument for what he calls "the psycho-biological theory of welfare", according to which having an interest in something need not be based on actual or hypothetical desires, but may merely be a biological fact about an organism. This distinction was first made in Regan (1976) and is also featured in Taylor (1986). Feinberg (1974) takes interests to presuppose cognitive awareness.

[7] It should be noted that Varner's psycho-biological account of interests is disjunctive (see 1998, p. 68). In addition to having biological interests, conscious organisms may have interest derived from their (informed) desires. In other words, Varner's account of interest is pluralistic. In this paper, my focus is on Varner's explication of the notion of biological interest. Varner recognises that biological and psychological interests may conflict, e.g., when he discusses the case of Maude, who has an informed desire to smoke, though it is not in her biological interest (1998, p. 62). However, he does not offer a principle for how to resolve this sort of conflict.

F is the biological function of S (some organ or subsystem) in A (some organism) if and only if:

(i) F is a consequence of A's having S, and
(ii) A has S because achieving F was adaptive for A's ancestors.[8]

The aetiological theory of biological function has the virtue of allowing us to appeal to the function of an organ or subsystem to explain its presence in the organism. The presence of my token heart is explained, in part, by what past token hearts did to help their possessors survive and reproduce to a greater degree than those members of the population that varied with respect to that trait.[9]

To illustrate how Varner's account of biological interest allows Varner to ascribe non-derivative biological interests to non-sentient organisms, consider a tree. A tree has a biological interest in sunshine if and only if sunshine contributes to the fulfilment of the biological function of one or more of its parts or subsystems. Now leaves are organs of trees that have the function of enabling photosynthesis. In order to perform photosynthesis, the leaves need energy from sunlight, and thus sunshine might be said to be in the interest of the trees due to its contribution to the function of their leaves.

The appeal to the aetiological theory of function also means that Varner's account of biological interest can ground the claim that "plants have needs in some sense in which artifacts do not" (1998, p. 62). Organisms have biological interests by virtue of the fact that they are products of natural selection. Artefacts, on the other hand, "can't have biological functions and biological interests for the simple reason that they are not products of natural selection" (Varner 1998, p. 68).

4 Why Appeal to the Aetiological Theory?

I have outlined Varner's attempt to provide an account of non-derivative interests that applies to non-sentient organisms and that are able to distinguish between organisms and artefacts. In this section, I will consider why Varner, together with a great many philosophers of biology, consider the aetiological theory to be a promising theory of biological function and why it seems to fit Varner's notion of biological interest.[10]

The main selling point of the aetiological theory is that it accommodates three intuitions about naturalistic function ascriptions: (i) citing the function of an item explains why it exists; (ii) function ascriptions are normative in the sense that when we say that the function of an item is to do F, we say something about what it is supposed to do[11]; and

[8] Influential versions of the aetiological theory can be found in Wright (1973), Millikan (1989), Neander (1991), Griffiths (1993), Godfrey-Smith (1994) and Mitchell (1995).

[9] I interpret Varner's use of "was adaptive for" as a requirement that there has been natural selection for a trait. I think this interpretation is justified by the fact that Varner illustrates the view by pointing out that the reason why sight is the function of eyes is that sight has been naturally selected for (1998, p. 68).

[10] The literature on aetiological theories of function is vast and addresses many issues that I cannot cover here. I will focus on what I take to be the virtues of aetiological theory most often appealed to by those who defend it, with a particular emphasis on Neander's aetiological account.

[11] It is worth noting that when aetiologists claim that functions are normative, they do not mean that functions supply agents with reasons for action (or belief). Nothing about what agents should do follows from the fact that leaves are supposed to contribute to photosynthesis.

(iii) not just any effect of an item is its function, so it must be possible to discriminate between an item's "accidental" effects and its function.

To illustrate, consider the case of the human heart. In accordance with biological and ordinary usage, the aetiological theory claims that the function of the human heart is to pump blood. By determining the function of the human heart on the basis of its history of natural selection, we can say the following: human hearts exist because, by pumping blood, hearts have made a causal contribution to the differential survival and reproduction of organisms that had them. Furthermore, we can say that even if making a thumping sound has occasionally contributed to the survival and reproduction of a human being, it is not a function of the heart because there has not been natural selection for that effect. Finally, because hearts and other organismic traits have a natural selection history, we can make sense of the idea that biological function ascriptions state what the function bearer is *for*. A heart that is not capable of pumping blood is not functionless, but malfunctioning, because it exists *for* pumping blood, that is to say, because it has a normative function.

Advocates of the aetiological approach often point out that the single most problematic implication of alternative approaches is that they do not account for the normative dimension of biological function. Let me briefly sketch the claims and criticisms of three significant *dispositional* accounts, which, in contrast with aetiological accounts, claim that the function of an item is a causal contribution that it actually makes to some capacity or goal of the system.

One of the most influential dispositional approaches is Cummins' systemic capacity account (Cummins 1975). Systemic capacity functions are relative to a salient capacity C of a system S that we want to understand in terms of a "functional analysis" in which a system and its parts are specified. In the systemic capacity account, the function of a part X of a system S is to F if and only if X has the capacity to F and X's capacity to F causally contributes to S's capacity to C.[12] While there might be contexts in which systemic capacity functions are useful for understanding a complex system, such functions do not say what their bearers are supposed to do. The systemic capacity account will ascribe functions to all sorts of items that we do not take to be supposed to do anything at all. Thus, the systemic account will arguably ascribe the function of causing earthquakes to tectonic plates (Neander 1991) and take it to be a function of clouds to make rain to fill rivers and streams (Millikan 1989).[13]

Boorse (1976, 2002) has suggested that the proper function of an organic part is its actual causal contribution to the goal of the organism, which, given the way in which organisms are disposed to adjust their activities in order to maintain life, he suggests is survival and reproduction. However, Boorse's statistical account of normal function seems unsatisfactory.[14] Boorse introduces a norm for the function of a trait in terms of the statistically normal contribution to survival and reproduction that the trait has within the relevant class of organisms (Boorse 1976). However, the statistical account

[12] For a vigorous and influential defence of the importance of Cummins's account in biological research, see Amundson and Lauder (1994).

[13] For an interesting criticism of the claim that the systemic capacity account must ascribe the function of filling rivers and streams to clouds, see Davies (2001, p. 75 ff.).

[14] For an excellent, recent discussion of Boorse's biostatistical theory of function, see Kingma (2010).

of normativity is problematic because it entails that, e.g., eyes are only supposed to contribute to vision if that is what eyes actually do statistically speaking. A statistical norm is basically a descriptive claim, not a normative claim about what a trait is supposed to do. The problem can be illustrated by imagining a case in which most people suddenly went blind. The statistical account implies that in such a case human eyes would cease to have the function of seeing. However, as Neander (1991, p. 182) points out, the correct description of this kind of case certainly seems to be that human eyes have the function of seeing, but a majority of them cease to perform their function properly.

A similar problem arises with respect to the propensity theory of Bigelow and Pargetter (1987). According to the propensity account of function, the function of a part of an organism, such as the human heart, is its disposition to enhance the chance of survival and reproduction, or the fitness, of the organism that has it. However, like Cummins' and Boorse's accounts, the propensity theory is unable to equip biological functions with a normative aspect. As Neander points out, a malfunctioning part does not dispose its bearer to survive and reproduce, but according to the propensity theory, this is not a case of a part that malfunctions but a case of a part that does not have a function at all (see Neander 1991, p.183).

It is by virtue of grounding the normativity of organismic functions that the aetiological theory is attractive to the biocentrist. Varner's own presentation of why he thinks the aetiological theory is appropriate is rather short (1998, p. 68). Hence, I will attempt to reconstruct the line of reasoning that I think underlies Varner's characterisation of biological interest in terms of aetiological functions.

The core service that the aetiological theory seems to provide for Varner's theory is that it can be used to make sense of the idea that when we say of something, e.g., a human organism, that it has an interest in vitamin C, it means that preventing a human organism from consuming vitamin C would result in various forms of organ failure. Similarly, when we say that a cherry tree has an interest in sunlight and water, this means that if prevented from getting these things, its parts will dysfunction. In contrast, according to the dispositional or descriptive analyses of function, to say that, e.g., vitamin C is in the interest of an organism, has nothing to do with whether or not having it results in organic defects; it is simply to say that vitamin C plays a causal role in relation to the organism's capacity to realise a certain behaviour, e.g., a certain form of protein synthesis.

Furthermore, biological interests, as defined in terms of the aetiological theory, will be interests that organisms have independent of the interests that humans take in them. Consider again a tree. The reason why a tree has an interest in sunlight is not relative to what interest an external agent has in the tree, e.g., that it grows fast. It is relative to the proper functioning of the parts of the tree itself, i.e., non-derivative. Thus, Varner's appeal to the aetiological theory establishes an intimate relationship between functions, normativity and interest on the basis of the aetiology of an organism and its parts.

Defining biological interests in terms of the aetiological theory of function also allows Varner to meet another requirement of his theory, namely that it must be possible to determine the interests of an organism in a non-arbitrary way (see Varner 1998, pp. 64–65). Whether or not something is in the biological interest of a non-sentient organism depends on objective facts about its evolutionary history, even if such facts are likely to be very difficult to discover in practice.

Summing up this section, I have shown how the aetiological theory of function is well-suited for Varner's biocentrist agenda because, unlike its dispositional competitors, it can ground the normative aspect of biological function.

5 Biological Interests and Synthetic Biology

I have presented Varner's account of biological interest. Trees and other non-sentient organisms have biological interests by virtue of having parts and subsystems with normative functions conferred on them by their history of natural selection. In this section of the paper, I will present a line of criticism of Varner's theory that is based on current work in synthetic biology. I argue that the possibility of artefactual organisms illustrates a problematic general feature of theories of biological interest that are grounded in aetiological accounts of biological function.

My focus will be on a problem that arises as a consequence of identifying the normative function of organismic parts with the effects that they have been selected for. The problem is that aetiological theories sever the relation between normative function and the current causal powers/effects of the function bearer. Here, my aim is not to assess whether the aetiological theory should be rejected as a theory of functions on the basis of this and other objections. Aetiologists are well aware of the problem and (as we have seen in "Section 3") their standard reply is that we cannot get, from any single theory of function, both normativity and a dispositional analysis that refers to the current causal capacities of the function bearer. Nevertheless, the historical aspect of the aetiological theory results in a highly objectionable consequence for Varner's biocentrism, and thus, in the next section, I will suggest that a functional account of non-derivative biological interest should appeal to an alternative account of normative function. However, first I will present my criticism, and in order to do so, it will be necessary to introduce the emerging field of synthetic biology and the notion of an artefactual organism.

5.1 Synthetic Biology and Artefactual Organisms

One of the defining aims of synthetic biology is to develop the ability to rationally design and fabricate organic systems or parts of such systems that have no natural counterparts.[15] Two approaches are standardly distinguished: a top-down approach that aims to create new forms of life by modifying extant life forms and a bottom-up approach which aims to create living systems from nonliving materials ("from scratch").

The top-down approach is exemplified by synthetic genomics research such as the widely reported project at the J. Craig Venter Institute. The ultimate goal of the synthetic genome approach is to develop a process which allows for large-scale production of microbial life, tailor-made to perform a wide range of useful functions, such as generating hydrogen for fuel or capturing excess carbon dioxide in the atmosphere.

[15] A similar characterisation can be found in Douglas and Savulescu (2010). Another influential definition of synthetic biology is that it is "the design and construction of new biological parts, devices and systems, and the redesign of existing, natural biological systems for useful purposes" (SynBERC 2012).

In 2010, a group of researchers from the J. Craig Venter Institute published a widely reported article presenting how they had created the world's first chemically synthesised genome (see Gibson et al. 2010). The research group fabricated a copy of the genome of the microorganism *Mycoplasma mycoides* and inserted it into an already living cell that was stripped of its original genome. The resulting microorganism, *Mycoplasma mycoides JCVI-syn1.0*, is a living, self-replicating cell controlled by a genome that has been spliced together by humans. It is worth emphasising that the synthetic genome is a man-made copy of the genome of an already existing bacterium. Commenting on the result, one of the members of Venter's team remarked that:

> With this approach we now have the ability to start with a DNA sequence and design organisms exactly like we want. (…) We can get down to the very nucleotide level and make any changes we want to a genome (Katsnelson 2010).

Venter et al.'s achievement means that it is now possible for humans to initiate a lineage of cells with genomes descending from a synthetic genome. An implication is that this will result in organisms and forms of life that have never existed before, and, depending on how we draw the distinction between modifications of existing life and the creation of entirely new forms of life, this may be technically true of Venter's organism. Thus, according to Preston (2008), there is a fundamental difference between synthetic biology and traditional biotechnology such as breeding and genetic engineering:

> In every case of traditional biotechnology—even in the case of transgenic organisms—the genome on which the modification takes place is either the product of natural evolutionary processes or is the descendent of such a product. In every case in traditional biotechnology, there exists prior to the modification a viable organism on which the manipulation takes place. This is not the case in synthetic biology. Synthetic biology does not start with a viable genome and modify it. It starts afresh with bio-bricks [DNA sequences with a defined structure and function] possessing known properties. There is no existing genome that undergoes modification. In the current state of the technology, the synthetically engineered DNA sequences have all been inserted into existing single-celled organisms. The idea, however, is not to preserve properties of the existing bacteria with modified behaviour. It is to create an entirely new organism with DNA constructed in its entirety according to human plan. The products of synthetic biology do not borrow any genetic function from genomes produced by the historical evolutionary process. To the contrary, synthetic biology is guided by the idea of leaving evolution and existing genomes behind in order to do a better job of creation with human goals in mind (p. 33).

If Preston is right, then synthetic biology seems to present a challenge to the aetiological theory of normative function similar to the challenge raised by the possibility of instant organisms widely discussed in the literature on functions.[16]

[16] For elaborate discussion of how the aetiological theory may deal with the alleged possibility of instantly created swamp organisms, see, e.g., Millikan (1996) and Neander (1996). See Davidson (1987) for the original swamp case scenario.

However, I find that Preston overstates the extent to which the synthetic organism, resulting from a process of synthesising a naturally occurring genome and inserting it into an enucleated cell, presents a radical break with natural evolution.

First, I think it is questionable whether replacing the genome of a cell with a synthesised copy of another naturally occurring genome, despite the significance of the genome in the functioning of the synthetic cell, amounts to a radical break with evolution. After all, a large proportion of the synthetic cell is made up of other crucial parts from the original cell. Thus, all the sub-cellular structures (mitochondria, liposomes, etc.) necessary for vital processes, such as the metabolism of the synthetic cell, are not synthetic but products of natural evolution.

Second, the synthesised genome in the synthetic cell created by Venter's group (except for a few "watermarks") is a copy of a naturally evolved genome and may, therefore, be considered a reproduction of a naturally existing genome albeit with an extraordinary causal history. As a matter of fact, synthetic biologists recognise that it is unlikely that humans will be able to design a synthetic genome in the near future that is not, largely, a copy of a naturally occurring genome with some useful modifications. Despite the impressive technical achievements in synthesis and transplantation of genomes, there is still a "very poor ability to de novo design (writing) genomes" (Porcar et al. 2011, p. 2). Thus, I submit that while synthetic genomics may shortcut natural evolution in various ways by creating organisms with genomes unlikely to arise through natural evolution, it is not likely to produce synthetic organisms that constitute a radical break with ordinary evolutionary processes.[17]

Preston's description of synthetic biology better describes the potential products of the bottom-up approach. Bottom-up synthetic biology is exemplified by protocell research. Protocells are characterised as microscopic, self-organising, evolving entities that spontaneously assembled from simple organic and inorganic materials. In the words of Bedau and Parke (2009):

> Protocells are alive; they are similar to single-celled organisms like bacteria, in that they grow by harvesting raw materials and energy from their environment and converting it into forms they can use, they sense and respond to their environment and take steps to keep themselves intact and pursue their needs, and they reproduce and ultimately evolve (p. 1).

One of the leading synthetic biology researchers, Martin Hanczyc (2011), provides the following description of the creation of simple protocells:

> The construction of a protocell begins with different types of both natural and synthetic molecules. The chemical and physical properties of individual molecules govern their formation into higher-order structures, such as synthetic cell membranes. The structures are collections of hundreds of millions of molecules that then possess properties not present in the individual molecules. Some structures, such as synthetic protocells, resemble roughly the architecture of

[17] It is also important to note that synthetic organisms will be subject to natural selection. When they reproduce, they will, in the appropriate circumstances, bring forth descendants that will constitute a population of organisms with members that vary with respect to traits that have an impact on fitness. See Sandler and Simons (2012) for similar criticisms of Preston.

> living cells with the same size scale (p. 27). (…) Because this type of protocell contains an interface boundary that is highly sensitive to the chemical environment, it is able to sense and respond to gradients in that environment (p. 28) (…) Due to the method of construction, the protocell may be programmed to contain various chemistries and metabolisms, from simple to complex. The protocell can therefore be programmed to consume or produce [products] selectively in a given environment (2011, p. 31).

The bottom-up approach of protocell research may very well enable synthetic biologists to create a minimal living system from non-living chemical components (i.e., "from scratch"). Artefactual organisms will be self-assembling and self-organising systems which are complex enough to instantiate crucial life processes such as metabolism, replication and the capacity to evolve without relying on components of natural life forms. Furthermore, as Hanczyc points out, protocells may be programmed to respond to their environment in useful ways, and thus serve as instruments, e.g., for consuming certain unwanted substances (e.g., CO_2) and/or producing other valued substances that may be used for clean energy production or in phamaceuticals.

In the rest of this paper, I will focus on the possibility of artefactual organisms. Unlike a synthetic organism, an artefactual organism is made from scratch in the way envisioned by protocell research without using material from extant life forms.

5.2 Artefactual Organisms and Biological Interests

The possibility of artefactual organisms provides an interesting challenge to any definition of biological interest that appeals to an aetiological theory of normative function. Consider Arto, an artefactual organism produced along the lines suggested by protocell researchers, except that it has not been programmed to do anything, but is able to survive and reproduce in a petri dish by virtue of having a physical boundary delineated by a membrane, the capacity to transform energy and grow (a metabolic network inside the boundary), and a genome that controls metabolism and enables replication.[18]

One of Arto's traits is its membrane, which plays a crucial role for Arto's survival and reproduction because it acts as a selective filter that allows only certain kinds of matter to enter and exit the cell. For example, some of the matter allowed to enter is transformed by Arto's metabolism to be used for, among other things, the growth and maintenance of the membrane itself. Imagine that at some point Arto's membrane is "damaged" in such a way that it is no longer able to control the inflow and outflow of matter to the degree required for Arto's survival, including Arto's capacity for maintaining the membrane itself.[19]

The aetiological theory entails that Arto's membrane would not have a biological function because Arto is an organism whose parts have not been shaped by natural

[18] My presentation relies on information found at http://flint.sdu.dk/index.php?page=protocell. For a recent overview of protocell research, see Rasmussen et al. (2009).

[19] Strictly speaking, it will not be correct to assert that Arto's membrane is damaged when it ceases to filter matter because this presupposes that there is something it is supposed to do, and according to the aetiological account there is not.

selection, even if, in a purely descriptive sense, this is what it does.[20] This means that, according to Varner's theory, Arto does not have a biological interest in the filtering of matter by its membrane. In turn, this means that there is nothing biologically wrong with Arto's membrane when it ceases to control the flow of matter in and out of Arto. Since Arto's membrane does not have "filtering" or any other effect as its biological function, it is not a case of biological malfunction when it ceases to have that effect.

Varner's theory requires that he reject the claim that Arto's interests are frustrated when its membrane ceases to filter matter. Arto does not have non-derivative biological interests because it does not descend from a population of organisms that has been subject to natural selection.[21] Varner is aware of this consequence, and he acknowledges that, according to his theory, there are possible scenarios in which some living organisms will not have biological functions and biological interests, and he admits that this makes his case for biocentrism *partial* (1990, p. 253; 1998, p. 70).

Now, my claim is that we can make the case for biocentrism *complete*.[22] Ultimately, this would enable the biocentrist, who thinks that yeast cells have non-derivative interests and that those interests are harmed when their membrane is damaged, to maintain that when Arto's functionally equivalent membrane ceases to filter matter, this is equally a state of affairs that frustrates Arto's interests. In the next section, I outline a theory of normative function that grounds the normative functions of organismic parts in the organisational, rather than historical, properties of individual organisms. In the final section, I show how this enables the biocentrist to recognise the biological interests of both natural and artefactual organisms.

6 The Organisational Approach to Normative Functions

I have argued that Varner's account of biological interest is unsatisfactory because it denies ascription of biological interests to organisms that have non-derivative interests in the way that trees and yeast cells do. In this section, I will offer an analysis of biological function which better suits Varner's definition of biological interest. More specifically, I will argue that the organisational account of function developed by Collier (2000); Christensen and Bickhard (2002); Mossio et al. (2009); and Saborido et al. (2011) provides a coherent and plausible analysis of biological function that is able to ground the normative aspect of function ascriptions. According to the organisational approach, the teleological and normative dimensions of biological function ascriptions are analysed in terms of the organisational features of organisms

[20] Arto's membrane might still be said to have a normative function according to the aetiological account, but in that case, it would be an artifactual function, i.e., a function that has been conferred on the membrane by the intentions of the bioengineers who have created Arto. However, artifactual functions do not give rise to non-derivative biological interests as defined by Varner.

[21] Furthermore, as I have pointed out, Arto might replicate itself, and in case the replication process results in a population that varies with respect to fitness-enhancing traits, Arto's descendants will come to possess normative functions and biological interests. However, it is also worthy to observe that in case Arto's descendants do *not* come to form such a population, then they will not acquire interests of their own. Thus, whether or not Arto's descendants will come to possess interests of their own depends on whether and when variation with respect to the right kind of traits arises in the population.

[22] I will assume that, while Varner and other biocentrists may not consider the partiality of his account to present a knock-down objection to it, they would prefer an account that is complete.

and not with reference to their origin in natural evolution. In what follows, I will outline the main theses of the organisational approach, which I think will be adequate for the purposes of this paper. I will focus on the most recent account given by Saborido et al. (2011).[23]

Proponents of the organisational approach begin by pointing out that it is by virtue of being self-maintaining systems that organisms realise "the relevant causal regime in which the teleological and normative dimensions of functions can be adequately naturalized" (Saborido et al. 2011, p. 592). Self-maintenance is characterised as a property of systems that are able to exert a causal influence on their surroundings in order to maintain (at least some of) the boundary conditions required for their own existence. A standard case of a self-maintaining system is a candle flame:

> [A candle flame] maintains above combustion threshold temperature. It vaporizes wax into a continuing supply of fuel. In a standard atmosphere and gravitational field, it induces convection, which pulls in continuing oxygen and removes combustion products. A candle flame, in other words, tends to maintain itself; it exhibits self-maintenance (Bickhard 2000).

Saborido et al. (2011) argue that the fact that a system maintains itself makes good sense of the claim that the system is teleological; it exists because of something it does. One case that seems to support this claim is a living cell, the paradigmatic case of a natural teleological system. Like Arto described in "Section 5.2", a living cell exists partly because of something it does. For example, cells produce their own physical boundary, their membrane, which facilitates the transportation of matter and energy necessary for the survival of the cell including its capacity for generating and repairing the membrane. Perhaps surprisingly, the organisational account also claims that flames are teleological systems. By virtue of causing the combustion of gasses in its vicinity, a flame continues to create the conditions under which it is capable of performing that very activity.

The fact that self-maintaining systems are teleological also confers a normative dimension on their activities. Because self-maintaining systems are causally responsible for producing some of the conditions necessary for their own existence, they are subject to norms of performance. There are certain effects that a cell or a flame is supposed to bring about in order for it to persist. In the words of Saborido et al. (2011):

> [The] mutual dependence between their existence and activity, which is specific to self-maintaining systems, provides an intrinsic and naturalized criterion to determine what norms the system, and its parts, are supposed to follow.

[23] The following presentation is not intended as an argument for the organisational approach, which I will assume is a plausible alternative to the well-known aetiological and dispositional analyses of function. Mossio et al. (2009) and Saborido et al. (2011) provide a detailed defence of the view. For important developments and critical discussions of the organizational approach, see Schlosser (1998), McLaughlin (2001) and Delancey (2006). Saborido et al. (2011) distinguish two versions of the organisational account in terms of whether they focus on the self-reproduction of traits (Schlosser 1998; McLaughlin 2001) or on the organisation of the system (Collier 2000; Christensen and Bickhard 2002; Mossio et al. 2009; Saborido et al. 2011).

> The conditions of existence of the system are here interpreted as the norms of its own activity: the flame must behave in a specific way, otherwise it would cease to exist (p. 593).

Varner introduces an aetiological theory of the biological function of organismic parts because it grounds teleology and normativity in organisms and thus it allows us to ascribe interests to them. The organisational account provides an alternative and coherent way of understanding the teleological organisation of organisms that does not require that they have been shaped by natural selection.[24] According to the organisational theory, self-maintenance is sufficient for teleology and normativity.[25] In the next section, we will see how this feature of the organisational account plays out in a revised version of Varner's definition of biological interest.

7 An Organisational Account of Biological Interest

Varner's suggestion was that we accept the aetiological account of biological function and define the notion of biological interest thus:

> Non-sentient organisms have a biological interest in X if and only if X contributes to the fulfilment of some biological function (1998, p. 68).

According to the organisational account of biological interest that I want to propose, biological interest is defined in terms of the notion of self-maintenance, as follows:

> Non-sentient organisms have a biological interest in X if and only if X contributes to the organism's self-maintenance.

Consider first the problem case of Arto, the artefactual organism. On the basis of the organisational account, we can ascribe non-derivative biological interests to Arto, despite its lack of a natural selection history. For example, Arto has an interest in the regulation of inflow and outflow of matter affected by its membrane because it is partly by virtue of the causal regime affected by the membrane that Arto is capable of the metabolic processes that keep Arto viable including the production and repair of the membrane itself.

Secondly, in addition to allowing for ascription of biological interests to artefactual organisms, the organisational account also has the virtue of providing an answer to the epistemological requirement that it must be possible to specify the biological interests of non-sentient organisms in a non-arbitrary way (see Varner 1998, p. 64). As I have already noted, the aetiological account suffers from practical inapplicability even if it may provide a principled guideline for determining biological interests. Even in the case of very simple organisms, determining their evolutionary history and whether their parts have been selected for their current activity in relation to past

[24] In order for the parts of a self-maintaining system to have functions, the system of which they are a part must also realise a specific kind of organisation, what Saborido et al. (2011, p. 593) call *organizational closure*. For a more detailed and valuable discussion of the contrast between the organisational and the aetiological approach to analysing function, see Christensen and Bickhard (2002).

[25] I am grateful to an anonymous referee for encouraging me to clarify this point.

environments can, in some cases, be quite difficult. In contrast, the organisational account makes it possible to determine the interests of a non-sentient organism on the basis of observation of its internal organisation and activity in relation to its current environment.

Thirdly, it may be asked whether the organisational account can support "the empirical claim" that organisms have non-derivative interests in a sense in which artefacts do not (see Varner 1998, p. 62). One might object that the organisational account will be troubled by the fact that there may come to exist artefacts, e.g., highly complex robots, which meet the required self-maintaining organisation. In reply to this criticism, one can point out that the claim is *empirical*, i.e., it might not be true at all times.[26] In any case, if we accept the organisational account, then the above empirical claim is true at least with respect to all past and present artefacts on which our intuitions are based.

Cashing out the notion of biological interest in terms of organisational maintenance should be attractive to the biocentrist because it does not involve ascribing normativity to parts of the organism per se. The parts of an organism are only supposed to do something in relation to the viability of the whole system, not in relation to norms governing their own type. This means that a biocentrist theory of biological interest grounded in the organisational account avoids the possibility of conflict between what an organismic part is supposed to do (i.e., what it has been naturally selected for) and what is in the interest of the organism.[27] The problem is that in some cases, a part of an organism may be selected for an effect that clearly seems to be detrimental to the good of the organism. For example, "the oncogene" in oncomice is selected for causing cancer, and thus Varner's theory entails that oncogenes are supposed to cause cancer, but cancer is clearly not in the interest of the organism.[28]

In sum, an alternative organisational account of biological interest is superior to Varner's aetiological account because it (i) can accommodate both artefactual and naturally evolved organisms, (ii) provides not only a non-arbitrary but also a practical way of determining biological interests, (iii) supports the claim that organisms have interests in a sense in which artefacts do not, and (iv) avoids the possibility of there being a conflict between what an organismic part is supposed to do and what is in the interest of the organism.

I will end by noting what I take to be the main problem facing the account of biological interest that I have proposed. If, with biocentrists, we think that all teleological systems have interests, then it would seem that the organisational account implies that flames and hurricanes will have interests in the same sense as flowers and butterflies. This consequence may seem implausible or even worse it may be viewed as an absurd consequence that amounts to a *reductio* of the theory.

As I see it, there are two ways to respond to this problem. One way is to bite the bullet. Another option would be to find some additional feature of organisms that would allow us to claim that self-maintenance is necessary but not sufficient for

[26] A similar claim is made in Delancey (2004).

[27] I owe this significant point to an anonymous referee.

[28] See also Delancey for a discussion of the case of oncomice in relation to Varner's aetiological theory of biological interest.

having interests. To have interests, one might argue, a self-maintaining system must possess additional features. For example, in order to exclude flames and other dissipative structures, one could suggest that a self-maintaining system must also realise organisational differentiation in order for it to have interests:

> A self-maintaining system is organizationally differentiated if it produces different and localizable patterns or structures, each making a specific contribution to the conditions of existence of the whole organization (see Mossio et al. 2009, p. 826).

That a candle flame is not an organisationally differentiated system is clear from the fact that it does not produce and regenerate mutually dependent substructures, which integrated activity enables it to maintain itself. In contrast, an organisationally differentiated system, paradigmatically a living cell, consists of a variety and hierarchy of mutually dependent material structures, which coordinated activity enables the cell to maintain itself and, in turn, enables it to maintain those very structures.

In my view, the way to go is to bite the bullet, and I don't think that it should be a hard bullet to bite. Naturalising teleology and normativity in the biological domain is an enterprise that may lead to a shift in the kind of objects to which we think these concepts apply. Importantly, the fact that the organisational approach entails that inorganic systems are teleological systems that have interests need not commit us to the claim that these interests are morally considerable. This is a question for another paper.

Acknowledgments I would like to thank two anonymous referees for their very helpful comments and the participants in the SYBHEL Project for valuable discussions. The research for this paper has been supported by the Danish Research Council (FKK) and Center for Synthetic Biology at University of Copenhagen funded by the UNIK research initiative of the Danish Ministry of Science, Innovation and Higher Education.

References

Amundson, R., & Lauder, G. V. (1994). Function without purpose: the uses of causal role function in evolutionary biology. *Biology and Philosophy, 9*, 443–469.

Bedau, M., & Parke, E. (Eds.). (2009). *The ethics of protocells moral and social implications of creating life in the laboratory*. Cambridge, MA: MIT Press.

Bickhard, M. H. (2000). Autonomy, function, and representation. *Communication and Cognition—Artificial Intelligence, 17*, 111–131.

Bigelow, J., & Pargetter, R. (1987). Functions. *Journal of Philosophy, 84*, 181–196.

Boorse, C. (1976). Wright on functions. *Philosophical Review, 85*, 70–86.

Boorse, C. (2002). A rebuttal on functions. In A. R. Ariew, R. Cummins, & M. Perlman (Eds.), *functions* (pp. 63–112). Oxford: Oxford University Press.

Christensen, W. D., & Bickhard, M. H. (2002). The process dynamics of normative function. *The Monist, 85*, 3–28.

Collier, J. (2000). Autonomy and process closure as the basis for functionality. *Annals of the New York Academy of Sciences, 901*, 280–291.

Cummins, R. (1975). Functional analysis. *Journal of Philosophy, 72*, 741–764.

Davidson, D. (1987). Knowing one's own mind. *Proceedings and Addresses of the American Philosophical Association, 60*, 441–458.

Davies, P. S. (2001). *Norms of nature. Naturalism and the nature of functions*. Cambridge, MA: MIT.

Delancey, C. (2004). Teleofunctions and oncomice. *Environmental Ethics, 26*, 171–188.

Delancey, C. (2006). Ontology and teleofunctions. *Synthese, 150*, 69–98.
Deplazes, A. (2009). Piecing together a puzzle. *EMBO Reports, 10*, 428–432.
Douglas, T., & Savulescu, J. (2010). Synthetic biology and the ethics of knowledge. *Journal of Medical Ethics, 36*, 687–693.
Feinberg, J. (1974). The rights of animals and unborn generations. In W. T. Blackstone (Ed.), *Philosophy and Environmental Crisis*. Athens, GA: University of Georgia Press.
Gibson, D. G., et al. (2010). Creation of a bacterial cell controlled by a chemically synthesized genome. *Science, 329*, 52–56.
Godfrey-Smith, P. (1994). A modern history theory of functions. *Noûs, 28*, 344–362.
Goodpaster, K. (1978). On being morally considerable. *Journal of Philosophy, 75*, 308–325.
Griffiths, P. E. (1993). Functional analysis and proper functions. *British Journal for the Philosophy of Science, 44*, 409–422.
Hanczyc, M. (2011). Structure and the synthesis of life. *Architectural Design, 81*, 26–33.
Katsnelson, A. (2010). Researchers start up cell with synthetic genome. *Nature*. doi:10.1038/news.2010.253.
Kingma, E. (2010). Paracetamol, poison, and polio: why Boorse's account of function fails to distinguish health and disease. *British Journal for the Philosophy of Science, 61*, 241–264.
McLaughlin, P. (2001). *What functions explain—functional explanation and self-reproducing systems*. Cambridge: Cambridge University Press.
Millikan, R. G. (1989). In defense of proper functions. *Philosophy of Science, 56*, 288–302.
Millikan, R. G. (1996). On swampkinds. *Mind and Language, 11*, 103–117.
Mitchell, S. D. (1995). Function, fitness, and disposition. *Biology and Philosophy, 10*, 39–54.
Mossio, M., Saborido, C., & Moreno, A. (2009). An organizational account of biological function. *British Journal for the Philosophy of Science, 60*, 813–841.
Neander, K. (1991). Functions as selected effects: the conceptual analyst's defense. *Philosophy of Science, 58*, 168–184.
Neander, K. (1996). Swampman meets swampcow. *Mind and Language, 11*, 118–129.
O'Malley, M. A., et al. (2008). Knowledge-making distinctions in synthetic biology. *Bioessays, 30*, 57–65.
Porcar, M., et al. (2011). The ten grand challenges of synthetic life. *Systems and Synthetic Biology, 5*, 1–9.
Preston, C. (2008). Synthetic biology: drawing a line in Darwin's sand. *Environmental Values, 17*, 23–39.
Rasmussen, S., et al. (2009). *Protocells: bridging nonliving and living matter*. Cambridge, MA: MIT.
Regan, T. (1976). Feinberg on what sorts of beings can have rights. *Southern Journal of Philosophy, 14*, 485–498.
Saborido, C., Mossio, M., & Moreno, A. (2011). Biological organization and cross-generation functions. *British Journal for the Philosophy of Science, 62*, 583–606.
Sandler, R., & Simons, L. (2012). The value of artifactual organisms. *Environmental Values, 21*, 43–61.
Schlosser, G. (1998). Self-re-production and functionality: a systems–theoretical approach to teleological explanation. *Synthese, 116*, 303–354.
Singer, P. (1975). *Animal liberation: a new ethics for our treatment of animals*. New York, NY: Random House.
Singer, P. (1979). The place of nonhumans. In K. E. Goodpaster & K. M. Sayre (Eds.), *Ethics and problems of the 21st century* (pp. 191–206). Notre Dame, IN: University of Notre Dame Press.
SynBerc (2012). http://www.synberc.org/content/articles/what-synthetic-biology accessed 16 March 2012.
Taylor, P. W. (1986). *Respect for nature*. Princeton: Princeton University Press.
Varner, G. (1990). Biological function and biological interest. *The Southern Journal of Philosophy, 28*, 251–270.
Varner, G. (1998). *In nature's interests? Interests, animal rights and environmental ethics*. Oxford: Oxford University Press.
Wright, L. (1973). Functions. *Philosophical Review, 82*, 139–168.