Original Paper *Forma*, **14**, 185–198, 1999

On Form, Mind and Matter (with special reference to 'Crystal Souls' by Ernst Haeckel, translated by A. L. Mackay)

Gustav BERNROIDER

Institute of Zoology, University of Salzburg, Austria

(Received August 6, 1999; Accepted October 24, 1999)

1. Introduction

The search for the origin of life and the traditional mind-matter dichotomy have many points of contact, but none is more appealing than the study of 'form' and symmetry. But what has 'form', 'shape' or 'pattern' got to do with 'mind and matter' or 'dead or alive'? These questions come into the centre of attention when we are confronted with *Ernst Haeckel's* drawings and his strangely coined expressions about a continuity from 'Crystallotics', Probiontics' and 'Radiotics' up to a science of 'Psychomatics' (HAECKEL, 1917). One is immediately led to Spinoza's 'panpsychism', where all matter carries a non-physical or mental property.

Recent chapters of neuroscience and neurophilosophy have revitalized the dispute between various shades of materialism (e.g. physicalism, neuralism, computationalism) on one hand and 'phenomenalism' on the other (e.g. neutral monism of RUSSEL (1954), naturalistic dualism of CHALMERS (1995), monistic idealism of GOSWAMI (1993)). The search for a scientific explanation of consciousness has encouraged this development, strangely provocating the highlights of materialism towards the end of a century dominated by materialistic science and war.

The effort of *Alan L. Mackay* to provide an English translation of Haeckel's strangest book on '*Crystal Souls*' (HAECKEL, 1917) should be seen within this exciting landscape. Today, this science landscape is really exposed to two opposing directions. Within biology, the more conspicuous side, loudly calling out it's spectacular results, is represented by mechanistic, molecular biology. The other, more modest side, involves holistic concepts and has strongly benefited from advances in systems and computational science. Therein, some landmarks have been established by St. Kauffman' s concept of self-organisation and complexitiy (KAUFFMAN, 1995) and the development of holistic, neuro-electrical field theories (KOEHLER, 1958; LASHLEY *et al*., 1951; PRIBRAM, 1995; LIBET, 1994). Even more fundamental, David Bohm's and Basil J. Hiley's interpretation of quantum physics within the theory of 'implicate order' marks a pleasing alternative to Cartesian concepts (BOHM and HILEY, 1993).

These reflections of the traditional dichotomy between 'factual truth' pronounced by materialistic concepts and 'conceptual truth', closer within the concern of holistic concepts,

are also of relevance in view of Haeckl's work. Behind Ernst Haeckel's outlines one can easiliy guess the urge to resolve this dualism. However, one cannot find a convincing solution for it.

A. Mackay may be right but also very optimistic, stating that '...the apparent conflicts of our time between molecular biology..... and the study of whole organisms, societies, etc... are really artificial' (A. MACKAY, this issue). At least this conflict has lasted more than some thousand years of human culture, taking *Plato's* reaction to Presocratic materialism as an early document of it (PLATO, *The Republic*, translated by Cornford, 1941). This persisting and rather obstinate duality appears to be inseperable from the way we perceive nature and precisely there might be the reason for 'artefact' in sense of Mackay. Also, Plato argues that '...any particular object that we experience with the senses is only a shadow or copy of the idea or form of that object...'. In this sense the idea behind form is more 'real' than the object itself. It is along this line that I will try to show what 'form' 'has got to do with mind and matter'. As the contrast behind mind and matter was superbly personalized by two Austrian philosophers, *Kurt Gödel* and *Ludwig Wittgenstein*, I will occasionally involve some of their arguments to highlight the far reaching consequences of the mind-matter conflict.

2. Matter and Mind behind Haeckel's Drawings

According to Haeckel's view the continuity of life from man down to atomic levels is basically due to the regularities of natural structure. So the resemblance behind symmetry displayed by crystals with many single cell life forms such as radiolaria (discussed in his chapter 3 'Radiotics'), demonstrates something like a 'common soul'. One finds that during evolution the 'mental', 'soul' or 'psyche' (Mackay's translation) in Haeckel's sense changes the role with respect to the relation or association to matter. Whereas our human brain cells are described as 'Seelenzellen' ('soul-cells'), protistic cells (e.g. protozoa) are seen to posess 'Zellseelen' ('cell-souls') (chapter 4, 'Psychomatics'). If not by accident (as Haeckel coined so many words, one is never really sure), then this is a serious and relevant difference. Haeckel's 'soul-cells' create the mind, whereas 'cell-souls' are subjected to the mind (or 'organizing principle' according to Mackay). So, in this view there is a dramatic change occuring during evolution. In the view of naive emergentism or neuralism ('brains produce the mind') and this was clearly Haeckel's position, this takes one into a considerable discomfort in relation to the temporal order intrinsic to the notion of evolution. The 'organizing principle', the 'soul' was there before it has emerged from soul-cells. Among others, this inconsistancy is characteristic for Haeckel's 'naturalistic monism'.

To put it another way, the question behind Haeckel's problem is, whether the resemblance or even identity of organizational principles necessarily implies functional equivalence. Here David Chalmers argument has made a strong impression on the community by showing that a phenomenal state such as conscious experience does not 'supervene' logically on the 'physical', but it is something extra, not within the realm of reductive materialism (CHALMERS, 1995). Applied to Haeckel's 'soul-cells' this would imply that even after a complete explanation of how brain-cells work, the fact that 'something mental' accompanies this function remains unexplained. The 'factual truth' behind brain organization does not entail the 'conceptual truth' of mind.

Chalmers reasoning cannot readily be applied to 'cell-souls' that in Haeckel's view inhabit all matter. In fact, 'panpsychism' is surprisingly resistant to conceptual or logical criticism. Probably Haeckel's cell-souls are to be seen as 'organizing principles underlaying the phenomenon of life' without involving those 'psychological' properties that one usually would attribute to 'souls' (Haeckel calls the 'Zellseele' of protists 'unconscious'). Within the aspect of 'life', as Mackay correctly lines out in his introduction, things have changed decisively since the time of Haeckel. Molecular biology has made a strong contribution to envisage the complex machinery inherent to all living cells. However, 'omnis cellula e cellula' (R. Virchov, 1821–1902) still remains valid and there has not been any assemblance of life from non-living components. We know a stubstantial amount of the functional organization of life today and this is different from the organization behind crystals. Similar to the phenomenon of 'consciousness', as suggested by Chalmers, 'life' seems to follow the principle of '*organizational invariance*'. That is, systems that share a specific functional organization are all 'alive'. This *functional isomorphism* of life cannot be found in stones, crystals, or potato chips (but it can be found in a potato). Haeckel's figures are similar and highly attractive physical realizations with quite different functional organizations. So finally, one must conclude that the factual truth behind Haeckel's soul-cells (neurons) does not necessarily imply the conceptual truth of mind and the conceptual truth of Haeckel's cell-souls (life) does not meet any factual truth in the described regularities of natural structure.

3. 'Form' from Mind and Matter—the Implication of Form

What is 'real' about form? Ideas are part of a conceptual truth involving properties such as 'apriority', 'innateness' and 'sameness'. This side of 'solid facts' was at the focus (and within the personality) of *Kurt Gödel* (see Hao Wang's reflections on Gödel's work, WANG, 1996). However, quite obviously 'sameness' (an aspect behind 'symmetry') is not everything that is signalled by the perception of form. As form appears to us, it is made up of differences, boundaries, parts and their relations. These 'things' appear to be 'real' and there is an usual identification of the real with the physical world. So the perceived form along with it's natural identification with the physical establishes another 'truth'—a 'factual truth'. This in turn was at the focus of *Ludwig Wittgenstein* (in RHEES, 1984). Along this reasoning, when talking about form one crosses a major barrier, a *rubicon* (CAMPBELL, 1994), taking us from a concept of 'sameness' to a concept of 'difference'. Both aspects turn out to be indispensable components contained within one solid fact of form. It looks, as if these properties behind form are that which specific percepts of living and dead matter share. In this view, the 'soul of matter' arises from experiencing it. Form appears as a natural combination of sameness—more a 'mental-like property' and 'difference'— more a 'matter-like' property. So, in some ways, Haeckel was not entirely wrong, his mistake was, being a materialist, not to seperate mind from matter conceptually and, consequently, to misinterprete the role of mind and matter in relation to experience and form. I am afraid he shares these flaws with a majority of reductive mechanists dominating the technological branches of life-science today.

Neither materialism nor mentalism can disentangle the dual aspects of form (Figs. 1a and b). Some progress can be found within the Russelian view of phenomenology (RUSSEL,

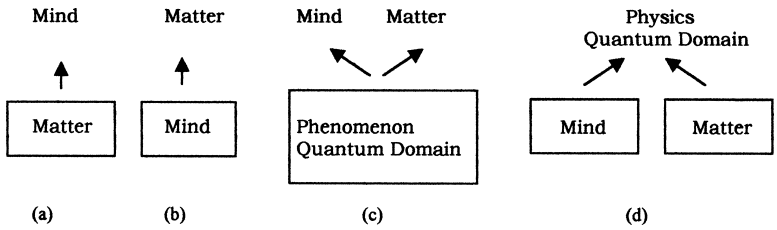

Fig. 1. Concepts on the relation of the 'real' (in squares) to the 'knowable': (a) materialism, (b) mentalism, (c) a Russelian view (phenomenon) or Zohar's view (quantum domain) and (d) the view of the present outline.

1954). There, a well balanced difference between mind and matter is recognized but not considered to be intrinsic. More recent interpretations identify the underlaying Russelian entity as the 'quantum domain' of physics (ZOHAR, 1996). Here the relation of a 'phenomenon' to a physical realization seems to be mistaken (Fig. 1c). It happens, that the role of physics in relation to the 'real' seems to be the major problem. Physics as a science is frequently and erroneously equated with a 'physical realization' of an underlaying phenomenon.

It is generally accepted that the quantum foundations of physics establish the true physical background and classical theories are merely approximations to this domain. The view holds, that quantum physics establishes relations between fundamental magnitudes within the frame of the 'knowable' rather than the 'real' (also Bohr and Heisenberg considered the quantum domain as the 'knowable'; BOHR, 1961; HEISENBERG, 1963). The magnitudes (e.g. location x and momentum p) carry a particular 'extension of spectral width' and are not considered as 'proper' or 'real' in the strict sense. Observations of these magnitudes take the 'knowable' into the 'real' by eliminating the extensions around them. For a particular combination of magnitudes (e.g. space and momentum x, p, energy and time E, t, and angular momentum and angle), the elimination of the extension of one magnitude leads to an infinite extension of the other magnitude. In other words, for a system to have a well defined 'real' momentum ($\Delta p = 0$), it must have an infinite characteristic spatial dimension as $\Delta x \longrightarrow \infty$, according to the spatial Heisenberg inequality and for a system to be in a proper state of energy ($\Delta E = 0$), it has an infinite temporal extension (or characteristic time) as $\Delta t \longrightarrow \infty$:

$$\Delta p.\Delta x \geq \hbar \quad \text{and} \quad \Delta E.\Delta t \geq \hbar.$$

Within the instantiation of the quantum domain itself the 'incompatible magnitudes' (such as x and p, or E and t) will always carry a finite extension with Planck's constant '$\hbar$'as the lower bound. The 'truth value' of propositions made about such a system might not be 'knowable' (x and p at a given time t is not knowable). This marks a distinct difference to what we call 'real', where for all propositions p either p is true or *not-p* is true and *not both* are true, must hold.

This is all well known. However, what has not been consequently seen is, that a systematization of physical extensions within the frame of their mutual relations leads to

a highly coherent concept revealing the relation of the 'knowable' to the 'real' or the 'true physical' (= the quantum physical) to the phenomenal (see Table 1). From this table it is palpable, that the realization behind physics emerges from a rather symmetrical composition, mixture or overlap of mutually incompatible magnitudes with the 'proper' or 'real' flanking the far end phenomenology of the scale. The reason for 'incompatibility' is seen to be due to instrinsic properties behind physics that justify the use of 'mental', 'idealized' or 'conceptual' on one end and 'material', 'factual' or 'stationary' on the other. For example, for 'matter' to gain physical meaning it requires proper states of energy ($\Delta E = 0$) and variation in space with proper location ($\Delta x = 0$) on one hand and 'stationarity' expressed by an infinite extension of the incompatible counterpart time (as $\Delta t \longrightarrow \infty$). One should note, that the 'characteristic time' is infinite for a strictly stationary character of a harmonic phenomenon—it never evolves on it's own—it is always there. The opposing 'mental' phenomena give rise to proper values of time ($\Delta t = 0$) and momentum ($\Delta p = 0$), but display infinite extensions in space ($\Delta x \longrightarrow \infty$) and energy ($\Delta E \longrightarrow \infty$). That is, for a system to be in a proper state of momentum it must have an infinite characteristic spatial dimension—it is identical to itself at all points in space with no defined energy (and hence mass equivalence in a relativistic sense). Intuition suffices to realize that this is what we mean by 'mind' or 'mental property' or, literally, 'sameness' in the sense of Gödel.

The view that I advocate here is topologically close to the double aspect concept of

Table 1. The relation of the 'knowable' quantum domain to the 'real' phenomenal expressed in physical magnitudes.

Levels of realization	temporal ext.	spatial ext.	energy ext.	description
material level matter	$\Delta t = \infty$ $\Delta p = \infty$	$\Delta x = 0$	$\Delta E = 0$	stationary, never evolving, but 'proper' energy and location
physics:	$\Delta t \rightarrow \infty$	$\Delta x \rightarrow 0$	$\Delta E \rightarrow 0$	diverging temporal extension,
Life and brains	$\Delta t \sim 1/\Delta\omega$	$\Delta x \sim 1/\Delta p$	$\Delta E \sim 1/\Delta t$	almost-stationary, evolving, limited dispersions,
	$\Delta t \rightarrow 0$	$\Delta x \rightarrow \infty$	$\Delta E \rightarrow \infty$	vanishing temporal extension diverging spatial and energy extensions
mental level:	$\Delta t = 0$ $\Delta p = 0$	$\Delta x = \infty$	$\Delta E = \infty$	ever evolving with proper time and momentum, unlocalized, with no defined energy and matter

Russel and even identical to the interpretation of Zohar (ZOHAR, 1996). The essential difference resides in the direction of 'emergence'. In Zohars double aspect position mind and matter are 'derived' from the quantum realm, whereas in the present view, the quantum domain is 'derived' from mind and matter (Fig. 1d). A physical realization crystallizes within the strangely opposing world of mind and matter. It is an 'implication' or 'enfoldment' of these phenomenological differences in the sense of Bohm. The 'laws' of physics describing the operation of 'observation' 'explicate' the mixture into a phenomenal truth—'idealizations' in the physical sense. Thus, the famous 'collapse of a quantum wave function' onto a proper state marks the transition from a knowable physical realization to a real phenomenal truth. So 'reality' is outside the physical sensu strictu. It is the mind of the observer that infers reality from the knowable and this is where the brain as a 'natural ingredient' in physics starts to play a decisive role[1].

4. The Perception of Form—the Explication of Form

The above ontological framework suggests several specific indications for the process of experiencing form. First, it seems obvious that our world experience involves the 'proper' or 'real' in the above sense, as opposed to the 'knowable'. The physical realization behind knowable states comes along with 'extensions' and 'ranges of uncertainty' that we do not perceive consciously. In addition, the physical states also involve the superposition of properties that are not part of our 'perceptive ability', they are not even conceivable (the concept of a quanton displaying wave-like and particle-like properties simultaneously, or the 'non-locality' of quantum states). *Thus experience deals with the 'real', that is the phenomenal*. However, the brain as a natural ingredient of nature following the universal laws of physical instantiation must be seen to be 'realized' at the level of the knowable or physical, that is, at the level of 'arbitrary states' displaying extensions of physical magnitudes. From this it follows, that the process of conscious experience, setting out from arbitrary quantum states of the brain, targets into simultaneous proper states of the engaged physical magnitudes. This is congruent with the notion of 'observations' in physics (where 'observing real quantities' corresponds to Hermitian type of operations applied to wave functions providing the state of a system) and it is coherent within the present ontological setting. Also, this view seems to reveal the role of quantum concepts with respect to brain function that has led to an intense and enduring dispute (e.g. BERNROIDER, 1996; HAMEROFF, 1996; SCOTT, 1996; STAPP, 1996). *Thus, perception of form involves a projection from arbitrary quantum states onto 'idealized' proper and phenomenal states*. But how could this transition occur ?

Several problems enter the stage. One basic problem becomes apparent from the above table of physical extensions. Only along compatible magnitudes (such as t and p in one direction or x and E in the other direction) can the spectral extension become eliminated simultaneously. Or in other words, only for a set of commuting operators Q, P can one expect unique eigenvalues for a given quantum state (so that $QP - PQ = 0$ and not

(1) Within the tradition of physics there is a certain 'bias' towards the proper states of matter, the stationary states in physics—this is also reflected by a certain psycho-physical preference for 'factual truth' as opposed to 'conceptual truth'.

$QP - PQ = i \cdot \hbar > 0$). In the present context, this would suggest that we can either experience 'mental-like' properties (as $\Delta t \longrightarrow 0$ and $\Delta p \longrightarrow 0$) or 'matter-like' properties (as $\Delta x \longrightarrow 0$ and $\Delta E \longrightarrow 0$) and not both within instanteinity. However, our reasoning was that 'form' involves both, mutually incompatible phenomena of sameness and difference, conceptual and factual truth. We experience matter and mind inseparably entangled within one solid fact of form. In addition, all of our experience seems to be embedded within a continuity of space-time. But space and time do not commute, their dispersion is not simultaneously zero. That is, 'explicating' space into a proper and localized state, would 'implicate' time into a completely stationary, never evolving state.

My work on quantum optics and the role of Quantum Electrodynamics (QED, FEYNMAN, 1961) to describe the interaction of light with matter (BERNROIDER, 1994), together with the results of a rigorous description of signal propagation in the brain, based on 'complex projection amplitudes' (BERNROIDER, 1996) and inspired by Pribrams 'the brain as a holographic device metaphor' (PRIBRAM, 1991), have let me to propose the following solution to this problem. Figure 2 provides us with an impression about the initial phenomenal landscape with the brain physically instantiated between the two opposing phenomenal ranges as reflected by Table 1. If every experience is laid out within the multi-model experience of space-time, then one needs to 'cross out' incompatible magnitudes

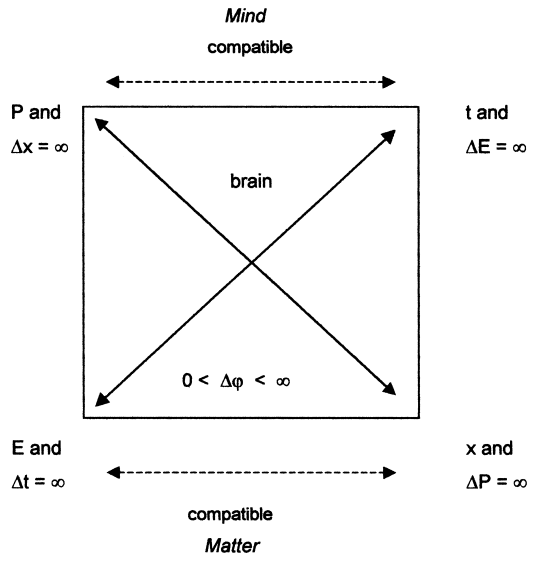

Fig. 2. The physical in relation to the phenomenal characterized by physical magnitudes and their dispersion. Mind opposes Matter within the 'real'—the area of transition composes the physical brain with finite extensions $\Delta\varphi$ (the 'knowable'). On both sides of the phenomenal we find mutually compatible magnitudes, such as energy and location (matter), or momentum and time (mind). The incompatible magnitudes can be found within opposing corners, such as momentum (p) and space (x) or energy (E) and time (t). The Fourier transform relates these incompatible magnitudes, producing a 'mixture' of intrinsic properties behind mind and matter (along the diagonals of the graph)—a space and time version (right hand side of the square) of these properties is what we consciously perceive.

such as energy-momentum into space and time producing the 'desired' mixture of mental and matter like properties into one coherent frame (Fig. 2). This is precisely what the Fourier-transform (or a lense) can achieve. The Fourier transform maps an energy-momentum presentation of a wave function into a space-time presentation. In one direction and one dimension one needs the complete and disjoint set of proper states of momentum to map an arbitrary brain state onto a state of proper localization (*Appendix*). The same reasoning holds for the energy—time projection. The coefficients of this Fourier transform evolve as projection amplitudes of the arbitrary brain state onto the proper states of momentum which are factorized by a complex wave function of momentum proper states to yield a state of localization. One should note that the wave function of the arbitrary brain state appears in this way as a 'superposition' of 'monochromatic waves' (e.g. LEVY-LEBLOND and BALIBAR, 1990). In the 1996 paper I have identified these 'waves' with propagating nerve cell potentials, that is propagating 'fields'. This would mean that the 'initial state', prior to conscious experience of a particular percept, is characterized by a complex superposition of cell potentials with (almost) proper states of momentum. Again this indicates that the corresponding probability density function (the square of the modulus of the complex wave function) is constant and independent of location x (as the proper states of momentum are associated with infinite spatial extension). These potentials are basically 'unlocalized'.

This is one side of the brains transforming ability. The second crossing line must start off with the complete and disjoint set of proper states of energy, to transform the arbitrary brain state into a proper state of 'time' —the instance of conscious experience. Proper states of energy are associated with large characteristic time intervalls, together accounting for the physcially important stationary states of matter. In a previous work I have identified the 'energy' within this context as a cell potential which, together with a 'threshold potential', determines the 'firing probability' of neurons and is seen to be equal to the square of the modulus of a complex wave function of energy proper states (BERNROIDER, 1996). According to the temporal Heisenberg inequality i.e. $\Delta E \cdot \Delta t \geq \hbar$, this entails an 'infinite' temporal dispersion and within the frame of a (classical) temporal spectral relation i.e. $\Delta\omega \cdot \Delta t \geq 1$, this implies that the underlaying phenomenon is characterized by a single and unique frequency (as $\Delta\omega \rightarrow 0$) of 'monochromatic behaviour'. So, taken together, the perceptive process sets out from an energy-momentum phenomenon that implies spatial invariance (as $\Delta x \rightarrow \infty$) and 'pure' or 'monotonous' behaviour (as $\Delta t \rightarrow \infty$ and $\Delta\omega \rightarrow 0$) of the underlaying physical signals.

From this the present concept allows several predictions on the nature of brain signals 'preceding' the moment of conscious (space-time and particular Cartesian) experience. The properties of signals engaged in this stage of no conscious experience seem to be 'everywhere' and rather monotonous which is in concert with empirical evidence on wide-spread, stereotyped synchronicity that can be found during seizures and slow-wave sleep, both reflecting either unconscious or reduced conscious states of persons, (STERIADE, 1997).

The situation changes to it's opposite as the Fourier leads into a space-time phenomenon. There the signals are expected to be 'focused' onto 'single space-time points' involving proper states of space and time—again constituting a 'mixture' of 'mental' and 'matter-like' properties. The nature of the underlaying brain signals would now be 'localized and

'particular' (action potentials ?) and in terms of variation (as $\Delta t \rightarrow 0$, we expect $\Delta\omega \rightarrow \infty$) a high degree of complexitiy and differentiation can be predicted. That is, the repertoire of different neural signals becomes large. These predictions, solely based on the present theory, are strongly supported by empirical case studies and find support, for example, by the double aspect 'dynamic core hypothesis' of Edelman (TONONI and EDELMAN, 1998).

Two final questions need to be addressed. What makes the brain perform a 'Fourier transformation' and what is the physiological equivalence of the engaged signals ? Any discussion of a physical state function laid out in space and time gains a particular meaning through the use of stationary states, the states of proper energy. These states allow one to configure all time-dependent projection amplitudes (state changes) as the sum of amplitudes that are themselves independent of time, multiplied by a harmonic factor carrying a proper value of energy. Thus the way to obtain 'time-dependent' wavefunctions in a physical realization involves projection amplitudes of a completely arbitrary state at an arbitrary instant of time onto stationary states (as coefficients) and an evolution factor of the type $\exp(iEt)$. In addition, there is an easy change of variables between the proper and compatible magnitudes of energy and momentum (in the view of $E = p^2/2m + V_0$). Taken together this configuration turns out to be precisely a Fourier transform equating a time-dependent spatial representation, (a '*x*-representation') with a time-dependent energy-momentum representation (a '*p*-representation'). The relations can of course be inverted involving a change of sign in the harmonic $\exp(-iEt)$. So, in the frame of physical magnitudes an evolution setting out from the 'knowable' to the 'real' necessarily entails operations that decompose arbitrary 'fields' into a superposition of harmonic functions according to Fourier. However, if the propagating system is confined (the brain potentials are not 'everywhere') the Fourier decompostion would loose its physical pertinence. One needs to replace space-time filling plane waves with restricted 'modes', e.g. in the sense of GABOR (1946), discussed in detail by PRIBRAM (1991).

The question about the physiological identity of the underlaying signals turns out to be difficult with relation to traditional neuro-physiology which is still a 'classical discipline', suitable for some explanations (such as learning and memory) but insufficient for others (such as conscious percepts, imagery, cognition and emotion). However, it seems possible to make a number of predictions on the nature of these signals, as above. A strict quantum manifestation necessitates action orders at the level of Planck's constant ($\cong 10^{-34}$ MKSA units). Such signals have not been plausibly identified yet. The present view would predict such signals between charged sites along long-ranged interactions of large integral membran proteins (ion channels). In addition, the description of these signals would require a relativistic approach as the constraining Coulombic interaction receives a significant photonic contribution in the sense of a Casimir-Polder effect (SPRUCH, 1996). Views along this line are only at the beginning (BERNROIDER, 1999). Another, quite attractive view considers the brain as a 'macroscopic quantum device' operative at 'normal temperature'. In fact, it can be shown that some of the 'dual aspect' properties behind 'beams' of electromagnetic waves characterized by their phase can be expressed within a 'number—phase inequality' that does not explicitely figure the quantum constant $\hbar$. Such a system gains its quantum nature through the coherent combination of two mutually incompatible magnitudes expressed by 'number' and 'phase' (BERNROIDER, 1999). This will be discussed elsewhere.

5. Conclusion

In conclusion, the present theory makes the following predictions. Experience targets into a combination of real phenomena underlaying the physical, provided by an intrinsic duality of mind and matter. Both phenomenal properties emerge into a physical realization comprising the 'knowable' which is physically established at the quantum domain. This 'realization' happens to be instantiated at the level of our brain. However, to transit from the 'knowable' quantum domain into the experience of the 'real', a particular combination of phenomenal or intrinsic properties (such as proper energy and momentum) is required to project undefined quantum states of the brain onto proper states of Cartesian space-time that usually accompany conscious percepts. So the 'physical brain' functions rather like a 'transit-station' projecting one set of phenomenal-mixture onto another set of phenomenal-mixture. Some aspects, the 'arbitrary states' are physical properties of the brain, whereas other aspects belong to the phenomenal (the 'proper states'). Although this projection of states occurs in 'both directions', from energy-momentum to space-time representations and vice versa, conscious experience is associated only along one direction. The combination of mutually incompatible magnitudes reflecting the opposing phenomenology of mind and matter becomes feasible by 'enfolding' the brains physical realization in a way that brings together proper energy and momentum on one side and proper space and time at the opposing side. As a result, the brains transformation process can be visualized as a single bidirectional projection along 'one dimension' (Fig. 3). If the underlaying phenomenal duality of conceptual (mind) and factual truth (matter) is assumed to be instantiated only at those locations where the brains physical realization occurs, the 'virtual enfoldment' of the brain, opposing energy-momentum and space-time proper states would turn out to be a truly (if not the only) significant differentiation of the universe. The question, why a projection of arbitrary states onto a distinct set of proper states (the space-time combination) makes itself 'felt' as 'qualia', as the contents of phenomenal experience, must reside within the phenomenal property of a particular combination of 'mind and matter' expressed within their intrinsic properties of time and space.

The view behind the present outline is definitly strongly simplified. For example, we have only considered extreme values behind the physical relations of dispersions. Strictly speaking, it is not possible to talk about propagation of signals (i.e. physical states) if the associated wavefunction involves stationary states of energy. The associated state would not be reasonably localized to be displaced. On the other hand a displacement of signals along proper states of locations would imply an undefined value of momentum. But velocity accompaning movement entails a well defined momentum. So the neurophysical realization can be expected to involve some 'balanced dispersions' (in the sense that $\Delta p \cdot \Delta x \cong 1$). Only where the dispersions become extreme (either zero or very large) the 'knowable' becomes equal to the 'real' (see also Appendix).

One essential prediction based on the present outline is the following: within 'balanced dispersions' the brain states occur to fluctuate between energy-momentum and space-time dominated states. These fluctuations involve a change in neurophysical properties that must be reflected behind brain signals. To allow the system to set out from a stationary state with proper values of energy and momentum but being basically unlocalized and transit into the counterpart of a localized state that is ever evolving comprising a large 'spectrum'

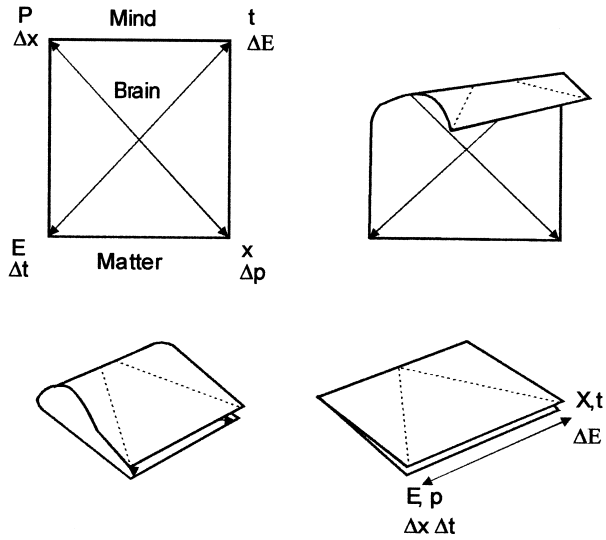

Fig. 3. The brains enfoldment. Setting out from the outline available in Fig. 2, a folding process involving the quantum brain domain brings together proper values of energy (E) and momentum (p) as well as location (x) and time (t) as intrinsic attributes belonging to the edges (where the 'knowable' is equal to the 'real' in the present context).The brains Fourier operation can then be seen along one dimension that opposes the incompatible magnitudes of energy-momentum and space-time. The brain states are suggested to 'fluctuate' between these two 'proper states'. Consciousness is assumed to accompany one direction, from (E, p) to (x, t). Every experience is basically embedded in the multi-modal concept of space-time.

of frequencies but with no strictly defined energy, one must expect a 'relaxation' of constraints for dispersions to gain physical meaning. For example signals must become 'reasonably localized', which in turn enables a certain spread around a maximum of momentum and an energy distribution which is the sum of two progressively moving waves in opposite directions (according to the two values of momentum associated with this energy $+p_E$ and $-p_E$ within a constant potential (see Appendix)). The space-time location of these states interfere during their mutual crossing. A 'likely' physiological equivalent for this to happen is during the delay introduced between synaptic arrival patterns (unlocalized state) and axonal departure patterns (localized state). The 'time-interval' would represent the finite dispersion in time Δt that is associated with the finite dispersion in energy. Pribram has considered this delay-time as essential for conscious experience (PRIBRAM, 1999).

Through our experience, form or pattern emerge as 'restrictions in space-time', sameness becomes confined into a difference. A view that I have advocated almost 15 years ago during a meeting in Tsukuba, Japan on occasion of the first international congress for 'Science on Form' (BERNROIDER, 1986). It was on occasion of this congress that I had the privilege to meet Alan L. Mackay and I am grateful that he again has encouraged a reflection on the strange world of mind and matter by his translation of Ernst Haeckel's book on 'Crystal Souls'.

Appendix

The brains Fourier transform:

It is straight forward to consider initially an expansion in momentum amplitudes for proper states of localization and subsequently apply the same procedure to amplitudes of the energy at $t = 0$, which generalizes to an arbitrary time by the insertion of an evolution factor of type $\exp(iEt)$:

The initial brain state—the physical state —is completely arbitrary —say '*a*' and we consider a transition form this state onto states of proper localization, say r_x (from 'real'). Applying the principles of i) superposition and ii) sequential factorization of quantum amplitudes, we can set for the desired wavefunction

$$\psi_a(x) = \langle r_x | a \rangle = \int \langle r_x | r_p \rangle \langle r_p | a \rangle dp$$

using the usual 'bra and ket notation'. Introducing $\psi^*{}_a(p) = \langle r_p | a \rangle$ as the momentum wavefunction and considering $\psi_p(x) = \langle r_x | r_p \rangle = A \cdot e^{ipx}$ for the usual way to write a complex wave amplitude of location, we obtain

$$\psi_a(x) = A \cdot \int e^{ipx} \psi_a(p)\, dp.$$

We find for the inverse transition, according to the rule of conjugation of complex wave amplitudes, i.e. $\langle r_p | r_x \rangle = \overline{\langle r_x | r_p \rangle} = A \cdot e^{-ipx}$

$$\psi^*{}_a(p) = A \cdot \int e^{-ipx} \psi_a(x)\, dx.$$

These are the position and momentum wavefunctions as related by the Fourier transform. Turning to the other set of mutually 'incompatibel magnitudes' energy E and time t, we obtain from the classical relation $E = p^2/2m + V_0$ a way which connects the spectrum of energy to that of momentum (within an assumed constant potential V_0). In particular, to a proper value of energy we find two proper values of momentum, as $p = \pm p_E = [2m(E - V_0)]^{1/2}$. One then finds for a time-dependent localization amplitude of the type

$$\psi_a(x;t) = \langle r_x | a(t) \rangle = \sum_E \langle r_x | r_E(t) \rangle \langle r_E(t) | a(t) \rangle$$

with the help of the mentioned evolution factor e^{iEt} (now turned into $e^{i(px-Et)}$), finally

$$\psi(x;t) = A \cdot \int_{-\infty}^{\infty} \psi^*(p) e^{i(px-Et)} dp$$

and we recover for $t = 0$ the spatial wavefunction $\Psi_a(x)$ above. Thus the space-time

representation turns out as a linear combination of time dependent wave amplitudes carrying proper values of energy and momentum with coefficients represented by projection amplitudes of the arbitrary brain state -*a*- onto proper states of momentum according to

$$\psi^*(p) = \langle r_p | a \rangle = \int \langle r_p | r_x \rangle \langle r_x | a \rangle dx.$$

In 'reality' it is more appropriate to relax the conditions of 'proper states' and constrain the dispersion around arbitrary states, that is to consider states for which $\Delta p \cdot \Delta x \cong 1$ and to look at 'almost stationary states' of energy. This would then allow the quantum state to 'move' across locations (within a limited Δx and a narrow Δp). A 'narrow' momentum dispersion is necessary to allow significant contributions to the above integral. For 'complex integration' it is essential that the phase does not vary strongly within a neighbouring domain, to avoid that the 'turn of amplitudes' compensates the sum. Thus, interference between the proper states of momentum must be constructive to generate a significant superposition along the set of partial amplitudes.

These constraints impose some physical properties that are important to allow a projection from energy-momentum representation to a space-time representation to occur within the 'realization of the brain' and to gain predictions about the nature of observable signals. For example constructive interference of momentum proper states implies stationarity of phases for 'average' momentum values. In turn, this implies that the state must move uniformly with velocity p_0/m for a sharply defined value of momentum p_0. Such a wavefunction is almost 'monochromatic'.

REFERENCES

BERNROIDER, G. (1986) Patterns are universal restrictions in space-time, a theory exemplified by sexual neurogenesis, in *Science on Form, Proc. of the First Int. Symposium for Science on Form* (eds. Y. Kato, R. Takaki and J. Toriwaki), KTK Scientific Publ. Company, Tokyo, pp. 319–328.

BERNROIDER; G. (1994) Processing biological images from very low light emissions, *J. Biolumin Chemilumin*., **9**, 127–133.

BERNROIDER, G. (1996) Neural phase-time coding from the view of an electrodynamic perturbation problem, *Forma*, **11**, 141–159.

BERNROIDER, G. (1999) The dark side of luminescence, in *Bioluminscence and Chemiluminescence*: *Perspecitves for the 21st Century* (eds. A. Roda, M. Pazzagli, LJ Kricka and PE Stanley), J. Wiley & sons Ltd., Chichester, pp. 57–61.

BOHM, D. and B. J. HILEY, (1993) *The Undivided Universe,* Routledge, London, New York.

BOHR, N. (1961) *Atomic Physics and Human Knowledge*, Science Editions, New York.

CAMPBELL, A. K. (1994) *Rubicon, The Fifth Dimension of Biology*, Duckworth & Comp., London.

CHALMERS, D. (1995) Facing up to the problem of consciousness, *J. Consciousness Studies*, **2** (3), 200–219.

CORNFORD, F. M. (1941) Plato, *The Republic*, Clarendon Press, pp. 318–321.

FEYNMAN, R. P. (1961) *Quantum Electrodynamics*, Frontiers of Physics, Addison-Wesley, Reading, MA.

GABOR, D. (1946) Theory of Communication, *Journal of the Institute of Electrical Engineers*, **93**, 429–441.

GOSWAMI, A. (1993) *The Self-Aware Universe: How Consciousness Creates the Material World*, Tarcher/ Putnam, New York.

HAMEROFF, St. and R. PENROSE (1996) Conscious events as orchestrated space-time selections, *J. Consciousness Studies*, **3** (1), 36–53.

HAECKEL, E. (1917) *Kristallseelen —Studien über das anorganische Leben*, Alfred Kröner Verlag, Leibzig.

HEISENBERG, W. (1963) *Physics and Philosophy*, Allen and Unwin, London.

KAUFFMAN, St. (1995) At Home in the Universe,Viking, London.
KÖEHLER, W. (1958) The present situation in brain physiology, *Am. Psychologist*, **13**, p. 150.
LASHLEY, K. S., CHOW, K. L. and SEMMES, J. (1951) An examination of the electrical field theory in cerebral integration, *Psych. Rev.*, **58**, 123–136.
LEVY-LEBLOND, J. M. and F. BALIBAR, (1990) *Quantics, Rudiments of Quantum Physics*, North-Holland, Amsterdam.
LIBET, B. (1994) Testable field theory of mind-brain interaction. *J. of Consciousness Studies*, 1 (1).
MACKAY, A. L. (1999) Citation of his work in this issue.
PRIBRAM, K. H. (1991) *Brain and Perception*, Lawrence Erlbaum Assoc. Hillsdale.
PRIBRAM, K. H. (1995) Brain in perception: from Köhler's fields to Gabor's quanta of information, in *Proc. of the 39th Congress of the German Society for Psychology*, pp. 53–69.
PRIBRAM, K. H. (1999) Brain and the composition of conscious experience, *J. Consciousness* Studies, **6** (5), 19–42.
RHEES, R. (1984) *Recollections of Wittgenstein*, Oxford Univ. Press, Oxford.
RUSSEL, B. (1954) *The Analysis of Matter*, Dover, New York.
SCOTT, A. (1996) On quantum theories of the mind, *J. Consciousness Studies*, **3** (5), 484–491.
SPRUCH, L. (1996) Long-range (Casimir) interactions, *Science*, **272**, 1452–1455.
STAPP, H. P. (1996) The hard problem: a quantum approach. *J. Consciousness Studies*, **3** (3), 194–210.
STERIADE, M. (1997) *Cereb. Cortex*, 7, 583 pp.
TONONI, G. and G. M. EDELMAN (1998) Consciousness and complexity, *Science*, **482**, 1846–1851.
WANG, H. (1996) *A Logical Journey, From Gödel to Philosophy*, The MIT Press,Cambridge, Massachusetts.
ZOHAR, D. (1996) Consciousness and Bose-Einstein Condensates, in *Toward a Science of Consciousness*, *The First Tucson Discussions and Debates* (eds. St. R. Hameroff, A. W. Kaszniak and A. C. Scott), The MIT Press, Cambridge Massachusetts, pp. 439–450.