Functionalism and multirealizability : on interaction between structure and function*

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Functionalism plays a crucial role in psychology in allowing to give a precise and hopefully operational definition of a *mental state*. The main idea of functionalism as the term is employed in psychology is derived from a causal analysis of mental states : the concept of a mental state "involves essentially the idée of a state being able to cause certain effects or to be the effect of certain causes et reduces to it" (Armstrong, 1981). What mental states causally determine are behaviors. For example, the desire to read leads one to buy a book, or to go to the library, or more plainly to take a book from the shelf at home and open it.There are two species of causes contributing to a shape a mental state ; the ones are the objects and events present in the environment, perceived consciously or not and shaping the behavior of the subject. The others are the other mental states which induce in interaction with each other the mental state considered. For example, the desire to read may be in part due to the sight of a book, the memory of a particular work to do, by the belief in the relevance of that book for that work, and so on.

It is a fundamental characteristic of functionalist approach that it invokes a causal network. It should be clear that the conditions present in the environment only belong to the causal network because they affect internal states which carry information about them. The mental states are supposed to play the role they do because they carry a certain content (about the perceived objects and events) and express a certain attitude towards that content (for example, the belief that this book is useful, or the desire to get a good grade). The main idea of functionalism is that what distinguishes a particular mental state is its sole in the psychological dynamics, a role which can be derived from the total set of its relations with the other states of the system, i.e. the input states, the output states, and the rest of the internal states. For example, being in the mental state “X wants to read” is not essentially to have a particular sensation, a qualitately specifiable experience. “Reduced to the essential, as Armstrong wold put it, this state can be defined by the set of its causal relations to inputs (I1..In), outputs (O1.. On) and other states, such a beliefs (B1.. Bn) and desires (D1.. Dn). In other, more technical words, the mental state is a theoretical term which can be explained out by its Ramsey correlate inside an ideally complete psychological theory.

Ramsey suggested in 1931 to reduce the theoretical terms of a formalized theory in an existentially quantified proposition contained only observational terms. Such a Ramsey Formula is constructed by replacing every token of a theoretical term by a variable (either of class or of relation), then by quantifying on this kind of functions in order to express the fact that there exists an entity, a class or a relation, such that it has all the properties descrived by the criteria. Once all the theoretical terms are translated in their observational correlates, only the observational basis is left, that is, in the present case, only inputs and outputs, plus a formal structure satisfying the conditions present in experience.

One might here object that the mental states I gave above as examples - such as the desire to read - are not the nodes of the relevant causal network. One should here be more careful to avoid begging the question of what the *explicandum* is, by only claiming that a mental state is any internal state in an information processing sequence causally involved in some behavior of the organism under consideration. One ordinarily distinguishes in this respect “functionalism” - i.e. the doctrin according to which functional Ramsey correlates specify mental states as defined by folk psychology - from “psychofunctionalism” which views them as theoretical terms of a scientific psychological theory.[1]

Initially, functionalism for mental states was defended by a specific brand of materialists about the mind, such as Lewis and Armstrong. For these “type-physicalists”, mental states defined by their causal roles are just identical with the cerebral states on which they supervene.[2] For example, Lewis (1972) defends a view in which a functional characterization should turn out carving up nature at the same joints as a physiological characterization :

> Mental state M = the occupant of causal role R (by definition of M).[3]
> Neural state N = the occupant of causal role R (by the physiological theory).
> Therefore mental state M = neural state N (by transitivity of =).

Since the early sixties on, the type-physicalist type of approach has been under heavy attack from functionalists such as Putnam (1960) and Fodor (1968). The central argument consists in taking seriously the claim that, reduced to the essential, mental states are those states which play a causal role in a behavior given an input and other internal states : why then should we restrict to neurophysiological systems those which are able to subserve those causal roles ? Why for example should a system have C-fibers to be able to have pain ? [4] Since an organism can be seen as a Turing Machine, or more exactly as a probabilistic automaton, it is possible to see the Machine Table as the functional organization of that system under a certain description. As Putnam emphasizes, "knowing the Total state of a system relative to a description (..) does *not* involve knowing the physical realization of the S_i as, e.g., physical-chemical states of the brain. The S_i (..) are specified only *implicitly* by the Description - i.e. specified *only* by the set of transition probabilities given in the Machine Table" (1967) *in* Block (1980, p. 226-7)

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My aim here will be to show that there is some distance between the conceptual possibility that psychological predicates could apply to artifacts and the theoretically grounded possibility of applying an anti-chauvinistic strategy. To show it, I will draw freely on Dennett's "homuncular functionalism" (Dennett, 1978). Such a functionalism, inspired by work done in Artificial Intelligence, is explicitly "top-down", insofar as it starts with a problem stated in intentional terms [5], which is further decomposed into sub-problems which are still intentionally characterized, until the point is reached where the required operations are so elementary that they can be performed by stupid agents, only able to discriminate a 0 from a 1.

This strategy of optimized functional analysis may be extended from A.I. to a variey of situations in which are involved human beings as well as animals, artifacts or plants. The question here is not whether the considered entities do in fact have mental states - but whether it is more economical to deal with them as if they had, rather than treat them as being organized at some lower level, for example at the design or at the physical levels. Two reasons may account for the economy which results from adopting the intentional stance. From the point of view of the user or of the interpreter, it is clear that he is at home with intentional idiom, for it is in this idiom that he naturally constructs representations of himself and others, and sometimes of Nature or Deity as well.From the point of view of what is being interpreted, the interpretation may also be easy and at hand, given that many systems can be described as an optimized functional system. So many, by the way, that the question arises as to what could *fail* to be so describable, if no constraints are put on the ways of defining inputs, outputs and internal states.

Such a nice match between the needs of the interpreter and the capacity of the interpretee to yield to them does not warrant us in taking that the postulated intentional states do indeed have a causal role, and that homuncular functionalism did “carve Nature at its joints”. In other words, the interpretive stance corresponds to a predictive strategy which does not have to be grounded on any substantive truth. It can be useful to say that a computer “understood” a question, or that a paramecia “tries to avoid acid water” without being committed to saying that it is the computer’s understanding, or the paramecia’s desire, which cause the corresponding behaviors. Although I do not share Dennett’s radical conclusions against realism which he draws from his view on the intentional stance, I agree that what he does show is that the simple conceptual possibility of applying a functional characterisation to the behavior of an organism does not suffice to show that the functional states so specified do indeed play a causal rolein that behavior, and I do not see how a functional role could indeed be shown to be causal without some specific physical implementation being involved as the relevant causal structure. The conceptual possibility of antichauvinism can be explained by the tendency of psychofunctional systems to export their own features to understand their own world. This by itself does not constitute a case against type-physicalism.

A second argument for multirealizability is derived from Lashley's views on neurological equipotentiality, according to which widely different brain structures can subserve a given psychological function.

> While the generality of this doctrine may be disputed, it does seem clear that the central nervous system is highly labile and that a given type of psychological process is in fact often associated with a variety of distinct neurological structures. (..) Physicalism, as we have been construing it, requires that organisms are in type-identical psychological states if and only if they are in type-identical physical states. Hence equipotentiality (if true) provides evidence against physicalism. (Block & Fodor, 1972, in Block, 1980, p. 238).

In his 1929 book, Lashley did question the causal relevance of local properties for neural activity. XXXX Lashley contends rather that it is the quantity of cortical substance, and *not* its particular anatomical location, which explains causally the ability of the organism to learn. Equipotentiality thus refers to the capacity for any brain area to control any particular behavior. It depends in turn on another property of cortical substance called plasticity, i.e. the capacity for certain neurons in a definite anatomic zone of the brain to take up functions previously fulfilled by neurons of another zone once the latter is damaged.

As a result of the doctrine of equipotentiality, physicalist reductionism seems to suffer a serious blow, insofar as it is seen as positing that particular, locally identificable neurons are ultimately responsible for information processing tasks and behavior control. But this very claim of the antiphysicalist stance may well in turn be questioned. It does not seem true that physical explanations have to give local explanations for any types of physical events to be hold explanations in due form. It may even not be true that causality itself operates at a single level of physical reality, e.g. at the quantum level, or whatever reduction basis one may chose. My point here is that the case for multirealizability has to provide such a reduction basis ; it has the onus of proof of showing why such a basis provides all that is necessary for physical science to couch its empirical regularities and its dependency relationships. Only once this is shown, should it be in a position to show that no such reduction basis is available in neurophysiological terms for stating regularities and dependency relationships between psychological states and processes.

My own strategy against Lashley-inspired anti-type-physicalism consists in offering some arguments against the generality of the Lashleyan doctrine as well as some evidence tending to speak in favor of a multiplicity of causally relevant levels in brain structure. Thus my point is *not* to prove that type-physicalism is right, but that it is quite plausible given the present state of knowledge in neurophysiology.

Let us remark first that several decades of research having elapsed since Lashley's work in the early thirties, we are now in a better position to tell whether a certain psychological function has to be subserved by a certain definite well-localized brain subsystem. D. Hubel and T. Wiesel's works have shown that there are indeed cases of ultra-specialization of brain structures, and that a failure to exercise these structures at sensitive times of development is followed by a loss of the corresponding function. The first kind of findings shows that specific cortex cells may be uniquely sensitive to specific types of information from the environment, such as orientation or luminance. The second kind shows the role of epigenesis in developing specialized structures. A cat whose visual arrays from birth on include horizontal, but no vertical lines will have an atrophy on verticality neurons. Epigenesis definitely lacks plasticity.

Antiphysicalists will retort that although developmental facts make plasticity difficult in virtue of the failure of a particular function to be learned, well-established psychological functions do display it.

Plasticity of implementation would then be viewed as a property of the mature mental functions. But of course, there is no general rule on plasticity in adult psychological functions as well. If some neuropsychological data show that patients are able to recuperate a psychological function some time after brain damage, others show no such welcome evolution. Contemporary connectionist models have a story for why a system may be robust to damage, without involving any strong commitment to multirealizability. The causally relevant brain structure is the neural network, a physical entity able in certain conditions to restore its own integrity through certain causally specifiable mechanisms. We will see in a moment that no change in the physical implementation has to be hypothesized to understand that capacity, and even that such a change would make causality in recuperation processes fully obscure. For the moment, it is enough to conclude that Lashley's intuition about the equipotentiality of brain structures is disconfirmed on a number of cases, and thus lacks the generality which its role in a case for multirealizability would require.

The second kind of rejoinder to Lashley's doctrine consists in questioning the identification of the appropriate level for a physical causal explanation as being a local one. [6] In the standard version of the argument, it is claimed that no single *neuron*, defined by its anatomical location, has to be firing for a particular psychological function to be subserved. Two arguments may release some of the appeal of such an intuition. First, it seems fully compatible with physicalism - in virtue of which a mental state should be analyzed in neurophysiological terms generalizable to mental states of the same type- that the neurophysiological facts relevant to various psychological functions may belong to different levels of organization. This way of introducing different levels of causation does not pose any particular problem when one attempts to reduce geology to physics, for example. Today, neurophysiologists such as Changeux (Changeux, 1992) or Edelman (Edelman, 1989) take up Hebb's idea that several levels of organization account for different types of mental processes. Whereas low-order functions can be subserved by neural circuits, i.e. small sets of neurons, larger *neural assemblies* subserve higher cognitive functions. The latters involve disparate neural groupings, which explains in part their resilience to lesion -

although a finer analysis would show at what level of performance the function is maintained. (ici note)

It is commonly assumed, in statistical mechanics, that a physical explanation of a phenomenon does not involve more than a probabilistic characterization of the causally relevant constituants. Analogously, it appears that the very notion of a level of organization undermines an analysis of psychologically relevant neurophysiological properties in terms of single neurons. What it favours rather is a hierarchical functional analysis in which larger structures supervene on lower substructures.

A second objection against the "local neuron" argument is suggested by the recent findings concerning the *temporal* properties of some of the psychologically relevant properties of neurophysiological states. Many researchers, such as A. Damasio, F. Crick and C. Koch or R. Llinas have insisted that coherent synchronous or semi-synchronous oscillations in neurons cooperation : the binding of activation seems to play a major role in the synthesis of aperception, as well as the establishment of circuits in the course of development. [7] If the properties of oscillations and neural rythmicity - modulated among other things by ionic mechanisms - partly determine cerebral connectivity, it is clear that one cannot expect to grasp fully the implementation of a particular function by looking only at anatomic regularities. It may not be the particular firing of a neuron or of a group of neurons which may be accomplishing that function, but rather some dynamical fact in virtue of which several neuronal circuits resonate in their on-going activation.

To conclude this first point against multirealizability, the Lashleyan line cannot warrant us in rejecting globally any search for neurophysiological regularities constitutive of mental state types. Pointing to a functional determination of neurons on the basis of intrinsinc (selfrythmic) and relational (oscillatory pairing) properties may help revealing neurophysiological invariants for psychological functions at relevant levels of organization.

A second argument offered by Block & Fodor in favour of multirealizability dwells on the existence of Darwinian convergences "applying to the phylogeny of psychology as well as to the phylogeny of morphology and of behavior" (in Block, 1980, p. 238). Convergence theory asserts that very different physiological structures, when submitted to similar pressures in similar ecological conditions, produce in phylogenetic evolution homologous morphological or behavioral configurations. What holds for anatomical or ethological resemblances seems also likely to hold for psychological resemblances :

> Psychological similarities across species may often reflect convergent environmental selection rather than underlying physiological similarities. For example, we have no particular reason to suppose that the physiology of pain in man must have much in common with the physiology of pain in phylogenetically remote species. But if there are organisms whose psychology is homologous to our own but whose physiology is quite different, such organisms may provide counterexamples to the psychophysical correlations physicalism requires. (Block & Fodor, 1972, in Block 1980, p. 238).

One could reformulate Block & Fodor's line of reasoning using Dingwall's distinction betwen two ways in which a functional resemblance can be the case. [8] Similar psychological states and processes in different species are said to bo *homologous* when their resemblances can be attributed to a common phylogenetic origin. They are said *analogous* when their resemblances are due to the pressures of environmental factors common to both species. What Block & Fodor maintain is that there may be across species psychological analogies as well as homologies, which therefore do not presuppose any common organic characteristic, holding as they do between widely different types of animals.

This argument presents an interesting difficulty which is sometimes seen as constituting the hard core of the motivation for functionalism : on what intuition exactly does one rely when invoking a "psychological resemblance across species" ? When one leaves the ground of neurophysiology, it seems that we lose useful criteria of what it can mean to say, e.g., that "such and such an organism feels pain". In which conditions will we be warranted to say that, for example, a species phylogenetically distant from *Homo Sapiens* feels pain or believes that the weather is hot ? If we follow the lead of homology, we may have some ground for saying that related nervous systems have related experiences and related networks of beliefs, desires, and plans for action. But the analogical lead will offer far less obvious clues. In a famous paper, David lewis (1980) examined the symmetrical cases of a mad pain and of a Martian pain. In the first case, a human subject feels the same qualitative experience as the other men in pain, with the nervous system typical for humans, but has deviant causal relations between pain inputs, outputs and other relevant mental states. For example, pain makes in his case concentration easier, invites him to do maths, etc. In the Martian case on the other hand, the non-human subject in pain has the same functional relations between mental states which defines pain for us, but these relations supervene on completely different structures. This example allows us to interpret what distinguishes homological from analogical psychological resemblances. Homological resemblance presupposes a common physiological structure, which make plausible the hypothesis of a similarity across species of perceptive experience, functional contingencies and bodily outputs. Although "mad pain" is not logically impossible, it is a worth to notice that the case has never been observed. The identity-theorist takes this fact for confirming that a functionally defined mental state is identical to a neurophysiologically defined cerebral state. It may be the case that another species could well have developed, in different circumstances, different functional contingencies. But evolution theory and biology are sciences have as their objects real, and not possible living organisms.

But when it comes to analogical similarity, we are at a loss when context can be varied at will. Our intuitions stay rather firm when functional characterisation for a state is unchanged, as in the case of Martian pain. But what of the analogy when *both* function and physiological realization are varied ? If pain, for example, is only *contingently* associated with a particular causal role and a physical implementation, homological similarity and analogical similarity should lead to constructing disjunctive classes of pain events.

It is obvious that evolution theory is called for at this point to warrant the functionalist point of view, by supposing that analogous *organic needs* - finding food, fleeing predators, mating - will tend to be competitively satisfied in similar *contexts*. These two constraints seem to maintain functional variation within a tolerably narrow range. Insofar as species have to perpetuate themselves in biologically similar and ecologically invariant conditions, i.e. insofar as the pairings input-output are constrained to be similar in important respects, that functional states can be said to be isomorphic even though the physiological states on which they supervene may vary from one species to the next. The question which is now raised is whether the latter variation can be used as an argument in favor of multirealizability. It can be the case only if the question at stake still makes sense in the new theoretical background. I would like to show that it does not.

For one can object here that the very notion of a *function* on which we are presently dwelling has nothing in common with the notion which inspired machine or computational functionalism. As Eliott Sober aptly remarks (Sober, 1990), Turing functionalism deals with the *mathematical* sense of the term, whereas evolution theory interprets it in a *teleological* sense. Whereas one speaks in the first sense of the *additive* function, which establishes pairwise correspondences between two or more numbers and their sum, one speaks in the second sense of the function of heart as being to pump blood. Sober shows that the teleological concept of function offers the means to solve problems concerning the identification of mental states and processes which the mathematical concept of function is unable to solve. For example, Turing functionalism has it that isomorphic systems have the same mental states. Thus even an entity constituted by suitably connected individuals - for example, in Ned Block's example, the entire Chinese people following a preestablished pattern of rules (Block, 1978) - should be recognized as having mental states if it correctly instantiates the set of causal relations which are typical of an individual's psychological processes. Teleological functionalism allows one to reject such an instanciation by relying on the idea of what the normal functioning of an organism, i.e. on the idea of adapted exchange beween the organism and its environment. What makes the Chinese people unsuitable for realizing a psychological functional system is that it is not the normal function of this entity to process the inputs and to plan the adapted actions as outputs which are required for its being isomorphic to another system whose normal function is precisely this.

But how can we distinguish between "normal" functions from simply "attributed" ones ? The notion of teleological function suggests to derive from Block's kind of counterexamples a constraint as to the kind of relationship between the organism and its environment which any functional attribution of mental states should fulfill. Let us call *functional context* the set of input-output pairings mediated by the postulated internal (mental) states. Two systems will only be functionally isomorphic if the inputs and outputs used in the functional characterization are described in a non-arbitrary manner, that is if they are compatible with the regulatory exchanges between the organism and its milieu as stated by a biological theory, at least in a subset of contexts where the functions are normal - or any other theory describing energetic exchanges between the entity and its environment.[9] One can then recognize a system as being *contextually functional* only if the process of information extraction as described by the kinds of inputs present in the functional characterization is such that it could, in certain favorable contexts, allow the organism to plan adequately its action. This precision excludes from being contextually functional entities such as the Chinese people, which are attributed inputs and motor decisions which have nothing to do with the physical equipment nor with the survival/maintenance needs of the given system. The concept of a "functional context" dwells on the idea that a system is teleologically functional only if the kind of information processing which can be attributed to a system corresponds to some intrinsic evolutionary pressure or physical constraint on the mind candidate. In virtue of this constraint, no functional isomorphism without a theoretically warranted functional context.

Given these precisions, we see that the concept of a teleological function is no more coextensive with the concept of a mathematical function. There are many examples of systems isomorphic to a bona fide mental system, i.e. of systems which satisfy the Ramsey formula of the latter's states, but which fail to fulfill the teleological constraint we just indicated.

But the teleological approach which we take as a necessary addition to classical functionalist approaches of the mind raises a secondary problem (cf. Sober (1990)). Is a functional characterization sufficient for identifying *all* psychological states ? In biology, there exists a number of functionally indistinct facts which nevertheless do play a causal role at a certain other abstraction levels. For example, the Java rhinoceros has two horns, wherreas the African one has only one. What does not make any difference in a narrow functional meaning does when the problem is to explain, for example, what kind of wound the horn can afflict to a given target. A difference without a functional value may thus be physically or even biologically significant. It is plausible to think that psychology is in a similar situation : there may be psychological states or processes which are functionally inert, plain "artefacts of functional organization" (Sober, 1990, 104).[10] To conclude from that fact that such states and processes do not have to be included in a psychological theory would undermine their having causal roles at a different level of explanation. On could expect, as is the case with the rhino's horns, that different computational states and processes may have the same functional role ; whereas it may be justified to treat them as equivalent at a certain causal level, it need not be the case at other levels.

This long detour which lead us from functional analogies to the limits of applicability of the very concept of a function puts us in a better position to evaluate the evolutionist argument in favor of multirealizablity. We should appreciate now why the problem of multirealizability of mental states in a psychology applying to man as well as to higher animals or machines is posed in a hopelessly vague way. The evolutionist argument does lead us to acknowledge the existence of psychological analogies, but does also stress the importance of the inner and outer constraints which are causal in thoses analogies. Thus this argument does not allow us to anticipate which species are sufficiently similar to be considered as functionally isomorphic. Take for example the cas case of perception. Insects have distinctive perceptive apparatuses according to whether they operate during the day, at night, or at sunset. Their composed eyes contain several thousands of small retinas, which receive the light rays in apposition, superposition or in a dual mode. It is clear that psychofunctional differences correspond to these neurophysiological ones. Considering first the relationship between inputs and perception, these various insects "do not see the same things" in the same conditions, not only in the sense that they have qualitatively different "images" of the world, but in the sense when some insect will spot a stimulus where another, heterospecific, won't. Second, how about the relations between internal states ? For certain species, like the glow-worm, visual perception plays the essential role in discovering a mate, whereas in very similar others, sound or olfaction are the main informational channels. Are'not we here in a situation close to mad pain instantiated by a Martian : when both functional organization and neurophysiological implementation vary simultaneously, a comparison may still have some interest, *but at a level which is less fine-grained that what mental causality requires*. For that matter, we have to rely on empirical psychology to determine, in which case, what is the type of the relevant inputs, outputs, and other mediating internal states. In this causal perspective, it is difficult not to take functional notions such as desire, pain, or perception, as being relative to a species. [11]

* I thank Pascal Engel, Pierre Jacob, Max Kistler, Elisabeth Pacherie and François Récanati whose remarks helped me to shape the position here defended. Mistakes remain mine.

[1] Cf. for example Block (1978) in Block (1980), p. 272.

[2] It is compatible with functionalism to enroll it within a dualist ontology such as Descartes'. The present work, as well as most of current research, tries to explore the ways in which the mental properties can be accounted for in monist, physicalist terms.

[3] Pierre Jacob noticed here that one usually considers mental state M as identical to causal role R, and not to the occupant of that causal role, because in the case of mental states, causal role specifies a mental state but is not "realized" by it. At the level of physiological characterization, on the other hand, one can consider that a neural state is the occupant of a causal role as specified in functional terms. David Lewis does offer a justification for his formulation in (Lewis, 1983, n. 6), by exploiting the idea

that functional states are relative to a world : in every world, “pain” refers to whatever state which in that world turns out to be the occupant of the causal role defining pain.

[4] The present argument does not address the specific difficulty having to do with the qualitative, subjective aspect of sensations which a functionalist approach is well-known to have trouble answering. See Shoemaker in Block (1980) for a possible solution. Second, this paper will deal with qualia on a par with propositional attitudes, considering that, from a functional point of view, they carry information, interact causally with other states, and determine the organism’s behavior. Even though one can maintain that qualia are “special” insofar as they possess some intrinsic qualitative property which cannot be determined relationally, the same thing seems to hold for propositional attitudes, which also carry “functionally inert” elements, which Frege named “style” or “lighting”.

[5] By an “intentional characterisation”, is meant a characterization referring to contents and propositional attitudes ; for example, the formulae describing machine states are interpreted as the desire to win or the belief that the opponent will move her Queen.

[6] Fodor & Block (1972) allude to this rejoinder without apparently taking it as a serious challenge to the anti-type physicalist strategy : “.. Though linguistic functions are normally represented in the left hemisphere of right-handed persons, insult to the left hemisphere can lead to the establishment of these functions in the *right* hemisphere. (Of course, this point is not *conclusive,* since there may be some relevant neurological properties in common to the structures involved.)” (in Block, 1980, p. 238).

[7] Cf. Damasio [1989], “The brain binds entities and events by multiregional activation from convergence zones”, *Neural Computation*, 1, 123-132 ; Crick F. & Koch C. [1990], “Towards a neurobiological theory of consciousness”, *Seminars in the Neurosciences,* 2, 263-275 ; R. Llinas, [1987], “Mindness as a functional state of the brain”, in *Mindwaves*, ed. par C. Blakemore & S. Greenfield, Oxford, Blackwell.

[8] Dingwall’s distinction is quoted in Tennant (1984), p. 96.

[9] The notion of a functional context can thus be extended to non organic entities, insofar as the inputs and outputs can in the latter case be constrained by possible intrinsic conditions such as energetic or maintenance needs.

[10] Cf. also Gould & Lewontin, (1979).

[11] Kim (1992) draws a similar conclusion from a different line of argument. Taking for granted the principle of causal individuation for natural species, in particular for mental ones, which Fodor (1988) advocates, and the principle of "causal heritage" in virtue of which