GROUND IN BIOLOGY

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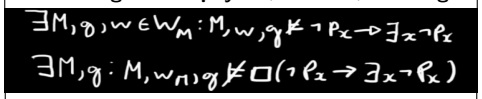
Grounding – Metaphysics, Science, and Logic



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Grounds and Functions in Biology (Casini, L. and Weber, M.) Philosophical accounts of biological functions fall into two broad categories, ætiological accounts (Wright, 1972) and dispositional accounts (Cummins, 1975; Boorse, 1976). The key difference between the two categories lies in their different interpretation of the question: What justifies ascribing a function to its bearer x (viz. to a biological trait)? Aetiological accounts maintain that asking this question amounts to asking: What explains the existence of x in the system s to which x belongs? Dispositional accounts read the question as asking: What is x's role in s? In both cases, the accounts aim to provide answers in line with current scientific standards, and thus involving no appeal to teleological notions.

The answers offered by the two classes of accounts may be put in the following generic terms. In ætiological accounts, the (or a) function of x in s is the activity ϕ iff x's existence DEPENDS on x's ϕ-ing, and on the prior ϕ-ings of occurrences of X in s's ancestors causing X to be selected. In dispositional accounts, the (or a) function of x in s is the capacity Φ iff some relevant biological fact about s, denoted as s's ψ-ing, (partially) DEPENDS on x's ϕ-ing in s. On the assumption that these analyses are broadly correct, the notion of function is successfully naturalized. Still, a further question naturally arises, which we aim to answer in this paper: What sort of 'dependencies' are involved in such analyses?

To begin with, one may note that such dependencies are meant to be (1) objective/ mind-independent (hence, non-teleological) and (2) asymmetric. Arguably, (1) and (2) are the sort of features that are apt to back *prima facie* legitimate explanations. Indeed, one may show how both analyses back explanations by replacing dependence-talk with because-talk. If this is correct, the notion of function may work as a legitimate explanans in virtue of the obtaining of those dependencies. Why is x there? Because x currently ϕ-s and certain causal processes obtained whereby X's that ϕ-ed were selected. Analogously, why does s ψ? Because (at least, partly) x's capacity Φ is actualized in s. An elucidation of the nature of such explanations promises to clarify the conditions for the notion of function to be scientifically acceptable, not only in the sense of being explained in naturalistic terms, but also in the sense of itself being capable of supporting explanations of further facts of biological interest.

Note that the above explanations are successful insofar as the explanans is 'more fundamental' (because non-teleological) than the explanandum. A candidate relation of ontological priority, which has recently attracted much attention, viz. *ground* (Rosen, 2010, Fine, 2012), promises to shed light on such explanatory dependencies. Although there is no unanimous agreement on the precise characterization of ground, a number of its features are widely agreed upon. Ground is a connective relating propositions, such that p BECAUSE $p_1, p_2, \ldots, p_n$ (or alternatively, a predicate relating facts, such that $[p]$ IS GROUNDED IN $[p_1], [p_2], \ldots, [p_n]$). Ground requires the truth of the related propositions (or alternatively, the obtaining of the corresponding facts). Full grounds necessitate the facts they ground. Ground is a strict partial order (irreflexive, asymmetric and transitive). Finally, some have proposed that there is a tight connection between the notion of ground and the notion of *essence*. For Fine (2012), p BECAUSE $p_1, p_2, \ldots, p_n$ iff (roughly) it is in the essence of p to be constituted by $p_1, p_2, \ldots, p_n$. For Correia (2013), p BECAUSE $p_1, p_2, \ldots, p_n$ iff (again roughly) it is part of the essence of p that, $p_1 \wedge p_2 \wedge \ldots \wedge p_n \rightarrow p$.

Our argument proceeds in two steps. First, we provide a 'meta-analysis' of the explanatory dependencies that back ætiological and dispositional analyses of functions. We show how ground plays a key role in at least dispositional accounts. This establishes not only that the notion of ground deserves further clarification in its own right, but also that it has the potential to orient revisionary attempts at improving the analyses themselves. Second, we point

to avenues for future research suggested by two formal properties of ground, viz. being a strict partial order and being connected to the notion of constitution via the notion of essence. In particular, we show how the ground interpretation may be expanded to define hierarchies of functions that map onto hierarchies of mechanistic decompositions, so as to to elucidate the intuition that functions are located at different levels of biological organization.

Dopamine and the Heuristic Identity Theory (Colombo, M. and Wright, C.) The mind/brain identity theory states that every type of mental state (and process) is identical with some type of brain state (and process). The canonical example is the mental state of being in pain: just as lightening turned out to be electrostatic discharge, and the property of saltiness is identical to sodium chloride, so too is pain identical with some brain state, such as neuronal C-fiber excitation.

The identification of pain with C-fiber excitation proved to be overly simplistic. Even putting aside the traditional a priori worries over both qualia and generalization to other non-human animals, C-fibers constitute only one type of part of the human nociceptive system. While the identification of pain with C-fiber excitation remains the canonical example, it is now known not so much for being an example establishing the mind/brain identity theory, but rather for exemplifying how premature early identification claims can be (and worse, how detrimental ignorance of psychology and neuroscience can be for philosophers of mind).

The failure of the canonical example is illuminating, for it points the way to an alternative version of identity theory—the so-called Heuristic Identity Theory (HIT)—which is touted for its increased sensitivity to scientific practice, and which allows for a more sophisticated alternative to the reductionism implied by traditional versions. A central difference between the traditional and alternative version of identity theory turns on how psycho-neural identities are used. The logic of the traditional (post-kripkean) identity theory requires psycho-neural identities to be necessary a posteriori. That is, they should be necessary conclusions or output of protracted research. By contrast, HIT inverts this requirement. Rather than generating psycho-neural correlations and accumulating evidence for identities to explain them, HIT suggests that scientists first hypothesize identities and then use them as a heuristic means of driving further research in a plurality of different explanatory directions.

HIT exploits the indiscernibility of identicals in order to foster empirical research. For any two entities (or processes) X and Y, if they are identical, then all the properties that belong to X belong also to Y, and vice versa. So, what we learn about X under one description will apply to it under its other descriptions. For advocates of HIT, what matters is not so much the metaphysical import of establishing identities, but the epistemic fruits that can be reaped from the amount of science generated based on hypothesized identities. Advocates of the heuristic identity theory typically use an inductive strategy grounded in historical case studies (e.g., McCauley and Bechtel 1999). For example, McCauley and Bechtel (1999) detail research on visual processing at different levels of explanation, and show how it productively stimulated increasingly sophisticated research by positing empirically testable identity claims that are later refined at different levels of analysis. As they aver, hypothesizing that types of mental states are identical to types of physical states 'is a perfectly normal part of research in cognitive neuroscience and that the results often provide ample support for these hypotheses' (1999: 67). Unfortunately, there has been relatively little philosophical work scrutinizing this idea.

The aim of this paper is to elucidate the type of identities involved in HIT and their relation to reductionism by focusing on the relation between dopamine and reward.

Advocates of HIT have to walk a fine line: being identity theorists (and so

having little margin for sloppy uses of 'identity'), while simultaneously trying to be sensitive to actual science (with all of its subtly-shifting prose) and then use it as evidence for their view. As scientific work on the relation between dopamine activity and reward processing demonstrates, 'identity' is hardly used in the senses of numerical or qualitative identity; it is used in the sense of localize, and other times in the sense of functional isomorphism. While the adequacy of any version of the identity theory should be assessed on the basis of its ability to make sense of scientific practice in psychology and neuroscience, positing that functions are localized in a certain brain structure is not tantamount to hypothesizing identities. Positing functional isomorphisms between the states of two systems is not tantamount to hypothesizing identities either. This suggests that historical cases in cognitive neuroscience vindicate the fruitfulness of research strategies that do not rely on hypothetical identities, but rather on increasingly refined localization/decomposition claims and/or functional isomorphisms.

Mechanism-dependence as the Ground of All Biological Phenomena (Glennan, S.) Grounding is the relation du jour in the analytic metaphysics community. Grounding is the relation that supposedly underwrites "in virtue of locutions" – that this fact holds in virtue of that. Grounding, especially metaphysical grounding, is taken to be a form of non-causal dependence. According to Jonathan Schaffer, grounding provides us an entirely new way to do metaphysics. It turns us away from the Quinean question of what there is towards (or back to) the Aristotelian question of what depends upon what. Kit Fine has suggested that grounding is the central relation in metaphysics, analogous to the causal relation in the sciences.

My aim in this talk is to give an account of the grounding of natural phenomena, and in particular of biological phenomena. The mechanical philosophy that I favor provides an answer to the question of what grounds what in the natural world. According to recent accounts, mechanisms are identified by the phenomena for which they are responsible. Put simply all mechanisms are mechanisms for some phenomenon. The relationship between mechanisms and their phenomena is naturally construed as a grounding relation, and when a phenomenon is so grounded I call it a mechanism-dependent phenomenon. My contention is that all natural phenomena, and a fortiori, all biological phenomena are grounded in the activities of mechanisms, Hence, mechanism-dependence is all the grounding that biological phenomena need.

I will consider an important objection that some philosophers of biology have raised about the hegemony of mechanism. Defenders of organicism have argued that living things have special properties (e.g., self-directedness, self-organization, growth) that cannot be grounded in mechanisms. I shall argue that this objection follows from adopting a machine-like conception of mechanism, and that there is a broader but still informative mechanistic analysis of living things and biological processes. I will though suggest that the organicist has an important point about the grounding of biological phenomena: in organic systems parts are not prior to wholes, but rather parts and wholes mutually determine each other. This will have consequences for our understanding of biological grounding.

On the basis of my account, I will also raise some questions about the larger enterprise of metaphysical grounding. Fine argues that grounding provides "a distinctive kind of metaphysical explanation, in which explanans and explanandum are connected, not through some sort of causal mechanism, but through some constitutive form of determination..." (2012, p. 37). Fines position sets up a dichotomy between the causal and the constitutive, and between the scientific and the metaphysical, which I reject. While I do not claim that all explanations are causal, I do think that all natural phenomena are grounded in what Salmon called "the causal structure of the world."

Is Mechanistic Constitution a Version of Material Constitution? (Harbecke, J.) Recent philosophy of neuroscience has made substantial effort to develop a conceptually sound and descriptively adequate account of "mechanistic constitution". The referent of this term is believed to be the relation that successful neuroscientific explanations characterize between the to-be-explained cognitive or neural phenomenon and the explanatory neural mechanisms underlying the phenomenon. Neuroscientists have also referred to the relation with terms such as "is responsible for" (Bliss and Lomo 1973, 331), "gives rise to" (Morris et al. 1986, 776), "plays a crucial role in" (Davis et al. 1992, 32), "contributes to", "forms the basis of" (both Bliss et al. 1993, 38), "underlies" (Lomo 2003, 619; Frey et al. 1996, 703), or "is constitutively active in [the phenomenon]" (Malenka et al. 1989, 556).

The philosophical literature contains several attempts to analyse the notion. The most widely known is the "mutual manipulability approach developed by Carl Craver (2007, 153). A more recent one is the regularity account of mechanistic constitution that has been developed in two versions by Mark Couch (2011) and myself (Harbecke 2010). The regularity approach characterizes the relation as reducible to a particular kind of minimized regularity among mechanistic types. It has been used for an account of "levels" in neuroscience and biology (cf. Harbecke 2014a), for a scientifically informed formulation of supervenience (cf. Harbecke 2014c), and for an explication of a general methodology for the establishment and integration of neuroscientific and biological theories (cf. Harbecke 2014b). In this sense, the approach has been developed into a comprehensive philosophical framework in the context of neuroscientific explanation.

So far, however, the regularity account of mechanistic constitution has not been systematically connected to the longstanding debate on material constitution and the grounding problem (cf. Bennett 2004; Paul 2010; Wasserman 2015). This is at least partially due to a mismatch of aims. Whereas the debate on mechanistic constitution is primarily concerned with questions about the norms of explanation in the sciences, material constitution targets a metaphysical relation between individuals. At the same time, however, for both debates the notion of mereological parthood plays a crucial role. Moreover, metaphysical questions about reduction and autonomy are central to both. In light of these analogies, it would be surprising if the two notions had no conceptual and logical connection at all.

In this paper, my aim is to unravel the similarities and differences, and in particular the logical and conceptual connections, of the regularity account of mechanistic constitution and the standard accounts of material constitution. The goal is to show that the two relations are of a different logical order, and that this relationship holds independently of whether one chooses a pluralist or a monist interpretation of material constitution. At the same time, there are several interesting analogies and connections between the two notions. In a final step, I demonstrate that, once the metaphysics presupposed by the regularity account is accepted, puzzles such as the statue-and-lump case disappear. They receive a radical eliminativist solution, which may be attractive in various respects.

The investigation proceeds as follows. In a first step, I reconstruct the context in which the question about mechanistic constitution arises. I then review the philosophical enquiry associated with mechanistic constitution, which includes a discussion of the regularity theory and of identity statements about phenomena and mechanisms. Subsequently, I review the problem of material constitution and the grounding problem. I then show that material constitution is to be distinguished from mechanistic constitution whilst there are various logical and conceptual connections between the two notions. In a final step, I suggest that the ontology presupposed by the regularity approach to mechanistic constitution offers an interesting radical eliminativist solution to the problem of mechanistic constitution and grounding and I inquire how

these proposals connect to Cravers theory of mechanistic constitution. The last section summarizes the argument and raises some open questions on the topic of mechanistic constitution and material constitution.

The Metaphysics of Constitutive Mechanistic Phenomena (Kaiser, M. and Krickel, B.) The notion of a phenomenon plays a crucial role in the debate about mechanisms and mechanistic explanation that has become popular in the philosophy of the life sciences in the last two decades. A central claim of the so-called New Mechanists is that scientific explanation consists in discovering and describing mechanisms that are responsible for phenomena. There is an ongoing debate about what mechanisms are and what characterizes mechanistic explanation. Surprisingly, though, there is almost no discussion about the nature of phenomena in the context of the mechanistic approach. The goal of this paper is to fill this gap by providing a coherent metaphysical analysis of constitutive mechanistic phenomena.

So far, no explicit account of constitutive mechanistic phenomena has been provided. We think that such an account is essential to the mechanistic approach because the most central assumptions about constitutive mechanistic explanations and mechanisms cannot be understood as long as one does not know what constitutive mechanistic phenomena are exactly. To see this, consider how three major claims of the New Mechanists hinge on the notion of a constitutive mechanistic phenomenon (note that the first claim applies also to etiological mechanistic phenomena):

1 Phenomena are the things that are *explained* by describing mechanisms.

2 Phenomena are the things that are *constituted* by mechanisms.

3 Phenomena are *individuative* for the mechanisms that constitute them.

The first claim states that phenomena are the things that are the objects of (constitutive) mechanistic explanations; they are the things that are *explained* by describing the mechanisms that constitute them. Obviously, in order to understand what exactly mechanistic explanations are, we also need to understand what the two parts of an explanation—the explanandum and the explanans—refer to. The explanans of a MEx (i.e. what does the explaining) is said to refer to a mechanism; the explanandum (i.e. what is to be explained) is supposed to refer to the phenomenon that is constituted (or caused) by the mechanism. Hence, we need to understand what mechanistic phenomena are in order to fully understand constitutive mechanistic explanations. The second point has already been introduced: in the case of constitutive mechanistic explanations, phenomena are supposed to be constituted by mechanisms. To understand this constitution claim we need to know what it is that is taken to be constituted by a mechanism. A third major claim of the New Mechanists is that mechanisms are individuated via the phenomena they explain (e.g. Glennan [2002], p. 344). Roughly, a mechanism is held to consist of only those entities and activities that are constitutively relevant to the phenomenon the mechanism is supposed to explain (Craver [2007], pp. 13960). The way in which the phenomenon is characterized thus determines the individuation of the mechanism, that is, it determines which entities and activities belong to the mechanism, and which do not (Craver and Darden [2001]). This implies that if we do not know what phenomena are, we cannot identify the components of mechanisms.

A first step towards such a metaphysical approach is to identify three criteria of adequacy that a plausible metaphysics of constitutive mechanistic phenomena must satisfy. We claim that an approach to constitutive mechanistic phenomena must account for how they are characterized in the explanatory and investigative practices of the life sciences (C1 descriptive adequacy), must be consistent with and make sense of the difference between etiological and constitutive MEx (C2 constitutive-etiological difference), and must be such that they can plausibly be constituted by mechanisms, which requires

that phenomena must have spatial and temporal parts (C3 constitution).

We then identify and critically discuss four different ways of spelling out the ontological nature of constitutive mechanistic phenomena. Each of these four options is implicitly or explicitly suggested by different authors working on mechanisms and mechanistic explanations. We argue that none of these suggestions meet all criteria of adequacy developed previously developed. That is, we reject the ideas that constitutive mechanistic phenomena are input-output relations, end states, dispositions, or bare behaviours.

Finally, we present an alternative account of constitutive mechanistic phenomena. According to our approach, phenomena explained by constitutive mechanistic explanations can best be understood as object-involving occurrents (OIOs), which are objects or systems that are involved in a certain process or event, or are in a certain state. Typically, the phenomena that are investigated by the life sciences are organisms or parts/groups of organisms, which are engaged in certain behaviours or activities. Understanding constitutive mechanistic phenomena as OIOs enables us to make sense of the three claims of the New Mechanists. First, in constitutive mechanistic explanations mechanisms explain the behaviours of objects. Second, the difference between etiological and constitutive explanations consists in the fact that the components of constitutive mechanisms occur during the same time span in which the phenomenon occurs, whereas etiological mechanisms occur before the phenomena they explain. Furthermore, in constitutive mechanisms most of the components are spatially contained in the OIO that constitutes the phenomenon, whereas etiological mechanisms are not spatially restricted. Hence, according to our view, a necessary condition for mechanistic constitution is the following: a mechanism constitutes a phenomenon only if every component of the mechanism occurs during the phenomenons occurrence, and most of the components are spatially contained in the phenomenon. Finally, our approach also clarifies the individuation-claim. A mechanism is composed of only those objects and occurrents that are constitutively relevant to the phenomenon that the mechanism is supposed to explain. According to our approach, this implies that a component of a mechanism must be relevant to a particular behaviour of an object, where it must be the case that the component-occurrent occurs during the phenomenon-occurrent, and the component-object is a spatial part of the phenomenon-object (at least most of them). Of course, this is only a necessary condition—one still has to specify when a putative component is relevant to the phenomenon.

Organisation as a Biological Ground (Mossio, M.) The central claim of this paper is that biological systems are first and foremost organised systems.

The emphasis on organisation has a long history in both biology and philosophy of biology, mainly in the so-called organicist perspective. In very general terms, the concept of biological organisation integrates two ideas. One the one hand, organisation is about relatedness, a certain way for the parts of the system to be related to each others and, as already underscored by Kant, a certain parts-whole relation. On the other hand, organisation involves self-determination: biological organisation determines itself in the sense that the effects of its activity contribute to establish and maintain its own conditions of existence: in slogan form, biological systems "are what they do". The general picture is roughly something as follows: biological organisation consists in a network of mutually dependent components, each of them exerting a causal influence on the condition of existence of the others, so that the whole network is collectively able to self-maintain.

Beyond these general aspects, however, the organicist tradition has not converged to a precise and shared understanding of biological organisation. My diagnosis is that previous accounts of closure fail to specify the relevant level of description at which biological organisation occurs. The analysis offered in this talk makes a further step, by claiming that biological organisation

should be understood as a closure of constraints.

What are constraints? They can be conceived as local and contingent causes, which reduce the degrees of freedom of the dynamics on which they act, while remaining conserved (at the time scale which is relevant to describe their causal action) with respect to those dynamics. Biological systems, as many other physical and chemical systems, are dissipative systems, which means that they are traversed by a far from thermodynamic equilibrium flow of energy and matter. What specifically characterises them is the fact that the thermodynamic flow is channelled and harnessed by a set of constraints in such a way as to realise mutual dependence – a closure – between these constraints. I claim that the closure of constraints provides a specific understanding of biological organisation: biological systems can be said to achieve self-determination as self-constraint since the conditions of existence of their constitutive constraints are, because of closure, determined through their mutual relations.

Understood in this precise sense, biological organisation constitutes the fundamental biological ground. By this, I mean that any specifically biological aspect or phenomenon relies on the realisation of organisation as closure of constraints. In particular, I argue in this talk that organisational closure grounds the very idea of biological function. My argument will consists in showing that closure provides a ground for the distinctive dimensions of function, i.e. teleology and normativity.

First, I argue that closure grounds the teleological dimension of functions: insofar as the activity of each constraint C subject to closure contributes to the maintenance of the whole organisation, and therefore of itself, the question "Why does C exist?" can be legitimately answered by "Because it does Y". This justifies explaining the existence of a system (and of each constitutive constraints) in "teleological" terms by referring to its causal effects. Second, closure grounds biological normativity. The telos of a closed organisation – its own maintenance – has an intrinsic relevance for the system; in turn this relevance generates a criterion for determining what norms the system is supposed to follow: the system (and its constitutive constraints) must behave in a specific way, otherwise it would cease to exist. The intrinsic goal of a system realising closure becomes its norm or, maybe more precisely, its conditions of existence are the intrinsic (and naturalised) norms of its own activity.

As a result, I submit that the causal effects of the constraints subject to closure, because of their inherent teleological and normative dimensions, correspond to biological functions. In this respect, I will emphasise that the idea of biological function not only relies on the teleological and normative dimensions, but also on the very idea of organisation A biological function is a kind of effect that is not only normatively oriented towards a goal, but also conveys the idea of a network of mutually dependent entities, each of them making different yet complementary contributions to the self-determination of the system. Ascribing functions requires distinguishing between different causal roles in self-determination: this is precisely what happens with a closure of constraints.

In the last part of the talk, I will discuss the relations between the organisational perspective and the mechanistic framework. By elaborating on two recent papers by William Bechtel on this issue, I will suggest that, although there is not inherent conflict between them, organisation provides a more fundamental ground for the biological domain. Indeed, mechanisms, which could be understood as architectures of constraints, are relevant explanatory tools in biology insofar as they reveal aspects of biological organisation, and account for the overall realisation of closure. Biological mechanisms can only be included in a biological organisation. That's why, in my view, the latter is a more fundamental biological ground.

How Objective Are Biological Functions? (Weber, M.) Biological functions, due to their teleological ring, have always been shady citizens of the objective world. To the extent in which functional attributions contain more than just an ascription of causal capacities, their objectivity or naturalness has been questioned time and again. A succinct version of this worry has been formulated by John Searle, who has argued that functions owe their existence to the value that we put into life and survival:

> [T]he discovery of a natural function can take place only within a set of prior assignments of value (including purposes, teleology, and other functions). Thus given that we already accept that for organisms there is a value in survival and reproduction, and that for species there is a value in continued existence, we can discover that the function of the heart is to pump blood [...]. When we discover such a natural function, there are no natural facts discovered beyond the causal facts. Part of what the vocabulary of functions adds to the vocabulary of 'causes' is a set of values (including purposes and teleology generally). It is because we take it for granted in biology that life and survival are values that we can discover that the function of the heart is to pump blood. If we thought the most important value in the world was to glorify God by making thumping noises, then the function of the heart would be to make thumping noise, and the noisier heart would be the better heart. If we valued death and extinction above all, then we would say that the function of cancer is to speed death (Searle 1995, 15).

In a first part of my talk, I will show that Searle's argument rests on a mistake, namely the failure to understand that functional predicates are (at least) three-place. These predicates relate not only a biological entity (e.g., the heart) and an activity that constitutes the function of this entity (e.g., pumping blood), they also contain a place for a goal state (e.g., survival or evolutionary fitness). A functional attribution without specification of such a goal state has no truth-value (of course, the goal state is often implicit in biological practice). But if completed by a goal state, functional attributions understood as at least three-place relations attain a truth-value, which is at least as objective as causal statements (provided that the latter are objective). There is nothing mysterious or subjective about these goal states they are perfectly natural properties of an organism. Thus, Searle critique breaks down. What Searle ought to have said is that our valuing survival or other goal states is the reason why biology seeks functional knowledge, but this has nothing to do with ontology.

There is nonetheless an important challenge in Searle's attack on the objectivity of functions, namely the question of what exactly functional facts add to the causal facts stating what certain parts of an organism do. The usual suspect is some kind of normativity that functions, unlike causes, appear to contain. However, it is precisely this alleged normativity that lead Searle to conclude that functions must depend on values. If we abstract from all values, all that functional attributions contain are causal attributions according to Searle. If will show in my talk that this is also not true. To identify something as a biological function amounts to more than just to locate its place in the causal nexus. Of course, parts of organisms entertain causal relations with other parts, and these causal relations are constitutive for their being biological functions, but this is not the full story.

The exact import of functional attributions becomes clear only once we take a closer look at what kind of relation a functional predicate is. On my analysis, functional predicates have the general form F: X's function with respect to goal state G in organism O is ϕ (for example: The bovine heart's function with respect to self-reproduction in bovines is to pump blood). ϕ will typically be a causal capacity or disposition. Such an account raises at least two important questions: First, can we give necessary and sufficient

conditions for an ordered quadruple $< X, G, O, \phi >$ to satisfy F? Obviously, this is no trivial task in light of the enormous literature on functions. But there is a second question that is no less important: Given that some ordered quadruple $< X, G, O, \phi >$ does satisfy F, what is the nature of the relation between ϕ and G? Is this a causal relation? Or a supervenience relation? Or something else?

I will assume along the lines of Casini and Weber (this workshop) that this relation is best construed as a relation of partial grounding. Thus, on this construal, the heart's pumping blood does not cause an individual bovines self-reproduction, it rather partially *grounds* it. Why not causation? Well, I am not at all opposed to interpreting statements such as "the bovines sudden cardiac arrest at time t caused it to die at time $t + 1$" literally in terms of some notion of causation. But in contrast to death, self-reproduction is not an event that follows some specific physiological event. But as temporal succession is required for causation, it seems more attractive to construe the relation between functional capacity and goal state as a grounding relation.

This underscores the objectivity of functions, for it is not ours to choose which capacities are able to ground self-reproduction and which ones don't. Blood-pumping by hearts partially grounds self-reproduction, making thumping noises doesn't.

The most difficult problem is clearly to specify the conditions under which such a relation of partial grounding obtains. It could be suggested that there is an easy operational criterion, to wit, an interventionist one. For example: X's function with respect to goal state G in organism O is to ϕ iff an intervention on X with respect to some of its causal descendants affects the goal state G. "Affecting the goal state G" could be interpreted in various ways, for example, the capacity for self-reproduction may be enhanced, diminished or completely obliterated.

Such a proposal looks attractive, not least because it would allow us to connect the function literature with the burgeoning literature on interventionist causality (Woodward 2003) as well as mechanistic constitution (Craver 2007). However, I will argue that a simple interventionist criterion will not do. The reason is that an intervention on a part of an organism might reveal whether that part is vital or that it plays some role, but not *qua what*. The heart partially grounds self-reproduction *qua* blood pump, not *qua* noisemaker. A simple intervention on the heart (or the heart rate) will not allow us to distinguish these possibilities, so we would have to intervene on the heart's blood-pumping while keeping all it's other causal outputs such as its noise-making constant. As this is 'not possible, it is necessary to consider how the hearts causal dispositions are embedded in a whole network of other functions, e.g., respiration, glucose metabolism, immune defense (cf. Weber 2005a,b). In other words, we must consider how the heart mechanism is hierarchically embedded in a whole system of mechanisms.