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Millikan, Persistence, and Direct Proper Functions: A Slippery Rockslide?

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This paper argues that Ruth Millikan's official definitions in Language, Thought, and Other Biological Categories admit persistence-based direct proper functions. These definitions do not require reproductions to involve numerically distinct persisting items, thus supporting a broader account than her surrounding prose suggests. I demonstrate how this interpretation extends through Millikan's first-order machinery and into her definition of direct proper function. Accordingly, direct proper functions can be conferred on synapses via synapse selection and, more implausibly, on rocks via rockfalls. I examine three strategies for blocking this result: a reproduction requirement, a population requirement, and a service requirement. Given Millikan's explanatory aims, I argue that she should reject these as general requirements, but accept them for theoretically important subclasses.

Keywords: Millikan; proper function; persistence; reproduction; selected effects; population

1. Introduction

This paper addresses a fundamental issue in Ruth Millikan's theory of *direct proper function*, as presented in her 1984 book, *Language, Thought, and Other Biological Categories*. The book contains the foundational statement of her theory of proper functions and underlies much of her subsequent philosophy of mind, language, and cognition. The standard interpretation assumes that this framework is reproduction-bound (Godfrey-Smith 1994, 346; Matthen 2012, 135; Garson 2011, 560, 2019, 75, 2024, 954f.; Artiga 2021, 3; Schulte 2021, 369; Roloff 2023, 71). Accordingly, direct proper functions are said to arise only through copying or reproduction.

Millikan's surrounding prose supports the standard interpretation. However, her definitions also admit a reading on which persistence can ground direct proper functions. In this paper, I defend this interpretation as both an open interpretive possibility and a theoretically preferable reading, given Millikan's explanatory objectives and subsequent work.

Section 2 develops the persistence reading of Millikan's definitions. Section 3 applies this reading to synapse selection and rockfalls, showing how persistence can confer direct proper functions in both cases. Section 4 considers whether reproduction, population and service requirements can block the rockfall result. I argue that these restrictions either fail or conflict with Millikan's explanatory aims.

2. Persistence in Millikan's First-Order Apparatus

For Millikan, in the simplest cases, an item has a direct proper function as a member of a first-order reproductively established family. In this family, items are related as "reproductions" of one another, though Millikan notes that the ordinary word "copy" may be more accurate (Millikan 1984, 19). However, her technical definition of "reproduction" is less restrictive than this framing suggests:

> "An individual *B* is a 'reproduction' of an individual *A* iff:
>
> (1) *B* has some determinate properties *p1, p2, p3*, etc., in common with *A* and [...]
>
> (2) [t]hat A and *B* have the properties [...] in common can be explained by a natural law or laws operative in situ, [and]
>
> (3) [f]or each property *p1, p2, p3*, etc. the laws in situ [...] are laws that correlate a specifiable range of determinates under a determinable under which *p* falls, such that whatever determinate characterizes *A* must also characterize *B*, the direction of causality being straight from *A* to *B*." (Millikan 1984, 19f.)

If these conditions are fulfilled, A is a model of B, and the properties p1, p2, p3, etc. are reproductively established properties (Millikan 1984, 20), which, taken together, form a reproductively established character (Millikan 1984, 23).

The question is whether A and B must be numerically distinct, persisting objects, or may be temporally distinct phases of one persisting item. On the broader reading, such phases can satisfy conditions (1)–(3).

Ordinary persistence typically involves the relevant lawlike and counterfactual dependencies. The later phase has the relevant determinate features because the earlier phase had them. Had the earlier phase differed in those respects, the later phase would have differed accordingly. For instance, earlier and later phases of a rock share properties such as composition, hardness, and surface features through causal continuity. The same is true for successive phases of a synapse, which can share connectivity, synaptic strength, and morphology.

Once phases are admitted as individuals, Millikan's technical notions of "reproduction," "reproductively established properties," and "reproductively established character" can be read in a persistence-friendly way. The rest of Millikan's first-order apparatus shifts accordingly. The first consequence is that first-order reproductively established families can be established through persistence:

> "Any set of entities having the same or similar reproductively established characters derived by repetitive reproductions from the same character of the same model or models form a *first-order reproductively established family.*" (Millikan 1984, 23)

If the conditions for “reproduction” can be satisfied by persistence, first-order reproductively established families may also consist of diachronically ordered phases of one persisting item, so long as those phases share the relevant reproductively established character and are linked by the appropriate chain of reproduction.

This has consequences for Millikan’s definition of "ancestor of a member of a reproductively established family." For the purposes of this discussion, only the first disjunct matters:

> “Any member of a (first-order) reproductively established family from which a current member *m* was derived by reproduction or by successive reproductions is an ancestor of *m*.” (Millikan 1984, 27)

Given the broader interpretation of “individual” and “reproduction,” earlier phases of one persisting item can also count as ancestors of later phases. Persistence can therefore satisfy Millikan’s first-order machinery. What remains to be shown is that it can also satisfy the more demanding conditions of direct proper function.

3. Direct Proper Function on a Persistence Reading

Based on the definitions cited in the previous section, Millikan defines “direct proper function” as follows:

> "Where *m* is a member of a reproductively established family *R* and *R* has the reproductively established [...] character *C*, *m* has the function *F* as a direct proper function iff:
>
> (1) Certain ancestors of *m* performed *F*.
>
> (2) In part because there existed a direct causal connection between having the character *C* and performance of the function *F* in the case of these ancestors of *m*, *C* correlated positively with *F* over a certain set of items *S* which included these ancestors and other things not having *C*.
>
> (3) One among the legitimate explanations that can be given of the fact that *m* exists makes reference to the fact that *C* correlated positively with *F* over *S*, either directly causing reproduction of *m* or explaining why *R* was proliferated and hence why *m* exists." (Millikan 1984, 28)

On the broad interpretation, introduced in the previous section, phases of persisting items belong to first-order reproductively established families with a reproductively established character. Accordingly, condition (1) is satisfied if earlier phases of a persisting item performed *F*. Condition (2) requires that *C* correlate positively with performing *F* over a set *S* that includes the relevant ancestors and other items without *C*. This condition does not require the members of *S* to be persisting items rather than phases. Condition (3) requires a legitimate explanation of *m*'s existence to refer to that correlation, either by directly causing the reproduction of *m* or by

explaining why *R* proliferated. In the first disjunct, "the reproduction of *m*" is best read as referring to *m*'s being produced as a reproduction. Absent an explicit restriction, the natural assumption is that 'reproduction' in clause (3) carries the same technical meaning fixed earlier. If so, clause (3), too, remains open to persistence. The question, then, is whether any actual cases satisfy conditions (1)–(3) on such a reading. I argue that they do.

Consider synapse selection (Garson 2011, 553ff., 2017, 532ff., 2019, chap. 5; Garson and Papineau 2019). New synapses form abundantly. Some are retained, while others are pruned. Let *S* include phases of synapses competing for the same target under a shared maintenance constraint, so that strengthening one synapse weakens others. Let *m* be a later phase of the retained synapse, *C* its connectivity profile, and *F* its contribution to activation of the target neuron. Earlier phases of the same synapse satisfy condition (1). If *C*-bearing phases activate the target neuron more frequently than non-*C* alternatives, *C* correlates positively with *F* over *S*. Under the shared maintenance constraint, the weaker performance and pruning of non-*C* alternatives contribute to the retention of the *C*-bearing synapse. If the alternatives had activated the neuron equally well, the focal synapse would not have been preferentially retained. Therefore, the *C*–*F* correlation over *S* explains *m's* existence. Conditions (2) and (3) are then satisfied. The later synaptic phase therefore has the direct proper function of contributing to activation of the target neuron.

In contrast, consider the following rockfall case (adapted from cases discussed by Conley 2020; and Schulte 2021, 373). Rocks of the same geological type, but varying in size and shape, tumble down a slope in several successive pulses. The slope contains a limited number of sheltering cavities. Some cavities can accommodate rocks of all sizes, while narrower ones admit only small rocks of specific shapes. Later impacts can dislodge a sheltered rock, allowing the process to recur further down the slope. Let *m* be a phase of one such rock after several pulses, *C* its particular size and shape, *F* remaining lodged in a sheltering cavity, and *S* the relevant earlier phases of the rocks in the fall, some with *C* and some without it. Earlier phases of the same rock repeatedly performed *F*. Over *S*, *C* correlates positively with *F*, since *C*-bearing rocks can use a wider range of cavities and lodge more often than non-*C* rocks. During several of these pulses, the focal rock secures a cavity that is also sought by a non-*C* competitor. Remaining lodged in the cavity protects the focal rock and prevents the competitor from using it. The latter continues down the slope and is destroyed. The progressive loss of non-*C* rocks also reduces competition during subsequent pulses. Had the focal rock lacked *C*, it would not have endured this sequence. Had the alternatives also possessed *C*, the focal rock would not have had the same repeated advantage. Therefore, the *C*–*F* correlation over *S*, including the alternatives' lack of *C*, helps to explain *m*'s existence. Conditions (1)–(3) are satisfied, and the later rock phase therefore has the direct proper function of remaining lodged in a sheltering cavity.

Given the broad interpretation of "individual", Millikan's definitions allow historically successful persistence to ground direct proper functions alongside successful copying. This conflicts with the standard interpretation. It also contrasts with Roloff's proposal, which introduces "persistence-gained direct proper functions" as a separate category defined in terms of a persisting individual, a persisting character, and earlier temporal parts as ancestors (Roloff 2023, sec. 4.1; for an argument in favour of the need for a separate category of persistence-based proper functions, see Fagerberg 2022). On the present view, however, that additional category is unnecessary, since Millikan's own definitions admit persistence-based cases.

4. Blocking the Rockslide?

Millikan's official definitions can be interpreted as permitting direct proper functions to be conferred through persistence. However, this reading also permits a rock to acquire a direct proper function through the cavity rockfall, rendering Millikan's account susceptible to the familiar liberality objection (Bedau 1991, 648f.; Kingsbury 2008, 496; Garson 2011, 557f., 2017, sec. 5, 2024, sec. 3; Garson and Papineau 2019, 11ff.; Schulte 2021; Roloff 2023; Dussault 2023; 2025a, 69ff.; 2025b). The worry is that persistence-based histories ascribe functions too liberally, extending them to rocks, clay crystals, and similar abiotic items. Critics argue that such histories are insufficient for teleology, fail to distinguish between function and malfunction, and may make functional explanations too cheap. The following

sections assess whether three restrictions can exclude such cases while preserving Millikan's explanatory aims.

4.1 Imposing a Reproduction Requirement

The first response is to restrict 'individual' to persisting items, thereby blocking persistence-based direct proper functions at their source.The first question is whether this is a plausible interpretation of Millikan's definitions. In Chapter 2 of *White Queen Psychology*, Millikan links the reproduction requirement to the leaking-hose case introduced by Christopher Boorse (1976, p. 72). In this case, a break in a hose releases gas that incapacitates the scientist who would repair it. According to Millikan, the break lacks the function of releasing gas because it is not its own ancestor (Millikan 1993, 34). This passage speaks against the persistence reading. If phases are possible relata of the reproduction relation, then an earlier phase of the break could be an ancestor of a later phase. The reproduction requirement would then fail to exclude the very case Millikan invokes it to screen off.

The next passage suggests a broader interpretation. Millikan introduces a counterexample that she says reproduction does not exclude:

> "This move doesn't, however, take care of the positions, vector velocities, and accelerations of the planets, for these are copied from one another. Within quite a large latitude, had the earth been in a different place going at a

different speed in a different direction last year, this placement and vector velocity would have reproduced itself this year." (Millikan 1993, p. 35)

Taken literally, the first sentence suggests that instances of a planet's position, velocity, or acceleration are themselves relata of reproduction. According to this interpretation, these instances of properties would have to share certain properties. It is questionable, however, what second-order properties these might be.

Millikan's next sentence suggests another interpretation. If the Earth had been in a different location and had moved differently last year, its placement and vector velocity this year would also be different. In this interpretation, successive phases of the Earth are the relata of reproduction, and position and velocity are reproductively established properties of those phases. Thus, the examples pull in opposite directions, leaving open the question of whether phases count as relata of reproduction.

Independently of the interpretive question, reproduction has important theoretical advantages: it supports cumulative selection (Neander 1995, sec. 4) and projects functional standards across numerically distinct tokens, allowing a token to have a function it has never performed (Artiga 2021, 12).

However, these advantages do not justify making reproduction a universal requirement. A growing body of work argues that historical success can involve persistence, retention, reconstruction, or sorting rather than differential reproduction. This applies not only to synapse selection but also to clonal systems

(Bouchard 2008, 562ff.; Garson 2019, 91f.), reconstructed multilineage systems such as holobionts and biofilms (Doolittle and Booth 2017), and social or cultural entities such as firms and institutions (Wallis 2014). A universal reproduction requirement also sits uneasily with Millikan's treatment of trial-and-error learning (1984, 28), whose causal structure is naturally described as the retention of a disposition reinforced through successful manifestations (Garson 2011, 559, 2019, 90).

4.2 Imposing a Population Requirement

A more concessive response retains persistence and restricts the reference class. Conditions (2) and (3) of the definition of direct proper function require the *C*–*F* correlation over *S*, including the fact that some members of *S* lack *C*, to help explain *m*'s existence (cf. Roloff 2023, sec. 2.2). The non-*C* items therefore cannot be explanatorily idle. Apart from this, however, Millikan does not impose any further restrictions on *S*.

Various authors require *S* to form a population, but disagree about what that entails. According to Garson's initial proposal, population members must interact in ways that are relevant to their persistence or reproductive prospects (2017, 2019, sec. 6.3). The cavity rockfall already satisfies this condition: by occupying the limited cavities, the rocks affect one another's persistence prospects. Schulte strengthens the requirement by demanding that members of a population must stand in a relation of competition, whereby *A* and *B* stand in such a relation iff "*A* exerts a negative influence on *B*'s chances of reproduction or persistence, because *A*

behaves in a way that enhances its own chances of reproduction or persistence" (Schulte 2021, 374). The cavity rockfall also satisfies this requirement. The focal rock's remaining lodged improves its own prospects while depriving the non-*C* rock of the same sheltering opportunity.

In his later account, Garson (2024, 963f.) proposes that populations consist of individuals of the same type whose use of a common resource *r* affects one another's ability to use *r* competitively or cooperatively. There are, however, two difficulties with this proposal. Firstly, if resources are understood in a narrow sense (i.e. as matter, energy or other maintenance requirements), then this proposal does not apply to some of Millikan's central examples of items with direct proper functions, such as public language devices (Millikan 1984, 52f., 2005), and behaviours acquired through trial and error (Millikan 1984, 28). These are retained through successful uptake or reinforcement, rather than through access to matter, energy, or maintenance resources. If resources include opportunities for uptake, attention, reinforcement, or shelter, the cavity rockfall qualifies. The rocks are of the same type, the cavities constitute resources, and when one rock occupies a cavity, it restricts the access to resources by other rocks. Secondly, even in biological cases, a common-resource requirement is not obviously the right restriction, since selection can also arise through common predation pressure, independent of competition for shared resources (Dussault 2025b, sec. 4).

Population criteria may be used to restrict the reference class S for some explanatory projects. Yet none of the criteria considered here excludes the cavity

rockfall while accommodating all the biological, psychological, and linguistic cases that are central to Millikan's project.

4.3 Imposing a Service Requirement

A third response would be to strengthen condition (3) of *direct proper function* by requiring that the relevant effect enter the explanation through a service relationship with another system.

Price (2001, sec. 2.2) suggests the weakest such repair. On a Millikanian adaptation, clause (3) would require that the fact that the reproductively established character *C* correlated positively with the performance of *F* over set *S* explains why the item in question (*m*) exists, because performances of *F* by ancestors of *m* contributed to some further item or system *e* doing some further thing *E*. This fits the synapse case but does not exclude all troubling persistence cases. Consider a region of Roman-style hot-mixed concrete containing lime clasts, which are hypothesised to release reactive calcium into water-filled cracks, thereby promoting mineralisation that fills the cracks (Seymour et al. 2023). Suppose this material was repeatedly exposed to cracking and water, and that the relevant microstructure was not intentionally selected or designed for its self-healing properties. Let *m* denote a later phase of this region, *C* the lime-clast-rich microstructure, *F* its supplying of reactive calcium when water enters a crack, *e* the surrounding cementitious matrix, and *E* the formation of crack-filling mineral phases. Let *S* include earlier phases of this region and otherwise similar regions of the same concrete, some with *C* and

some without it. Suppose further that the regions are hydraulically coupled. *C*-bearing regions seal their own cracks, while non-*C* regions disintegrate progressively and open drainage paths. These reduce the pressure on the remaining regions. The *C*–*F* correlation over *S* then explains why *m* exists. If the earlier phases of the focal region had lacked *C*, they would have disintegrated. Similarly, if the alternative regions had possessed *C* and sealed their cracks, the pressure on the focal region would have remained too high for it to persist. Price's condition is satisfied because the lime clasts' performances of *F* (releasing calcium) directly enable the matrix *e* to perform *E* (building mineral phases). However, this remains an abiotic persistence case, which the service response was designed to eliminate.

A stronger repair is suggested by Dussault (2023, sec. 10.3; 2025a, 82f.; 2025b, sec. 2). An adapted clause (3) would require that the fact that *C* correlated positively with *F* over *S* explain why *m* exists because performances of *F* by ancestors of *m* contributed to a complexly organised system *T* composed of functionally differentiated parts and persisting through their combined activities. Dussault thus generalises Godfrey-Smith's stricter requirement that a function bearer be part of a larger biologically real system and selected through a positive contribution to its fitness (1994, 349). A sufficiently demanding interpretation would plausibly exclude the concrete case. However, the principal attraction of Dussault's proposal is that it captures what it is for an item to have a function *for a system*. The distinction matters across explanatory projects. In teleosemantics, it distinguishes states whose effects serve the organism—and are candidates for representational functions—from

states with merely retention-based functions. In philosophy of medicine, apparently conflicting function and dysfunction attributions may be disambiguated by appeal to system-relativity rather than by treating reproduction and persistence as grounding different kinds of function, as suggested by Fagerberg (2022). A cancer cell may be dysfunctional relative to its functions for the organism while its lineage acquires functions of its own.

However, this does not prove that all direct proper functions must be system-relative. Public language devices give reason for doubt. In these cases, what is reproduced is a two-part pattern of speaker contribution and cooperative hearer response (Millikan 1984, chaps. 3–4; 2005, 190). The relevant speaker–hearer pair may exist only for the duration of an interaction and thus need not be a persisting system of functionally differentiated parts. A linguistic community might instead be proposed as a candidate for *T*. But then the relevant selection would have to proceed through a contribution to that community's persistence. Millikan's explanation instead runs through the effect that sustains the continued reproduction of both the linguistic form and the cooperative hearer response (2004, 25f.; 2005, 58f.). Within the broader Millikanian framework, Dussault's proposal may therefore be used to identify an important subclass of system-relative direct proper function, though it does not provide a general condition.

4.4 Living with the Rockslide

Reproduction, population, and service requirements each capture a feature of some direct proper functions, but none of these apply across Millikan's project as a whole. This suggests that they should be treated as project-specific rather than universal requirements.

This conclusion aligns with Millikan's methodology. Rather than providing a conceptual analysis, she presents her account of proper function as a theoretical definition of a technical notion (Millikan 1984, 18, 1989, 290). She also contrasts her view with Karen Neander's defence of the etiological account as a conceptual analysis of biologists' usage of the term "function" (Millikan 1989, 290 fn. 1).[1] In later retrospective remarks, she describes the original definition in more stipulative terms and offers it "as a handle by which to grab hold of the analogies" (Millikan 2022, 361).

Millikan evaluates theories by explanatory depth and unity rather than conformity with pre-theoretical intuitions. Millikan explicitly accepts this price: "If crystals can have functions … that is fine by me" (Millikan 1993, 39 n. 7). From this perspective, accepting counterintuitive consequences is not a *reductio* by default; if anything, for Millikan it is the default (cf. Millikan 1984, 93f., 2010, sec. 12 on Swampman, 1984, 91f. on meaning rationalism).

The restrictions can instead be understood as capturing paradigmatic (cf. Artiga 2021) or theoretically central and interesting (cf. Bourrat 2021) cases of direct

[1] Millikan refers to the unpublished manuscript of Neander (1991).

proper function, or as requirements for particular explanatory projects. Millikan's official machinery defines the broader category. Reproduction, population, and service requirements specify important subtypes.

5. Conclusion

I have argued that Millikan's official definitions permit persistence-based direct proper functions. However, this comes at a cost. Besides plausible cases, such as synapse selection, the reading admits the troubling cavity-rockfall case. While the main repair strategies identify important subclasses of direct proper functions, none provides a plausible universal requirement.

The significance of this result is that on the defended reading, persistence is admitted by the same notion of direct proper function that underlies Millikan's accounts of biological normativity and malfunction (1984, chaps. 1–2), public language and standards of linguistic correctness (1984, chaps. 3–4, 2005), intentionality and mental content (1984, chap. 6, 2004, pt. IV), perception (2004, chaps. 3–4 and 9, 2017, chap. 14), and cognition, concepts, and same-tracking abilities (2000, chaps. 1 and 4, 2017, chap. 5). The question is therefore which additional restrictions are appropriate to these different explanatory projects. The

unity of Millikan's naturalism would then lie in a shared historical-explanatory core, not in uniform restrictions across all domains.[2]

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References

Artiga, Marc. 2021. "Biological Functions and Natural Selection: A Reappraisal." *European Journal for Philosophy of Science* 11 (2): 1–22.

Bedau, Mark. 1991. "Can Biological Teleology Be Naturalized?" *Journal of Philosophy* 88 (11): 647–55. https://doi.org/10.5840/jphil1991881111.

Boorse, Christopher. 1976. "Wright on Functions." *The Philosophical Review* 85 (1): 70–86. https://www.jstor.org/stable/2184255.

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Bouchard, Frédéric. 2008. “Causal Processes, Fitness, and the Differential Persistence of Lineages.” *Philosophy of Science* 75 (5): 560–70. https://doi.org/10.1086/594507.

Bourrat, Pierrick. 2021. “Function, Persistence, and Selection: Generalizing the Selected-Effect Account of Function Adequately.” *Studies in History and Philosophy of Science Part A* 90 (December): 61–67. https://doi.org/10.1016/j.shpsa.2021.09.007.

Conley, Brandon A. 2020. “Review: What Biological Functions Are and Why They Matter.” Notre Dame Philosophical Reviews. https://ndpr.nd.edu/reviews/what-biological-functions-are-and-why-they-matter/.

Doolittle, W. Ford, and Austin Booth. 2017. “It’s the Song, Not the Singer: An Exploration of Holobiosis and Evolutionary Theory.” *Biology & Philosophy* 32 (1): 5–24. https://doi.org/10.1007/s10539-016-9542-2.

Dussault, Antoine C. 2023. “Do Clay Crystals and Rocks Have Functions? Selected Effects Functions, the Service Criterion, and the Twofold Character of the Function Concept.” In *Functions: From Organisms to Artefacts*, edited by Jean Gayon, Armand de Ricqlès, and Antoine C. Dussault, 135–58. Springer.

Dussault, Antoine C. 2025a. “Generalized Selected Effects Functions, the Liberality Problem, and Interspecific Competition.” *MEFISTO. Journal of Medicine,*

Philosophy, and History (IT) 9 (2): 65–87. https://doi.org/10.4454/mefisto.9-2.1497.

Dussault, Antoine C. 2025b. "No Function without Service: Selected Effects Functions, the Liberality Problem, and Whole Organisms." *The British Journal for the Philosophy of* Science. https://doi.org/10.1086/735278.

Fagerberg, Harriet. 2022. "Against the Generalised Theory of Function." *Biology & Philosophy* 37 (4): 1–25.

Garson, Justin. 2011. "Selected Effects and Causal Role Functions in the Brain: The Case for an Etiological Approach to Neuroscience." *Biology & Philosophy* 26 (4): 547–65. https://doi.org/10.1007/s10539-011-9262-6.

Garson, Justin. 2017. "A Generalized Selected Effects Theory of Function." *Philosophy of Science* 84 (3): 523–43. https://doi.org/10.1086/692146.

Garson, Justin. 2019. *What Biological Functions Are and Why They Matter*. 1st ed. Cambridge University Press. https://doi.org/10.1017/9781108560764.

Garson, Justin. 2024. "Functions and Populations: Sharpening the Generalized Selected Effects Theory of Function." *Philosophy of Science* 91 (4): 950–68. Cambridge Core. https://doi.org/10.1017/psa.2024.3.

Garson, Justin, and David Papineau. 2019. "Teleosemantics, Selection and Novel Contents." *Biology & Philosophy* 34 (3): 36. https://doi.org/10.1007/s10539-019-9689-8.

Godfrey-Smith, Peter. 1994. "A Modern History Theory of Functions." *Noûs* 28 (3): 344–62. https://doi.org/10.2307/2216063.

Kingsbury, Justine. 2008. "Learning and Selection." *Biology & Philosophy* 23 (4): 493–507. https://doi.org/10.1007/s10539-008-9113-2.

Matthen, Mohan. 2012. "Millikan's Historical Kinds." In *Millikan and Her Critics*, edited by Dan Ryder, Justine Kingsbury, and Kenneth Williford, 135–54. Wiley.

Millikan, Ruth Garrett. 1984. *Language, Thought, and Other Biological Categories: New Foundations for Realism*. MIT Press.

Millikan, Ruth Garrett. 1989. "In Defense of Proper Functions." *Philosophy of Science* 56: 288–302.

Millikan, Ruth Garrett. 1993. *White Queen Psychology and Other Essays for Alice*. MIT Press.

Millikan, Ruth Garrett. 2000. *On Clear and Confused Ideas: An Essay About Substance Concepts*. Cambridge University Press.

Millikan, Ruth Garrett. 2004. *Varieties of Meaning*. The Jean Nicod Lectures 2002. MIT Press.

Millikan, Ruth Garrett. 2005. *Language: A Biological Model*. Clarendon Press.

Millikan, Ruth Garrett. 2010. "On Knowing the Meaning; with a Coda on Swampman." *Mind* 119 (473): 43–81. https://doi.org/10.1093/mind/fzp157.

Millikan, Ruth Garrett. 2017. *Beyond Concepts: Unicepts, Language, and Natural Information*. Oxford University Press.

Millikan, Ruth Garrett. 2022. "Rescuing Proper Functions." *Australasian Philosophical Review* 6 (4): 360–66. https://doi.org/10.1080/24740500.2024.2370622.

Neander, Karen. 1991. "Functions as Selected Effects: The Conceptual Analyst's Defense." *Philosophy of Science* 58 (2): 168–84. https://doi.org/10.1086/289610.

Neander, Karen. 1995. "Pruning the Tree of Life." *British Journal for the Philosophy of Science* 46 (1): 59–80. https://doi.org/10.1093/bjps/46.1.59.

Price, Carolyn. 2001. *Functions in Mind: A Theory of Intentional Content*. Clarendon. https://doi.org/10.1093/acprof:oso/9780199242009.001.0001.

Roloff, Jakob. 2023. “Populations of Neurons and Rocks? Against a Generalization of the Selected Effects Theory of Functions.” *Kriterion – Journal of Philosophy* 37 (2–4): 69–87.

Schulte, Peter. 2021. “No Functions for Rocks: Garson’s Generalized Selected Effects Theory and the Liberality Problem.” *Analysis* 81 (2): 369–78.

Seymour, Linda M., Janille Maragh, Paolo Sabatini, Michel Di Tommaso, James C. Weaver, and Admir Masic. 2023. “Hot Mixing: Mechanistic Insights into the Durability of Ancient Roman Concrete.” *Science Advances* 9 (1): eadd1602. https://doi.org/10.1126/sciadv.add1602.

Wallis, John Joseph. 2014. “Persistence and Change in Institutions: The Evolution of Douglass C. North.” In *Institutions, Property Rights, and Economic Growth*, 1st ed., edited by Sebastian Galiani and Itai Sened, 30–49. Cambridge University Press. https://doi.org/10.1017/CBO9781107300361.004.