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Citation for published version:

Schyfter Camacho, P 2015, 'Function by Agreement' *Social Epistemology*, vol 29, no. 2, pp. 185-206. DOI: 10.1080/02691728.2013.796426

Digital Object Identifier (DOI):

[10.1080/02691728.2013.796426](https://doi.org/10.1080/02691728.2013.796426)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Social Epistemology

Publisher Rights Statement:

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Function by Agreement

Pablo Schyfter

Abstract

Philosophers of biology have developed an extensive literature on biological functions. Here I propose a treatment of the topic based in social studies of science. I posit that the chief philosophical accounts of biological functions all rest upon a realist ontology of biological functions, one that conceives functions as human-independent qualities of things. Rather than being conceptualised as a property of traits or structures, function should be understood as a status granted by communities acting in accordance with specific domains of knowledge and practice. Function becomes not a property of things, but a collective good: not of things, but by communities. I survey the existing explanations of biological functions from the philosophical literature and identify what I take to be those accounts' shared complications. I then employ Martin Kusch's communitarian epistemology as a point of departure for a sociological conception of function and develop an explanation of function that rests on an understanding of it, as a status granted by epistemic communities. I follow by illustrating the usefulness of my account by means of a case study from synthetic biology—a nascent field of bioengineering. Finally, I discuss function as a conferred status deeply involved in collective ordering practices.

Keywords: Function; Synthetic Biology; Philosophy of Biology; Kusch

Introduction

That the biological sciences employ concepts suggestive of teleology has been a focus of curiosity and concern for philosophers, and has given rise to an expansive literature on what such concepts mean, entail, and require to be less disquieting. Most significantly, philosophers have problematised statements of biological function—for instance, ‘the function of the heart is to pump blood’—and have sought to exorcise the teleological demon implicitly present in such statements of purpose and ends. These efforts have produced an extensive and diverse literature on the topic of biological functions. Social studies of science, although equally concerned with examining institutions of science, have not dedicated comparable attention to the matter of function in living things¹. There are compelling reasons to remedy this gap in the literature, and my article presents an initial step in this undertaking.

I posit that the chief philosophical accounts of function in the biological sciences all rest upon a ‘realist ontology’ of biological functions, and demonstrate that an alternative position, based on precepts from social studies of science and the sociology of knowledge, may lead to better-suited methodologies and analyses. Rather than being conceptualised as a property of traits or structures, function should be understood as a status granted by communities acting in accordance with specific domains of knowledge and practice. Rather than conceive of *function* (a noun) as a human-independent and asocial quality, traits and structures should be understood as rendered *functional* (an adjective) in contingent, communally-specific ways. Function by this view is then not a property of things, but a collective good: not *of things*, but *by communities*. As a collective good, function reflects the character of those scientific groups within which it is developed as a concept and attributed to parts of living things. That is, function is conventional.

It is not a status granted arbitrarily, but because of particular causes, including social and physical ones.

My argument first surveys the major explanations of biological functions from the philosophical literature and identifies what I take to be those accounts' shared complications. I then present my own position on the matter—taking as a point of departure Martin Kusch's communitarian epistemology—and discuss its chief implications. I follow by illustrating the usefulness of my account by means of an empirical case study from synthetic biology: the production of photosensitive *Escherichia coli* and bacterial 'photography'. Last, I present function as a conferred status deeply involved in collective ordering practices: a social phenomenon through and through.

Before presenting my argument, a word on the nature and balance of its content is warranted. This article dedicates considerable attention and space to examining various theories from the philosophy of biology, as well as presenting my competing understanding of function. The focus given to philosophy and social theory is perhaps greater than commonly found in the science studies literature, and that given to empirical material less than ordinary. I ask of the reader to view this discrepancy as a necessary condition for this argument. As has often been the case in social studies of science, familiarity with the philosophical literature can contribute to a robust social perspective. I explore the philosophy of biology's work on function in order arrive at a sociological account useful for science studies.

Functions as properties

While circumscribed to a general sphere of enquiry, philosophical analyses of biological function are varied in their particular interests and applicability (see Ratcliffe, 2000). Nonetheless, the chief accounts of function share a common postulate: that functions exist as ‘*real*’ⁱⁱ, *human-independent properties of traits or structures*. I refer to this position as a ‘realist ontology of functions’. Although the three explanations of function surveyed here do so in different ways, each invests function with the quality of a human-independent, asocial property (each subscribes to a ‘realist ontology of function’). In contrast, my own position advocates a conceptualisation of function as *status*. At this point, I believe it necessary to note that while I refer to a particular ‘ontology’ of function, my concerns here are more epistemological than ontologicalⁱⁱⁱ. That is, my interest concerns knowledge claims regarding functions. These have ontological ramifications, but the focus of this article is epistemic.

Etiology and proper functions

Originally devised by Larry Wright (1973), etiological accounts conceive of function as that for which traits or structures were selected: *why* they exist in nature. Wright formulated this claim as follows:

‘The function of X is Z’ *means*:

- X is there because it does Z
- Z is a consequence (or result) of X’s being there

(1973: 161, emphasis original)

Thus, a statement such as ‘the function of the heart is to pump blood’ encompasses two intertwined claims: first, that hearts exist because they pump blood; second, that pumping blood is a result of the existence of hearts. Pumping blood is the “historical *raison d’etre*” (Millikan, 1999b: 119) of hearts.

Wright’s parsimonious definition of function has since been supplemented with qualifications, although its insistence that function refers to the ‘whence’ of traits and structures has remained undisturbed. Ruth Millikan’s notion of ‘proper functions’ is perhaps the most prominent and certainly the most influential (1998, 1999a) of the latter-day etiological accounts of function. Millikan carries Wright’s historical emphasis further: function is to be understood solely with regard to the evolutionary history of a trait or structure, rather than any current qualities or capabilities (Buller, 1999). Thus, the heart’s current physical capability to circulate blood does not define its proper function. Instead, the heart’s evolutionary history as a structure that has been preferentially selected determines the organ’s proper function. ‘Proper functions’—a technical term devised by Millikan and defined as explicitly distinct from common uses of ‘function’—are those properties of a trait that account for its selective success.

Etiological—cause-based—accounts of function serve explanatory and descriptive purposes. Wright took functions as properties of traits or structures that explain why those traits or structures exist (an explanatory aim). Other authors have taken the real purpose of etiology as descriptive. I believe that such a descriptive role cannot be divorced from a broader explanatory aim. That is, I take etiological descriptions ultimately to be in the service of some explanatory

account of organism evolution. In either case, etiological functions are invested with the quality of ‘real’ properties. That functions explain why and how traits were favoured in natural selection suggests that: first, they are qualities independent of human beings and scientific practice; and second, that they exist in such a way as to effect causal relationships between traits and organisms’ survival.

Propensity and fitness

Despite the etiologists’ broad success, a number of scholars have critiqued what they view as an untenable focus on a trait’s or structure’s evolutionary genealogy. Philosophers such as Enç and Adams (1998), and Walsh and Ariew (1999) are unsatisfied with the etiological perspective’s incapacity to account for *new* functional traits or *recent changes* to the functionality of long-present traits. Other critics argue that functions fundamentally cannot be employed in an explanatory capacity: first, because traits are *antecedent* to the functions they enable; second, because all functions are only *potential*, rather than inevitable, capabilities.

Bigelow and Pargetter propose to replace the etiological-historical account with a propensity-based, forward-looking understanding of function (1998). This argument renders biological functions as those capabilities of a trait or structure that *may*, if active at a future time, positively contribute to an organism’s adaptive fitness. Function is that contribution of a trait that has the propensity to increase an organism’s fitness (see also Walsh, 1996). Bigelow and Pargetter’s propensity account—unlike that posited by the etiologists—is ostensibly capable of explicating recent and novel biological functions, and can serve the study of ‘established’ functions as well.

Nonetheless, it does so by giving license to a biologist's prediction of future events, or by necessitating the following caveat: 'one may only *postulate* potential functions; their true quality *as functions* is determinable only by a future empirical analysis of adaptive fitness'. It is also worth noting that this definition relies on a number of contentious and nebulous terms, not the least of which are 'adaptive' and 'fitness'.

Propensity-based explanations of function ultimately serve different ends from those of the etiological accounts. Rather than resolve the question of *why* a particular trait exists, they seek to analyse *how* a particular trait may influence an organism's fitness and adaptive success. The two analyses of biological function are not in themselves exclusive of each other; they may in fact serve as complementary perspectives. At their basis is a shared conception of functions as 'real' properties. For Bigelow and Pargetter, functions are those qualities which enable particular capabilities. To state that functions give traits the propensity to increase an organism's fitness is to endow those functions with a causal role as 'real' properties of the trait, independent of human knowledge-making.

Capacities and analyses

Unlike the two preceding account—as well as the majority of the philosophical literature—Robert Cummins' 'capacity-based argument' (1975) does not engage with evolution, adaptive fitness, selection or any other biologically-specific concept. Cummins does not seek to devise an explanatory account of traits' existence, nor does he aim at a descriptive study of traits' roles in organisms' fitness. Instead, he discusses the manner in which 'functional analysis' may be

employed to partition a system into constitutive sub-systems. Each sub-system manifests a particular ‘capacity’ that is necessary to the working of the encompassing system’s global capacity. Neither the evolutionary history of traits nor their contribution to fitness is a relevant consideration.

By this view, functions are those capacities of component sub-systems that contribute in an indispensable manner to the working of a larger system *according to a particular analytic account*. Cummins argues that it is only within a specific functional analysis that a system is sectioned into constitutive sub-systems, and only within a specific functional analysis are certain capacities and not others chosen as those of interest. For instance, contemporary biology identifies certain key systems, such as the circulatory system. These are divided into constitutive organs, such as the heart. Each organ is then attributed a function based on the overall system’s capacity; the heart pumps blood and enables the circulatory system’s circulation of blood. ‘Pumping blood’ is of interest because the analytic account identifies the circulation of blood as an important phenomenon. Cummins argues that a different account might identify ‘to make beating noises’ as a function of the heart instead. If the individual constructing the functional analysis is a medical practitioner, and the heart’s role as a reporter of internal health conditions is the key axis of analysis, then surely beating noises have tremendous functional value to the doctor armed with stethoscope. Put differently, Cummins does not seek—as do Wright, Millikan, Bigelow and Pargetter, and countless others—to discriminate strictly between effects and ‘true’ functions, or ‘a’ and ‘the’ function of a trait or structure. That form of differentiation is left to the party devising any given functional analysis. The measure is the functional analysis^{iv}.

Cummins' explanation does not recognise intrinsic functionality, and relativises functions as conventions of particular analytic accounts. My understanding of function holds a similar position. Nonetheless, my goal is not to simply modify Cummins' account. Instead, I hope to demonstrate the usefulness of an analysis based in the sociology of knowledge and social studies of science. Importantly, while Cummins offers a compelling account, even he fails to extricate himself entirely from the will to 'naturalise' functions as properties of things. While the analytic account is the measure of relevance, functions are ultimately still grounded in the physical capacities of traits and structures. Functions are capacities—properties of traits.

Shared complications

The three accounts presented above share a number of complications and undesirable implications. Here, I will summarise these. I later return to them in detail. As I have noted, it is my position that existing philosophical accounts of biological function fail by subscribing to a realist ontology of functions. This ontological posture—a conceptualisation of functions as human-independent qualities of things—results in a host of significant problems. As I demonstrate below, these problems are resolved by embracing a perspective from social studies of science and the sociology of knowledge.

First, consider the desire to 'naturalise' biological functions. That is, the will to find some grounding for biological functions in human-independent features of the world, rather than the character of particular epistemic communities. The view that functions are to be located 'out there' among the qualities of living things implies that strict delimitations of which properties

‘count’ as functions are possible. Moreover, the position suggests that such discrimination is also desirable. Philosophers of biology have historically assigned themselves the role of constructing methods for identifying ‘real’ functions and discarding ‘mere’ effects and so-called ‘accidental functions’.

Second, a realist ontology of functions promotes a fragmentation in types of questions about function. In the best of circumstances, two very different questions exist. First: ‘what *are* functions?’ Second: ‘how do biologists *use* the *term* ‘function’?’ If functions are ‘really’ ‘out there’, then these two questions are fundamentally different. The first is ontological, while the second is about epistemology and language.

Third, the functions-as-properties position encourages debates about the reconciliation of biological and technological functions—both of which are ostensibly ‘real’. After all, references to ‘function’ are ubiquitous in everyday speech about technical things and in engineering practice. The function of corkscrews is ‘to remove corks from bottles of wine’. The function of sparkplugs is ‘to ignite compressed fuel in an engine’s cylinders’. Debates about the relationship between biological (natural) and technological (human-made) functions result in the forming of two camps: ‘incommensurabilists’^v and ‘unificationists’^{vi} (for lack of better terms). The former posit strict delimitations between biological and technological functions, while the latter propose a unitary explanation of all function.

Functions as statuses

In contradistinction with the above accounts, I suggest that functions should be understood as *statuses*: enabled and sustained by, and intelligible only within communities of epistemically-coordinated agents. Function is not a property of things; it is a standing within collectives. This conceptualisation remedies the above complications associated with traditional approaches to the question of biological function, and creates a space for empirical research in science studies. Additionally, a status-based enquiry into function can absorb etiology, propensity, and capacity analyses—as well as their unique contributions to the debate—without experiencing their concomitant limitations and complication. I detail the approach here; in the following section, I offer an example of its use.

From sociology of knowledge to function as status

My understanding of functions as statuses follows from Martin Kusch's work on 'communitarian epistemology', articulated most comprehensively in his *Knowledge by Agreement* (2002). While the volume's treatment of knowledge and epistemology encompasses an argument broader than my own here, Kusch's argument is an excellent point of departure. Kusch posits an epistemology for which the community is the measure and final arbiter of knowledge. This position is widely accepted in social studies of science, which views knowledge claims as conventional products of collective human action. Kusch argues:

... the term 'knowledge' and its cognates, like 'know' and 'knower', mark a *social status*—like 'head of department'. It follows from this idea that the existence of knowledge is dependent upon the existence of communities. Social statuses exist only in

so far as there are communities that constitute, impose, or grant these statuses. (2002: 1, emphasis original)

Stated succinctly, Kusch argues that beliefs must be *granted* the status of knowledge. This granting is carried out by communities of epistemically-coordinated agents—that is, by collectives of individual embedded in a shared “nexus of epistemic commitments and entitlements” (2002: 71-72). Knowledge is not a thing that may be possessed like a commodity. Neither is it a mental condition experienced by individuals; indeed, knowledge is *by its very nature* not an individual phenomenon. It is a communal good through and through: without communities^{vii}, knowledge does not exist.

My study of functions follows similar lines. To emphasise its debt to Kusch’s argument, my position may be articulated as:

The term ‘function’ and its cognates, like ‘functional’ and ‘functions as/to’, mark a *social status*.

That particular traits or structure are rendered as functional entities is an act of epistemic communities. Only within such collectives—with their nexus of commitments and entitlements—does and can the attribution of functions occur. This contention is best argued in four steps: first, ‘real’ empirical phenomena underdetermine attributions of function; second, the identification of causal entities is a mode of classification, and is thus conventional; third,

ontological and epistemic commitments will affect teleological claims; last, the ‘existence’ of a *function* (noun) is captured by the act of rendering entities as *functional* (adjective).

Empirical underdetermination

That the empirical world *underdetermines* our knowledge about it is a position that follows from W.V.O. Quine’s masterful work (1973, 1975), and has been a claim central to the development of social studies of science. Quine’s argument holds that all natural science is underdetermined in the sense that scientific practitioners may produce multiple, separate and irreducible frameworks of explanation from the same empirical data: empirical equivalency may lead to theoretical multiplicity. Empirical equivalence need not equate with theoretical identity because natural scientific knowledge is “under-determined not just by past observation but by all observable events” (Quine, 1975: 313). Following work in the sociology of knowledge and social studies of science (see e.g. Barnes, Bloor and Henry, 1996), I take Quine’s work to demonstrate that physical entities and occurrences (empirical evidence) are not in and of themselves sufficient to justify one knowledge claim over another (one theory over another). Quine’s argument speaks volumes to the grounding of biological function in the observation of phenomena.

I take Quine’s argument to suggest that the empirical world presents us with entities and phenomena, but prefers no explanations above others. Empirical observation (and the evidence it produces) does not in and of itself lead to scientific theory (or any kind of scientific knowledge claim). That organisms experience particular events and engage in particular acts cannot secure

the indefatigable validity of any claim of biological function, since claims about biological function are pieces of scientific knowledge. Our observations suggest that hearts are involved in the circulation of blood. Hearts also produce beating sounds. To proceed from either statement to a claim about *the* function that 'it' *has*—that is, to proceed from an empirical statement of phenomena to a claim about the intrinsic properties of entities involved in those phenomena—is to grant argumentative force to that which simply happens. In a similar argument focused on archaeological studies, Rudwick convincingly demonstrates that structure underdetermines functional statements (1998). The physical character of biological fossils cannot result in an unchallengeable claim about the function of traits in ancient organisms. Moreover, suggesting that hearts are 'for' pumping blood or 'for' making beating noises does not interfere with the predictive ability of either claim for what the organ will do at a future instance of observation. That is, each function has equal predictive ability. Each forms part of an internally-consistent and predictively-successful explanatory framework.

While the empirical world certainly constrains the list of plausible claims an observer might make regarding a trait and function, it does not contain the indisputable justification for a single claim about 'the' function of that trait. Indicating that we can observe the heart's action moving blood around the body does not in itself tell us why we should care, nor why we should exclude all other phenomena as possible functions. Biological function does not follow self-evidently from phenomena. The material qualities and behaviour of living things unquestionably matter, but they do not interpret themselves.

Classification and convention

Cummins' capacity-based account of biological function advances a crucial claim. He argues that functional analyses begin with a partitioning of living systems into component elements:

The biologically significant capacities of an entire organism are explained by analyzing the organism into a number of "systems"... each of which has its characteristic capacities. These capacities are in turn analyzed into capacities of component organs and structures. (1975: 760-761)

The act of sectioning an organism into sub-systems and components—even the very notion that such a division is warranted or desirable—is vulnerable to the same underdetermination identified in the preceding section. Traits and structures are of interest only with reference to some given analytic framework, as are the containing systems within which such traits and structures serve a compositional role. The biological sciences have accepted methods for analysing organisms into constitutive systems, organs, tissues, and so forth, but acceptance does not make those methods any less conventional. In fact, collective acceptance is precisely what makes them conventional. The heart is 'for' pumping blood only once researchers have developed an interest in blood and organisms have been identified as possessing a particular system—a circulatory system. Blood may stream through veins independently of science, but the notion that hearts have a specific purpose is a claim bound by epistemic commitments. Those commitments must be established before one can speak of the heart having a particular purpose and causal role. The stuff of organisms must be divided and classified in a particular way to

render functional ascriptions possible, and classification is a conventional practice (see Barnes, 1981 and 1982 for detailed arguments).

The conventional character of biological systems analysis is also evident with regard to causality. Each of the above accounts of function rests—to differing degrees—on the causal power of specific traits and structures. That given traits are able to be selected, have the propensity to increase fitness, or contribute to the capacity of a containing system imply that functions have a causal role as properties of those traits. Such causal arguments are conventional in two senses. First, to argue that a particular trait is implicated in a causal relationship is to accept a particular partitioning of an organism that identifies that trait as a focus of interest. As the previous paragraph argues, such partitioning is a conventional practice. Second, to ascribe a causal role to a trait is to select a specific cause-effect sequence of interest. Cause-effect relationships are relations in time, with no self-evident or indisputable validity^{viii}. To avoid infinite regresses, choices must be made about which events mark the beginning and conclusion of a cause-effect cycle^{ix}. Thus to say that the heart is ‘for’ pumping blood is to limit the event of such pumping to the muscle contractions of the heart. Conceivably, an analysis might argue that the brain is ‘for’ pumping blood, since the nervous system’s electrical signals stimulate the muscle activity needed for circulation. The biological sciences choose to construe the problem otherwise. This is a convention of the field, not an incontestable statement. After all, living things are highly integrated; we divide them and isolate sections to study for pragmatic reasons. Clearly, the choice of which events to study in the first place—in this case, the circulation of blood and the muscle contractions of the heart—is also a decision guided by epistemic commitments.

Theory and purpose

For much of the philosophical literature, the problem of biological function is at heart a problem of teleology's place in the modern biological sciences (see e.g. Allen, Bekoff, and Lauder, 1998; Ayala, 1998; Brandon, 1998; Ruse, 2002). Biologists routinely speak of 'roles', 'functions', and 'purposes', while other contemporary scientific practitioners—for instance, physicists and geologists—do not employ language suffused with teleological connotations. The philosophy of biology initially undertook a project to replace teleology with a 'naturalised' conceptualisation of function. Ratcliffe convincingly argues that an alternative understanding of teleology's place in biology is possible and preferable:

Teleology is to be found, not by examining features of the mind-independent world, but instead examining the structure of the understanding, and the cognitive role that teleology plays... It is a tool or methodological device through which we approach our investigations and not part of the objective worldly subject matter of scientific investigations. (2000: 118)

The study of traits' functions is framed by the assignment (not the discovery) of ends and purposes^x. These ends structure questions to be asked, perspectives to be employed, and help epistemic communities unite in common research efforts. Ruse makes a similar argument in considering what role function plays within biological knowledge-making, and whether it is possible to eliminate function discourse entirely from evolutionary biology (2002).

My claim—that functions should be understood as communally-attributed statuses rather than human-independent properties—follows from Ruse’s and Ratcliffe’s arguments and sits neatly within social studies of science. Of the three accounts of function discussed above, two follow the biological sciences in recognising organismic survival as the appropriate—the *only* appropriate—measure for determining a trait’s function. For Millikan this entails the selective history of a species and the survival of favoured variants; Bigelow and Pargetter emphasise trait’s propensity to increase the likelihood of organisms’ survival. Ratcliffe argues:

Some ends can become so stable that they are implicitly assumed in almost all discussion, like the end of organismic survival in much biological-morphological teleology. (2000: 126)

The stability of this particular epistemic commitment obscures its conventional character. After all, simply because a program of research based on evolutionary theory recognises the survival of organisms as a useful heuristic in inferring function from structure does not give to organism survival indisputable validity or universal epistemic priority.

Epistemic commitments underlie how communities posit teleological claims, which themselves help steward research and justify the assignment of particular functions to given traits or structures. Speaking of the unique epistemic challenges faced by biology vis-à-vis the physico-chemical science, Ruse states:

Different modes of understanding are required, and, thanks to teleology, different modes of understanding are supplied. It is as simple as that. (2002: 56)

Where epistemic hurdles differ, so will epistemic tools. Teleological claims may be useful, or they may find no place. Similarly, differing epistemic commitments will result in differing attributions of function. As Searle argues, to posit beating noises as the ‘true’ function of the heart from within an explanatory system that gives to beating noises epistemic priority is internally consistent and no less valid than our conventional biomedical understanding of the circulatory system (1995).

Function and functional

My argument advocates a departure from accounts that give to functions the quality of human-independent properties of biological things, in favour of a conceptualisation of function as *status* attributed by communities of epistemically-coordinated agents. In a sense, it is the replacing of ‘function’ (a noun) with ‘functional’ (an adjective). The claim ‘the function of the heart is to pump blood’ is supplanted by ‘the biological sciences render the heart functional as an organ that pumps blood’. Here ‘render’ should be read not as ‘make physically capable of, or construct’ but rather as ‘enable a particular representation or understanding, or make intelligible in a specific mode’.

The heart ‘has’ a function insofar—and *only* insofar—as it has a status enabled by a particular epistemic community. Note that denying functions the quality of human-independent properties

is not a promotion of idealism; I am not suggesting that functions are merely in practitioners' heads. Functions are collective goods. Should I—as an outsider to the biological scientific community—propose that hearts are 'for' making beating noises, my claim would not instantly gain acceptance. For that matter, no single biologist can simply bring a functional attribution into being. Attributing functional status to a trait of structure requires communal assent, and that assent depends on such things as experimental procedures, publication of results, refutation of challenges, and congruence with existing knowledge claims. Assent depends on the very processes and practices that social studies of science examines.

Preliminary implications

The claim that functions are communally-contingent statuses, rather than human-independent properties of things, carries with it a number of considerations that challenge basic positions frequently held by philosophers of function. These considerations also create a space for research in science studies.

First, the distinction drawn between 'a' and 'the' function of a trait or structure is not an indisputable principle, nor is it a claim that reflects the ontological 'reality' of functions. To state that *the*, or the *true*, or the *proper*, function of the heart is 'to pump blood', in exclusion of all other potential functions that may be attributed to that organ, is to make a claim already situated within a given nexus of epistemic commitments and entitlements. There exist no indefatigably correct functional statements—all are conventional, all are potentially revisable, and none can claim future validity with absolute certainty.

Second, the questions ‘what *is* a function?’, ‘how is ‘function’ *used*?’, and ‘what does ‘function’ *do*?’ are not distinct queries, as is often held in the philosophical literature. Generally, the first is held to be an ontological question demanding conceptual analysis; the second to be a question about language, discourse, and scientific knowledge; and the third to be about what role—epistemic and methodological—the concept plays in the pursuit of biological knowledge. This strict division of questions is proper to an enquiry committed to a realist ontology of functions; to an analysis of function as status, the distinctions are less pronounced. To exist as a status, functional attribution must be carried out in verbal utterances, written statements, graphical representations, and other manners of communication. The use of the term is not dissociable from the existence of the status, and the form of term use will affect the mode in which the status exists. Consequently, what the concept *does* is in part reflected by the manner in which entities are rendered as functional objects. The work accomplished by the concept, through its use by epistemically-coordinated agents, is among other things the constitution of entities as functional: the term is performative. The three questions listed above cannot be dissociated, nor can they be addressed independently. They are facets of one social phenomenon: the attribution of functional status.

Third, there exists no single account of function capable of explaining all uses and conceptualisations of the term with any disciplinary specificity. That is, no account will capture the nuances of function as it is employed by the biological sciences, while also capturing the subtleties of function as used by mechanical engineers. These two communities are comprised by distinct forms of knowledge and practice, and concurrently each conceives of function distinctly.

An account of function as status makes this plurality and contingency manifest by emphasising the community's role in functional attribution. As I note above, functions tells us less about things than they do about social collectives. To study functions is to study communities. Thus both 'incommensurabilists' and 'unificationists' are shown to hold erroneous positions: the latter seek unity at the expense of empirical variations; the former locate difference only at an ill-defined nature-artifice boundary, rather than at the mutable borders of epistemic communities.

Function in practice: A case study from synthetic biology

By way of illustration and evaluation, I will employ my formulation of function to study a particular case: the making of photosensitive *Escherichia coli* and bacterial photographic systems. The research in question falls within the rubric of *synthetic biology*—a nascent field of scientific and technological practice.

Synthetic biology's most vocal proponents and practitioners hope to make of the living world a substrate for engineering practice much in the same manner as inanimate matter provides the base stuff for civil, mechanical, and electrical engineering (Andrianantoandro *et al.*, 2006; Endy, 2005; Heinemann and Panke, 2006). This broad goal is supplemented by narrower commitments to the use of established engineering principles. These include abstraction of complexity (Endy, 2005), decoupling and modularity of operational elements (Hartwell *et al.*, 1999; Sauro, 2008), standardisation of those elements (Arkin, 2008; Canton *et al.*, 2008), and quantification of performance (De Lorenzo and Danchin, 2008). Biological organisms are to be approached,

studied, understood, and fabricated as are existing products of human artifice. This aim is the principal motivation for choosing a case study from synthetic biology.

Function in synthetic biology is open intuitively to either a biological or a technological rendering, and there is no self-evident way to disqualify either approach^{xi}. A contributing spur is synthetic biology's discursive and practical emphasis on 'function'. For instance, synthetic biologists routinely differentiate between 'natural' and 'novel' functions (e.g. Anderson *et al.*, 2010; Dougherty and Arnold, 2009; Isaacs and Collins, 2005); cast their field as one concern with systematic and predictable functionality (e.g. Barrett *et al.* 2006; Brent, 2004; Endy, 2005); and use 'function' to define critical concepts, such as 'standardised biological parts' (e.g. Endy, 2005; Grünberg and Serrano, 2010; Hartwell *et al.*, 1999; Lucks *et al.*, 2008; Purnick and Weiss, 2009). Finally, despite the concept's prevalence within the field, there is a near-absolute lack of a concomitant analysis of synthetic biological functions (either by scientific practitioners or scholars from science studies). Function is central to synthetic biology, but is still a fluid one (as with much in the field). Currently, it is moulded greatly by visions of engineering. This is my starting point for this analysis.

My discussion of photosensitive *E. coli* is one component of a larger sociological exploration of synthetic biology. Although I rely primarily on technical literature here, my argument is based on in-depth qualitative interviewing of 24 synthetic biologists, an 18-month ethnographic study of a leading research group, and shorter field studies of other synthetic biology laboratories. One of these additional groups conducted the research discussed here.

'Bacterial portraiture': Building photosensitivity into E. coli

Past and ongoing work at the Voigt Laboratory has aimed at developing photosensitivity, the ability to sense light, in *Escherichia coli* (*E. coli*). This capability is not found in 'wild-type' or standard laboratory strains of this bacterium. Such efforts have been motivated by broader aims of synthetic biology: the successful construction of progressively larger bioengineered 'circuits' from modular components; the development of novel and predictable behaviour through systematic means; and the introduction of new methods for precise control of living systems.

The Voigt Lab's initial work with photosensitivity in *E. coli* focused on appropriating a set of relevant traits from the cyanobacterium *Synechocystis*. Cyanobacteria, often referred to as blue-green algae, are capable of sensing light and modifying their behaviour in response. For instance, light stimulus is used by cyanobacteria to generate energy and track the passage of time.

Extensive scientific treatment and study of cyanobacteria, including *Synechocystis*, has yielded significant information on the genetic traits considered responsible for the organisms' photosensitivity (Yeh *et al.*, 1997), as well as methods for isolating and transplanting these traits. The Voigt group was able to excise a photoreceptor from *Synechocystis*—something not normally found in *E. coli*—and connect it to an existing intracellular regulatory system found in the latter. Put differently, the team took the ability to respond to light from *Synechocystis* and added it to an existing stimulus-response system in *E. coli*. The modified organisms were now capable of sensing light and activating particular genetic sequences in response. Effectively, and

as is reflected in the resultant publication's title, the bacterium was now able "to see light" (Levskaya *et al*, 2005).

Having satisfied the goal of rendering *E. coli* photosensitive, the Voigt Lab proceeded to develop a reporter system. Experimenters employ reporter systems to identify when events of interest occur in cells. Often, such systems work with visual chemical outputs. It was this second component that enabled colonies of bacteria to operate 'photographically'. The engineered photoreceptor was coupled with a commonly-used reporter gene—*lacZ*. When *lacZ* is activated in the presence of a particular compound, a precipitate is formed. This phenomenon is generally employed to monitor the activity of genes of interest. Experiments couple *lacZ* with the gene whose activity they want to monitor. When a precipitate forms, researchers can infer that the gene of interest is active. The Voigt Lab used this process to form images. Light stimulus controlled the expression of *lacZ*. When experimenters introduced the partner compound^{xii}, expression of *lacZ* formed a dark precipitate. Effectively, the production of dark pigment was linked to light stimulus^{xiii}.

Much as silver nitrate is used in monochromatic photography, the biological pigment produced by colonies of such bacteria can be used to form images. When experimenters exposed plates of the altered *E. coli* to patterns of light—say, an image of a face—the organisms produced a biochemical 'photograph'. The team made a series of such 'photographs', including simple portraits (e.g. of Albert Einstein and the Virgin Mary) and text messages (e.g. "Hello World").

To summarise: Synechocystis has a behavioural capability of interest—photosensitivity, the ability to detect light stimulus. *E. coli* does not in naturally-occurring varieties possess this trait. The synthetic biologists excised from *Synechocystis* the genetic material suspected of responsibility for photosensitivity and incorporated it into *E. coli*. The latter was now also photosensitive. This ability to sense light was coupled with a genetic element called *lacZ*, which produces a chemical. When the *lacZ* chemical reacts with another compound in the environment, a dark pigment is formed. Modified *E. coli* cells reacted differently to different intensities of light. When researchers projected an image onto a colony of such bacteria, they formed a chemical reproduction.

Accounting for synthetic biological function

What is to be made of functional ascription in the case of photographic bacteria? The Voigt Lab's publications on the research contain numerous instances of functional descriptions. The appropriated traits were used to “[create] a light sensor that *functions* in *E. coli*” (Levskaya *et al.*, 2005: 441, my emphasis). The work allowed “bacteria to *function* as a biological film” (Levskaya *et al.*, 2005: 441, my emphasis). The end result of the team's efforts was the “creation of a novel genetic circuit with an image-processing *function*” (Levskaya *et al.*, 2005: 441, my emphasis).

I will consider first how philosophical accounts of function might address this case. As I demonstrate, none of these analyses satisfactorily resolves the question of function in this instance. An alternative approach is warranted.

Consider first the *etiological* account of function. Functions are those properties of traits which can account for the presence of those traits in organisms. Functions are the historical-genealogical causes for the existence of traits. Such an account works well in studying the case of naturally-occurring photosensitivity in *Synechocystis*. A biologist might argue that photosensitivity developed at some earlier point in time because it provided *Synechocystis* with a fitness advantage. Photosensitivity rendered certain organisms with a greater adaptive fitness, and eventually the trait moved to fixation within the species.

Such an understanding does not apply with equal success in the case of modified *E. coli* and synthetic biology. Plainly, an evolutionary argument for the presence of photosensitivity in *E. coli* is wholly incorrect: 'wild-type' *E. coli* have not evolved to possess this trait, and those that have been modified with the capability gained it through the employment of human artifice. The 'why-is-it-there' of photosensitivity in *E. coli* is comparably straightforward. The trait is present because experimenters intentionally introduced it. No etiological-historical argument can be made, because no history of selection for the trait exists.

Next, consider the *propensity to increase fitness* account. Functions are how traits contribute positively to the fitness of an organism. Functions are those things that have a propensity to increase the ability of an organism to survive and reproduce. Naturally-occurring photosensitivity in *Synechocystis* is amenable to this form of argument. That certain organisms in a population of bacteria were able to modify behaviour in response to light may have provided them with increased fitness. For instance, such an ability is necessary for photosynthesis. Being

able to generate energy from an abundant source like the sun may have yielded adaptive benefits. Thus, the trait enabled a particular increase in fitness.

In contrast, the presence of photosensitivity in *E. coli* does not carry with it a propensity to increase adaptive fitness. The photographic potential of modified bacteria does not render them more capable of survival and reproduction. In fact, the metabolic cost associated with producing the images may have an overall deleterious effect on the bacteria. Put differently, the energy expended by a bacterium in sensing light and producing a pigment may detract from other, more essential processes needed for survival. Moreover, it is difficult to speak of fitness advantages under laboratory conditions. Bacteria live in a rich medium and are carefully monitored to ensure survival. Otherwise valuable time and energy might be lost with the death of a colony under study.

Last, consider Cummins' *capacity-based* account. Functions are those properties of traits that enable a contributing capacity to the working of an encompassing system's global capacity. Functions are what things do within a nested set of systems. The way organisms are divided into systems and which capacities are of interest depends entirely on who is doing the analysis. A study of photosensitivity in *Synechocystis* might take a number of forms in this case. A biologist might study photosensitivity as one element within the organism's broader capacity to generate energy from sunlight. Alternatively, the same biologist might look at the bacterium's ability to track time. In either case, a Cummins analysis is satisfactory.

A Cummins analysis is also tenable in the case of synthetic biology. The synthetic biologist might be likely to view photosensitivity in *E. coli* much as Cummins understands functions. The photoreceptor taken from *Synechocystis* is one component of a larger system, and its function is what it does in the service of bacterial photography. Note, however, that the success of a 'capacity-based' account comes at the cost of biological-specificity. That is, Cummins' view is not bound to any particular characteristics of *biological* function. The evolutionary history of the trait in *Synechocystis* may be of ancillary interest, but it is ultimately immaterial to explaining functional statement in synthetic biology. Thus, Cummins' capacity-based approach implicitly accepts one of my central claims: that function is conventional. Function takes different forms in different fields.

Each knowledge community renders functionality in accordance with its epistemic commitments and entitlements, as well as its disciplinary ends. For the biologist, function serves an explanatory end: tracing the evolutionary genealogy of a species. For the synthetic biologist, function serves only an analytic and practical end: how one may construct a particular system with specified behaviour. Questions of foremost importance to the biologist—How did the trait get there?—are entirely irrelevant to the synthetic biologist—It's there because we put it there. Similarly, concerns for synthetic biology—How can we use this trait?—are not of principal concern to the biologist, whose aim is not that of making technologies.

Fields and functions

The above disparities are symptoms of divergent epistemic commitments and disciplinary aims. The manner and modality in which traits and structures are accorded functional status will be conditioned by the epistemic character of the community in question. Thus, function has less to say about traits than it does about the community whose interest in and work with those traits renders them functional. This supports my claim that a conceptualisation of biological functions as human-independent properties must be supplanted by one that emphasises the communal rendering of things as *functional*.

Functions by agreement and as ordering

Functions are not properties of things, but statuses conferred by epistemic communities. They are not *of things*, but rather *by communities*. This point is further developed by taking a second cue from Kusch's communitarian epistemology. In addressing the epistemology of testimony, Kusch writes:

... instances of testimony will acquire the status 'knowledge' for those that are willing to join the testifier in a nexus of epistemic commitments and entitlements; they will acquire the status 'knowledge' for those that join the testifier in a 'community of knowledge'.
(2002: 71-72)

Kusch's epistemological argument again holds potential for the study of functions and functionality. The above quotation can be reformulated in two modes:

(A) Traits and structures will acquire the status ‘functional’ for those that are willing to join proponents of the given functional attribution in a nexus of epistemic commitments and entitlements; they will acquire the status ‘functional’ for those that join proponents of the given functional attribution in a community of knowledge.

Or, alternatively:

(B) Functional attributions will acquire the status ‘valid/accepted/correct’ for those that are willing to join the attributer in a nexus of epistemic commitments and entitlements; they will acquire the status ‘valid/accepted/correct’ for those that join the attributer in a community of knowledge.

Statements A and B are fundamentally interchangeable: that something gains a function depends upon a functional attribution being made; for a functional attribution to be made requires something to attribute with function.

For functions to be conferred, for them to have the gravity and stability of fact, requires a collective of epistemically-coordinated agents. For me to accept that the function of the heart is ‘to pump blood’, I must accept the ontological and epistemic commitments that underlie such a claim. These commitments those associated with the biological sciences and conventional Western biomedicine. Outside an understanding of animal bodies that partitions them into distinct systems (e.g. the circulatory system), divides such systems into sets of organs (e.g. the heart), and grants to such systems nested sets of purposes (e.g. the circulations of the blood, the

pumping of blood), it makes little sense to attribute functionality to the heart as a blood-pumping entity. Importantly, the ontological and epistemic commitments associated with function extend beyond just the division and characterisation of organisms' structures and behaviours. Reference to the heart as functioning to 'pump' blood further contributes to a mechanistic, fundamentally analogical conceptualisation of organisms (see Lewens, 2000 and 2004). Attributions of function also guide medical intervention—the heart is expected 'to pump blood' in particular ways, and its deviating from such expectations guides evaluations of illness and treatment practices. Thus functionality affects our comportment towards entities and phenomena.

Functional attribution should then be understood as more than the characterisation of entities—it is an *act of ordering*. For a biologist to claim that photosensitivity in *Synechocystis* is a trait selected for by evolutionary processes positions the trait (and the organism) within a particular set of orders. The trait serves to further justify evolutionary theory; it is characterised as having a particular origin and genealogy; it becomes related to comparable traits in other species; and it is positioned in relation to a particular end: survival and reproduction. That a synthetic biologist refers to appropriated traits from *Synechocystis* as serving a photographic role in modified *E. coli* accomplishes a similar ordering. The trait serves to support a modular, combinatorial ontology and epistemology of nature; the trait is disconnected from evolutionary-historical accounts; it becomes a technological contrivance, rather than a biological development; and it is likewise positioned in relation to a particular end: bacterial photography. In each case, functional attributions follow from and contribute to the maintenance of a community's system of knowledge and practice. In the first case, function is a claim based in, and further substantiation

for, evolutionary theory; in the second, function follows an engineering epistemology and supports the physical and functional modularity of biological entities.

In the case of synthetic biology, ordering-through-function also serves a number of pivotal disciplinary ends. The authors of the Voigt Lab's image-capture work write:

Our creation of a novel genetic circuit with an image-processing function demonstrates the power and accessibility of the tool sets and methods available in the nascent field of synthetic biology. (Levskaya *et al.*, 2005)

If it is to be 'true' biological engineering, synthetic biology must make of living systems objects of and for human utility. That is, its practitioners must grant living systems with utilitarian purposefulness—technological function. The Voigt Lab's attribution of function contributes to ongoing efforts to substantiate synthetic biology's premise that natural systems can be designed and fabricated as are other engineered contrivances. The system's technological functionality is indicative of the "power" of the field, it is claimed: a useful rhetorical act. Moreover, the successful attribution of a technological function supports the field's assertion that it is in the business of developing 'novel' (human-made, technological) functionality from 'natural' (human-independent, biological) functionality. This vital trope is employed to distinguish the field from earlier variants of genetic engineering.

For synthetic biology, function reflects commitments to the premise that nature is modular (an ontological claim), should be studied as systems with technological modularity are studied (an

epistemic claim), and should be used to construct biological technologies in accordance with a combinatorial logic (a methodological claim). Moreover, practitioners hold that ‘novel’ functionality can help the field in its ongoing efforts to distinguish itself as a research discipline (a disciplinary claim). For those who accept such commitments, synthetic biologists’ functional ascriptions will be valid.

Conclusion

Writing about functions in biology and technology, MacLaughlin makes the following claim:

... our use of functional ascriptions to explain certain kinds of objects can tell us something significant about how we fundamentally conceptualize these objects and about the presuppositions we make in doing this. (2000: 8)

That is, functional ascriptions betray the ontological and epistemic commitments to which the ascribing community adheres. Functions teach us the contingent character of epistemic communities, rather than the inherent quality of worldly things.

Standing philosophical accounts of function—etiological, propensity-based, and capacity-based among these—rely to differing degrees on a realist ontology of functions. Of these Cummins’ account (1975) moves farthest from a strict fixation of what is to ‘count’ as a function, although it ultimately does not escape a rendering of function as property. The argument presented here dispenses with this premise and places in its stead an understanding of function *as status*. As I

note in various places above, functions are not *of things*, but rather *by communities*. As such, they demand sociological treatment.

Recasting function in this manner presents no small advantage to studies of functional ascription. First, there is no need to ‘naturalise’ functions through some human-independent property of the world. Functions exist as products of epistemic communities: no communal consensus, no functional attribution. Second, by casting aside a realist ontology of function, the need to construct strict delimitations of what is validly a function and what is simply effect or accident is dissipated. Although the ornate formulations advocated by deductive-nomological analyses of function (e.g. Nagel, 1961; Hempel, 1965) no longer command a dominant position in the philosophy of biology, the drive to strict definition persists. A more fruitful approach looks to communities as the final arbiters of the validity of any functional ascription. Third, the fracturing of questions regarding function (see Ratcliffe, 2000) is avoided: *how* the term is employed is not distinct from its epistemic *role* in biology, and both underlie what functions ultimately *are* (see Ruse, 2002). Perhaps the most important benefit on my perspective on function is that it demands further analysis from social studies of science.

The extensive use of functional statements in the biological sciences calls for an equally extensive treatment of this practice by social studies of science. I have attempted here to lay the groundwork for such a venture: first, by providing an overview of existing analyses of function from philosophy; second, by supplanting these with a formulation that makes clear the social character of functions.

Studying function as statuses enabled and sustained by epistemically-coordinated agents draws attention to how and why functions matter. It is also an avenue toward further understanding of the biological sciences. Assigning functionality is an act of ontological, epistemic, and methodological ordering: of making things intelligible in specific modes; of validating and articulating knowledge claims; and of guiding and justifying practice.

ⁱ A search for studies on biological function revealed only a few exceptions. Among these are Calvert's study of gene patenting (2007) and Elton's argument on persons, animals, and machines (1998).

ⁱⁱ In brief terms, I employ the term 'real' to indicate a quality of ontological independence from human social practice.

ⁱⁱⁱ See Schyfter, 2012 for an ontological argument concerning synthetic biology.

^{iv} Cummins admits "no functions *sans phrase*" (MacLaughlin, 2000: 55).

^v See e.g. Searle, 1995; Preston, 1998; MacLaughlin, 2000; Lewens, 2004.

^{vi} See e.g. Longy, 2009; Perlman, 2009; Preston, 2009.

^{vii} Here I mean both 'in the absence of communities' and 'outside of communities'.

^{viii} This argument is based in no small part on Hume's discussion of causality and necessary connection in *An Enquiry Concerning Human Understanding*, Section 7 (1999 [1748]).

^{ix} Neander recognises this difficulty (1999).

^x Ratcliffe's argument is fundamentally Kantian: teleology is a 'regulative' rather than a 'constitutive'. Teleology is heuristic. This position is sometimes discussed as 'eliminativist,' because some authors argue that 'function-talk' may be excised from the biological sciences. Ruse takes function to be heuristic, but argues that its usefulness should keep it from being removed (2002).

^{xi} My focus in this article is on issues of *biological* function. I have discussed *technological* function elsewhere. See Schyfter, 2009 and 2012. The latter concerns synthetic biology specifically.

^{xii} 3,4-cyclohexenoesculetin- β -D-galactopyranoside (also known as S-gal)

^{xiii} Specifically, light ‘turns off’ the production of the precipitate. As such, dark portions of a projected image will drive the production of a dark region on the colony of bacteria.

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