Title: Why (a Form of) Function Indeterminacy is Still a Problem for Biomedicine, and How Seeing Functional Items as Components of Mechanisms Can Solve it

Abstract: During the 1990s, many philosophers wrestled with the problem of function indeterminacy. Although interest in the problem has waned, I argue that solving the problem is of value for biomedical research and practice. This is because a solution to the problem is required in order to specify rigorously the conditions under which a given item is "dysfunctional." In the following I revisit a solution developed originally by Neander (1995), which uses functional analysis to solve the problem. I situate her solution in the framework of mechanistic explanation and suggest two improvements.

Keywords: Biological function; function indeterminacy; mechanistic explanation; philosophy of biology; philosophy of medicine

1. Biomedicine Needs a Solution to the Problem of Indeterminacy

The central organizing principle of biomedical intervention is that of *fixing dysfunctional items*. This is not to say that biomedical practitioners do not do other things besides fixing dysfunctions. Sometimes, instead of fixing dysfunctional items, practitioners simply remove those items from the body, or they supplement their activity, or they inhibit their activity so as to restore proper physiological functioning. Yet the idea of fixing dysfunctions is an organizing principle of biomedicine in the sense that it illuminates most of the other sorts of goals that biomedical practitioners have (with the exception of goals such as cosmetic surgery, or pain relief during labor). For example, when practitioners choose to remove, supplement, or inhibit dysfunctional items, rather than fix them, they typically do so because of various limitations on the ability to fix them. Moreover, the idea of repairing dysfunctions is also an organizing principle because it works as a heuristic for biomedical research. This is because researchers often do not feel that they entirely *understand* a pathological process until they know what they would need to do, in theory, in order to fix it.

Biomedicine is limited in its ability to fix dysfunctions because of various epistemic, technical, and sociopolitical obstacles. At least one of those obstacles, however, is conceptual, or, if you will, "metaphysical." The ability to carry out the ideal of fixing dysfunctions requires, in the first place, that we are able to clearly *articulate* the conditions under which an item is functional and the conditions under which it is dysfunctional. Yet this is precisely what, according to one version of the function indeterminacy problem, is precluded (e.g., Dretske 1986; Neander 1995). Consider a well-worn but lucid example: the heart beats. In doing so, it circulates the blood. In doing so, it brings nutrients to cells and removes waste. In doing so, it contributes to survival and, ultimately, to reproductive success. Yet which of these activities constitutes the *function* of the heart? Any one of them would be licensed by standard theories of biological function, and in particular, theories that tie function to selection history or current adaptiveness (see Garson 2015). (I will refer to both groups of theories as "evolutionary" theories of function because they tie function to evolutionary considerations, despite the fact that one set of theories focuses more on history and another on present-day activity. I am not here concerned with Cummins-type (or "causal role") functions, in which the function of a trait simply consists in its contribution to some systemic capacity of interest to an investigator. This theory will come into play later. I will also justify this exclusion later.) The problem arises most clearly for evolutionary theories, though a version of the problem could arise for causal role theories as well. I will refer to this as the "hierarchical" version of the problem of functional indeterminacy for reasons to be explained in the next section.

Here is where the problem comes in for biomedicine. Suppose that one succumbs to the temptation of pluralism, and asserts that there is no *principled* and *context-independent* way of selecting one of those descriptions of the heart's function (e.g., in terms of beating, circulating blood, bringing nutrients to cells, etc.) as the uniquely correct description of its function. Any of those activities, one might hold, may constitute the heart's "function," depending on factors such as disciplinary interest, convention, or personal predilection. The pluralist solution runs into trouble when we realize that these different function ascriptions can conflict with one another. Specifically, it is possible for the heart to carry out one of these activities and not the other. For example, suppose that the heart beats, but, due to a massive brain hemorrhage, the heart cannot circulate enough blood to keep the individual alive. Should we say that the heart is failing to perform its function of circulating blood (or not at the appropriate rate)? Or should we say, instead, that the heart is functioning successfully because it is performing its function of beating, despite the fact that, due to the hemorrhage, the activity is not associated with its normal contribution to survival?

Intuitively – if you and I share the same intuitions – we should say that the heart is functioning. It just cannot make its normal contribution to fitness because some *other* item is dysfunctional, namely, the ruptured artery. After all, the heart is only "doing its job," but the artery isn't doing *its* job. Deciding whether or not the heart is functioning in this situation is like trying to locate blame in a large corporation. But in saying this, we are privileging one activity over another as having a greater claim to constituting the function of the heart: the claim that the function of the heart is to *beat* is "privileged" in a way that the claim that the function of the heart is to *circulate blood* is not. Moreover, it seems to be privileged in some principled, context-independent way. This is precisely what the pluralist solution forbids. So, how can we justify this assertion that the one function ascription ("the heart beats") is more correct than another ("the heart circulates blood")?

Keep in mind that our solution – that in the case of the hemorrhage, the heart is "functional" and not "dysfunctional" – is not *only* intuitively correct. To maintain otherwise would be counterproductive or contrary to the needs to biomedicine. This is because, when we say that an item is *dysfunctional*, we indicate that the item in question is a prime target for direct biomedical intervention, such as repair or replacement. But if the heart cannot circulate blood effectively because of a ruptured artery in the brain, we presumably want to fix the artery, not the heart!

As a consequence, any attempt to articulate clearly the conditions under which an item is dysfunctional entails, as a necessary condition, a solution to the problem of function indeterminacy. In other words, if one *can* articulate clearly the conditions under which an item is dysfunctional, then one can use those conditions to state, in a principled and context-independent way, which of the multiple function ascriptions legitimized by evolutionary considerations is uniquely correct (or at least one can reduce the plurality of reasonable function ascriptions down to a small number of equally correct ascriptions). Conversely, if one possesses a solution to the problem of function indeterminacy, then (presumably) one could apply that to resolve such conflicts in the biomedical context. How shall we proceed?

In the following I will do three things. First, I will revisit a solution proposed by Neander (1995). In short, in her view, in order to identify the (determinate) function of any given item, we can utilize the framework of functional analysis. The (determinate) function of an item is identified with its "most specific function," which turns out to be its causal role within a certain mechanism. Next, I will describe that solution using the framework of multi-level mechanistic explanation as it has been developed over the last two decades (Section 2). Finally, I suggest two improvements to that solution (Section 3), one minor and one more substantial. The first is to replace talk of the "most specific function" with the "differentiated function" of the item. The second is to draw attention to *two* dimensions of indeterminacy, a "horizontal" dimension and a "vertical" dimension, and to suggest how mechanistic modeling can resolve both types.

2. Seeing Functional Items as Components in a Nested Hierarchy of Mechanisms

The central idea of the solution to the problem of indeterminacy that I will present here advances Neander's (1995) solution by anchoring it more firmly within the literature of the new mechanism tradition (e.g., Bechtel and Richardson 2010; Glennan 1996, 2005; MDC 2000; Craver 2001; Darden 2006; Craver and Darden 2013). It then develops it in two ways. In short, we can solve the indeterminacy problem by construing the functional item as a component within a mechanism, or, more precisely, within a nested hierarchy of mechanisms.

More specifically, the hierarchical version of the problem of indeterminacy stems from the fact that for any given item and any given function, there is a hierarchy of activities that explains why the performance of the function is (or was) associated with some biological advantage for the organism. Quite fortunately – and this is the key to solving it – that hierarchy of activities is mirrored by a corresponding hierarchy of mechanisms. Moreover, these mechanisms are nested, one within the other. For example, suppose A and A′ are two activities "adjacent" to one another on the functional hierarchy, where A′ is "higher" than A (see Figure 1). Suppose A is the activity of beating, and A′ the activity of circulating blood. On the corresponding mechanistic hierarchy, there is a mechanism, M, for A, and another mechanism, M′, for A′. In this case (and simplifying tremendously), M is comprised of the heart, and M′ is comprised of the circulatory system, which includes, in addition to the heart, the brain and blood vessels. M and M′ are nested in the sense that M can be construed as a component part of M′.

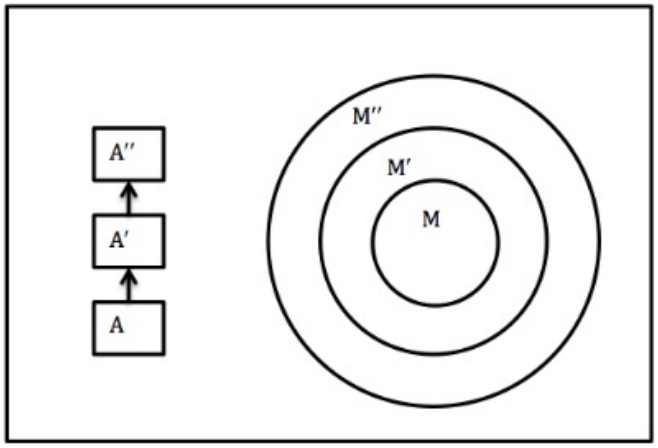

Figure 1. Functional and mechanistic hierarchies

With this framework in mind, we can solve the function indeterminacy problem by identifying the function of any particular item as *its differentiated contribution to the activity of the mechanism of which it is a component* – that is, the mechanism in which it is most "immediately" contained. For example, in this framework, it would be correct to say that the function of the heart is *to beat*, since that is its specific contribution to the activity A′ (blood circulation) of the mechanism M′ (circulatory system) in which it is "immediately" contained. To put the point differently, and somewhat more methodically: in order to identify the function of an item, we first construct our functional hierarchy. This hierarchy will be determined, in part, by our theory of function and in part by the empirical facts. We then construct a corresponding mechanistic hierarchy. Then, beginning at the uppermost level of the mechanistic hierarchy, and we work our way "downwards," level by level, until we reach the level at which the item in question emerges as an unanalyzed component (Neander 1995, 129). This is the "bottom-out" level as far as our analysis is concerned. Then the *indeterminate* function of the item can be rendered *determinate* by identifying it with the contribution that the item makes to the activity of the mechanism of which it is a component.

The same solution can, if necessary, be cast in a more historical vein, for example, in terms of the selected effects theory of function. The solution simply requires that instead of analyzing the trait's *current* contribution to fitness, we attempt to reconstruct, historically, how it may have contributed to fitness in the past. As noted above, I do not wish to take a stance, in this context, on *which* evolutionary approach to function is preferable, the approach that focuses on history or the approach that focuses on current-day performance (and, within each set of theories, which version of the theory is superior). The point is that the mechanistic framework could be adapted easily to suit the needs of either.

It would be natural at this point for one to wonder how this solution differs from the Cummins' type causal role theory of function (Cummins 1975), or its more recent variants, such as the mechanistic causal role theory of function (e.g., Craver 2001, 2013). In Cummins' theory, the function of a trait consists in its contribution to some systemic capacity picked out by an investigator. In the mechanistic causal role version of this theory, the function of a trait consists in its contribution, in tandem with the other parts of the system, to a systemic capacity of interest, and the whole system is described using the framework of mechanistic explanation. Isn't what I've presented *just* the solution that the Cummins-type theory, on its own, would entail?

The main difference is that in the view presented here, the function of the item is first identified by utilizing an evolutionary framework, and specifically, by considering the item in light of its selection history or its current contribution to fitness. That evolutionary framework provides a rationale for selecting a certain hierarchy of activities (pumping -> circulating blood -> bringing nutrients to cells -> helping creature survive and reproduce) as constituting the heart's (indeterminate) function. (Of course, which specific sequence of activities we identify depends partly on which specific theory of function we select within that family of theories, a topic on which, again, I wish to remain neutral at present.) A problem with this solution, of course, is that it creates the hierarchical version of the problem of function indeterminacy. We *then* apply a mechanistic framework to resolve that problem in a principled way. The hierarchy of functions that has been identified by evolutionary considerations is converted into a framework for identifying the relevant hierarchy of mechanisms, and we then look for the function of the item *qua* mechanistic causal role. Mechanistic considerations merely help us to make the transition from an indeterminately-specified function to a determinately-specified one. They do not supplant evolutionary considerations.

Even if this solution differs from the causal role theory of functions, one might wonder why the solution offered here is preferable. Why not just drop the evolutionary framework and go straightaway to a Cummins-type framework? The reason is that utilizing the evolutionary framework allows us to avoid certain recalcitrant problems associated with the Cummins-type theory, in particular, the problems of overbreadth and normativity. The first is the classic problem of overbreadth (e.g., Millikan 1989, 294; Kitcher 1993, 390). In Cummins' view, as in the mechanistic causal role view, the choice of a "top level" function for a given system is largely a matter of caprice. (I mean this in the sense that there is no objective, mind-independent fact of the matter regarding what the "top-level" function of any given system is, and not in the sense that it is somehow unmotivated or unjustifiable in any given case.) A consequence of this is that Cummins' framework licenses wildly counterintuitive function ascriptions (for example, Cummins' (1975, 752) own example that the function of the appendix could be to produce appendicitis. Incidentally, he raises this as a problem for Nagel's theory, but does not suggest how his own theory would resolve it). Alternatively, theories of function that tie function to evolutionary considerations have the implication that there *is* an objective fact of the matter regarding what the function of a given item (albeit indeterminate) actually is, and it yields function ascriptions that are (typically) in line with biologically-informed intuitions. At least some philosophers find that to be a welcome implication.

Additionally, Cummins-type theories have a notoriously difficult time explaining the *normativity* of functions, by which I mean the fact that it is possible for something to possess a function without being able to perform that function (e.g., Neander 1991, 181-2; though see Hardcastle 2002; Cummins et al. 2010). That is because, on Cummins' view, the function of a trait is a *disposition* (Cummins 1975, 758). If a trait loses the disposition to perform a certain activity, then, at least on the classic view, it loses the function itself. In that case, how can a trait dysfunction? These two problems (overbreadth and normativity) provide some motivation for retaining an evolutionary perspective for thinking about function, but supplementing, rather than supplanting, that perspective with considerations drawn from mechanistic explanation.

3. Hierarchical and Sequential Aspects of Function Indeterminacy

Up until this point, I have largely described Neander's solution, or re-described it slightly. Yet I propose to extend that solution in two ways. The first is fairly minor and the second more substantial. First, for Neander, the correct way of describing the function of an item (in cases of conflict, e.g., in the biomedical context) is in terms of what she calls the item's "most specific function." But I would prefer to speak of the item's "differentiated function" (which is to be distinguished from the developmental process of "differentiation," as in, e.g., cell differentiation). The phrase, "most specific function," contains an ambiguity that can be clarified using the framework of mechanistic explanation.

As she recognizes, the "most specific function" of an item can be described in at least two ways (Neander 1995, 118-119). From one perspective, we can describe the activity that the item produces without indicating *how* the activity contributes to the mechanism of which it is a part (for example, "the function of the heart is to beat"). From another perspective, we can merely indicate *that* the activity contributes to the activity of the mechanism of which the item is a part, without specifying the "intrinsic" nature of the activity (for example, "the function of the heart is to help circulate blood"). Craver (2001, 65) makes the same distinction, and describes these in terms of the "isolated activity" and "contextual role" of an item. It seems to me that, from the biomedical perspective, the former ascription ("the heart beats") is the more informative of the two, because the latter is overly generic: it does not differentiate the function of the heart from that of the other components of the circulatory system. Moreover, since we are envisioning the heart as a component within a mechanism for circulating blood, the fact that the heart contributes to blood circulation will be implicit in the models that we use to represent the mechanism. Instead of describing the item's "most specific function," then, I will describe the item's "differentiated function." Talking of the "differentiated function" of the heart brings to the front and center of attention that the heart is part of a *system* in which each part has a distinct, and different, causal role. It draws attention to what the heart does that *differs* from what the other components do. The “differentiated function” of the heart, for example, is to beat, not to help circulate blood.

Secondly, Neander describes the “most specific function” of the item as the activity that it can perform “more or less on its own”, rather than “in collaboration with other components” (118). Applied to the heart, the idea would be that the most specific function of the heart is to *beat*, rather than to *circulate blood* or to *deliver nutrients to cells*. However, in what sense is it true to say that the heart beats “more or less on its own?” Suppose that the function of the heart is to *beat*, but the heart stops beating, or stops beating at the appropriate rate, because, due to a lesion in the medulla, it is not receiving the proper impulses from the brain. Is the heart dysfunctional? Intuitively, it is not dysfunctional; rather, it has been placed in an abnormal circumstance in which it cannot perform its function. It has, as it were, merely been deprived of the right inputs, similar to an unplugged electrical toy. But it seems both counterintuitive, and counterproductive, to say that the heart is dysfunctional if it stops beating just because it is not receiving the right inputs. (Of course, there is one sense in which the heart beats “more or less on its own,” namely, that in which it may continue to beat very briefly after removal from the body, as after pithing a frog. But that phenomenon is pretty short-lived!)

So, there is no obvious sense in which *beating* is something the heart can do more or less on its own. It requires the right sorts of inputs from other sources. This suggests that, when we are attempting to articulate clearly the conditions under which an item is dysfunctional, it is not enough simply to point to its causal role within a *hierarchy* of mechanisms. Rather, we must also provide at least a “mechanism sketch” of the way in which the item interacts with others, at the same level, to produce the activity of the mechanism of which it is a part. We must adopt, not only a hierarchical (or vertical) perspective, but a sequential (or horizontal) perspective on the mechanism as well. In order to state clearly the conditions under which an item is dysfunctional, that item’s performing a function (e.g., the heart’s beating) must be seen as *one stage in a productive sequence of activities* that are collectively responsible for yielding the activity of the mechanism as a whole (blood circulation). In light of such a mechanism sketch, we have the tools to specify that the item is question is dysfunctional *not only* when it cannot perform its differentiated function, but when it cannot perform its differentiated function *even when the other parts of the system have performed their own characteristic activities in their appropriate sequence* (see Garson and Piccinini 2014). Thus, a full specification of the conditions under which an item is dysfunctional can be made so long as we have some characterization of both the hierarchical and the sequential aspects of the mechanism in which the item is embedded.

To give a simple example: suppose we want to provide a mechanistic explanation for how the gut digests food. We would analyze it into several parts, such as the mouth, tongue, esophagus, stomach, small and large intestine, and anus, each with its differentiated function. Using the solution to the indeterminacy problem developed here, we could say that the function of the stomach is to break down food and transfer it to the duodenum. (Note that the stomach has several functions, for example, to protect the inner organs from the highly corrosive acids it contains. Nothing in the solution to functional indeterminacy precludes the possibility that one trait or organ possesses several distinct functions, each associated with its own indeterministic "hierarchy.") Suppose, however, at a given moment, the stomach is not digesting any food. That does not mean that it is dysfunctional. After all, it is possible that the animal is fasting and there is no food to digest. Functions are "situation specific" (Kingma 2010). It is only dysfunctional if it is not breaking down food *and* all of the preceding stages (e.g., functions) in the sequence of digestion have taken place (culminating with food being delivered by the esophagus to the stomach).

A concern one might have with the introduction of this "horizontal" approach to defining dysfunction is that it appears, on the surface, to involve circularity. That is, we are trying to explain how it is that a trait can dysfunction (e.g., the stomach) and in so doing, we are appealing to the functions of the other parts of the system (e.g., the fact that the esophagus has discharged its function of bringing food to the stomach). But there is no circularity here. We first use the "vertical" approach to identify the *determinate* function of any given trait. That approach does not involve any apparent circularity because in order for me to identify the (determinate) function of the stomach (namely, to pass food along to the duodenum), I don't have to have already identified the (determinate) functions of the other parts of the system. It is enough that I have identified their indeterminate functions.

Once we have used that vertical method to identify the determinate functions of several components of a system, we can *then* deploy the "horizontal" perspective to identify precisely *the conditions under which any given component is dysfunctional.* At this stage (that is, in trying to understand when a part of the system is dysfunctional) we are free to make use of our knowledge of the determinate functions of the other parts of the system. What we are *not* allowed to do is to identify the determinate function of a component of a system by appealing to the determinate functions of the other parts of the system. What we are also not allowed to do is to identify the conditions under which an item is dysfunctional by appealing to the conditions under which some other item is dysfunctional. The approach I have outlined here avoids both sorts of circularity. In this way, the tools of mechanistic explanation help solve both of these aspects of the indeterminacy problem and allow us to state clearly when a given item is dysfunctional. More generally, this analysis suggests the importance of philosophical work on integrating considerations drawn from the traditional body of philosophical literature on biological function, and those drawn from the philosophical literature on mechanism.

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