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TRANSITIVE AND INTRANSITIVE SELECTION PROCESSES AND THEIR EFFECTS

Abstract. Karen Neander's (1991a, b) Selected Effects (SE) theory of biological proper functions argues that the function of a trait is the action for which it was "caused" to be selected by natural selection. Her life's work has already left a lasting impact, however SE theory has yet to be more properly formalized as a conceptual analysis of biological functions. Although other SE theories have sought to build upon Neander's work (e.g., Garson, 2017), there remains an ambiguity in the theory's use of causal descriptors. For the success of her successors, delineating the function of causality for SE theory is of utmost importance. Here, I systematize Neander's theory according to the different senses of causation inherent to it. I argue that structuring SE theory in terms of causal transitivity and intransitivity reveals that Neander's analysis not only supersedes her detractors but likely exposes areas of vulnerability in others' SE theory derivatives.

Keywords: biological proper functions, selected effects theory, functions pluralism, causal pluralism, grammatical tenses

1. Introduction: Speaking of Biology

Within philosophy of biology, the debate over classifying biological traits, as according to their evolutionary functions and the nature of the causal relations inherent to these functions, has yet to cease causing controversy (Fagerberg, 2022; Ginnobili, 2022; Ratti & Germain, 2022; Artiga, 2021; Garson, 2019, 2018, 2017). This paper is aimed at intervening in these philosophical disagreements by taking a step back from them, so as to reorient oneself (or, that is, to get a better aim at their intended target). As such, I do not intend on handling any one specific dispute over biological function ascriptions, whether pertaining to trait heritability (Lu & Bourrat, 2022; Veigl, Suárez & Stencel, 2022), the function(s) of "junk DNA"

(Linquist, 2022), possible functions of transposons (Garson, 2022), evolutionary and developmental plasticity (Matthewson, 2020), or the nature of evolutionary change or progress in populations and species (Bourrat, 2021; Desmond, 2021; Birch, 2016; Margulis, 1971).

I moreover do not intend on addressing biological research evidence in any depth, despite my conviction that this paper is indeed addressed to those depths. I maintain that my arguments herein pertain to "on-the-ground" and philosophical investigations in biology, alike, but I primarily expect philosophers to (hopefully) understand my claim as to why this is so. That is, this paper's application of necessary and sufficient conditionals will seem antiquated to many, especially to non-philosophers. There will no doubt follow from this impression the reader's sense that, being so, the paper's conceptual analysis might not "map onto the real world" in any significant manner. However, part of my reasoning for proceeding forward in this analysis of proper function ascriptions is due to my (Wittgensteinian) understanding that language provides no such a map.

Language instead provides us with tools to communicate ideas, beliefs, intents, desires, and feelings. Thus, language should not be understood to map *onto* the world but rather *into* it—i.e., to tell others, in the world, of our expectations *about* the world. I therefore turn to describing biological functions according to necessary and sufficient conditions simply because all language seeking to account for things not originating from within oneself will (necessarily) conform to such a structure. This need not imply that the world (sufficiently) conforms to the same structure, per se, but any attempt at explaining events' happenings will do so indeed. It is for lack of attention to this simple fact, so I claim, that the debate over biological function ascriptions has continued on for so long. Peeling the issue back to its most fundamental form, in language, helps us pinpoint exactly what is meant by our terms.

Oddly enough, other recent attempts at terminological clarity have appeared to advocate for abstaining from function-talk in favor of standardized convergence on terms specific to one's discipline (e.g., Ratti & Germain, 2022), as opposed to the present paper's more modest and realistic expectation: That biological disciplines ought to heed closer attention to their use of English grammar already at their fingertips. Nowhere herein do I suggest that either terminological abstinence or conformity would be helpful. I do, however, intuit that the proper grammatical application of biological function ascriptions will ease the suspicions of even those of whom are uneasy when it comes to evolutionary proper functions.

Outline

Being so, work remains to be done in formalizing Karen Neander's (1991a, b) Selected Effects (SE) theory of functions. Such work, taken up here, will lay bare the precise causal relations pertinent to selection and function *ascriptions*—i.e., to language. One's sense of causality affects their assumptions about selection processes and SEs. My arguments herein turn on the expectation that biological function descriptions invoke multiple causal relations manifesting under variable necessary and sufficient preconditions, of which I elaborate in Section 2. I sense that the historical debate over function ascriptions in philosophy of biology (see Section 3) demonstrates that confusion regarding causality can be ameliorated by differentiating a given event's proper conditionals, so distinguishing between transitivity, intransitivity and contiguity. I will clarify, in Section 3, which sorts of necessary and sufficient conditions belong to each causal category per distinct senses of *function*, specifically characterized through focus on the debated works of Larry Wright (1973), Robert Cummins (1975) and, of course, Neander in both Sections 3 and 4.

This framework will specify how the selection of traits and other biological entities (henceforth *entities*) incorporates multiple kinds of causal relations, as does an entity's function cause different kinds of effects (insofar as they are described in language). As such, overall, the analysis offered in the remaining pages finds that Neander's SE theory elegantly utilizes the intransitive form of causation, as with when a trait has been "caused to be selected" for the effect it has produced, therefore circumventing concerns regarding modes of evolutionary change, as brought up, for instance, by Cummins and Roth (2010; more in Section 3; also Ratti & Germain, 2022). But first, let us "get on the same page," so to speak.

2. Causes, Effects and Grammatical Tenses

Transitivity and Intransitivity

Transitive and *intransitive* verbs can each describe an event or action in diverse ways. Either way, an ideal description of an event should account for the causal factors both necessary and sufficient for its occurrence. *Transitive verbs* describe subjects of sentences directly acting on their objects, e.g., "The wind stole my kite" or "I am eating food." Such verbs, expressing *causal transitivity*, will therefore denote instances wherein A results in B and B results in C, such that A can be said to have caused C. The sufficient preceding conditions for such causal relations can be determined by counter-

factual statements of the form: If A *had not* resulted in B then B *would not have* resulted in C and so A *would not have had* caused C; but, wherefore it is given that C *has been* caused, A *has* therefore caused C (Neander & Menzies, 1990; emphases indicating, respectively, the grammatical first, second and third conditional tenses, and two forms of the zero conditional tense).

Clearly, however, counterfactual statements do not provide necessary conditionals for C's having been caused. C's being caused needn't always entail that A is responsible. The necessary conditions for C are particular to the nature of C. The wind can steal one's kite, as could a bird or envious onlooker. Each of these examples are *independently sufficient* for kite-stealing, but none are *exclusively necessary*. The necessary conditions for events described by transitive verbs can only be provided by premises specifying the nature of the event described such that C *will have been* sufficiently caused whenever all necessary premises obtain (future perfect continuous tense). A kite will have been stolen *iff* (i) a kite-owner comes to own one less kite, (ii) this is against their will, (iii) etc...

Sentences containing *intransitive verbs* describe states of being or general events. "I am eating," for example, could describe transitive causal relations if food is inferred. Otherwise, this statement is intransitive, because the subject is described as being in the state or process of eating. Contradistinctive to sentences using transitive verbs, the causal relations in events described by intransitive verbs are only ever sufficiently true when situationally specific premises obtain (stated in the future perfect continuous tense), and they are only ever necessarily true *iff* the contents of the proposition are *factive*.

Factivity entails necessary conditions for statements like, "I am eating," obtain *iff* the contents of the proposition are true (present perfect conditional tense). Notice, such statements are unlike those describing transitive causation, because their sufficient conditions cannot be grammatically determined counterfactually. "I am eating" could be true regardless of whether or not "I had eaten," "I have been eating" or "I will eat" are also true statements. This should be expected for states of existence: something either exists or it doesn't.

Continuity and Contiguity

Contiguous causal relations are trickier. Transitive and intransitive verbs both describe causality inherent to one event, meaning these actions comprise an entire event's causally *continuous* relations within it (hence the grammatical tense used for premises, future perfect continuous). Events can also be causally contiguous between one another, such that the final

event in a sequence is the consequence of (is contingent on) the causal relations contributed by previous events. Most explanations as to *why* something happened are aimed at describing contiguous relations, despite its being impossible to identify every necessary and sufficient condition explaining *how* such events occurred. As with the examples, "I am eating because I was hungry" and "Germany's invasion of Poland started WWII," any full account would prerequire one to sufficiently explain every continuous cause comprising each contiguous event, but such are the respective jobs of neuroscientists and historians—of whom they themselves struggle to describe everything!

Whether the logician is satisfied by it, we speak like this because complex events are *described* as states of being ("Germany's invasion of Poland"), despite their consisting of transitive actions (Trabasso, et al., 1998). One way to justify these descriptions is by appealing to J. L. Mackie's (1965) so-called "INUS condition," which is an acronym denoting "an *insufficient* but *necessary* part of a condition which is itself *unnecessary* but *sufficient* for the result" (p. 245). Basically, an INUS condition balances the asymmetry between transitive descriptions of the interactions between each intransitively described events in a contiguous sequence (Kim, 1971; Papineau, 1985).

Since events in sequence, ABC, are each described intransitively, one need only know that AB obtains (their propositions *are* factive, present perfect) to argue that A and B are *mutually necessary* for the final event C to *have* occurred (present perfect). Conversely, the influence each event has in the sequence, being causally transitive, can be *sufficiently* accounted for counterfactually: If not A then neither B nor C, but C thus ABC. In this way, we avoid the labor of identifying every necessary and sufficient conditional premise—whether for transitive necessary proof or intransitive sufficient proof of its obtaining.

When dependent on an INUS condition, one need only INtransitive events to be true to satisfy the statement's necessary conditions and transitive interactions between them to be counterfactually true to easily satisfy the statement's SUfficient condition. (The mnemonic device reads "INSU" and so isn't perfect, I know; this is because Mackie's formulation was inverted, denoting insufficient intransitive premises and unnecessary transitive premises, whereas I have aimed to describe the issue positively; see Table 1).

Obviously, each sense of causal sufficiency and necessity contains complications, but this should suffice (for more, see Lewis, 1974; Gauker, 1987; Jackson, 1979; Godfrey-Smith, 2010). Philosophy of biology's "functions de-

Table 1
Summary of Necessary and Sufficient Conditions between Transitive and Intransitive Event Descriptions

Grammar	*Metaphysics*		*Grammar*	*Metaphysics*	
Verb Description	**Condition**	**Proof of Condition**	**Grammatical Tense of Proof**	**Nature of the Events' Causal Relations**	
Transitive	Necessary	Premises	Future Perfect Continuous	Continuous	X
Transitive	Sufficient	Counterfactual Statements	0–3 Conditional		Contiguous (INUS Condition)
Intransitive	Necessary	Factivity	Present Perfect	Continuous	
Intransitive	Sufficient	Premises	Future Perfect Continuous		X

bate" ultimately reveals that different understandings of causation at work in biology elicits different senses of "function," and, being so, much of the earlier dispute over biological functions has consisted of philosophers talking past one another. To comprehend this more clearly, I shall now turn to formalize a definition of biological functions as SEs by sorting conditionals according to their senses of *causation*—that is, as maintained per the constructs of Wright, Cummins and Neander.[1] For those familiar with the functions debate in philosophy of biology, the following (Section 3) will serve as an overview reminder. Section 4, however, begins working more closely with Neander's SE theory in a manner as of yet unconsidered. I will argue that, in order for Neander's sense of proper function to confirm the veridicality of its sufficiency condition, the condition will be required to incorporate explanations of the very kinds of conditionals poised by her detractors as supposed reasons to forget *functions*.

3. The Causal Roles of Biological Functions

Wright's Functional Ontology

The selectionist's notion of biological functions seek to account for a trait's existence by appealing to its ancestral history of adaptive success. In its simplest terms, "the function of a trait is, roughly, whatever it was selected for" (Garson & Papineau, 2019, p. 4). Wright (1973) set the

stage for thinking of functions in this way by formulating a general yet pithy definition of the term:

> "'The function of [an entity] *X* is [to do] *Z*' means:
> (a) *X* is there because it does *Z*, [and]
> (b) *Z* is a consequence (or result) of *X*'s being there" (p. 161).

This definition might seem redundant, at a glance (and circular, at another). However, it is strategic in at least two ways.

Necessary

According to Wright, clause (a) is aimed at explaining an entity's existence on functional grounds by differentiating between the necessary actions it performs and any accidental actions it produces. The common example posed to clarify this distinction is that a heart's function is to circulate blood, not to produce thumping noises. Despite the usefulness of the hearts' thumping noises for doctors seeking a disorder's etiology, this accidental effect does not account for its existence in the organism.

As Wright explains, the necessary actions an entity performs can only be defined as such by their distinction as being goal-oriented, i.e., teleologically structured. An entity can only be said to exist *because* it does something if its non-accidental actions serve a "purpose." This is easily understood for intentionally designed objects; a stapler might "function" well as a doorstop, but stopping doors is not the action which answers to the reason staplers are designed and manufactured so to exist. We can say staplers' function is to staple paper together *because* this effect is what they are designed and manufactured to do.

One may likewise appeal to natural selection as grounding teleological descriptions of an entity's "natural function" (p. 159). On this interpretation, the function of the heart is to circulate blood because that is why hearts were selected. Wright argues that one's sense of natural selection as being non-accidental and thus purposive (what he calls "consequence-selection") motivates our teleologically structured description of traits' effects—as in, "because it does *Z*." He argues that this teleological structure specifies an action as necessary for the trait, accounting for *why* the action-producing "*X* is there" (pp. 163–164). So understood, (a) is formulated as an entity's intransitive ("is there," being) necessary condition, proven by the factivity of the statement. One's heart is there, indeed, because it circulates blood.

Sufficient

Clause (b) specifies that X is an independently sufficient condition for bringing about Z. It is thus etiological in that it "diagnoses," so-to-speak, some action Z as being causally contingent on X. As X is "upstream," or, causally prior to Z, the etiological condition (b) specifies that such functional descriptions must single out an entity as sufficient for producing the effect (under normal circumstances). If hearts could be removed with no consequence to blood circulation, we wouldn't be so quick to say that the heart's function is to circulate blood. Surely, multiple organs can share functions and/or assist one another in executing a function well, such as the liver and kidneys. So too could one's heart hypothetically share its function with another blood-circulating entity.

However, removing one's liver, for example, would do nothing to their kidneys' independently sufficient actions resulting in blood filtration; the final result would merely be accomplished less efficiently overall. Likewise, if hearts were not independently sufficient causes of blood circulation, their pumping actions could not be *why* blood circulates. Clause (b) so identifies an entity's transitive sufficient condition, proven counterfactually; it (b) therefore determines that whenever X "is there," Z should normally be able to happen. Otherwise, Z is not the function of X.

Asymmetry

It is significant for Wright that the causal descriptions "because" in (a) and "consequence" in (b) are not interchangeable. If they were, then both (a) and (b) should be able to be inverted to signify one another's meanings. We cannot invert (a) to read "Z is there because it does X," even after liberally interpretating "does" to mean "creates," "sustains," or even "explains." Nor can (b) be inverted to produce the statement, "X is a consequence of Z's being there," which is blatantly backwards. The causal relations do not make sense in either inverted version of Wright's clauses.

An entity's actions alone do not account for its existence (which is why Wright grounds them teleologically, in an external frame of purposive reference), nor can the actions account for themselves by producing the entity that performs them (which is why Wright grounds them etiologically, in the entity). Z is necessary for X, and X sufficient for Z; but it is wrong to assert the opposite, either that X is necessary for Z (the kidneys and liver both share the same function, meaning neither are strictly necessary to perform it) and/or that Z is sufficient for X (an entity's actions cannot exist before the entity does, so as to cause its own existence). These inversions convert the descriptive need for nec-

essary conditionals into transitive statements, only proven by premises, and for sufficient conditionals into intransitive statements, also proven via premises.

Entities cause many effects, and it is the purposive nature of some of these effects that signify them as the reasons any given entity exists—thus being their functions. Wright's definition of "function" was formulated in the recognition that there exists an "asymmetry" between types of causal explanation, and this is precisely what prevents it from being circular (p. 161–162). Because of this, (a) and (b) compliment rather than contradict or nullify one another. "Not only is chlorophyll in plants *because* it allows them to perform photosynthesis," Wright contends, "photosynthesis is a *consequence* of the chlorophyll's being there" (p. 160; emphases in text).

In sum, clause (a) offers the *necessary* condition for an *entity's* existence (intransitive) by appealing to a *teleological* explanation of its *effects*, whereas (b) offers the *sufficient* condition for an *action* (transitive) by appealing to an *etiological* explanation of its *causation*, as resulting from the entity. Together, clauses (a) and (b) are poised to ground the efficacy of functional descriptions as ontological explanations, because, according to Wright, they balance out the asymmetry inherent to causal and functional descriptions. Meaning, "because" in (a) accounts for the necessary existence of X on the basis of Z, and "consequence" in (b) accounts for the sufficient existence of Z on the basis of X.

Cummins' Causal Roles

Many philosophers of biology have found Wright's characterization of functions lacking. For although his arguments relied on natural selection, his formula does not explicitly include it. He has even stated that "the exact nature of the [trait's historical selection] conditions is inessential to the possibility of this form of explanation: it can be looked upon as a matter of mere etiological detail, nothing in the essential form of the explanation" (1973, p. 164). Not everyone has been so nonchalant as Wright when it comes to natural selection's supposedly "inessential" causal influences on traits (and thus on our definitions of their functions).

Robert Cummins has notoriously rejected all such "neo-teleological" functional descriptions within the natural sciences (1975; 2002; Cummins & Roth, 2010). According to him, any "selectionist" notion of proper function reeks of fallacies regarding evolutionary foresight and the illusion that evolution "produces" traits at all. He argues that traits are not selected for their own functional merit; traits are at the mercy of their hosts' overall adaptive fitness, which is either heightened or hampered by its other traits

and, moreover, is measured with respect to the relative adaptiveness of the host's conspecific competition. A trait's function needn't be the reason it has persisted. It may very well persist by virtue of the hosts' other traits' robust advantages by comparison to the host's competitors' relative ineptitude (2002, pp. 168–170).

He further maintains that traits do not exist as adaptive "products" from selective pressure, because natural selection merely preserves variation in traits by preserving the developmental mechanisms which produce them (2002, p. 167). By this view, hearts exist because random, heritable variations in proto-liquid-circulating-mechanisms' development were differentially preserved and, over time, accumulated variations so to come to resemble what we now call "hearts." He thus deems proper functions inadequate ontological descriptions, because "selection acted on variation in traits that all shared the same function, [so] appeal to function cannot explain why traits [...] are there" (Cummins & Roth, 2010, p. 77).

Cummins' point is not that complex traits, such as hearts, could not have arisen under natural selection. As he clarifies, although "somewhere in our ancestral line is to be found the first appearance of centralized blood circulation," these ancestors were invertebrates and contained nothing like human hearts (2002, p. 164). Cummins' argument is rather that the types of functions Wright and other "selectionists" have in mind are not applicable to the types of entities that show variability in populations, and therefore proper functions are not subject to natural selection. Cummins expresses this nuance in saying, "Adaptiveness is a matter of degree; having a function is not" (p. 167). One's heart may be better at circulating blood than is either my neighbors' or early ancestors', but all of their functions have been to circulate blood.

Necessary

Cummins thus advocates instead for what he calls *functional analysis*, by which functional explanations describe the "causal-role" (CR) or "systemic capacity" any given entity might serve relative to its "containing system" (Garson, 2008). Specifically, CR functional analyses differentiate between two levels of causal explanation. Firstly, it might be directed towards explaining (a') traits' actions in terms of how they contribute to the overall operations of the greater system in which they subsist. Circulation is the heart's "end goal" as its transitive causal context in one's body. On this level of explanation, hearts function to pump blood *because* the circulatory system is the containing system in which hearts help deliver oxygen to other bodily systems—not *because* blood circulation enhances adaptive

fitness. Hearts are necessary for blood circulation because they fulfill the context-specific conditional premises required of them.

Sufficient

Secondly, functional analyses can describe (b') the proximate causal mechanisms comprising the subsystems responsible for a trait's existence. On this level of explanation, Cummins' sense of functions reduces, say, hearts to the transitive proximate mechanisms causally responsible for developing and maintaining them within individual organisms. As such, this level of explanation is more properly etiological than Wright's construction, according to Cummins. In this context, it makes sense to say that a heart's function is to circulate blood *because* cardiac muscle tissues receive rhythmic depolarizations from pace-maker cells in such a way that causes blood to circulate—not *because* ancestral hearts circulated blood. In this way, hearts are sufficient for blood circulation because the causal mechanisms contributing to this operation can be counterfactually proven to have been sufficient to bring about the effect.

For Cummins, there is no need—and even less desire—to appeal to evolution in order to understand the biological functions of a trait. Any scientific explanation for the existence of an entity can (only) be accomplished through transitive descriptions. This makes functional analysis quite broad. Its aims are applicable to any present system. CR function ascriptions describe an entity's exhibited operation on the interrelated levels of (a') systemic function or capacity and (b') proximate causation, in leu of a more evolutionarily grounded (a) teleology.

Notice that Cummins' argument is only leveled against Wright's use of teleology. It is significant that functional analysis, as described by Cummins, is compatible with (b) the notion that actions must be sufficiently, transitively caused by some entity for such an action to be described as its function. If anything, CR functions expound upon the possible causal mechanisms implicit in Wright's (b) sufficiency clause (Garson, 2013). Cummins' use of "functional explanation" thereby avoids what he understands as the selectionist's pitfalls. However, I argue further on, in Section 4, that Cummins' proposal to do away altogether with selectionist functions confuses the descriptive use of causality they seek to deploy (or, at least, *should* seek to deploy).

Neander's Selected Effects

Selected Effects (SE) theorists find functional analyses unsatisfactory alternatives to Wright's definition. The task of ameliorating Wright's omis-

sion of evolutionary theory was thus effectively taken up, independently yet simultaneously, by Ruth Millikan (1984; 1989a, b) and Neander (1988; 1991a, b). They were the first to successfully align Wright's contribution with neo-Darwinian evolutionary theory, in the service of defining traits' *biological proper functions*. Of course, similar debates prior to this had gone on under the heading of *teleonomy*, and even then, prior to this, biological thought most broadly construed had maintained its teleological orientation since Aristotle had set the trajectory (Ginnobili, 2022; Ratti & Germain, 2022; Corning, 2019; Garson, 2019, 2016, 2008). The point in identifying Wright, Cummins, Millikan and Neander as setting their own standards for contemporary debate is not to ignore previous considerations. Rather, I am locating contemporary debate as progeny to these two mothers of evolutionary thought, if you will, because their impact has so far been the most far-reaching and long-lasting, as compared to the competing legacies of their interlocutors. This is especially so when taken into consideration of their role in working towards bridging the "explanatory gap" between a theory of mental content and that of physical phenomena (for lack of an unabridged connection between one's phenomenologically conscious experiences of such mental contents and their physicality notwithstanding).

Generally, Millikan and Neander's collective insight is that any given trait's *proper function* is the action for which it was inherited by the organism to perform and so contribute to the host's adaptive fitness. By elaborating Wright's criteria that traits merely have inferred evolutionary histories, Millikan and Neander argue that a trait or entity's proper function performs as such due to its ancestrally proven ability to enhance its host's chances of differentially reproducing. Due to minor differences and for the sake of continuity, I will focus on Neander's formulation for the remainder of this discussion.

There is a lot to unpack here. The proposal merges Wright's clauses (a) with (b) together, along with Cummins' (a') and (b'), *as well as* with the principles of neo-Darwinian evolution. To help clarify, Neander has systematically stated the idea twice over, as follows:

> It is the/a proper function of an item (X) of an organism (O) to do that which items of X's type did to contribute to the inclusive fitness of O's ancestors, and which caused the genotype, of which X is the phenotypic expression, to be selected by natural selection (1991a, p. 174; italics in text).

and,

> Some effect (Z) is the proper function of some trait (X) in organism (O) iff the genotype responsible for X was selected for doing Z because doing Z was adaptive for O's ancestors (1995, p. 111).

Let us first lay out the steps of her causal description in chronological order.

We can assume that the causal pathway runs from ancient past into the present, teleological proper function performed by some trait in question in a living (or recently living) organism (also Godfrey-Smith, 1994). So, *O's* ancestors (O_A) are bearers of the genotype (G) which is phenotypically expressed as the trait X's type (X_T). We can say that this first step occurs at time t_1. Next, we learn from Neander that X_T, in the past, does some action Z^* that, by virtue of contributing to O_A's inclusive fitness, "causes" G to be selected by natural selection. We will say that this occurs over the duration t_{1-2}. Finally, at a (much) latter time, at t_2, it is implied that O inherits and bears G so to expresses X of which the proper function can now be identified as Z.

Necessary

From this Neander's (a") Intransitive Connection Condition of Independent Necessity, as I will call it, is first revealed:

(a") Intransitive Connection Condition of Independent Necessity:
X is there (at t_2) because it does Z.

> Meaning: The purposive, teleological quality of Z consists solely in the necessary causal connection between the action Z^* performed by X_T at t_1—for which G was first "caused" to be selected in O_A—and Z's being performed by X at t_2.

Said somewhat differently, (a") posits that, in order for a trait's actions to be called its proper function, the actions must meet the necessary condition that there exists a causal connection spanning t_1 and t_2 of which can account for X's "being there" as "because it does Z." Only then would it make sense for the trait's actions to even possibly be teleological, and only then will it make sense to identify Z as being the independently necessary action, performed by X, for which it is thus ascribed as being the proper function of X.

As such, Neander's (a") constitutes a teleological "forward-reference to the effects the items or traits are supposed to have" (1991a, p. 467); but what exactly "consists in the causal connection" between t_{1-2}? The proof

for necessary conditions of intransitive causality is their factivity (re Table 1), but precisely what statement(s) ought to be true in order to justify one's function ascriptions? To answer requires more clarity on the terms her conceptual analysis introduces. This will be easily accomplished, in the next section, in chronological order: t_1, t_{1-2} and t_2.

4. Deriving Neander's Sufficiency Condition

In the first step, at t_1, Neander introduces the concept of a trait type (also, trait token) X_T in order to indicate a sufficient degree of *similarity* between the countless variations of X that will have been expressed in any given population spanning the past few millennia.[2] She recognizes that entire structures, such as hearts, did not appear out of nowhere and are instead the products of a multitude of variants being selected and reselected, so to accumulate adaptive changes over time.

The concept of X_T captures the idea that natural selection preserved a contiguous chain of proto-X variants in such a way that their adaptive changes, in the past, trended towards what we can observe to be the present, t_2, expression of X. Whatever X_T's actual selection history factually *was*—which, whatever it was, *was* causally sufficient to bring about X on account of X existing—is however yet unnecessary for us to know in order to make reasonable inferences about what conditions would have been necessarily true to bring about X. That is, it can be counterfactually reasoned that only a contiguous chain of G's expressing sufficiently similar X_T's, over the duration t_{1-2}, was necessary to "cause" X to exist at t_2.

Selection's Causal Feedback Loop

Next, over the (long) duration t_{1-2}, a causal feedback loop recurs as O_{A1} expresses X_T which does Z^* which "causes" G to be selected via contributing to O_{A1}'s inclusive fitness thus causing G to be inherited by O_{A2} who thus expresses X_T and so on. To better understand exactly how this looping effect is created, we need to understand what Neander intends by "inclusive fitness," as well as what sense of causation is being used to refer to Z^*'s "causing" G to be selected.

Inclusive fitness is a measure for the frequency of genetic transmission between lineages in a population over time, with the end goal of inferentially correlating this with the adaptive fitness value of specific genotypes (West & Gardner, 2013). Higher frequencies of genetic inheritance, relative to frequencies of the population's genetic transmission, incur more robust

"fitness advantages" on their bearers. As the underlying concept of *differential reproduction* posits, differential frequencies of genetic transmission in a population occur on the basis the phenotypes they express.

Genetic sequences (G) are inherited, expressed proximally via causally transitive cellular mechanisms, and result in phenotypical structures, systems or behaviors—i.e., traits (X_T). The operations (Z^*) of X_T interact with the ancestral organism's (O_A) environment, such that variations in some X_Ts are more successful than others in the population. This is precisely the degree of relative success that the transmission frequency of G is theorized to measure, because G is understood to be reliably causally correlated with X_T.

To note, what makes inclusive fitness "inclusive" is that social animals are capable of influencing the likelihood that their genes are successfully passed on *indirectly*, by supporting the livelihood of the progeny of one's kin (who share at least half of their genes). The details of "kin selection" are unimportant for understanding Neander's SE theory. She uses the term for technical accuracy, but as we have already seen she is not concerned with the accuracy of any one specific account of historical selection events. For her, all that matters is that the principles of evolutionary theory offer the tools to begin crafting her (b") *sufficient* condition for the presence of some trait X's actions Z, insofar as they appear *uniform across entire species and/or populations* (1995, 2017a, b). Neander (2017b) has more recently clarified her idea, stating that:

> Given an etiological theory of functions, functions are selected effects, or so we say. But we may also describe them as selected causal roles or selected dispositions. In a paper titled "Functions as Selected Effects," this author argued (no surprises here) that functions are selected effects (1991a). But my aim in that paper was to argue that functions are *selected* effects, rather than selected *effects*. The contrast of interest was between effects for which traits had been selected in the past and effects presently produced and adaptive. I analyzed functions (of the kind due to phylogenetic selection) in terms of what traits of the type did in the past that contributed to the inclusive fitness of ancestors, and which, as a result, caused that type of trait to be selected. (p. 129; Neander's original emphases).

As such, one need not become too concerned with the evolutionary pathways of exerting selection pressure, since the exact causal histories will depend on a vast array of variables, including the transitive or intransitive nature of whatever effect is being selected (for an excellent analysis of causal descriptions at this juncture, see Ross, 2021). The point is, at this point, rather

that it was selected, as can be determined counterfactually upon observing the SE in a population or species.

Finding Proper Functions within Present Populations

This finally permits our discussion of events occurring at t_2. Neander's theory only applies to individual iterations of X if they exist in relation to an historical population, i.e., a lineage. In her final step, it is merely implied that O inherits G, presumably because stating the matter outright would confuse the scope of SE theory. Of importance is that entire populations inherit G. This may seem innocuous at first, however its consequence on one's causal descriptions of such events entail their intransitivity. As described, the form of proof required to justify sufficient conditions of intransitive causation is a list of premises.

To arrive at these premises, Neander implicitly grants Wright's clause (b) by stipulating token traits' actions can reliably measure their hosts' inclusive fitness. That is, Neander's sufficiency condition (b") retroactively assumes Wright's sufficiency condition (b) in order to justify (a"). Wright's analysis was devoted to particulars, but Neander is interested in trait tokens found throughout populations. Although (a") also shows interest in individual traits' actions, it is to the end of describing their necessary effects on the fitness of ancient populations; it is in this context that classifications of present traits as adaptations make any sense (Rosenberg & Neander, 2009). However, Neander is aware of the difficulties time imposes on this task. As she argues,

> transitivity will hold in cases in which, as we trace back the causal ancestry of the explanandum event, we continue to find causal conditions which make it sufficiently probable in the light of presupposed background information. But transitivity will fail in those cases in which the probability of the explanandum event falls below the required threshold when we trace its causal ancestry far enough back (Neander & Menzies, 1990, pp. 464–465).

Because of her understanding that transitivity fails past certain temporal distances, she further assumes Cummins' clauses (a') and (b') in place of Wright's (a) since, recall, CR functions are compatible with (b). Therefore, whereas Wright's definition of function found need to posit two conditions, I perceive embedded in Neander's definition not only the postulation of one (a") necessary condition *for a trait's teleological proper function in an individual*, but five additional conditions designed to provision the (b") sufficient condition *for a trait's etiological, normal proper function in populations* (Neander, 2002, 2009). I refer to this as (b") The Intransitive

Connection Condition of Mutual Sufficiency, of which is itself comprised of an INUS condition that is further broken down into more subconditionals, for confirming the veridicality of transitive causal claims!

For now, however, we only need to identify these sub-conditionals as the: (b"a) The Causal Strength Condition of Intransitive Necessity, (b"a') The Systemic Capacities' Causal Strength Condition of Transitive Necessity, (b"b') The Proximate Mechanisms' Counterfactually Reliable Condition of Transitive Sufficiency, and (b"b) The Counterfactual Reliability Condition of Transitive Sufficiency. These conditions identify each discrete sense of causation which has been smuggled into Neander's proper function ascriptions upon incorporating evolutionary theory (summarized in Table 2).

Below lays bare the temporally contingent claims intrinsically made in silence by the assertion that (a") some entity necessarily comprises proper functions in virtue of its having evolved, as such, to be within an organism. That is:

(a") The Intransitive Connection Condition of Independent Necessity:
X is there (at t_2) because it does Z.

We now know the duration between t_{1-2} is to be filled with *the correct kinds* of causal interactions–transitive and intransitive—in order for (a") to be sufficiently warranted. X's proper function Z will have only been selected as so if the following sufficient condition (b") and its respective subconditions (b"$_{a,a',b',b}$) obtain:[3]

(b") The Intransitive Connection Condition of Mutual Sufficiency:

O_A's expressing X_T which resulted in Z^* at t_1 and O's expressing X which resulted in Z at t_2 are connected by a persisting genotype G or <u>contiguous series</u> G's in O_A's over the duration t_{1-2}, such that Z^* (intransitively) "caused" G to be selected.

That is, it is (b"a) *necessarily* the case that O_A bore G which expressed X_T and performed Z^* and was thus (b"$_b$) *sufficient* to "cause" G to be selected by natural selection as a consequence of Z^*'s "being there" over the duration of t_{1-2}, such that:

(b"$_a$) The Causal Strength Condition of <u>Intransitive Necessity (IN)</u>:
"O_A bore G which expressed X_T and did Z^*," must be factive.

Meaning:

(b"$_{a'}$) The Systemic Capacities' Causal Strength Condition of Transitive Necessity:
The recurring development of X_T was a *mutually necessary* condition to (transitively) cause Z^* (e.g., a heart's

successful development is a necessary condition for the capacity to cause blood circulation within the circulatory system, as is proper neural signaling, nutrition, existence of blood, etc.); and

(b"$_{b'}$) The Proximate Mechanisms' Counterfactually Reliable Condition of Transitive Sufficiency:
G's recurrent inheritance was an *independently sufficient* condition for the (transitive) production of its phenotype X_T (i.e., X_T was not preempted by another sufficient causal process).[4]

If G had not been inherited by O_A then G would not have resulted in X_T and so inheriting O_A's genes would not have had caused X_T in O_A's progeny; but, given that X_T has been caused, inheriting G from O_A has caused X_T. Therefore:

It is true that O_A's inheriting and bearing G so to recurrently express X_T over the duration t_{1-2} will have been sufficient for X_T to have necessarily caused Z*.

(b"$_{b}$) The Counterfactual Reliability Condition of Transitive Sufficiency (SU):
It follows counterfactually that, if X_T *had not* done Z* at t_1, G *would not have* enhanced the inclusive fitness of contiguous lineages of O_As over t_{1-2}, and thus a population of O's *would not have had* inherited G to express X to do Z at t_2. However, given that the inverse is factive—O inherited G from O_A, G did express X and X has done Z—then the proper function of X is Z.

Altogether, then, Neander's formulation contains six conditions, including its subconditionals. The subconditionals supplement, at each level, any location wherein premises are required to be listed in order to determine the fulfilment of the condition. Rather than list premises where the Intransitive Sufficient Condition arises, Neander's SE theory, it can be argued, moves to decompose the condition further, into another paired set of conditionals. Crucially, the subconditionals convert intransitive causal processes into their transitive components, played out over time.

Simply, when Neander and others colloquially claim some function Z* "caused" the trait X_T to be selected, they mean that the continuous transitive causal relations (a', b') comprising the relevant intransitive events are substituted for premises denoting states of being ("to be inherited," "the expression of"). Neander's analysis is thus capable of intransitively describ-

ing the contiguous causal relations between theoretical evolutionary events without disclosing every continuous cause comprising them, as Cummins thinks necessary. SE theory does not ignore Cummins' criticism.

For (b"$_a$) to carry any authority, its intransitive relations must be translated into premises denoting their necessary and sufficient transitive causes. However, these needn't be addressed in every instance of ascribing proper functions. The shorthand afforded by Mackie's INUS condition incorporates Cummins' protests into the very clause modeled after Wright's (a); precisely where Cummins found teleology inadequate, Neander's SE theory wields CR functions to the end of bolstering teleology! (See also, Povich & Craver, 2017).

Table 2
Summary of Necessary and Sufficient Forms of Conditional Proof between Wright, Cummins and Neander

Author	*Necessary Conditions*			*Sufficient Conditions*		
	Notation	**Grammatical Form of Causality**	**Form of Proof**	**Notation**	**Grammatical Form of Causality**	**Form of Proof**
Wright	(a)	Intransitive	Factivity	(b)	Transitive	Counterfactual
Cummins	(a')	Transitive	Premises	(b')	Transitive	Counterfactual
Neander	(a")	Intransitive	Factivity	(b")	Intransitive	Premises
	(b"$_a$)	Intransitive	Factivity	(b"$_b$)	Transitive	Counterfactual
	(b"$_{a'}$)	Transitive	Premises	(b"$_{b'}$)	Transitive	Counterfactual

5. Transitive and Intransitive Selection and Its Effects

To close, I will offer some brief reflections on grammatical illusions of function ascriptions, obscuring their underlying causality (summary in Table 3). Selection processes can exact transitively or intransitively. For SEs to have been transitively selected, the selection event(s) will have been both necessary and sufficient to cause the effective entity to be differentially preserved or reproduced (Garson, 2017). For an effect to have been intransitively selected, the event(s) will have been sufficient—but unnecessary—to "cause" the SE to be differentially preserved or reproduced. We saw from Neander's conceptual analysis of natural selection that its happenstance intransitivity need not inhibit SE function ascriptions.

That intransitive selection processes result in traits which have "come to be" does not entail selection occurred independently of effects, though these feedback loops are more elusive than their transitive counterparts. Feedback loops constitutive of domestication and artifact selection are easy to identify (Neander, 2006); but intransitive selection is less obvious (see also, Poddiakov & Valsiner, 2013). This essay showcased an example of intransitive selection's complexity, but it has yet to be determined whether natural selection is the only process of its kind occurring naturally within biological systems. (I suspect that metaplasticity may provide companionship to natural selection, however discussing the issue is beyond the capacity of this discussion; see Abraham & Bear, 1996).

SEs are necessarily described much like the selection processes which "produce" them—that is, by use of either transitive or intransitive verbs. This becomes confusing, however, since many proper functions were selected not for their ability to act on direct objects (transitive) but for their state of being (intransitive). The former are both necessary and sufficient—the latter merely necessary—to causally enact their function. For example, birds fly (by transitive actions) necessarily and sufficiently with their wings, but feathers might have patterns that are necessary but insufficient on their own to provide camouflage (intransitive; only advantageous for hiding the bird from predators when in contextually appropriate background environment). Camouflage is therefore *mutually necessary* but not *independently sufficient* for being advantageous. Meaning, both bearing camouflage patterns and being in the proper environment are together necessary for any camouflaging effect to occur and thus be selected for.

This is striking (and precisely where confusion may begin to settle in), considering that natural selection is intransitive whilst being the exact opposite, *independently sufficient* without being *mutually necessary*. That is, ecological systems simply exist, and this alone is sufficient for contiguous chains of selection events to occur, irrespective of other conditional factors necessarily obtaining. In the case of natural selection, this result make sense on account of its intransitive processes encompassing all relevant interacting elements. Or, that is, natural selection is not the manifestation of merely one thing but rather the specific relations constitutive of nearly everything; it therefore is constituted on large enough of a scale to be incapable of sharing its burdens. It cannot be mutually sufficient nor mutually necessary, since it stands alone and is constantly at play. I suspect that the reason intransitive SEs do not share this feature is due to scale rather than metaphysical causation (cf. Dussault, 2022).

Table 3

Examples of Transitive and Intransitive Selection Processes and Their Effects

Selection Processes			*Selected Effects*		
Causality	**Condition (Proof)**	**Examples**	**Causality**	**Condition (Proof)**	**Examples**
Transitive	Necessary (Premises) Sufficient (Counter.)	• Some neural selection (e.g., dopaminergic reinforcement) • Artifact selection	**Transitive**	Necessary (Premises) Sufficient (Counter.)	• Reinforced Behaviors; • Addiction; • Staplers, etc.
Intransitive	~~Necessary (Factivity)~~ Sufficient (Premises)	• Natural selection (by sub-premises b"$_a$ & b"$_b$)	**Transitive**	Necessary (Premises) Sufficient (Counter.)	• Wings, hearts, etc.; • B cells' capacity to select antibodies
Transitive	Necessary (Premises) Sufficient (Counter.)	• Domestication (selecting coat, friendliness, etc.) • Antibody selection	**Intransitive**	Necessary (Factivity) ~~Sufficient (Premises)~~	• Dogs' coat color or overall beauty, friendliness, etc.; • Antibodies (identify antigens "passively")
Intransitive	~~Necessary (Factivity)~~ Sufficient (Premises)	• Natural selection • TBD: Synaptic Metaplasticity	**Intransitive**	Necessary (Factivity) ~~Sufficient (Premises)~~	• Camouflage; • Sensory Dispositions; • TBD: Memories, via metaplasticity

Moreover, linguistic conventions do not always reflect the causality they describe. The above example would read more accurately as, "wings fly birds," which simply sounds strange. Whether "birds fly with wings" or "wings fly birds," grammar renders "to fly" transitive either way, insofar as wings are made the subjects of sentences aimed at ascribing their functions. "Wings fly" is intransitive but untrue, since they do not fly themselves. "Birds fly" is intransitive and obviously true, but the whole point is that to say traits perform functions at all (which is so far uncontroversial) is to make traits the subjects of sentences that describe their actions. As strange as it sounds, birds themselves do not have the function of flying; birds fly because their wings have the function of flying birds, yet selectionists call both transitive and intransitive kinds of actions one kind of proper function. The conceptual analyses of either their necessary or sufficient conditions however reveal dissociations between the two, obscured by the English language.

6. Concluding Remarks

Such illusory aspects of proper function ascriptions, I hope to have demonstrated, are more easily apprehended when homing one's descriptive focus on whether or not the SE and its corresponding selection process in question are comprised of continuous transitive or intransitive events or are instead a contiguous complex of both. In the future, I hope to extend this discussion into one on *grammatical aspect* or, i.e., *aspectuality*, so denoting the duration of some event. Wouters (2003) four notions of function, for example, are ripe for conceptual analysis in light of Zeno Vendler's (1957) four-fold classification of aspectual classes. That is, my future work will hopefully demonstrate just how perfectly Wouters' classification matches the grammatical concepts already well defined by linguists (e.g., Beavers, 2013).

Until then, Neander's legacy will survive far into future generations. This paper's treatment of her analytic framework is a necessary (but insufficient) step towards that end. Hence, my current work elsewhere (in review) aims to apply this framework to Justin Garson's (2017) Generalized Selected Effects (GSE) theory, which describes the advent of novel proper functions through individuals' ontogenic selection processes (such as reinforcement conditioning). I predict the work provisioned here will fortify GSE theory in many ways while complicating intuitions about metaplasticity, neural selection and memory.

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Finally, I want to dedicate these meek, preliminary remarks on function ascriptions to the memory of Karen Neander (March 24, 1954 – May 6, 2020). Her passing so near the time I had (mostly) completed writing this paper has found me holding a depth of gratitude of which I wish to carry forward, in my work on memory.

NOTES

[1] For detailed reviews on the history of this debate, see Garson (2008, 2016, 2018, 2019) and Godfrey-Smith (1993).

[2] *Similarity*, here, needn't imply *morphological similarity*. Neander is aware that signal transduction pathways constitute SE "response functions," for instance (2017b, p. 129). One slight change in the causal cascade might result in any vast array of distinctive,

downstream morphological differentiations; yet the effects of the cascade itself will bear resemblance to those *possible* of its progenitors, assuming that it has been inherited from them. Or, said differently, the effects of some entity need not bear resemblance to those of its parental entities, so long as the parent *could have* produced, counterfactually, an effect resembling that of its offspring, if it were to manifest the same environmental conditions and correspondent molecular chain reactions. Degrees of similarity have historically been measured by statistical analyses of linkage estimates and ANOVA, but this practice has recently received scrutiny (Veigl, Suárez & Stencel, 2022; Bourrat, 2022). At present, I am only concerned with what we mean to signify in our descriptions of some trait's evolved proper functions, not with any one particular methodology or tool for determining their truth values.

[3] I would like to acknowledge that this general structure of necessary and sufficient conditions is an adaptation of Sven Bernecker's (2010) Causal Retention Theory of Memory's fifth condition, "the connection condition," and its subconditionals (p. 242). It is more than serendipitous that conceptual analyses of memory traces and proper functions require similar conditions to cross an temporal divide, but such is the topic of another essay.

[4] This does not imply the independent sufficiency of genetic material itself, absent of its developmental context, but rather of the inheritance of proper developmental mechanisms as a reliable measure of phenotypic expression.

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