Biofunctions: Two Paradigms[1]

' 1. Functions

Listed in Websters 3rd International Dictionary under "function" are

2a. The natural and proper action of anything; special activity; office, duty, calling, operation, or the like.

2b. The natural or characteristic action of any power or faculty.

10. Physiol. The normal and special action of any organ or part of a living animal or plant.

According to The American Heritage Dictionary, Windows version, a function is

1. The action for which one is particularly fitted or employed.

2a. Assigned duty or activity. 2b. A specific occupation or role...

4. Something closely related to another thing and dependent on it for its existence, value, or significance".

I don't know of any discussion of function in philosophy or biology that doesn't fit under one or more of these clauses. Nor is the use of the term "function" in contemporary biology tightly defined or univocal, either within or across subdisciplines. Argument over THE correct analysis of THE concept of function either in ordinary life or in biology is, I believe, quite pointless. On the other hand, questions about the applicability, clarity, determinateness, and usefulness to biology of various

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[1] Parts of this paper are drawn from (Millikan 1999) with kind permission of The Journal of Philosophy.

different possible notions of function, and about the relations of various notions to one another, are important.

I will explore two notions of function apparently useful in biology, along with certain subvarieties. The first notion is that of "proper functions" as defined in my Language, Thought and Other Biological Categories (Millikan 1984, hereafter LTOBC). The second is the notion of functions described in Robert Cummins' well known paper "Functional Analysis" (Cummins 1975),[2] which functions I will simply call "Cummins functions." I will also discuss what I take to be two subspecies of Cummins functions, namely, "exaptations" (Gould and Vrba 1982; Gould 1991) and biologically useful "spandrels" (Gould and Lewontin 1979). When I say that I will "explore" these various notions, nothing even remotely resembling conceptual analysis is intended. Rather, I will take the stipulative definition of "proper function" from my LTOBC and I will take Cummins' description of "functions" from "Functional Analysis," compare the biological phenomena that fit under these two definitions, inquire how determinate each of these notions is when applied to biological

[2] In (Millikan 1989) I remarked on Cummins' discussion of functions that its aim was entirely different from my own in LTOBC. I said it again in (Millikan 1989b) while discussing the proper functions specifically of biological kinds, and in (Millikan 1993, chapter 2), where I emphasized that the proper functions of biological kinds overlap with functions in Cummins' different but equally legitimate sense. Unfortunately, the literature on functions continues to set me over against Cummins, or to claim that I take proper functions and Cummins' functions to apply in different domains. I hope that this essay will help to make clear why both these notions of function are useful although it is important to keep them straight.

phenomena, discuss possible useful adjustments to tighten them up where needed, and propose a useful tightening up of Gould and Vrba's notion "exaptation." That is, I will be exploring consequences and suggesting prescriptions for usage, rather than attempting descriptions of usage, for these various terms.

'2. Proper Functions

Neither "proper functions" nor Cummins' "functions" were originally defined with specifically biological applications primarily in mind. Cummins said that his definition of function was designed to explicate "the central explanatory use of functional language in science" (p. 746), but what he was especially interested in was cognitive science and he wrote at a time when minds were more likely to be compared to computers than to biological systems. According to LTOBC, the definition of "proper function" was needed

> in order to talk about analogies and disanalogies among things belonging to quite diverse categoriesCbody organs, tools, purposive behaviors, language elements, inner representations, animal's signals, customs, etc. ...[the] purpose being to make as explicit as possible analogies among categories of things, which analogies had struck me as useful to reflect on...the spirit in which I offer them to the reader is as a handle by which to grab hold of the analogies. (p. 38).[3]

[3] Proper functions are of great interest, I argued, because they correspond to a pattern that

recurs in a large variety of forms, on many levels and in many domains, and seems to be found wherever purpose and/or intentionality are naturally ascribed. Purpose and intentionality were the phenomena (contrast "the words," "the concepts") I was interested in. There are lots of borderline cases of proper functions, if not so many in nature, certainly in possible worlds. What is interesting about proper functions is not their discreteness, not their dramatic difference from all other possible things, but the diversity among the actual items that have them, the great variety of their manifestations. What is surprising is that so many of the various actual things that are thought of as having purposes or meanings seem to be strung on a common thread, to be variations on a common theme. The description of "proper functions" was an attempt to describe what is most central in these patterns, patterns that underlie, though they do not directly govern, our usage of the notions of purpose and meaning. Should they correspond to what purpose and meaning "really are," it would be the way being HOH corresponds to what water "really is," or the way in which loose bonding but without crystallin structure corresponds to what a liquid "really is" (but from which it follows that glass is a liquid).

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> "Proper function" is intended as a technical term. It is of interest because it can be used to unravel certain problems, not because it does or doesn't accord with common notions such as "purpose" or the ordinary notion "function." My program is far removed from conceptual analysis; I need a term that will do a certain job and so I must fashion one. However...the things that have "proper functions" do seem to coincide with things (omitting God) that have, in ordinary parlance, "purposes." (p.2)

From these passages, and also from the definition I gave, and from the discussion that followed, much of which was about language function, I assumed it would be clear that the term "biological" in the title of LTOBC was used not literally, but broadly or metaphorically. But the definition was immediately praised/blamed as a right/wrong analysis of the notion of biological function.[4,5] It is for this reason that I wish to be

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[4] For example, Neander 1991; Walsh & Ariew 1996; Amundson & Lauder 1994.

[5] Writing about proper functions in (1989a) I said that it was fine to take the definition as stipulative, but certainly, please, not as a conceptual analysis of anything. Commentators continued to claim not just that I had given a correct/incorrect analysis of biological function but a correct/incorrect analysis of the notion of function itself...of THE notion of function! Indeed, there actually were claims that I had given an incorrect analysis of what "proper functions" are,

particularly careful here to make clear that the notion "proper function" is not offered as an analysis of biologist's usage, but merely as a fairly well defined term that is applicable and, I believe, useful in biological contexts.

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though that term was entirely my own coinage.

The term "proper function" was my own coinage. I intended (as suggested at LTOBC p. 2) Webster's first meaning of "proper," which coincides with that of the Latin proprius meaning one's own.[6] Especially, "proper" was not intended to be a prescriptive or evaluative term. I have sometimes emphasized that proper function is a "normative" notion, but normative terms are not always evaluative.[7] Normative terms are used to indicate any kind of measure from which actual departures are possible. For example, a numerical average is one kind of norm, as is any sort of regularity: "With that kind of sky in the west it ought to be sunny tomorrow". (Proper functions do not correspond to averages or regularities either, of course. They define a standard of their own kind.) Certainly the point of proper functions was not to capture normativity generally. Purpose and intentionality were the original targets. The kind of error or mistake that stands over against functioning "properly," in this technical sense, is unfulfilled purpose and its relatives (of which one form, I argued, is false representation).

I will not try to repeat here the two detailed chapters defining proper functions in LTOBC-- chapters 1 and 2. Roughly, the idea is, first, that proper functions are

[6] The root is found, for example, in "property" and the verb " to appropriate." "Functioning properly" is, of course, a perfectly ordinary English phrase, but there "proper" tends instead toward an evaluative meaning.

[7] In LTOBC I sometimes spoke of proper functions as functions things are "supposed to" perform. But the term "supposed to" was defined naturalistically and, indeed, entered in the "Glossary of Technical Terms" at the end of LTOBC.

associated with reproduced or, broadly speaking, copied items, certain effects of whose ancestors have helped account for the survival, by continued reproduction, of the item's lineage. This simple description, however, also fits each of the stages of any cyclical process. To have a proper function an item must also come from a lineage that has survived due to a correlation between traits that distinguish it and the effects that are "functions" of these traits, keeping in mind that a correlation is defined by contrasting positive with negative instances. Intuitively, these traits have been selected for reproduction over actual competitors. Because the correlation must be a result of a causal effect of the trait, the trait will not merely have been "selected" but will have been "selected <u>for</u>" (Sober 1984). Thus a thing's proper functions are akin, intuitively, to what it does by design, or on purpose, rather than accidentally.

An important clause in the definition of proper functions allowed for certain devices that are (in a carefully defined sense) "malformed" to have proper functions despite being unable to serve these functions. Such devices have still been "designed" to serve their functions. For example, a mispronounced hence misunderstood word may still have the proper function(s) of the lineage from which it was copied, and a deaf ear still has enabling hearing as a proper function. Thus enters the (non-evaluative) "normative" dimension associated with proper functions. It enters also when items don't perform their proper functions because background conditions that helped to support performance of these functions in ancestors are absent. Then they may fail to perform properly (in the defined nonevaluative sense) through no abnormality of their own.

The most familiar examples of items with proper functions are various traits of biological forms that have been selected for by Darwinian natural selection and that are reproduced genetically. Call functions of this kind "proper biofunctions." My focus in this paper will be on proper biofunctions and their relation to Cummins functions found in biological contexts. Most biological traits have numerous proper biofunctions, some more proximal and others more distal, each of which helps to effect the next in the series. There is, I think, never such a thing as THE proper biofunction of a biological device.

Besides the most obvious examples of proper biofunctions there are also "relational," adapted" and "derived" functions which include, I have argued, both explicit human purposes and the functions of activities and artifacts produced in accordance with human purposes. Later I will discuss the rationale for the notions "relational," "adapted" and "derived" as applied to proper functions in considerable detail. I will do so because these notions have been nearly universally overlooked or misunderstood in the literature on "teleosemantics" and related issues.[8] Moreover, these more complex proper functions have exact parallels in the realm of Cummins functions, where it is important that they be recognized as well.

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[8] For example, Preston 1998; Matthen 1997, 1998; Walsh 1998; Rowlands 1997; Wagner

'3. Cummins Functions

1996.

Cummins began his paper on functional explanation (Cummins 1975) by arguing that it is a mistake to suppose that reference to the effects of a biological trait helps to explain its presence in an organism. It is the genetic program, he says, that actually explains any such presence, this in turn being explained by the vagaries of mutation, rather than by the fact that the trait was selected for. This may be an error on Cummins part. Any trait that was selected for performing its current function has historically caused an increase in fitness. That is what it means to say the trait was selected for rather than merely selected (Sober 1984). And that means the trait must actually have made a yes or no difference concerning survival and/or reproduction for at least some ancestors having the trait, hence must have helped account for the existence of current progeny having the trait. Any inherited trait that has helped to explain why an ancestor survived or reproduced ipso facto helps to explain why the current animal, hence the trait, is here. Nothing has a single cause. That the genetic program was a cause does not entail that nothing else was a cause.[9]

But if this was an error on Cummins' part, although it needs to be mentioned if the relation of Cummins functions to proper functions is to be distinctly understood, the error does not infect the central purpose of Cummins definition of "function." The important point is that Cummins' definition of function is designed to clarify a completely different kind of "functional explanation" than the "why is it there?" kind.

[9] See also Neander 1995.

It is designed to clarify the sort of functional explanation that "explains the biological capacities of the organism" (1975 p.751). It explains how the organism's system works, rather than why the traits contributing to these capacities or workings are there.

Cummins functions are such relative to a chosen "containing system" which has, as a whole, a certain "capacity," that is, a certain "disposition" or dispositions, that we are interested in having explained. Cummins functions are dispositions of parts of this containing system, or simpler dispositions of the whole system that, added together, account for the complex capacity that needs explaining. Because items have Cummins functions not absolutely, but only relative to a chosen capacity or capacities of a chosen containing system, the point of ascribing a certain Cummins function to an item will depend entirely on one's explanatory interests:

> [f]or no matter which effects of something you happen to name, there will be some activity of the containing system to which just those effects contribute, or some condition of the containing system which is maintained with the help of just those effects. (Cummins 1975, p. 752)

> The explanatory interest of an analytical account is roughly proportional to (I) the extent to which the analyzing capacities are less sophisticated than the analyzed capacities (ii) the extent to which [they] are different in type...(iii) the relative sophistication of the program appealed to, i.e., the relative complexity of the organization of component parts/processes that

is attributed to the system. (p. 764)

In contrast to proper functions, Cummins functions, merely as such, have nothing to do with why the thing having the function is there, and nothing to do with its purposes. Cummins functions can be contrasted with "accidental effects" only in the sense of effects that don't help to explain the capacity one has chosen to analyze. Nor are Cummins functions defined such as to contrast with malfunctions or with failures to perform functions. For example, in considering the rain-cycle system, in accordance with which the lakes and rivers are periodically refilled and so forth, the Cummins function of cumulus clouds is to produce rain, but there is no such thing as malfunction for this system nor is it the purpose of clouds to cause rain. Cummins functions are simply dispositions of a system or of parts of a system, and it is definitional of having a disposition that, if the conditions of the disposition are met, the disposition is manifested. On the other hand, just as biological traits typically have a whole series of proper functions from more proximal to more distal, more proximal or more distal Cummins functions may also be described, depending on how fine grained the functional analysis is.

'4. Specifying Input, Background Conditions and State Changes for Cummins Systems

In this section I will be describing what I take to follow from Cummins characterization of functions and of functional analysis as descriptions of dispositions to function rather than norms of function. It is not always easy to keep these two straight, and some of the language that Cummins uses invites a confusion that we need to avoid. When we avoid it, we will be able to see more clearly what will need to be supplied if the notion of a Cummins function is to do any work in biology.

In describing the general form that functional analyses take, Cummins mentions flow charts, circuit diagrams and computer programs. Notice that representations of this kind generally specify ideal rather than actual systems. The circuit diagram that comes with your washing machine represents how it was designed or intended to function, not necessarily how it does function. Moreover, it was designed to function that way not unconditionally, but given quite specific background conditions and quite specific inputs. For example, it was designed to operate upright on a relatively level, stable and rigid floor, under about one g gravitational force, surrounded by air at about one atmosphere pressure, protected from large magnetic forces, heavy blows, strong vibrations, heavily corrosive gasses, and so forth. And it was designed to take as input, fed in at designated places, an electric current of about 110 volts alternating at 60 cycles, hot and cold water, certain kinds of emulsifiers, clothes or other cloth materials soiled with a reasonable amount of ordinary dirt (not completely soaked, for example, in wet tar or wet paint) and mild forces in designated directions on certain of its buttons and dials.

Specifications of this sort concerning background conditions of operation and allowable input must also be assumed for any system to be given a Cummins-style functional analysis-- we can say, for any "Cummins system". This is because a Cummins system is analyzed as having a certain set of determinate dispositions of the whole and of the parts, and these dispositions will be determinate only in so far as limits on background conditions and inputs to the system are determinate. Cummins systems cannot be said to fail or malfunction as such, but they do have to be specified in relation to delimited possible background conditions and delimited possible inputs, implicitly or explicitly specified in some manner. To describe a Cummins system is to describe a set of dispositions. But a set of dispositions is a set of responses to possible, not merely actual, inputs and conditions. A set of dispositions corresponds to a set of counterfactuals. To describe a Cummins system, then, is not to describe actual historical conditions and actual historical inputs. Nor is it to describe, for some actual object, every result of every possible input under every possible condition. In this respect, Cummins systems correspond to ideal types, not to actual historical tokens or kinds. Extreme care must be taken if we are to avoid confusing, in any given case, the boundaries we must set to delimit this ideal with some kind of prior unexamined normative boundaries. For example, we must avoid implicitly assuming reference to inputs or conditions that accord with design. No reference to design is legitimate when dealing with Cummins functions pure.

It follows that no chunk of matter, such as a washing machine or an elephant, determines a Cummins system when considered just as such. First, as Cummins explicitly noted, we must specify which of the various output capacities of the chunk is to be analyzed. If the washing machine, for example, is to be analyzed for its capacity to turn out clean clothes rather than to rattle the dishes in the cupboard or to warm up the room, this needs to be specified. Second, we must specify what will count as allowable conditions of operation for the system. The washing machine may turn out nicely washed clothes if instead of being left on after it is filled, the floor under it vibrates or rotates in just the right way. If this method of operation is not within the domain to be explained by the intended functional analysis, this must be specified. The machine taken by itself describes no such limits. Third, we must specify what will count as allowable input to the system. Given a modern washer, pouring hot water in the top from a bucket, or turning the agitator by hand, are not intended inputs, although with washers of the 1920s this sort of input was part of the Cummins system intended. Possible input from a repair man also is not part of the system's intended operation. But the machine taken by itself is silent about the kind of Cummins system it prefers to exemplify.

A chunk of matter, depending on what are considered its allowable inputs and background conditions, may exemplify many different Cummins systems at once, even many different Cummins systems with the same output capacity. What counts as a Cummins function is relative to choice of an ideal type to be explained. If we are to make use of the notion of Cummins functions in biology, an important question, then, will be how to specify principled and useful ways to delimit biological Cummins systems. The essential role played by the interests and intentions of the one who analyzes a chunk of matter as exemplifying a certain Cummins system suggests that we must pay close attention to the move from a certain historical member of a species, or from the historical species as a whole, to specifying nonarbitrary and objective Cummins biofunctions of various of its traits.

Living chunks of matter don't come, just as such, with instructions about which are allowable conditions of operation and what is to count as allowable input. Similarly, they do not come with instructions telling which changes to count as state changes within the system and which instead as damage, breakdowns or weardowns. Nor do they come with instructions about which processes occurring either within the organism or outside it are to count as occurring within and which as irrelevant or accidental to the system. What one analysis describes as the system's yielding its designated outcome according to a legitimate Cummins analysis another may describe as yielding it "serendipitously." What counts as "damage" on one account may count as irrelevant change external to the system on a second, for example, because the second imposes different limitations on "normal" input or on "normal" surrounding conditions, adjusted to insure that the change has no effect on the capacities of the system to be analyzed.

These problems are difficult, and I am actually not sure how satisfactorily they can be addressed.[10] They are made especially interesting by the fact that the currently controversial notions of useful "spandrels" (Gould and Lewontin 1979) and, more generally, "exaptations" (Gould and Vrba 1982, Gould 1991) seem to rest on a notion of function of the kind Cummins describes.[11] Thus "exaptations" are said to be traits that have "vital current utility based on cooptation of structures evolved in other contexts for other purposes (or perhaps for no purpose at all)" (Gould 1991, p. 46). That is, I believe, they have Cummins functions in the life system of the animal --Cummins biofunctions-- that are not also proper biofunctions. But there are also indeterminacies connected with the notion of a proper biofunction --a subject to which I will turn directly.[12] I will return to the question how a biological system might be delimited and described as a Cummins system in '8 after more tools have been assembled in the toolbox.

But before proceeding, one more note may help on the nature of the project I am attempting. Concerning development of the terms "Cummins biofunction" and "proper

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[10] In (Millikan 1999) I assumed they could not be solved. Now I am somewhat more optimistic, as will emerge below.

[11] Gould vacillates in his usage of "spandrel," sometimes meaning merely any structure or process that is an accidental side effect of structures designed for other purposes, other times implying that the structure has current utility as well. In the latter case, I will speak of "useful spandrels" or just "exaptations." Gould is also indiscriminate in his use of "exaptation," sometimes covering with it any structure that had its origin in a prior structure originally selected for a prior purpose. But of course every adaptation has such an origin if one looks far enough back, so that no distinction at all between adaptation and exaptation is then drawn.

[12] Peter Schwartz has urged this point, causing me to rethink a major chunk of this paper.

biofunction," it seems to me that the sensible strategy is as follows. First describe what the paradigm cases are like, the cases in which there can be no question about the application of these notions of function as already defined. Second, explore the various dimensions in which slippage can occur, in particular, the kinds of contingencies that can make application of these notions less than clear-cut. Third, stop! Do not attempt to give these notions entirely clean boundaries. Nature has many important joints, but these joints are seldom clean. Definitions that cut sharp edges where there are none in nature are of little use in the understanding of nature. On the other hand, exploring dimensions of slippage may also reveal places where the notions themselves are inelegant or gerrymandered, or worse, open ended like a Christmas stocking with the foot cut off. Fix this if possible. (Later I will argue that the notion of an exaptation is such a Christmas stocking.) But most important, to be avoided at all costs is the attitude that there must be some "correct" way of using these terms, some preordained way waiting to be discovered.

'5. Vaguenesses in the Notion of a Proper Biofunction

In paradigm cases the genes responsible for traits with proper biofunctions have forced their alleles to extinction through their superior effects upon fitness. Even tiny differences in fitness values, if consistent over enough generations, typically lead to extinction of the less fit alleles. But differences in fitness values are not always consistent over the generations, due, for example, to fluctuating environmental conditions. Then fluctuating changes in the gene pool may result, with certain alternative traits also surviving the generations. Theoretically possible here is a continuum of cases from traits having minimal to maximal effect on the statistics in the gene pool over a period of time. There is no benefit in inventing some definite criterion for how much influence over what period of time a trait's effect must have had on the constitution of the gene pool for this effect to be counted as a proper function. In some cases, however, systematic selection pressures have been brought to bear only on well circumscribed portions of a population of organisms, artificial selection by humans for certain purposes being one obvious case. It seems reasonable to say, for example, that the proper function of certain of the collie dog's behaviors is to aid in herding sheep, regardless of how local a portion of the entire dog species exhibits these behaviors. Similarly, the fitness of a trait sometimes declines as its frequency in the population increases, so that it persists but only in equilibrium with alternative traits controlled by its alleles. But its presence, when it is present, is still accounted for by its correlation with a certain effect. Perhaps we should say that it has a proper function, but only when sparsely distributed.

The genes responsible for a trait sometimes become fixed owing to more than one function that is served when perhaps none of these functions taken alone would have fixed them. There might, for example, be countervailing effects of the trait that would have lead to its extinction had only one of its disjunct of positive effects been present. Just how small a contribution to increase in fitness should be allowed to count as bestowing on any one of these effects the name "proper function"? --That is exactly the kind of question I recommend we not ask; it seems clear that "answering" it would not serve any theoretically interesting purpose.

A dimension of indeterminacy for proper biofunctions addressed in the literature concerns traits that once were selected for a function but that no longer serve that function (Godfrey-Smith 1994; Griffiths 1993; Schwartz, this volume). In White Queen Psychology, Chapter Two (Millikan 1993) I pointed out that if a trait is now serving a different function than it was originally selected for, then it probably has more recently been under selection pressure precisely for serving that new function. I thus suggested a form of what Godfrey-Smith later termed a "recent history" view of proper functions (1994). Schwartz correctly points out, however, that there are factors other than selection that can account for persistence of a trait that was once selected for, and suggests counting as proper functions just those effects that a trait was both selected for and still sometimes performs (this volume). This seems sensible to me. Certainly it would be confusing to say of a vestigial trait that could no longer serve a certain function that that was its proper function. On the other hand, one could also just allow oneself to say, in certain cases, that although such and such is the proper biofunction of a certain trait, it seldom or never performs it anymore. For example, if a human infant is dropped into very cold water, it stops breathing and instantly goes into hibernation. That is a trait that may very well have been selected for, if not in humans specifically, then in a wider clade of which we are members. This capacity very seldom serves its proper function in the modern world, but it seems reasonable just to say that, rather than to prune the definition of a proper biofunction artificially.

'6. The Descriptive Generality Requirement

The next dimension of possible indeterminacy in the notion of a proper function applies to Cummins functions as well. It is important enough to deserve its own section and to require tightening up on both definitions. It is common for a trait to be selected for serving a function that might be defined either more broadly or more narrowly. A text book example is offered by Elliot Sober in The Nature of Selection (1984). Fruit flies subjected over many generations to high-temperature stress develop thickened skins to protect themselves from the heat. Being good insulators, these skins would protect them from cold as well. Should we say that the proper function of these thickened skins is, more narrowly, protection against heat or, more broadly, insulation? Sober opts for insulation, and I think his choice is, in the end, the only reasonable one. The general principle involved is prevention of heat exchange, so that the thickened skin not only serves the same purpose, namely, keeping the fly at a uniform temperature, in both overheated and overcooled environments, it performs this function in accordance with the same explanation. A more narrow description either of the function served or of its explanation would be as inappropriate as saying that a car was wrecked because it went off an asphalt road through some grass and into an embankment rather than just because it went off the road into an embankment. Similarly, it is a proper function of our semicircular canals to help keep us upright in a gravitational field, not just in a gravitational field of one G. Moon walkers do not employ their semicircular canals for functions they were not designed for. Nor do we employ our digestive systems for functions they were not designed for when we eat newly hybridized fruits, or even Fritos and Coke. Similarly, a proper function of my heart is to help me to wiggle my toes, but only as falling under the much more general description of supplying my organs with oxygen and nutrients so that they may do whatever their individual jobs may happen to be.

The requirement that proper biofunctions should always be described according to the most general principles available is a requirement that seems equally sensible when applied to a description of Cummins functions. To describe how my semi-circular canals work by telling separately how they react under an oblique force of one G, then of .9 G, then of .8 G and so forth, naming each of these a separate Cummins function of the canals would clearly be absurd. Similarly, a good Cummins function description will describe the digestion of carbohydrates, fats and sugars, not the digestion of navel oranges, Fritos, Coke and hummus. I will refer to this principle as "the descriptive generality requirement."

'7. Relational, Adapted, and Derived Proper Functions[13]

A central application of the descriptive generality requirement concerns what I have called "relational," "adapted" and "derived" proper functions (LTOBC, Chapter Two). All adapted and derived proper functions admit also of more basic relational descriptions, and the relational descriptions are the more general. It is easy to suppose that a function is new or that it must be separately described because its adapted or derived character is novel, whereas a closer look would show that under a relational description it is the same old function over again. Let me first explain extremely carefully what these three kinds of functions are, for as mentioned earlier, they have very often been either ignored or misunderstood. As I proceed I will explain how the descriptive generality requirement applies, and how it applies to exactly the same functions when these are viewed as Cummins functions.

[13] The following section on relational, derived and adapted proper functions is derived and adapted from (Millikan 1999).

Begin by considering an adding machine. Does it do the same thing every time you use it? One time it returns the number 237, the next time the number 257,000. But the important thing is that it turns out, every time, the sum of the numbers fed into it. Under this general description, it does the very same thing every time. Its effect is always production of the very same abstract relation between input and out put. If one were to give a Cummins description of the adder, that is how the descriptive generality constraint would require that its basic function be described. If the adder exists as a small part of a larger machine that performs more complex functions that depend in part on the adder, the adder's function should, of course, still be described relationally. Suppose the adder needs to handle only numbers under 1000. Then one could give a list of its "adapted" functions. If 7 and 3 are put in, its adapted function is to outputs 10. If 59 and 79 are put in, its function is to output's 138, and so forth. But that description would not meet the descriptive generality requirement.[14] Similarly, if we take the adding machine apart to see how it works inside, the description of each operation inside, in so far as it varies systematically with input, needs to be described relationally. Now suppose further that the adding mechanism is part of a creature designed by natural selection and that the mechanism has been selected precisely for its capacity to add something the creature needs added, say, as part of a smart foraging

[14] Unless, of course, it does this by accessing a huge lookup chart where all the sums are posted in advance. In that case there is no general principle involved getting each sum right, that is, there is no correct relational description of how it adds.

strategy. Then the adding mechanism's Cummins functions and the Cummins functions of its parts are proper biofunctions as well as Cummins functions and, of course, must still be described relationally.

Let me introduce some examples now that are more plausible biologically. Having relational proper functions is typical of the behaviors of organisms. These functions, in higher species controlled mostly by the perceptual and\or cognitive systems, are preformed by altering the relation between the organism and the environment as needed so that the environment will provide advantageous surrounding conditions and inputs for the organism. Some of these functions involve changing the environment to fit the organism, some involve changing the organism to fit the environment, some involve changing merely relations between organism and environment, or involve some combination of these three. The systems responsible for these changes have, first, relational proper functions of one kind or another. That is, their job is to make it the case that the organism and the environment bear some particular relation to one another. Their job is to create relational structures. As with any other proper function, a relational proper function of a mechanism corresponds to an effect that ancestors of the mechanism have historically had that helped account for their selection. In this case the effect was creation of an abstract relational structure.

The example I originally used of a mechanism with a relational proper function was the chameleon's pigment rearranging mechanism (LTOBC chapter 2). Its function is to produce the relational structure *skin-bearing-the-same-color-as-its-background* for the chameleon, a further proper function being, of course, to prevent predators from seeing the chameleon. To create this relational structure, the mechanism effects changes in the chameleon but not in the environment. Other animals effect production of a similar relational structure by moving into parts of the environment that match them, that is, by changing the spatial relation between themselves and the environment. And likely there are also animals that change the environment, say, the surroundings of their nests, in order to produce this kind of relational structure.

Notice that in order to produce the relational structure *skin-bearing-the-same-color-as-its-background* the chameleon does not need to produce both relata. It produces only one of the relata, the skin color, but in such a fashion as to bring into existence the designated relation. Nor is there any cheating here. No device can produce an effect, a result, a product, ex nihil. Every function is performed only by using materials of some kind, relying on certain properties of materials already at hand. Producing a relational structure by being guided by one relatum to produce the other is as legitimate a form of producing as producing a wooden spoon by choosing a piece of wood and carving it.

There are a great number of relational structures besides those involving sameness relations that behavioral mechanisms may have as proper functions to produce. Another well worn example (I fear I have worn it out) is the mechanisms that produce the dance of the honey bee. The job of these mechanisms is to produce a relational structure having a location of nectar as one relatum and a certain aspect of the pattern of the dance as the other. The relation in question is the one given by the abstract function (mathematical sense of "function") describing the semantic rules for the B-mese used by the particular species of bees. In most species, an angle that the dance movement marks out relative to gravity or to aspects of the hive always bears the same definite relation to the angle of the location of nectar relative to hive and sun. The properly functioning dance mechanism always produces exactly the same thing, namely, this designated relational structure. The mechanisms that produce bee dances have as a further proper function, beyond producing the dance, to send watching fellow bees off in a certain direction. The relational structure thus produced has as relata (1) the orientation of the dance relative to the hive and (2) the angle in which the watching bees fly relative to the hive and the sun. The mechanisms create this relational structure by making changes not in the organism itself but in its environment --changes not in the dancing bee itself but in the bee's fellow workers. As a result of producing, first, the proper dance/nectar-location structure, the properly functioning dance-making mechanism later effects always exactly the same thing, namely, existence of this second relational structure between angle of dance and angle of flying workers. (This requires the right environment, of course, one in which there are well functioning fellow workers available. Their presence is what I called, in LTOBC, an "historically normal condition" for managing to perform this function.) It should go without saying that a Cummins analysis of how the wider system works that effects the cyclical reproduction of honey bees needs to make reference to each of the above relational functions in exactly the same way as is required for an analysis by proper functions. Similarly, it should easily be seen that every point made below about proper biofunctions applies equally to the same functions viewed as Cummins functions. I will not keep repeating this.

Where the proper function of a trait is to produce a series of effects each effecting the next, it is also the proper function of each stage to produce the next stage. So what we have here is the production of one relational structure -- dance/nectar-location -- having as a proper function the production of another -- dance/direction of flying. Finally, and as a logical result (given Euclidean geometry), one more relational structure is produced, namely, workers flying toward nectar. This is typical. Proper biofunctional relational structures typically do their jobs by producing further relational structures that eventually produce a relation between organism and environment yielding conditions or inputs the organism needs. Sometimes the whole process involves changing only the environment, and sometimes only the organism, but sophisticated relational proper functions typically involve both. They also typically cooperate with other structures having other relational proper functions, such as the bee dance producers' cooperation with answering mechanisms in fellow worker bees, which mechanisms could be given a similar relational analysis.

The general picture, then, is of proper functional processes that involve series of interweaving stages each of which is an abstract relational structure, some moments in these processes producing changes in the organism, others producing changes in the world, but involving always the exactly the same relations, although among different relata each time they are run. They are reproduced invariant processes, always the same when described in the most general way that explains how they work, yet different in their elements each time. It is to simplify the description of these complex relational structures and processes that I introduced the terminology "adapted proper function" and "derived proper function" in LTOBC. This terminology adds nothing to the original definition of "proper function," but affords a way of talking more easily about phenomena already captured by that notion, given that traits and mechanisms can have relational proper functions. Caution is needed in the treatment of these functions, however. Every reference to an adapted or derived proper function is really an implicit reference to one or more deeper relational functions. If we don't keep that in mind, adapted and derived functions are liable to be confused with brand new quite separate functions -- for example, as we will soon see, with exaptations. Similarly, if we don't keep in mind the descriptive generality requirement when trying to locate Cummins biofunctions.

When a mechanism has a relational proper function, it may produce one of the relevant relata while the other relatum is not affected, either (1) remaining the same or (2) undergoing its own independent course of development. A simple example of (1) is the chameleon's pigment arranging mechanism which changes the chameleon's color while the color of the background remains the same. An simple example of (2) I take from B.C. Smith (1996). Suppose that a species of sunflower not only tracks the sun, but continues to move when the sun goes behind a tree so as to catch up with it on the other side. Here the mechanism produces changes in the organism designed to maintain a certain organism-environment relation, and does so as the environmental relatum itself is changed, though not, of course, changed by the flower. Similarly, the relational structure consisting in the image on a male hoverfly's retina mapping the position and angle of approach of a passing female has as an eventual proper function production of another relational structure consisting in the male's path crossing the female's.[15] As with the sun and the sunflower, the female is (as yet) unaffected by the male. Only a change in the direction of flight of the male is effected.

Now examine the relatum that is actually <u>produced</u> by a mechanism with a relational proper function. Consider the brown skin produced by the pigment arrangers of the chameleon sitting on a brown background. The job of the pigment arrangers is to produce the relational structure, *skin-color-matching-its-background.* But neither

[15] For details, see (Millikan 1993).

relatum, brown background nor brown skin, is an operative part of an historically normal set of sufficient conditions explaining the capacity of the chameleon to become camouflaged. Either relatum might have been replaced, and so long as the other was similarly replaced, the chameleon would have been properly camouflaged. Being brown is not a part of an historically normal set of conditions for performance of any of the chameleon's proper functions. Neither the relatum produced nor the independent relatum has a proper function. Not all by itself! Only the whole relational structure has a proper function. Similarly, for a sensible Cummins functional analysis.

However, given that brown is the color of the background, the job of the pigment rearrangers is certainly to make the skin brown. I call this kind of job an "adapted proper function" of the mechanism. Turning the skin brown is not usually a proper function of the mechanism, and it will not remain a proper function of the mechanism when the chameleon no longer sits on something brown. However, right now, given that it is on a brown background, it is an adapted proper function of the mechanism to make the chameleon brown. Turning the skin brown is a proper function of the mechanism "as adapted to" the brown color underneath. It is not of course a simple, but only a conditional proper function of the mechanism, an "iffy" proper function, but the "if" part has been asserted. The product produced by a device performing an adapted proper function I call an "adapted device." The chameleon's brown color is an adapted device. It is not, of course, brown itself that is an adapted device, but only the brown skin color of a chameleon produced in the right way in the right circumstances. Similarly, it is reasonable in this sort of context to speak of "adapted Cummins functions." For notice that the use of the word "adapted" here is not connected to its occurrence in the word "adaptation."

Now ask about the functions of the relata themselves in a proper functional relational structure. The function of a whole relational structure, as was said, is often to produce another relational structure. The bee-dance mechanism produces the relational structure, *dance-mapping-the-location-of-nectar*, a function of which is eventually to produce another relational structure, *worker-bees-heading-toward-nectar*. The nectar, of course, is and remains an independent relatum, so taken by itself, it cannot have a proper function derived from that mechanism. But the other relatum, the bee dance, is produced by the mechanism in accordance with an adapted proper function: it is an adapted proper function of the mechanism, as adapted to the location of the nectar, to produce a certain bee dance, one that maps this location. Further, it is an adapted proper function of the dance-producing mechanism to produce, as a result, a certain direction of flight in fellow worker bees. <u>Is</u> <u>it</u> <u>also</u> a proper function of the dance itself to produce this direction of flight?

The answer may at first seem to be *no*, for it seems theoretically possible, at least, that the particular bee dance has no ancestors. Perhaps no bees in the bee's lineage ever danced this particular dance, because there never happened to be nectar located in this particular direction from their hives. Then this particular bee dance, having never occurred in the past, certainly could not have been selected for any effects that it had, hence could not possibly have any proper functions at all.

But notice that this overlooks the descriptive generality requirement. We must describe functions and how they are performed in the most general way possible. Because bee dances that map different directions are different from one another in specific respects does not mean they are not also the same in more general respects. Indeed, the various dances of a given subspecies of bees are very much the same, to an untutored observer, hardly discriminable. And when they function in the way that has accounted for the natural selection of their producers and of their answering mechanisms in other workers, they always do exactly the same general thing. They produce a direction of flight that is a given function (mathematical sense) of certain aspects of their form-- in every case exactly the same function of that form.[16] The bee dance has been selected in part for its capacity to cause other worker bees to be guided in their direction of flight by its form. In this respect, all bee dances of the same bee species have exactly the same proper function -- also, of course, the same Cummins function. This function is a relational function. The dance's job or, on a Cummins analysis, its disposition, is to cause the workers to fly in a direction that bears a certain

[16] In LTOBC I put this rather awkwardly by saying that they have ("direct") proper functions which are adapted to their own concrete forms (LTOBC, chapter 2 and elsewhere). I am not sure that I have explained it less awkwardly here, but the phenomenon itself is really quite easy to grasp.

relation to itself (e.g., LTOBC p. 42).

Because of this relational function, depending on the particular form of the bee dance, it has as an adapted function to cause worker bees to fly in some particular direction, say, south-south-west -- just as the relational function of making the chameleon's skin match its background results in an adapted function to turn the skin brown when the chameleon is sitting on something brown. I call this kind of function a "derived" function, derived originally from the relational function of the producing mechanism plus it's context, in this case, from the adapted function of the dance-producing mechanism as operating in a certain context. All derived functions (whether derived proper functions or derived Cummins functions) are ipso facto adapted in this way. Things said to have derived proper functions are being named or described in accordance with their adapted aspects (they point in different directions, they are different colors) not the aspects that make them like their ancestors (they are all bee dances, they are all pigmented skins of chameleons). Their derived functions are what these adapted aspects must do in order for the whole relational structure of which they form a part to perform its further function(s). Again, derived functions can easily appear to be new functions, when they are really just fragments torn from the same old relational functions operating in new contexts.

Consider any mechanism that has as a function to produce any kind of learning on the basis of experience, for example, a mechanism that effects trial and error learning, or learning by imprinting, or learning by imitation, or learning by reasoning something out given premises derived from experience. Any such mechanism has, as such, a relational function or functions. It is designed, or (for Cummins functions) disposed, to turn out behaviors (or, say, beliefs or desires) as a certain function (mathematical sense) of certain designated kinds of input from experience. The sea otter, for example, learns what to eat from its mother, the mechanism that effects this being, in part at least, quite specific, that is, not of more general purpose or effect. Perhaps a combination of mechanisms helps to effect this learning, but a relational function of this ensemble is to create in the baby otter a complex state that produces a disposition to eat-whatever-mother-eats. Given that its mother eats sea urchins, then, it is an adapted function of the mechanism to produce a state that effects a disposition in the baby to eat sea urchins. And once this complex state is in place in the baby, it has as a derived function to produce sea-urchin collecting and eating. Other baby otters whose mothers eat abalones acquire complex states whose derived function is to effect abalone collecting and eating.

Generalizing from this, there can also be relational functions that produce adapted devices themselves having relational functions (for example, the functions involved in effecting empirical concept formation) producing more adapted devices having further relational functions (for example, the functions involved in fixing beliefs) to any degree of nesting. Out of this sort of structure can come things (tokens) seemingly very new indeed under the sun but that still have merely derived functions when examined more closely.

'8 Cummins Biofunctions and How Descriptive Generality Constrains Exaptations

According to Cummins, "...functional analysis can properly be carried on in biology quite independently of evolutionary considerations: a complex capacity of an organism (or one of its parts or systems) may be explained by appeal to functional analysis regardless of how it relates to the organism's capacity to maintain the species" (1975 p. 756). But a functional analysis of how the heart makes sounds, for example, is surely not what biologists are interested in, nor is ignoring evolutionary considerations the same thing as ignoring the organism's capacity to maintain the species. Rather, it seems reasonable to consider the capacity of the organism to maintain and reproduce itself to be exactly the capacity implicitly under analysis when Cummins biofunctions are in question. I take it that these are the capacities referred to by various authors as "current uses" (e.g., Gould 1991), "system functions" (Preston 1998), "algorithmic functions" (Rowlands 1997), "causal role functions" (e.g., Amundson and Lauder 1994) and, when they are not also proper functions (not "adaptations"), as "exaptations" (Gould and Vrba 1982) and as useful "spandrels" (Gould and Lewontin 1979).

Earlier I noted that a difficulty in applying Cummins' notion of functions directly to biological processes is that an organism plus some capacity that it has does not by itself yield a determinate Cummins system. It does not by itself determine what are to count as allowable background conditions and allowable input for the system's operation, nor what will count as state changes within the system's operation rather than external to it, or what is to count as the system's no longer existing, that is, as its having been dissolved or broken. A first and obvious step toward making these parameters determinate is to say that the appropriate conditions, inputs and state changes must characterize, or have characterized, various actual members of the species under analysis. But which actual members? We cannot innocently add that these must be "normal" or "healthy" or "undamaged" members, for these notions have not been defined either. Perhaps best to begin by limiting the relevant members to ones that have actually maintained themselves and reproduced, and then look for commonalities among the actual historical processes that achieved those results.

Notice that this first step -- surely a necessary and innocent one --moves in a direction that parallels an analysis by proper functions. First, the analysis must be given against the backdrop of the actual historic situation of the species. Second, because for many species survival and reproduction is not average, indeed, it may be achieved by only one in hundreds or thousands, it follows that what should be considered normal conditions and normal input to the biological system might stray very far from average conditions that members of the species actually find themselves in, or average inputs received by these members. But in searching for Cummins biofunctions, we have put aside the striking paradigm that is fixation or maintenance of a trait owing to its effects. Only statistical frequencies of the various processes propelling -- or drifting -- various individuals toward reproduction are left as guides for separating Cummins biofunctions from accidentally propitious effects.

A search for commonalities among these individual historical processes naturally leads us back to the requirement of descriptive generality. The only way to describe Chamileo's avoidance of a predator by turning green and Chamilea's avoidance of a predator by turning brown as exemplifying a common Cummins biofunction is to describe this function relationally. Each turns the same color as its nether environment. Similarly, the dog that brings the newspaper to its master for a reward employs its mouth in accordance with what is undoubtedly one of its <u>proper</u> functions, namely, carrying things, but carrying, specifically, <u>newspapers</u> is only an <u>adapted</u> proper function of its mouth, given the dog's previous experience. In exactly the same way, carrying newspapers should be considered only an adapted Cummins biofunction of its mouth (contrast Preston 1998). Thus it is that individual animals in a species can lead very different lives, and humans can live and have lived under widely differing cultural conditions, yet their activities may continue to exemplify very many of exactly the same Cummins biofunctions -- as well, of course, as the same proper biofunctions.

Employing this principle uniformly will show, I believe, that there are many fewer exaptations, many fewer plausible Cummins biofunctions that are not also proper biofunctions, than some have supposed. Thus Gould claims, "Surely exaptations of the brain must greatly exceed adaptations by orders of magnitude" (1991, p. 57). Unfortunately, many of his examples are offered without an argument that they have any kind of functions at all, proper, Cummins, or otherwise. He gives no argument, for example, that music, or religion, granted they might be spandrels, also have "vital current utility." Also, very many of the examples he gives turn on counting anything that originated from a structure originally designed for a different function as an "exaptation," no matter how long there have been selection pressures on it, preserving and adapting it to newer functions. But apart from these vaguenesses and excesses, he makes a more interesting claim. "..[J]ust make a list of the most important current uses of consciousness. Start with reading, writing and arithmetic. How many can even be plausibly rendered as adaptations?" Well, I suggest, how many can be plausibly rendered as having "vital current utility," that is, I suppose, Cummins biofunctions? Given the requirement of descriptive generality, they will have only adapted and derived Cummins biofunctions, and these will be exactly the same as their adapted and derived proper biofunctions. All have been learned through the adapted employment of very general learning mechanisms, such as learning from trial and error, from imitation, from instruction, by figuring things out from prior premises, and so forth. They have Cummins biofunctions only by reference, when correctly described, to very general, highly relational descriptions. Reading, writing, and doing arithmetic are like turning green and turning brown, or like collecting and eating sea urchins, or like carrying newspapers in the mouth. But then where is the argument that they are not also they are not also derived proper functions -- applied, facultative adaptations?

'9 A Survey of Numerous Vaguenesses in the Notion of a Cummins Function; An Attempt to Stop Some of the Leaks

'9.1 The First Leak

Harder questions for a useful definition of Cummins biofunctions concern what should count, in Gould's terms, as "having vital utility." A Cummins biofunction is supposed to be one that "contributes to the maintenance or reproduction" of an organism, but what, exactly, is that? Suppose we begin by trying this. We will require for paradigmatic cases of traits with Cummins biofunctions that serving this function always makes a difference between surviving and reproducing and not surviving and reproducing, or not reproducing so prolifically. Less paradigmatic Cummins biofunctions will make this difference only for some significant proportion of individuals in a species.

Suppose, for example, there are some individuals for whom presence of a trait, and others for whom absence of the same trait, would save them from dying or would aid reproduction. Consider the grey squirrel's characteristic path when fleeing from danger. Running zigzag is a very good strategy when a heavier predator is chasing you, but not when a car is approaching. Perhaps in the modern world, dropping this behavior would save more squirrels than retaining it. We will say then that only if the trait increases fitness is the mechanism or process by which it does so part of the squirrels' Cummins biosystem. That is, we will use a counterfactual analysis. For each actual squirrel we will ask whether it would have lived longer and had more babies if it had not zigzagged when fleeing from danger, and the statistics on this will determine whether zigzagging has a Cummins biofunction or not, and if so how paradigmatic or important it is.

The difficulty here is the usual one with counterfactuals. There is no such thing as taking a world and just dropping a fact from it to see what would happen without it. No determinate possible world is constructed by merely dropping a fact from the actual world. Any fact that is dropped has to be replaced with a determinate contrary fact. What will the squirrel do instead of zigzagging? Yes, it is obvious that what we had in mind was the squirrel running in a straight line. But perfect obviousness to us that this is what we have in mind does not make it the one objective thing to have in mind. In fact, it is entirely indeterminate what the squirrel would do instead if it did not run from danger in a zigzag line, and our agreement on what we would like to put in place of this zigzagging does nothing to make it less indeterminate.

A different illustration may make this easier to grasp. Consider the question what Cummins biofunctions human shoulders have, if any. For example, is one of their Cummins biofunctions to keep one's clothes from falling off, hence to keep one warm? Well, suppose you didn't have shoulders, what then? --Exactly! What would you have then? Does religion have "vital current utility"? Suppose that people were not disposed to be religious, what then? These questions have no determinate answers in principle. It is not just that the answers are hard to discover. The notion that a trait can increase the fitness of an animal makes sense only in the context of natural selection where there are determinate traits that are selected against. Then there are determinate traits for the selected trait to be more fit than.

Cummins biofunctions must be abstracted then, not by using counterfactuals, but merely by reference to chains of causes and effects that culminate in reproduction and are common to historical members of the species.[17] Leave aside the question to what proportion of members of the species these causal chains should be common, but let paradigm Cummins biofunctions be performed in nearly all reproducing members of a species.

'9.2 The Second Leak

Suppose that nearly all kittens exhibit the same sort of playing behaviors -- say, they all chase their tails. Or suppose that nearly all 15 month babies tumble down and then pick themselves up again and again before moving on to a more equalibrious

[17] Some philosophers believe that causality must be understood in terms of counterfactuals. This turns things upside down in my opinion.

stage. Or suppose that all human hearts make thumping noises that occasionally are listened to by their owners at night, causing a few minutes delay in falling to sleep. Each of these processes takes place on the way to reproduction. Each is a part of the mammothly complex causal process that culminates in reproduction. Leave reference to any of these happenings out in the case of an individual animal and the result is a gap in the full explanation of the path by which the individual arrives at reproduction. Keeping in mind that there is no determinate answer to the question what would have happened in individual cases had one of these processes not occurred, which ones should be mentioned in giving a Cummins-style functional analysis of the propensity to survive and reproduce? How do we determine which processes are merely byproducts and byways and which are functional parts of the Cummins biosystem? Which loops, which physiological or behavioral detours can be ignored in a Cummins-style analysis? Which are mere "spandrels," accidental side effects, superfluous aspects, perhaps even detracting inefficiencies, in a perhaps far from ideal biological system?

Perhaps a sensible answer begins this way. We view the system exactly as Cummins suggested, as exemplifying something like a flow chart or circuit diagram or computer program. This involves "modularizing" the self-sustaining and reproducing system in terms of a series of prior capacities, and modularizing many of these capacities into still prior capacities, and so forth, where the output of each subcapacity serves as input to one or more other functional modules, under stated conditions. This kind of analysis may proceed and be fully explanatory while ignoring much of the detail of actual causal chains produced within or beyond average organisms. It may ignore, for example, most of the noises produced inside and outside, most odors exuded, all those effects on the environment that do not feed back in systematic ways, in accordance with a uniform explanation so as to become input to the functioning modules. All that seems easy and obvious enough. Perhaps all we need to ask then is how regularly such a causal chain should be exemplified to be considered part of a Cummins system rather than a serendipitous occurrence, and then answer, as before, by an appeal to paradigms and a tolerance for vagueness.

'9.3 The Third Leak

Many of the normal conditions and inputs for operation of particular modules of a Cummins biosystem are regularly provided by the system itself. Thus the circulating blood supplies oxygen and nutrients as input to the various organs of the body, while other body systems keep these organs at a normal temperature. Other inputs and conditions normal for the system are regularly donated by the environment -- "regularly donated" in the sense that they are donated wherever individuals of the species manage to survive. Thus the oxygen in the air, and its normal pressure without which most animals would collapse or burst. Most wild seeds land on infertile ground, but those that reproduce are, quite regularly, ones that do land on sufficiently fertile ground. Few just-hatched green turtles are lucky enough to find interstices between hungry birds in their first dash for the sea, but those that survive are regularly ones that did accidentally slip through these cracks. Other normal conditions and inputs to biological systems may fall between these extremes. They are supplied by the organism itself but only with the help of the environment. Frequently they are supplied due to certain behaviors of the organism, but only under favorable environmental conditions. The hunting behaviors of most animals are met with favorable conditions (an unwary rabbit, a gazelle in poor condition) that produce edible input to the digestive systems only occasionally. Immune systems are able to control harmful bacteria or viruses they encounter only some of the time. A small running child can negotiate the ground it finds underfoot without tripping and falling only some of the time. Indeed, surely it is true of all kinds of animal behaviors that they merely raise the probability of arriving in favorable circumstances and receiving normal system inputs.

On the other hand, it seems clear enough that biological systems are also often involved <u>accidentally</u> in causing their own situations, whether these turn out to be helpful or harmful. Activities or properties of the system often result in the presence of conditions or inputs that are not produced in accordance <u>with</u> the system. They are not explained merely by a Cummins analysis of the system. If John runs after a wild turkey he is hunting, depending on accidental conditions in his vicinity it may happen that this helps cause him to find a honey tree, or that it helps cause him to fall, breaking a leg. Surely the normal (digestive) input that results from his chasing behavior in the first case is not explained on a Cummins analysis any more that his encounter with unsuitable conditions for remaining upright are in the second. But exactly what criterion distinguishes cases where, as it were, the system serendipitously helps itself to suitable input Cummins-accidentally from cases where it helps itself Cummins-systematically? When the help is not effected by traits or behaviors that have been selected for producing help in this way, this equals, of course, the question how an exaptation should be defined.

Porcupines fall out of trees surprisingly often. About 40 percent of porcupine skeletons show broken or healed bones of a sort probably due to this infirmity. Very likely, however, porcupines are sometimes saved from breaking bones by the springiness of their quills. Is this then a Cummins biofunction of their quills? Because they are especially fond of the bark of pine trees, when porcupines fall it is often onto a bed of pine needles below, and surely this too often saves them from breaking bones. Is preventing bone fractures a Cummins function of the porcupine's especial fondness for pine bark? Given the conditions that obtain in a modern hospital, the sounds that a person's heart makes often contribute to quick diagnosis and medical attention for a life threatening heart ailment, producing helpful inputs to the biological system via needles and pills, respirators and so forth. If these conditions and inputs are not normal inputs for a human Cummins biosystem, exactly why are they not? Compare them, for example, with what parents from all cultures typically supply for human infants. A carefully structured environment and proper input is necessary for the continued functioning of many interesting Cummins systems.

One suggestion, of a kind that should now be familiar, would be to say that in paradigm cases a Cummins function is performed in all or nearly all cases of survival and reproduction, and that as the statistical frequency of performance decreases, the function becomes less and less of a Cummins biofunction, or a less and less important function. Another possibility would be sometimes to relativise Cummins functions to designated populations, places, periods of time and so forth. Then the sounds of the human heart have a function but only in quite modern times and in certain places and only in certain populations, while the sickle cell gene has a function in malaria infested areas. Similarly, the tufted-tail nosemuffs and snowshoe feet of snow leopards in zoos have no Cummins biofunctions. Is it then a function of the human disposition toward religion in certain special environments to result in bibles in breast pockets that stop stray bullets that would otherwise kill soldiers? Is doubt about this justified only because the case happens to lie very far from the central paradigms of Cummins functions?

Notice that on either of these latter treatments of Cummins biofunctions, the baby's disposition to hibernate when dropped into ice water falls about as far from the paradigm for having a Cummins function as does the function just suggested for the disposition to religion. Currently it probably saves a comparable number of lives. On the other hand, there is a whole host of traits that turn out to have rather bizarre yet close to paradigm functions on analyses of this kind. Mice and spiders are regularly saved from damage when they jump or fall down long distances by the fact that they weigh almost nothing. Is their slight weight an exaptation for preventing this damage? (Is the weight of elephants an exaptation for preventing them from climbing trees thus ensuring that they won't fall out?) Tape worms tend to be quite particular about their hosts and are usually adapted to resist being digested in the stomachs only of one species or small range of species. Do the stomach juices of cats then have as Cummins biofunctions digesting dog and rabbit tape worms so as to avoid infestation by them, and the other ways around? Are the poor fur and the scavenger habits of the possum exaptations for preventing humans from hunting them for their pelts or their meat? Is the beauty of butterflies an exaptation to prevent humans from swatting them as they do other insects? Is the size of the moose an exaptation to prevent its being eaten by foxes? Clearly such examples could be multiplied indefinitely.

'9.4 The Fourth Leak

A different kind of example illustrating the openendedness of the notion of a Cummins biofunction concerns protective reactions and healing powers of organisms. Suppose that the porcupine's quills are not regarded as exaptations for cushioning falls.

Or suppose that hibernating when dropped into ice water is not regarded as a Cummins function. Since infants dropped into ice water don't survive if left there long in any event, a corollary might be that ice water is not an allowable surrounding environment for the Cummins biosystem that is a human infant. Similarly, since much or perhaps most of the time animals don't survive bone fractures either, perhaps the sorts of impacts that break bones are not allowable inputs to these Cummins biosystems. And if these inputs are not allowable, another corollary would seem to be that bone-healing mechanisms have no Cummins biofunctions. Since invading bacteria and viruses often kill as well, perhaps the same should be said of the immune systems. And since cold often kills, perhaps human adaptations to withstand relatively extreme cold are not part of the human Cummins biosystem. Indeed, most people have lived in warm climates and never used these adaptations. Perhaps Cummins-style functional explanations of biological systems should treat ice water and other sources of extreme cold, bone-breaking impacts, germs and parasites -- maybe even predators -- as well as respirators, zoo keepers, and antibiotics, merely as irrelevant non-allowable surrounding conditions and inputs. Similarly, as mentioned before, a Cummins-style explanation of how the washing machine gets the clothes clean might well leave out the repair man.

' 10 How to Fix All the Leaks at Once

The notion of a Cummins biofunction seems to be nearly as open-ended as the amorphous notion of explanation itself. Whatever happens --regularly happens, often happens, or sometimes happens-- on the way to eventual reproduction is something the how of which can be explained. A lesson is that anyone using the notion of Cummins functions, or "current uses," or "system functions," or "algorithmic functions," or "causal role functions," or useful "spandrels" (have I missed any?) owes us an explanation of how each of the above four leaks is to be dealt with.

Is my own conclusion that the notion of a Cummins function is pretty useless in biology? Recall once again what Cummins said about functional analyses:

> The explanatory interest of an analytical account is roughly proportional to (I) the extent to which the analyzing capacities are less sophisticated than the analyzed capacities (ii) the extent to which [they] are different in type...(iii) the relative sophistication of the program appealed to, i.e., the relative complexity of the organization of component parts/processes that is attributed to the system. (p. 764)

I think we can add, for traits of biological systems, that interest in discussing them generally depends on how improbable or unique their effects seem to be, and how improbable their functional design seems to be. That is, our interest turns on exactly the same characteristics of traits that suggest that these traits are adaptations. Whether we see the hibernation of iced babies as corresponding to an interesting Cummins function will depend, for example, on whether we suspect that it is merely an expected side effect of the mechanisms by which the metabolic systems of babies usually function, or whether there are interesting quirks and additions to these systems that produce the effect. Roughly speaking, the interesting Cummins functions associated with the mechanisms and traits of an organism will be exactly the same as the proper functions. The difference is, in the first instance, only one of emphasis. Cummins emphasized the project of finding out how the biological system works, not just finding out what it does. But, of course, finding out what it does in detail, what all its proper functions are and all the proper functions of all its parts, IS finding out how it works.

That is true as a first approximation at least. There is, however, a very interesting kind of exception to this rule. There is one kind of Cummins function that is quite neatly delimited, cleanly definable by reference to proper functions, but that does not itself correspond to a proper function. I propose that the term "exaptation," which we have found to be disastrously undisciplined in current usage, should be co-opted and used for this kind of function.

'11 A Notion of Exaptation That Might Actually Do Some Work

An adaptation is always an adaptation to or within a certain environment. Fully to explain how an adapted trait works necessarily involves reference to its interaction with its environment. Adapted traits typically have co-opted certain aspects of their environments for use. And typically the most important factor in the environment of an evolved trait is the rest of the surrounding organism. Many traits, of course, have co-evolved, each adapting to the other. But other times, one trait helps effect another's proper function merely by serving as a needed aspect of the environment in which the other has evolved. Traits already present in an organism for quite different reasons are co-opted for use along with newly fashioned traits to serve new functions. Thus they end up helping to serve functions that are proper functions, but that are not their own proper functions. And of course they must be mentioned in giving a Cummins analysis of how the new proper functions that they now help to serve are effected.

It is traits that are co-opted in this way that form the only clearly defined category of exaptations. Beyond this category, I think one should be very careful in handling the notion of exaptation, for, resting as it does on the leaky notion of a Cummins function, it easily becomes harmfully undisciplined. When understood in this way, however, it still covers all of the interesting classic examples.

Darwin's famous example, taken from Paley, was the sutures in the skulls of human fetuses that make parturition easier. These sutures exist even in reptiles and birds that only need to break out of an egg, and probably result from deep mechanisms of ontogenesis, having been merely exapted during evolution of the birth process for humans. These sutures have to be mentioned in a full Cummins analysis of the human reproductive process, but in this context they have only Cummins functions, not proper functions. Other classical likely examples of exaptations are the color of blood which makes blushing possible (assuming that blushing has a proper function), the weight of the flying fish which returns it to water, and the front flippers of sea turtles, designed for swimming but used for digging holes during egg laying (Lewontin 1978). Easy additions to this list are the sea otter's fat tummy which it uses for a dinner table at sea and the warm part under the wing where a bird instinctively tucks his beak to keep it warm.

There are many birds that literally "feather their nests" in order to keep their young warm, using down plucked from their own breasts. Likely these species of birds grow breast feathers more abundantly because of this. But if so, it is likely that the selection pressures producing this effect impinge through the birds' original need to keep their own bodies warm, rather than impinging directly on the survival of the young. Then even if the abundant growth of breast feathers has resulted from their use to line the nest, keeping the bird warm is the only proper function of the abundant growth. This is a different variation on the theme that traits designed for another purpose (or no purpose) may be co-opted to serve new proper functions. The abundant growth is reasonably considered an exaptation for keeping the babies warm.[18]

On the other hand, there are items that have been cited in the literature as exaptations that this way of handling exaptations does not admit. Griffiths (1993) wishes to admit the snail shell that the hermit crab (soldier crab) carries on it 's back as

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[18] In White Queen Psychology Chapter 2 I suggested considering exaptations of these kinds to have "proper functions." I now think that would be a mistake, that it would confuse together issues that should be kept distinct. On this, see (Preston 1998; Millikan 1999).

having the function of protecting the crab. Since the systems that are hermit crabs don't participate in the reproduction of snail shells, this would be analogous to admitting the eggs that you eat as having the function of nourishing you (Dennett 1998) or admitting the atmosphere as having the function of helping you breathe. Yes, of course one could consider the egg as part of the human Cummins system and also the hen that makes the egg, and one could consider the oxygen as part of the human Cummins system --and also the sun that helps photosynthesis hence the production of oxygen, and so forth. But a more reasonable place to draw a line around a Cummins biosystem excludes factors that are not reproduced by the organism. Probably nonreproduced factors are better considered just normal supporting conditions or normal input to the biological system.

On this way of handling exaptations, it is also possible by appeal to the descriptive generality requirement, and the notions of relational, adapted and derived functions, to excuse noses from being exaptations for supporting eyeglasses, to excuse shoulders from being exaptations for holding up clothes, and so forth. If we adhere to the descriptive generality requirement, our functional explanations of complex relational capacities will be relational too. For example, we will explain the sea otter's food-procuring propensities not by reference to, in one case a crab stimulus, in another an abalone stimulus, but by reference to encounter again with that-which-its-mother-has-taught-it-to-eat. Similarly, noses and shoulders will figure in biological Cummins-functional explanations of how humans sometimes equip themselves against bad eyesight and cold, not under the descriptions "nose" and "shoulders," but under highly relational descriptions, indeed, perhaps under the same description. The relevant relational descriptions of my nose and my shoulders will treat them abstractly as being just the same, for purposes of biological explanation, as any other objects in the world that I have learned by imitation, or trial and error, or by figuring it out, how to employ toward some purpose I have acquired from experience, in a way normal for humans. The principles involved here are highly abstract and general, certainly not peculiar to noses and shoulders.

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