PUTTING EXAPTATIONS IN THEIR PROPER PLACE

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A suggestion about Exaptations

Currently popular notion of an "exaptation" (Gould and Vrba 1982, Gould 1991). Gould & Lewontin, "Spandrels of San Marco," Fodor, Chomsky.

Gould (p. 46) says that"Exaptations" are 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*).**" **For "other purposes" means selected for.**

Unfortunately, many of his examples are offered without an argument that they have any kind of functions at all. Thus he gives no argument that *music* or *religion* or *consciousness*, granting they may well 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 many changes have been made since and 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, there are two less obvious features of his claim that seem to me dubious and I would like to discuss.

(1) What is meant by saying that exaptations are structures "evolved in other contexts for other purposes," that is, how do we determine sameness of function; what counts as "the same" function?

(2) How do we define capacities having "current vital utility"?

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 function of these thickened skins is, more narrowly, protection against heat or, more broadly, insulation? Sober opts for insulation, and surely this choice is the only defensible one. The general principle involved is prevention of heat exchange, so that the thickened skin not only serves the same purpose, in both overheated and overcooled environments, namely, keeping the fly at a uniform temperature, it performs this function in accordance with the same explanation. Similarly, it is a proper function of our semicircular canals to help keep us upright in a gravitational field, not just at one G. Moon walkers don't employ their semicircular canals for functions they weren't designed for. Nor do we employ our digestive systems for functions they weren't designed for when we eat newly hybridized fruits, or even Fritos and Coke. Similarly, a proper function of my heart is, indeed, 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. Adaptations, I suggest, should always be described according to the most general principles available. I call this "the descriptive generality requirement."

A paradigm for the application of this principle is the case of "relational" and "adapted" proper functions [explain "proper functions"]—these are the kind of functions that the behaviors of organisms typically have. But let me begin with an illustration by considering an adding machine. Still easier, a Xerox machine. Does it do the same thing every time?

The 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. That is how the descriptive generality constraint would require that its basic function be described. Suppose 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, functions given the current situation. 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.[1] 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 and is designed to vary 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 strategy. Then the functions of these parts must also be described relationally.

Having relational proper functions is typical of the behaviors of organisms. These functions, in higher species, are controlled mostly by the perceptual andcognitive systems, and 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 (nest building, beaver dam building), some involve changing the organism to fit the environment (chameleons, ermine—and learning!), some involve changing merely relations between organism and environment (locomotion, food ingestion), 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.

Look at learning in this connection. Consider any mechanism that has as its function to produce learning on the basis of experience. Take a mechanism designed to effect trial and error learning, or learning by imprinting, or learning by imitation, or learning (discovering) by reasoning something out given premises derived from experience. Such a mechanism has a relational proper function or functions. It is designed to turn out behaviors (or, say, mental states such as beliefs or desires) as a certain function of certain designated kinds of input from experience. The sea otter, for example, learns what to eat from its mother, and is probably designed to learn that, quite specifically. Probably a combination of different mechanisms helps to effect this learning, but a relational proper 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] proper 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] proper function to produce sea-urchin collecting and eating. Other baby otters whose mothers eat abalones acquire complex states whose [derived] proper function is to effect abalone collecting and eating.

The function of mechanisms in rats to produce avoidance of whatever made them or their friends nauseous.

Generalizing from this, there can also be relational proper functions that produce adapted devices themselves having relational proper functions (for example, the functions involved in effecting empirical concept formation) producing more adapted devices having further relational proper 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 functions that are merely adaptations. [Thus we must apply the descriptive generality requirement.] What looks new may be very old—depends on the description.

Gould claims, "Surely exaptations of the brain must greatly exceed adaptations by orders of magnitude" and he says, "..just 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, they all can, indeed, in accordance with the descriptive generality requirement, they <u>must</u> be so rendered. 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 are all adaptations under very general, highly relational descriptions Reading, writing, and doing arithmetic are [like turning green and turning brown—*explain*], or like collecting and eating sea urchins. They are applied <u>facultative</u> adaptations.

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 what the sea otter does when it encounters again that-which-its-mother-has-taught-it-to-eat. Similarly, noses [Rousseau and Dr Pangloss] will figure in biological explanations of how humans sometimes equip themselves against bad eyesight and cold, not under the description "nose" but under a highly relational description. The relevant relational description of my nose will treat it 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.

(2) How do we define "having current vital utility"?

Or, as these are referred to by other authors, having "current uses" (e.g., Gould 1991), having "system functions" (Preston 1998), having "algorithmic functions" (Rowlands 1997), having "causal Role functions" (e.g., Amundson and Lauder 1994) or being useful "spandrels" (Gould and Lewontin 1979).

Preston explicitly equates her "system functions" with functions in the life system of the animal of the sort Cummins described in his classic piece "functional analysis," and something like that does seem to be the only option available. 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 explaining. 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. [Automobile, physiology, the rain cycle: How can the water keep flowing and flowing and never run out?]

The difficulty that must be faced by those wishing to use Cummins' notion of function in biology, however, is to define, in an objective nonarbitrary way, the <u>limits</u> of the biological system represented by a biological species. What is part of "the life system of the organism? Let me explain.

In describing the general form that functional analyses take, Cummins mentions flow charts, circuit diagrams and computer programs. But of course representations of this kind generally specify <u>ideal</u> rather than actual systems. The circuit diagram that comes with your washing machine represents how it was <u>designed</u> or <u>intended</u> to function not necessarily how it <u>does</u> function. Moreover, it was designed to function that way not unconditionally, but given quite specific background conditions and quite specific inputs. For

example, it is 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 is 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 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 be assumed before a Cummins-style analysis can be given of any system. A Cummins system is analyzed as having a certain set of determinate <u>dispositions</u> of the whole and of the parts, but these dispositions will be determinate only in so far as limits on background conditions and inputs to the system are determinate.

The way your washing machine was "designed" or "intended" to function has its parallel, of course, in the selectionist pressures determining which are the adaptations of a species, but clearly the friend of "exaptations" cannot make use of this, but must limit "proper operation" of the system, "appropriate input" and "appropriate background conditions of operation" in some other way. For no chunk of matter, such as a washing machine or an elephant, <u>determines</u> a Cummins system when considered just as such. Given a modern washer, for example, 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. 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.

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. They don't come with instructions telling which changes to count as state changes within the system and which instead as damage, breakdowns or weardowns. They don't 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. I will try to illustrate these points.

A first and obvious step toward making necessary parameters determinate by reference to the way various actual members of the species under analysis have actually functioned. But which actual members? You can't just say they must be "normal" or "healthy" or "undamaged" members, for it is exactly these notions have not been defined. But we might begin with members that have actually maintained themselves and reproduced, and then look for commonalities among the actual historical processes that achieved those results. For many species, survival and reproduction may be achieved by only one in hundreds or thousands, so this may limit what are to be considered normal conditions and normal input to the biological system quite severely. —not, however, severely enough.

Here are some examples to illustrate the difficulties. There are at least four kinds of difficulties, each of which I will have time only to touch on. Then I will make a positive suggestion about how we might delimit the notion of an exaptation so that it has some definition.

Leak #1: Our problem is to decide which traits not tailored by natural

selection should be considered, as Gould puts it, to "have vital utility." Consider, for example, 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. Perhaps we should say then that if a trait increases fitness then the mechanism or process by which it does so part of the biological Cummins system. 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 <u>we</u> had in mind was the squirrel running in a straight line. But perfect obviousness to <u>us</u> that this is what <u>we</u> 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 <u>like</u> 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 <u>would</u> you have then? 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 for a selected trait to be <u>more</u>

fit than.

Leak #2: 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 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. If you leave reference to any of these happenings out in the case of an individual animal, the result will be a gap in the full explanation of the path by which the individual arrives at reproduction. Keep 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 accidents and 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?

The Third Leak: Many of the normal conditions and inputs for operation of particular modules of a biological system 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. These various conditions must be consistently supplied or the organism dies.
Other normal conditions and inputs to biological systems are irregularly supplied, often by the organism itself with the help of the environment. 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. 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. Contrast the washing machine where each regular input and part of the cycle is either regularly supplied or the system breaks down. The stochastic nature of the behavioral systems. They work only some of the time and have multiple backups. This happens in accordance with design.

On the other hand, it seems clear enough that biological systems are also often involved accidentally in causing their own situations, regardless of whether these turn out to be helpful or harmful. Activities or properties of the system often result in the presence of advantageous conditions or inputs that have not been produced in accordance with the design of the system. Which of these should be considered part of a Cummins system, part of "vital utility"? If John runs after a wild turkey he is hunting, depending on accidental conditions in his vicinity on the one hand it may happen that this helps cause him to find a honey tree. On the other hand it may help cause him to fall, breaking a leg. Surely the normal (digestive) input that results from his chasing behavior in the first case is not a result of good design any more than his encounter with unsuitable conditions for remaining upright are in the second. How will we draw the line between what happens in accordance with the system and what happens outside it or accidental to it in the case of a the Cummins system? What criterion will distinguish 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.

Here is an example. 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 biological Cummins function of their quills? One of their "current vital utilities"? 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 system, 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 biological systems.

One suggestion might be to consider statistical frequency of performance of a certain function. As the statistical frequency of performance decreases we will just say that the function becomes less and less important. Or we might relativise 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 biological Cummins functions.

The trouble is that on this analysis, there may be a whole host of traits with bizarre yet close-to-paradigm functions. 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? 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? "Current vital utility"?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? Clearly such examples could be multiplied indefinitely.

Leak #4: Still another kind of example concerns protective reactions and healing powers of organisms. Human infants, when dropped into ice water hold their breath and go instantly into hibernation. But since babies don't generally survive ice water very long anyhow, rather than say that this behavior has the Cummins function of saving the baby, we might just say that ice water is not a normal surrounding environment for the biological system 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 normal inputs to biological systems. Then we won't have to regard the porcupine's quills as exaptations for cushioning falls. But if falls are not normal inputs to the porcupines system, then the porcupine's bone-healing mechanisms have no biological Cummins functions, no current vital utility. And since invading bacteria and viruses often kill as well, perhaps the same should be said of the immune systems. No current vital utility. After all, a Cummins-style explanation of how the washing machine gets the clothes clean leaves out the repair man. 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 abnormal conditions and inputs.

The notion of a Cummins biofunction is 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 sensible way to understand "exaptations"?

But Cummins himself said about functional analyses:

> "the explanatory interest of an analytical account [depends in part] on 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 them often depends on how improbable or unique their effects seem to be, and how improbable their functional design seems to be. How well suited to performing a certain function. And those are exactly the characteristics that suggest that these traits are adaptations. Whether we see the hibernation of iced babies as corresponding to an interesting Cummins function —whether we find it interesting to explain it mechanism— may depend, for example, on whether we suspect that it is merely an expected side effect of the mechanisms by which their metabolic systems usually function, or whether there are special quirks and additions that produce the effect. But although it is primarily the operation of adaptations that we want to explain with Cummins analyses, these very explanations may sometimes refer to prior traits and processes that weren't themselves designed to contribute to these functions but instead to other functions.

Consider: an adaptation is always an adaptation to or within a certain environment, the most important factor in the environment often being, exactly, the rest of the surrounding organism. Lots of traits have co-evolved, each adapting to the other. But other times, one trait serves merely as the environment in which another evolves. Traits already present in an organism for quite different reasons are coopted for use along with newly fashioned traits to serve new functions. Thus they end up helping to serve functions that are proper functions, but these functions are not their own proper functions. A Cummins analysis of how the new functions are served will have to mention the new contributions of the old traits.

It is traits that are coopted in this way that form the most clearly defined category of exaptations. Beyond this category, I think one should be very careful in handling the notion of exaptation, for it can easily become harmfully undisciplined. When understood in this way, it covers all of the most 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 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 [or between the wings] 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 coopted to serve new proper functions. The abundant growth is reasonably considered an exaptation for keeping the babies warm.[2]

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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 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.

1 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.

2 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).