The Modal Theory of Function Is Not about Functions

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In a series of papers, Bence Nanay has recently put forward and defended a new theory of function, which he calls the 'Modal Theory of Function'. In this article, I critically address this theory and argue that it fails to fulfill some key desiderata that a satisfactory theory of function must comply with. As a result, I conclude that, whatever property Nanay's notion of function refers to, it is not the property having the function that is standardly attributed in science.

1. The Modal Theory. For many years the debate on the notion of function has been dominated by two main contenders: etiological and Cummins-style theories. Yet in recent times new approaches are trying to provide a novel perspective on this topic, which may substantially change the shape of the debate. Nanay's Modal Theory of function is one of the most recent and original proposals.[1]

Nanay's (2010) approach has two leading ideas. First, in contrast to most current accounts, on his theory functions are primarily attributed to not trait types but trait tokens, since he argues that this is the only way of providing a coherent and noncircular theory. Second, functional ascription does not rely on any current, past, or future effects of a trait. According to Nanay,

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1. Some articles have already discussed Nanay's work (Kiritani 2011a, 2011b; Neander and Rosenberg 2012), but they have primarily focused on rescuing etiological theories from the objections raised by Nanay, rather than concentrating on the Modal Theory.

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traits have functions in virtue of having certain modal properties, which he defines by appealing to counterfactuals. More precisely, according to **Modal Theory**:

> Performing F is a function of an organism's (O's) trait (token), *x*, at time *t* if and only if:
>
> *a*) There is an accessible[2] close possible world, *w*, where *x* is doing F at *t*;
> *b*) Doing F at *t* contributes to O's inclusive fitness in *w*;
> *c*) This world, *w*, is closer to the actual world than any other accessible world in which *x* does F at *t*, but this does not contribute to O's inclusive fitness (Nanay 2010, 422),
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> where the accessibility relation is determined by our explanatory purposes.

According to this account, a particular kidney has the function of filtering wastes from blood because, given our explanatory purposes, (1) there is an accessible close possible world *w* where the kidney filters wastes from blood, (2) this activity increases the inclusive fitness of the organism having it at *w*, and (3) *w* is closer to the actual world than any other accessible possible world in which the kidney filters wastes from blood, and this activity does not increase inclusive fitness. For clarity purposes, in what follows I use 'N-function' to refer to a modal property attributed by Modal Theory.

Now, certainly Modal Theory seems to describe a property of some trait tokens. For instance, it is very plausible that kidneys have the N-function of filtering wastes from blood and that flippers have the N-function of propelling animals through water. However, the question I would like to address is whether, as Nanay suggests, N-functions should be identified with the property that we attribute when we ascribe functions to traits. The claim I defend is that it should not; the Modal Theory is not a theory about functions.[3]

2. Nanay talks about "relatively close" possible worlds. I think that cashing out the theory in terms of 'accessible possible worlds' clarifies very much the discussion and avoids certain ambiguities of the original paper, but nothing important is supposed to depend on this choice.

3. Of course, since Nanay intends his theory to describe the property having a function, there is a trivial sense in which his account is indeed about functions. However, what I will argue is that the property attributed in Modal Theory is not the thing that is normally called 'function' in science and common sense. In other words, I defend that functions are not N-functions. Similarly, my primary aim is not to do conceptual analysis; I am interested in whether the properties usually referred to by standard uses of 'function' are indeed N-functions. I want to thank to an anonymous referee for pressing me on this issue.

I would like to raise three kinds of considerations in defense of that contention. First, there are certain concerns related to the desiderata set up by Nanay. Second, it seems that the N-functions attributed by Modal Theory systematically differ in extension from the functions attributed by science and common sense. Finally, I will argue that assuming that the Modal Theory is the right theory of functions would have deleterious consequences for science.

2. Desiderata. Nanay lists three desiderata that any theory of function should comply with:

1. **Multiple Functions:** The theory should make it possible for a trait to have more than one function at the same time.
2. **Context Dependence:** Function attributions can depend on the explanatory project at hand.
3. **Normativity:** The theory should be able to account for malfunctioning.

Certainly, Nanay's theory satisfies 1,[4] and it might have the resources for dealing with 3 (although see sec. 4). However, there are two concerns related to 2 and, more generally, to this list of desiderata.

First of all, consider desideratum 2, that is, the claim that function attribution can depend on the explanatory project. This assertion can be understood in two different ways. First, it could mean that, given a set of functions a trait has, which function is attributed in a given context depends on our explanatory interests. For instance, the pancreas has two main functions, producing hormones and secreting pancreatic juice containing digestive enzymes. Which of these functions is attributed in a given context depends on our explanatory project: if we are describing the endocrine system, we will mention the first function, and if we are interested in the digestive system, the second one. This is a fairly uncontested fact.

But there is a second interpretation of this desideratum. This claim could be understood as suggesting that whether a trait has a function depends on our explanatory project. On this reading, whether a pancreas has the function of secreting pancreatic juice depends on our explanatory project.[5] This is surely an unusual desideratum. Indeed, many defenders of etiological theories think this is an objectionable consequence of some theories (see, e.g., Neander 1991, 181; Millikan 1999).

4. It is worth pointing out, however, that this desideratum seems to be satisfied by etiological theories, propensity theories, systemic theories, and organizational theories, among others. So it fails to provide any significant advantage for the Modal Theory.

5. This confusion is not uncommon in the literature. See, e.g., Hardcastle (2002, 147).

The problem is that Nanay's theory is committed to the truth of both interpretations. The reason is quite simple indeed: the Modal Theory specifies a set of conditions for function possession, but whether the three conditions are satisfied partially depends on the set of worlds that are accessible, which is determined by our explanatory interests. Hence, whether a trait has a function is utterly context dependent. For many people, this is not a desideratum but a reductio of the theory.[6] Furthermore, if this notion of function is supposed to be employed in a naturalistic account of teleology or intentionality (as suggested by Nanay 2012, 2014), this is a serious difficulty. If one's theory makes function attribution depend on the explanatory goals of certain intentional agents, one cannot attempt to naturalize teleology or intentionality by appealing to functions. That would render the whole project circular.[7]

Second, there is a more general worry with Nanay's list: he does not mention some desiderata that are usually accepted by many contenders (e.g., Ariew, Cummins, and Perlman 2002; Wouters 2005). For instance, many people assume that a trait's function plays an important role in explaining the trait's existence (Nagel 1977, 291; McLaughlin 2001, 168; Mossio, Saborido, and Moreno 2009). Similarly, he does not consider the distinction between essential and accidental effects (Wright 1973). This is not a minor oversight, since prima facie it is not obvious how the Modal Theory can deal with them (see below).

In what follows, I would like to focus on two other desiderata, which are especially troubling for Modal Theory:

4. **Ascription Adequacy:** The functions ascribed by an adequate theory should roughly correspond with the functions attributed by science and common sense (Neander 1991).

If N-functions systematically differ from the functions attributed by science and common sense, that would provide strong reasons for rejecting Modal Theory as a theory of function. Second,

6. It is interesting to note that, while Nanay (2012) and Neander and Rosenberg (2012) think that they are agreeing on that point, I think they have indeed conflicting views. While Neander and Rosenberg accept the desideratum of Context Dependence on the first reading and would probably reject the claim on the second interpretation, Nanay is committed to the truth of both.

7. Let me add that a full assessment of Nanay's theory would require more details about the dependence relation of functions on explanatory interests. There are different ways a property can be context dependent, and Nanay does not specify which one is he favoring. For instance, he could be saying there are no functions simpliciter, but only functions relative to a certain context. Alternatively, he could be claiming that there is indeed such a thing as having a function simpliciter, but whether a trait has this property depends on the explanatory context.

5. **Use Adequacy:** A satisfactory theory should make sense of the biological explanations and distinctions in which the notion of functions plays an essential role.

Desideratum 5 seems to be a widespread assumption in debates on functions. For instance, the fact that etiological and Cummins-style theories seem to make sense of the uses of 'function' in different areas of biology has been adduced in order to defend some kind of restricted pluralism (Godfrey-Smith 1993). More precisely, many people accept that the etiological theory is probably the right account of function in evolutionary theory and behavioral ecology, while Cummins-style functions are more suited for physiology and developmental biology (Millikan 1989, 175–76; Godfrey-Smith 1993, 200–201). The fact that each of these theories can make sense of some uses of 'function' in different areas of biology is interpreted as suggesting that each approach is the right theory of function for this field. Of course, I am not arguing here for this form of restricted pluralism; I am merely trying to illustrate the fact that making sense of functional discourse in science is an important consideration in favor of or against any theory. In the remainder of the article, I argue that Modal Theory does not satisfy desiderata 4 and 5.

3. Functions and Traits. First of all, I would like to show that the Modal Theory does not satisfy the Ascription Adequacy desideratum, because the N-functions attributed by Modal Theory systematically differ from the functions attributed by science and common sense. There are different kinds of examples in which Modal Theory yields the wrong predictions. Think first about the standard distinction between essential and accidental effects mentioned earlier (Wright 1973). Pumping blood is one of the heart's essential effects, while making thump-thump noises is one of its accidental effects.[8] Now, if N-functions were functions, there would not be any distinction between a trait's essential and accidental effects. Consider a hypothesis about the N-function of the nightingale's song. Since the nightingale's song pleases humans in the actual world, there are probably many accessible close worlds where the nightingale's song pleases humans, and that fact increases the nightingale's inclusive fitness (e.g., by being fed). Furthermore, this world is probably closer to any world in which pleasing humans does not increase its fitness. Therefore, according to Modal Theory, providing pleasure to humans is an N-function of the nightingale's song. Similarly, Modal Theory entails that the N-function of poor fur and scavenging habits of the opossum is to prevent humans from hunting them for their pelts or their meal (Millikan

8. Let me mention that these names are unfortunate. 'Accidental effects', for instance, might be necessary effects of a trait (e.g., a side effect of a necessary effect).

2002, 138) or that the function of noses is to support glasses (Wright 1973). They satisfy the three conditions stated in Modal Theory: they seem to be effects of these traits in accessible close possible worlds, these effects increase the inclusive fitness of the organisms having them, and those worlds where these effects are fitness enhancing are closer than those worlds where they are not. This problem suggests that Modal Theory fails to adequately draw the distinction between functional and nonfunctional effects (see Wouters 2005, 134). Almost any effect that turns out to be beneficial in relatively close possible worlds turns out to be a function to a trait (some replies will be discussed below).

Second, if the Modal Theory were right, many traits would have preposterous functions, as Neander and Rosenberg (2012) suggest. Consider a beneficial mutation that will occur in a trait T. This mutation will enable the organism to have a positive effect F*, while at the moment it is only able to do F. Now, Modal Theory entails that T currently has the N-function to perform F*, because there seems to be an accessible close possible world *w* where T does F*, that effect increases fitness at *w*, and there is not any close possible world where F* fails to increase fitness. As a result, Modal Theory entails that any trait has the N-function to carry out many activities that it is unable to perform and that no trait of the same type has ever performed.

This problem is even more general than Neander and Rosenberg suppose. Since Nanay wants his theory to be independent of any past, actual, or future effect of the trait token, there is no restriction on the set of effects that can be evaluated. Accordingly, Modal Theory can attribute functions to traits that they have never performed or will be able to perform, as soon as this effect is fitness enhancing in every accessible world. That suggests that Modal Theory might systematically attribute inadequate functions.

Before moving on, let me consider an obvious possible reply on behalf of the Modal Theory. When discussing these and similar objections, Nanay (2010, 425; 2012, 626–27) has sometimes appealed to the context dependence of the accessibility relation: since the set of accessible worlds depends on our explanatory interests, whether a particular effect can qualify as a function utterly depends on our interests. For instance, against Neander and Rosenberg (2012), he has replied that the worlds in which mutation F* takes place might not be accessible due to our explanatory purposes (Nanay 2012, 625). That is, since we are not usually interested in F*, we would not consider worlds where F* occurs, so the first condition of Modal Theory is not satisfied. Thus, the context dependence of the accessibility relation might help to avoid this extreme liberalism by constraining the set of effects that can qualify as functions.

However, there are two ways in which this response is deeply unsatisfying. First of all, the whole work is done here by the accessibility relation,

but this key notion is left unexplained. As a result, it is difficult to assess whether in every reply explanatory interests side with the Modal Theory.

Furthermore, if we try to clarify this notion further, we get into serious trouble. Consider the following question: whose explanatory interests determine the accessibility relation? In answering this challenge, the supporter of the Modal Theory faces a dilemma. If, on the one hand, there are as many explanatory purposes as agents, then we are left with a relativistic (and highly implausible) view, according to which hearts might lack a function and the human appendix might have one. This notion would surely be useless for scientific purposes and would fail to make sense of scientific disagreements (see sec. 4).

The obvious alternative is to restrict the relevant explanatory interests to the scientific ones, but here is where we face the most important difficulty for this reply: if the accessible worlds are determined by scientific interests, then the Modal Theory might be smuggling in what it is trying to explain. Functions are effects in which scientists are especially interested, so if scientific purposes determine which effects are relevant, only effects that scientists intuitively think are functions will fit their explanatory purposes and, hence, will be 'within the accessible worlds'. In other words, the supporter of the Modal Theory can reject any counterexample by claiming that this effect is uninteresting, so it is not within the accessible worlds and, consequently, does not satisfy condition *a*. But, in a sense, a theory of function is supposed to explain why certain effects (functions) rather than others are especially interesting. The Modal Theory seems to be presupposing an answer, rather than providing one.

Finally, even if Nanay's reply worked against the previous objections, it would have a limited force. There is a further difficulty based on condition *c* of Modal Theory, which in contrast to the conditions *a* and *b* does not depend on the different specifications of the accessibility relation. This is the last reason why Modal Theory does not satisfy the Ascription Adequacy desideratum.

The third objection is that many traits that we think have functions lack N-functions, because they fail to satisfy condition *c* of Modal Theory. Hence, the Modal Theory not only attributes too many N-functions, but it also fails to attribute many N-functions to traits that intuitively have functions. Suppose that my retina and my optic nerve are both damaged. Since in the closest possible world where the retina reacts to light photons the optic nerve is still damaged, at that world the fact that my retina reacts to light does not increase my fitness. As a result, condition *c* of Modal Theory is not satisfied, and my retina lacks a function (notice that, in this case, the accessibility relation is not doing any important work). Even worse: this account entails that if my optic nerve were not damaged, then my retina would have a function. So, whether my retina has a function utterly depends on there being a functional optic nerve.

This problem also generalizes. If in the actual world not only a particular functional item but also the conditions that usually sustain its functioning well are damaged (or are present only rarely), then this item will lack N-functions. The reason is that according to condition *c* of Modal Theory, *x* has the function to F only if the accessible world where *x*'s doing F increases fitness is closer to the actual world than any other accessible world where *x*'s doing F does not increase fitness. Therefore, if the closest possible world is one in which F does not increase *x*'s fitness, *x* will not have F as one of its functions. Yet this is precisely what happens when the background conditions necessary for functioning well are rare or damaged. Therefore, many traits that intuitively have functions lack many N-functions.

In conclusion, assuming that N-functions are functions yields highly counterintuitive attributions. In some cases, the Modal Theory is too liberal and in others it is too restrictive. Furthermore, the reason Modal Theory misattributes functions seems to be well entrenched in some of the key assumptions of this account. So it is not easy to see how these different kinds of counterexamples can be avoided.

4. Scientific Explanation. The Modal Theory also has trouble accommodating desideratum 5; that is, it cannot make sense of many biological explanations in which the notion of function plays an essential role. The main reason is that this theory fails to make important distinctions that are of central importance in many areas of biology. Some illustrative cases follow.

Let me start with an example suggested by Nanay (2010, 242). When there is a violent conflict between two male baboons, sometimes one of them picks up an infant in the middle of the fight. What is the function of this behavior? One possible answer is that males carry the infants of higher-ranking opponents in order to defuse the latter's aggression (this is called 'agonistic buffering'; Deag and Crook 1971). A second hypothesis is that the function of this behavior is to protect the baby. Nanay claims his theory predicts that this behavior has both functions, and I agree; nonetheless, this result raises two kinds of puzzles.

The first one is that the kind of considerations that would settle the dispute according to Modal Theory does not seem to be related at all to the kind of facts that scientists would think are relevant. Among other things, in order to discover the function of this behavior scientists might take into consideration the intentions of baboons, the behavior of newcomer males, when this behavior was performed, or whether males are related to the infants they pick up (Taub 1980; Collins 1986). In contrast, the possible ways the world could be seem to be completely irrelevant for function attribution. To see why, suppose we know that male baboons intend to protect infants with this behavior, that in the actual world picking up an infant does not decrease the probability of being attacked, and that the male baboon's behavior was selected for because of parental care; furthermore, let us stip-

ulate that in all accessible possible worlds parental care and agonistic buffering increase fitness. Scientists would surely conclude that the parental care hypothesis is probably true and the agonistic buffering hypothesis probably false. Whether the latter hypothesis is right in accessible possible worlds would be deemed completely irrelevant. Scientists seems to be looking for some kind of causal explanation concerning what really happens in our world, rather than envisaging what would happen in certain counterfactual cases. In this scenario, the Modal Theory clearly yields the wrong prediction.

A related point is that the Modal Theory is too coarse-grained to help scientists resolve controversial questions. Consider the unsettled debate about the function of the butterflies' eyespots (also called 'ocellus'), an eye-like marking that they usually have on the forewing's underside. There are different hypotheses about their function: since they resemble eyes, they might deceive potential predators; or they might draw the predator's attention away from the most vulnerable parts; or they have some influence in sexual selection (akin to the peacock's display feathers; Stevens 2005; Vallin et al. 2005). All of them are plausible hypotheses that can only be settled by a careful examination of evidence.

Now, if the Modal Theory were right, it would almost trivially follow that the butterflies' eyespots have all these functions: on the one hand, there are certainly close possible worlds where the eyespots have these effects, and surely they increase the butterflies' fitness: there is probably no close possible world where deceiving predators, intimidating them, or being sexually attractive is not fitness enhancing. After all, this is why they are plausible hypotheses. Consequently, if the Modal Theory was right, a sensible debate would not make any sense.

Again, I think the problem is far-reaching. Debates about the trait's functions usually involve plausible hypotheses, that is, hypotheses that seem to be true in close possible worlds. The question in many of these cases is whether they are also true in our world. Unfortunately, whenever we have a set of nonequivalent plausible explanations, the Modal Theory renders them automatically true (think about the example of male baboons discussed earlier). Consequently, many disagreements concerning plausible and alternative hypotheses cannot be accommodated by the Modal Theory.[9] It is too coarse-grained for the task at hand.[10]

9. Of course, they are alternative in the sense that an organism could have one of these functions without having the others, not in the sense that having one precludes the possibility of having others.

10. Let me stress that the point is not that Modal Theory can never account for alternative hypotheses or resolve a dispute in favor of one or the other. Rather, I am arguing that in many cases, it is too coarse-grained for making sense of certain debates involving interesting and plausible hypotheses, because they are too easily made true.

The Modal Theory is also unable to make many distinctions in which the notion of functions plays an essential role. Consider the distinction between vestigial and dysfunctional traits. Vestiges are kinds of traits that used to have a function but lost it. In contrast, a dysfunctional trait is a trait (token) that has a function but fails to comply with it. Now, consider a kiwi (family *Apterygidae*), which has vestigial flight organs, and a sparrow that has a deeply malformed wing due to some genetic mutation. Neither bird can fly in the actual world, and let us suppose that the worlds where they can fly are approximately at the same distance from the actual world. The Modal Theory has exactly the same prediction for the wings of a kiwi and the malformed wing of a sparrow: since the worlds where flying increases fitness are closer than those worlds where flying does not increase fitness, either both traits have the function of enabling flight or they lack it. What the Modal Theory cannot get, however, is the result that one is an exemplar of a vestige while the other is a malformed (but functional) trait.[11] This is a also significant result because it casts doubt on Nanay's claim that his theory can adequately distinguish failing to have a function from having it but malfunctioning (cf. Nanay 2013, 523). Consequently, it is not obvious that his theory can indeed satisfy the desideratum 3 set up above.

In a parallel fashion, Modal Theory cannot distinguish features that provide an advantage in virtue of design from features that provide an advantage in virtue of constraints or pure physical laws. For example, it is sometimes said that the light body of spiders and other insects helps them to avoid being injured from falls. If that is true, it is certainly an effect of its body configuration that increases fitness in all accessible close possible worlds, but this is not one of its functions. Similarly, gravity causes the adult kokanee salmon (*Oncorhynchus nerka*) to return to water after jumping, but they lack this function (Lauritzen et al. 2010). Certainly, this fact increases fitness in accessible close worlds, but this is a mere consequence of physical law (Buller 1998). These distinctions play a central role in many scientific explanations.

Summing up, I think that the Modal Theory blurs many distinctions that are relevant from a scientific point of view. Furthermore, this approach cannot make sense of some scientific debates in which the notion of function plays a central role. As a consequence, assuming that Modal Theory is the right theory of functions would have negative consequences for science.[12]

11. Note that Nanay cannot appeal to the fact that most sparrows use wings to fly, because one of his main goals is to develop a theory that applies at the level of tokens. This is precisely his main criticism to etiological theories (Nanay 2010, 2011, 2013).

12. In that respect, let me stress that Modal Theory cannot be considered a refinement of systemic (Cummins-style) functions (Cummins 1975). Usually, systemic accounts claim

5. Conclusion. I have argued that the Modal Theory does not satisfy the desiderata of Ascription Adequacy and Use Adequacy and that the way it satisfies Context Dependence and Normativity might also lead the theory into problems. For this reason I think N-functions should not be identified with functions. Perhaps the property described in Modal Theory corresponds to some other property related to usefulness, which may have interesting applications in some particular field,[13] but it is probably not the property having a function that is attributed and discussed in science. Thus, whatever the merits of the Nanay's approach are, the Modal Theory is not a theory of functions.

REFERENCES

Ariew, André, Robert Cummins, and Mark Perlman, eds. 2002. *Functions: New Essays in the Philosophy of Psychology and Biology.* Oxford: Oxford University Press.

Buller, David J. 1998. "Etiological Theories of Function: A Geographical Survey." *Biology and Philosophy* 13:505–27.

Christensen, Wayne, and Mark Bickhard. 2002. "The Process Dynamics of Normative Function." *Monist* 85 (1): 3–28.

Collins, Anthony. 1986. "Interactions between Adult Male and Infant Yellow Baboons (*Papio c. cynocephalus*) in Tanzania." *Animal Behavior* 34:430–43.

Cummins, Robert. 1975. "Functional Analysis." *Journal of Philosophy* 72:741–65.

Deag, John, and John H. Crook. 1971. "Social Behaviour and 'Agonistic Buffering' in the Wild Barbary Macaque, *Macaca sylvana*." *Folia Primatologica* 15:183–200.

Godfrey-Smith, Peter. 1993. "Functions: Consensus without Unity." *Pacific Philosophical Quarterly* 74:196–208.

Hardcastle, Valerie G. 2002. "On the Normativity of Functions." In Ariew et al. 2002, 144–57.

Kiritani, Osamu. 2011a. "Function and Modality." *Journal of Mind and Behavior* 32 (1): 1–4.

———. 2011b. "Modality and Function: Reply to Nanay." *Journal of Mind and Behavior* 32 (2): 89–90.

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that functions are contributions that features make to some goal of a system. One of the main motivations for adopting this notion of function is that it keeps the intuition that if I want to know the function of the timing belt of my car I just need to look at the contribution it makes to the engine. According to this approach, function attributions depend on what traits actually do or can do within a system, rather than on facts that are far away from the particular entity we are attributing a function to. Defenders of this approach accuse etiological theories of 'epiphenomenalism', i.e., being insensitive to the actual capacities of the trait token (Christensen and Bickhard 2002). Now, Modal Theory seems to be an epiphenomenalist account in that sense; it attributes functions in virtue of things happening in certain possible worlds, irrespective of what the trait actually does or can do in the actual world. So it lacks the key advantage motivating Cummins-style theories.

13. Nanay (2012, 422; 2013, 525) briefly considers that option. His reply is simply to bite the bullet: "this notion of function may have a lot to do with usefulness. But it is important to distinguish usefulness from use." Certainly usefulness is different from use, but as I argued, usefulness is also very different from function.

Lauritzen, Dean, Fritz Hertel, Laura K. Jordan, and Malcolm Gordon. 2010. "Salmon Jumping: Behavior, Kinematics and Optimal Conditions, with Possible Implications for Fish Passageway Design." *Bioinspiration and Biomimetics* 5 (3): 035006.
McLaughlin, Peter. 2001. *What Functions Explain: Functional Explanation and Self-Reproducing Systems*. Cambridge: Cambridge University Press.
Millikan, Ruth G. 1989. "In Defense of Proper Functions." *Philosophy of Science* 56 (2): 288–302.
———. 1999. "Wings, Spoons, Pills and Quills: A Pluralist Theory of Functions." *Journal of Philosophy* 96 (4): 191–206.
———. 2002. "Biofunctions: Two Paradigms." In Ariew et al. 2002, 113–44.
Mossio, Matteo, Cristian Saborido, and Álvaro Moreno. 2009. "An Organizational Account of Biological Functions." *British Society for the Philosophy of Science* 60:813–41.
Nagel, Ernest. 1977. "Functional Explanations in Biology." *Journal of Philosophy* 74 (5): 280–301.
Nanay, Bence. 2010. "A Modal Theory of Function." *Journal of Philosophy* 107:412–31.
———. 2011. "Function, Modality and Mental Content." *Journal of Mind and Behavior* 32:84–87.
———. 2012. "Function Attribution Depends on the Explanatory Context." *Journal of Philosophy* 109:623–27.
———. 2013. "Artifact Categorization and the Modal Theory of Artifact Function." *Review of Philosophy and Psychology* 4:515–26.
———. 2014. "Teleosemantics without Etiology." *Philosophy of Science*, in this issue.
Neander, Karen. 1991. "Functions as Selected Effects: The Conceptual Analyst's Defense." *Philosophy of Science* 58:168–84.
Neander, Karen, and Alex Rosenberg. 2012. "Solving the Circularity Problem for Functions: A Response to Nanay." *Journal of Philosophy* 109 (10): 613–22.
Stevens, Martin. 2005. "The Role of Eyespots as Anti-predator Mechanisms, Principally Demonstrated in the Lepidoptera." *Biological Reviews* 80 (4): 573–88.
Taub, David M. 1980. "Testing the 'Agonistic Buffering' Hypothesis." *Behavioral Ecology and Sociobiology* 6:187–97.
Vallin, Adrian, Sven Jakobsson, Johan Lind, and Christer Wiklund. 2005. "Prey Survival by Predator Intimidation: An Experimental Study of Peacock Butterfly Defence against Blue Tits." *Proceedings of the Royal Society* B 272 (1569): 1203–7.
Wouters, Arno. 2005. "The Function Debate in Philosophy." *Acta Biotheoretica* 53 (2): 123–51.
Wright, Larry. 1973. "Functions." *Philosophical Review* 82 (2): 139–68.