Sheldrake's Ideas from the Perspective of Modern Physics

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1. Introductory Remarks

Rupert Sheldrake and I are both natural scientists. He is a biologist, while I am in physics—to be more precise, the physics of the smallest things, of molecule, atoms, and elementary particles. So, as far as the dimensions of our "objects" are concerned, we are separated by at least 12 orders of magnitude. He is concerned with living creatures. I deal with inanimate matter. So what could I contribute that is important to his individual, unconventional interpretations of the expression and interaction of biological systems?

At the moment, biology is undergoing turbulent growth. In recent decades, it has developed from a "soft" science with an emphasis on natural history, the collecting of phenomena, more and more into a causal-analytical, "hard" natural science, oriented to the model of an "exact" science, represented most impressively by physics. The original emphasis on the whole in consideration of living things, their shapes and gestalts, has been replaced by a fragmentating, functionalist description, in which, for an explanation of the sequences of events, the focus is on the substance, matter, and its building blocks, the molecules, and their interactions. The surprising thing about this development from holism and even vitalism to molecular biology is that it is occurring some decades after—and not before—a profound change in just the opposite direction took place at the foundations of natural science, in microphysics, during the first third of the century that recently ended. There, fundamental limitations of the fragmentating, reductionist way of looking at things had become apparent. Divisible substance revealed in a strange way holistic aspects. This peculiar discrepancy between the modern biological and physical view drew my attention to Sheldrake's ideas.

By his own account, Sheldrake came to his ideas because he had difficulties in making his personal observations of plants and animals agree with the explanations generally favored by biologists in his student days and now, which are based essentially on the mechanistic conceptions of the physics of the eighteenth and nineteenth centuries. He sees the difficulties less in obvious contradictions—due to the high degree of complication of biological systems, it is almost impossible to determine these without doubt—than in a lack of plausibility of the conventional argumentation.

I can very well understand Sheldrake's general dissatisfaction. However, as an atomic physicist and long-time coworker of Werner Heisenberg, my initial situation was quite different from his. I grew up entirely in the unconventional milieu of modern physics. In contrast to Sheldrake, who is disturbed by the unsuitability of the physical description of biological phenomena preferred at present, I emphasize rather the importance of physics for biology. But the physics I mean is a different sort than the one the biologists take as a basis today, which they adopted from the chemists. Thus, I approach his concerns from the opposite direction. For me, it is difficult to understand why modern biologists do not make more use of the revolutionary ideas of modern physics, seeing that the processes of life, as Sheldrake makes obvious, seem predestined to act as a bridge.

In the 1930s and 1940s this possibility was indeed perceived by the quantum physicists: initially by Niels Bohr,[1] and then by Pascual Jordan[2,3] and Max Delbrück[4]—who later switched completely to biology—and others, but later dropped again for the most part, because the necessary insights on collective excitation of many-particle systems had not yet been gained. Appropriate methods for this did not become available until the 1960s and 1970s,[5,6] leading to important insights in elementary particle physics,[7] and three years later to a Nobel Prize for Physics.[8] Only afterward did a few physicists, especially Herbert Fröhlich,[9,10] concern themselves more intensively with biological questions again. During the past three decades, this has led to a little-noted renaissance in this interest, the results of which I will discuss in a bit more detail later. However, most biologists did not respond to this, presumably mainly because of the predominant opinion among them that the new physics revealed in the microcosm is irrelevant in the relatively large biological systems, as in everyday objects. But this assumption is not so entirely valid. Numerous examples show us in what unexpected ways the new laws of the microcosm manage to affect the macrocosm that is directly accessible for us.

However, the hesitancy of other natural scientists in following the physicists along the new path at once is understandable. For the new physics, quantum physics, does not mean merely a small correction to the previous conceptions of classical physics, or a change in paradigms, in the sense of Thomas Kuhn,[11] but requires a fundamental transformation in the scientific world-view. And it is no coincidence that it was physics, and in particular a part of it whose successes to date had been the most convincing, namely mechanics, which led us onto the new track. For this section of the natural sciences is so simple and straightforward that there was no chance of simply attributing the persistent internal contradictions to a degree of complication that was not yet fully understood.

So my interest in Sheldrake's ideas is mainly directed to the question of whether the observations he cites, and the interpretations he offers, which he calls "unconventional," might be interpreted as indications that biological processes should be regarded as directly connected—and not merely by analogy with—the dynamics familiar to an atomic physicist. In my view, as a quantum physicist, the burden of proof ought to be reversed: it is not the advocates of a more holistic point of view who should be obliged to convince those who argue for an analytical/mechanistic approach of the necessity of additional structures of relationships; on the contrary, the mechanists ought to explain why the more complex structure of relationships that undoubtedly exists at the foundations, and is well-known to us from physics, should remain so totally invisible. An important point here is that the new physics includes the classical physics as a limiting case. Therefore, in a sufficiently imprecise view, the new physics should not contradict the established findings of the mechanists (Bohr's correspondence principle), but only refine and supplement them.

If a close connection can in fact be established between the phenomena of living creatures and the peculiarities of the new holistic physics, then this would mean that we cannot limit ourselves to the concepts of the everyday world familiar to us—that is to say, of classical physics—in the description of biological phenomena, any more than in that of the microcosm. This would apply, for example and in particular, to the concept of a "field," which plays a central role for Sheldrake in the context of his "morphic field." As a gravitational or electrical and magnetic field, such classical fields have a more or less comprehensible meaning for us. But the new physics has shown that the "quantum fields" introduced there as a description have a considerably more abstract significance, which is no longer descriptive and comprehensible in conventional language.

2. The Wave Nature of Matter and the Holistic Structure of Reality

The break with our understanding of reality that the new physics requires is radical. For this physics indicates that the essential reality, whatever we may mean by this, is basically not a reality in the sense of a tangible reality. Reality now manifests itself fundamentally as a potentiality, as "both one and the other" or more generally an "as-well/as," that is, only as the possibility of the reality familiar to us, which expresses itself in material phenomena that are subject to the logic of "either/or." Potentiality appears as a unity—or rather, as a non-twoness—that cannot be separated or divided. In the context of our accustomed concepts, which are decisively shaped by the classical physical world-view, this sounds outrageous, indeed unacceptable.

In addition, the historically determined conservative and defensive nature of the terms that characterize the new physics, such as "quantum mechanics" and "uncertainty principle," contribute to relativizing and disguising the essential innovations. Thus, the concept of the "quantum" arose from an investigation of the properties of light, which had been clearly and impressively revealed as a wave phenomenon of an electromagnetic field by the famous work of Faraday and Maxwell in the latter half of the nineteenth century. But much more astonishing was Louis de Broglie's discovery that matter in the strict sense, as embodied in its elementary components, the atoms and their constituents, for its part dissipates into the incomprehensible world of the extended and wave-like. In other words, it turned out that both light and matter have a dual particle/wave nature, which is unacceptable from the classical point of view.

The apparent contradiction between the particle and wave views was "clarified" in a certain sense by Heisenberg's formulation of his uncertainty principle (indeterminacy relationships), but only at the price of a fundamental uncertainty, which was unacceptable to many people. But this "uncertainty" does not refer to a lack, but is, on the contrary, the result of a much more intimate linkage between present and future, in which "everything is connected to everything else" in a more comprehensive manner. The "uncertainty" is the expression of a holistic structure of reality.

According to the concepts of modern physics, the particle in the old classical sense does not exist at all, that is to say that strictly speaking there are no objects that are identical to themselves over time. And, therefore, the objectifiable world that exists continuously over time, that seems so self-evident to us, basically does not exist. No observation of all the facts in the present, no matter how accurate, is sufficient in principle to predict future events unequivocally. Instead, only a "field of possibilities" is revealed, for whose realization certain probabilities can be given. Future events are no longer determined absolutely in their temporal sequences, but rather remain open in a certain sense. So events in nature are no longer to be seen as like mechanical clockwork, but instead have the character of a continuing evolution. "Creation is not finished"—the world occurs anew every moment, in a certain sense. And the world appears as a unit, as a single being that can no longer be interpreted strictly as the sum of partial states. The world "now" is no longer substantially identical to the world "before." Only certain properties of form ("symmetries") remain unchanged over time; this finds its phenomenological expression in the shape of conservation laws, such as the law of conversation of energy. However, the "world now" predetermines the possibilities of future worlds in such a way that, from a certain cruder view, it appears as if it were comprised of parts, and as if certain material outward forms, such as elementary particles or atoms, preserve their identity over time. Matter appears as congealed potentiality, as it were, as congealed form.

The translation of this holistic reality, inaccessible to us descriptively, into a comprehensible, tangible reality, in other words, the process of "congealing" from open potentiality to actual reality, is made possible by highly sensitive measuring instruments. For this purpose, the instruments must be in a suitable state of unstable macroscopic equilibrium (for example, by cooling the gas in a Wilson cloud chamber below the dew point). In such a situation, the potential particle (such as an electron) can then trigger an "avalanche," so to speak, consisting of a huge number of gas particles (that are also only potential), which finally corresponds macroscopically to the phenomenon of an "actual" droplet. It becomes clear that, in order to describe the irreversible process of "congealing," i.e., the factual realization of potential reality (Wirklichkeit), quantum systems with very many (actually, infinitely many) degrees of freedom are needed. In contrast to the old, non-relativistic quantum mechanics, this precondition is fulfilled automatically in the relativistic quantum field theories. Therefore, classical structures can occur, in the form of Bose-Einstein condensates of infinitely many quanta in the ground state (spontaneous symmetry breaking, solitons, etc.), for example.

Such realizations occur not only during a measurement process, but proceed constantly as natural processes, since instable configurations, which find expression in "chaotic" process sequences, exist in many systems. From the viewpoint of quantum physics, the future is fundamentally open and undetermined. The past, on the other hand, is knowable and determined by documents, which is by "facts" that have been created by irreversible, macroscopic processes. In the final analysis, all we learn about the past is what is tangible, and is documented in the present in the form of materially expressed facts. The present is the point in time when potentiality "congeals" into reality, possibility into facticity. Therefore, an extrapolation into the future is fundamentally impossible in major aspects.

From the point of view of the new physics, a relationship structure arises not only from a manifold and complicated kind of interaction between the conceived "components" (atoms or molecules) by means of the forces known to us already (for example, by the electromagnetic forces of the atomic shell), but also exists due to the considerably more intimate and holistic relationship structure typical of quantum physics. Strictly speaking, this does not let us speak meaningfully of components, which is "parts" of a system, at all. For quantum-mechanical systems are not only highly complicated, but also highly complex systems. By "complexity," I mean here that such systems simply cannot be reduced to simpler systems without rupturing some links. Strictly speaking, therefore, the reductionism that is customary in our science, and methodically necessary in the final analysis, fails in these cases. Furthermore, modern chaos theory teaches us that, for intrinsic instabilities, such a reduction is not even approximately possible, since even the weakest effects can lead to entirely different developments.

While the analysis of a system was always simpler than the subsequent synthesis of the insights obtained from its parts, the complete synthesis of the total system, under the conditions of the new physics, becomes a much more difficult venture - indeed, impossible in the end. In the old view, it was only necessary to analyze the properties of the parts, which included their dynamic effects, as accurately as possible. In the synthesis, the substance of the parts had to be added up, and their dynamic effects had to be overlaid appropriately, as well. For a large number of parts, this can easily become an extremely complicated problem, but one that remains solvable in principle, and in general, it can be dealt with in practice by statistical methods, too.

But the statistics used for quantum physics is a degree more sophisticated than the conventional statistics that we apply in cases of insufficient knowledge of the facts of a case. For quantum statistics is based on the "as-well/as" potentiality, and not on an uncertain "either/or" reality. In contrast to the probability with which we are familiar, which can assume any value from zero (impossibility) to one (certainty), the potentiality of quantum physics is not absolute-valued. It is complex-valued and can vary in a wavelike fashion from +1 to -1. If several waves are superimposed—which is the characteristic nature of waves—it can not only be reinforced, but—depending on their phase relationship (the relative position of the crests and troughs of the waves)—it can also be weakened, even completely extinguished.

Thus, in the new view, what is separate (such as in the concept of isolated atoms) is not the foundation of reality, but rather an approximate separation is a possible result of a formation of a structure, namely the creation of disconnectedness by extinction in the intermediate region.[12] So the relations between the parts of a whole are not a secondary consequence of the interaction of originally isolated things, but are the expression of a primary identity of all. Therefore, a relationship structure arises not only by communication, a mutual exchange of signals amplified by resonance, but also by "communion," so to speak, by identification.

3. Consequences of Modern Physics for Our Living World

Probably our (conscious) thinking evolved in connection with our prehensile hand. By means of a virtual test run, as it were, of the intended physical acting and grasping, it is supposed to help us increase the success of our actual either/or acting and grasping (in the literal sense). So it is understandable that the "also" structure of reality, that is expressed in its wave nature, seems so alien and incomprehensible to our way of thinking. Since, in the world that is directly accessible to our senses, in which we have to get along and succeed in the Darwinian sense, we only need to handle very large numbers of these strange entities, which are somewhat misleadingly termed the "elementary components" of matter, we are only ever dealing with statistical populations, in which any local peculiarity and diversity is largely averaged out. Therefore, the presumption that we really should not bother ourselves about the exotic microcosm of the new physics with respect to the objects of the world in which we live, which have trillions of trillions of molecules and atoms, seems entirely justified. In other words, what is fundamentally an "also" reality presents itself in the macroscopic, thoroughly mixed world that we can experience directly, to an extremely close approximation, as the familiar, divisible, objective, material "either/or" reality for which our reflecting rationality (our reason) has evolved and adjusted so superbly.

We already know that this presumption cannot be generally valid in this form. After all, any physical measurement that reveals the peculiarities of quantum physics to us shows a way in which the microcosm can become apparent macroscopically. This always requires some sort of amplification mechanisms that are linked to instabilities and resultant avalanching chain reactions. Individual processes trigger other similar processes by positive feedback, thus leading to a practically unlimited irreversible increase, which can then be registered macroscopically as a fact.

The attractive forces between "elementary particles" of matter with opposite electrical charges enable local accumulations of large quantities of such components to occur. Due to the thermal agitation of these elementary particles, it is assumed that the phase relationships of the associated matter waves average out. Thus, the quantum-mechanical, holistic relationship structure would be lost in effect, making the customary classical description possible. However, at very low temperatures, close to absolute zero, under certain conditions the thermal agitation can almost freeze up and become so weak that the quantum-mechanical coherence of the matter waves is no longer blurred. In this case, quantum states of macroscopic dimensions are formed. They possess peculiar properties, such as superconductivity and superfluidity, which disappear again above characteristic transition temperatures of a few kelvins (degrees absolute).

But even at room temperatures, similar macroscopic quantum structures can develop, under suitable dynamic effects. For example, the magnetic interaction of the electrons in the shell of iron atoms (below iron's characteristic Curie temperature of about 770°C) forces a spontaneous alignment in one direction of the spins of all the electrons, creating through this mutual enslavement process a phenomenon familiar to us as ferromagnetism. Gases, liquids, and amorphous and crystalline solids develop structures of spatial ordering to a greater and greater degree (in conjunction with correspondingly stronger "breaking" of the spatial symmetries). They display not only classical properties of matter (simulated by averaging), but also the collective phenomenon (connected to the breaking of spatial translation symmetry) of the longitudinal propagation of sound, which depends on bosonic quantum degrees of freedom, the phonons. A detailed description would be too much here. But I should point out that it is not clear whether a purely classical description, which ignores phase relationships, is entirely suitable from the point of view of physics, or instead can only be considered a permissible approximation for certain questions. In the latter case, phase-sensitive measurements might reveal further, previously hidden, "information" (perhaps in the sense of "imprints").

An important observation for all the examples given is that the size (in the sense of not being small) of an object alone is not a sufficient criterion of a total suppression of the holistic states characteristic of quantum physics, and thus the expression of purely classical phenomena.

Let me go a step further. The macroscopic quantum structures I have cited so far are still quite specialized, since they all only develop near the system's thermodynamic equilibrium state. Entirely novel phenomena of ordering occur if we move far away from this equilibrium state. This requires a continuous external supply of work-capable (ordered) energy to the system. The best-known example of this is the laser ("Light Amplification by Stimulated Emission of Radiation"), also known as a quantum generator. In this, a medium which is pumped up to an unstable configuration of state (population inversion) in a suitable fashion, by irradiation with light, discharges in the form of a collective, quantum-mechanically coherent (i.e. strictly phase-correlated and monochromatic) multiple-photon light wave. So the continuous throughput of energy enables the microscopic, fundamental quantum-mechanical structure to be expressed macroscopically in this case, as well. To a certain extent, this process is a quantum-mechanical analogue of the behavior of classical dissipative systems far from thermodynamic equilibrium, which tend to form certain patterns of order, as described by Prigogine and others.[13]

The possibility of macroscopic quantum structures (coherence) developing in energy-pumped systems suggests going beyond systems of "inanimate" nature. In this context, the interesting hypothesis suggests itself that the phenomenon of life might be connected directly to the newly discovered fundamental holistic structure of reality. Biological systems might indeed function similarly to a laser. For biological systems are, like lasers, open systems requiring a continuous input of available energy; they obtain this from their metabolism by ingestion of food. By means of a sufficiently strong energy pump, it might be possible to create thermal disequilibrium states in suitably designed macromolecules or molecular systems, embedded in certain substrates, and thus excite certain low-frequency collective oscillation modes coherently with great power, perhaps via mechanisms similar or analogous to Bose-Einstein condensation. Fröhlich,[9] in particular, and subsequently other researchers, have given interesting examples of this kind in quantum field theory, which appear to be suitable for an interpretation of living systems. I myself only learned of this recently from Gerard J. Hyland, a pupil of Fröhlich, at a conference.[14] E. del Giudice and others have summarized the considerations of quantum field theory developed in interesting papers.[14-16] I will return to certain points of this later.

If such an approach should prove successful, it would mean that the classical pattern formation in chaotic, dissipative systems[13] often enlisted as an explanation of life, could, in addition, lead, under certain circumstances, to an expression of macroscopic quantum structures, in which the holistic relationship via phase correlation (coherence) should play a major role, as in the microcosm.

4. Quantum Interpretation of Life

A "quantum interpretation" of life does indeed provide an attractive perspective, that we no longer need to locate all phenomena of animate nature, including human beings, outside the rest of nature, what is called "inanimate nature." In that case, the difference between inanimate and animate systems would only consist of the different levels of a hierarchical structure of ordering on which they are located. The holistic aspects of reality, which are expressed in the new fundamental structure of matter, would provide the decisive prerequisite to prevent the characteristics of life that are essential for us not to be mutilated to mechanistic functions. For in this conception, "vitality" exists already, in a certain sense, at the very roots of reality in an "embryonic" form, and is, therefore, active throughout nature, even in "inanimate" nature (although more or less marked). In particular, a "quantum biology" might, to put it cautiously, bridge the gap to what we usually term the "mental" or even "spiritual," and thus create in principle the possibility of finally overcoming the fundamental distinction between human beings and the rest of nature, which seems artificial.

The new physics has taken a first major step to shake off or loosen the fetters of strict determinism, which would hinder this. The future is open in principle! This is true: but this step only takes us a little way in the desired direction, for the liberation of processes from strict determinism made possible by changes in the laws of the microcosm is not sufficient to justify the supposed freedom of human will and decision making. Firstly, these freedoms are in principle very modest, due to the probabilities of the occurrence of future events, which are still strictly determined in quantum physics. Secondly, this relatively small openness is, as we have seen, usually suppressed entirely in macroscopic conglomerations by the almost complete averaging out of microscopic "vitality," except if a coherence of the potentiality waves can develop macroscopically by mechanisms of the kind described above—which is the great opportunity.

In conventional microbiology, the question of coherence has not played any role so far, since it is assumed as a matter of course that the rough approximations of the chemists are basically sufficient for describing atoms and molecules; in their models, only the intensities (probabilities of encounter), but not the phase relationships of the electrons' matter waves are taken into account.

Let me use the familiar space-filling model of the DNA double helix for an example of the consequences. The plan for the development of a life-form is supposed to be encoded in this macromolecule by the specific sequence of certain base molecules (nucleotides)—see Fig. 1—as by separate letters in a book. The overlapping spherical caps of the linked atoms forming these molecules are intended to give a rough idea of the electron distributions in the atoms. To put it more precisely: in the physicist's view, these spherical caps

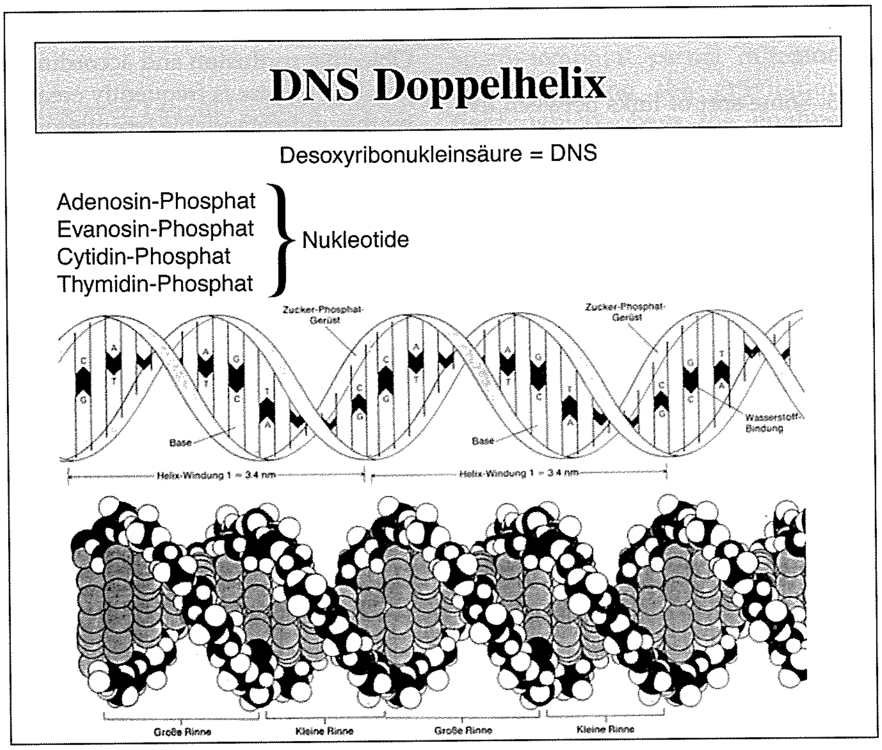

***Figure 1:** DNA Double Helix*

illustrate the region of space in which there is a high probability of encountering an electron. The important point is: in this model, only the intensity, and not the phase of the electron waves, is represented, although this plays a major role in the regions of overlap of the segments. For, due to this overlapping, the individual electrons can no longer be assigned individually to the various cores of the atoms. Therefore, the DNA macromolecule, with its hundreds of thousands, or even millions, of electrons should (in the physicist's view) be considered rather as a single indivisible overall electron cloud. Under suitable conditions, this might even be capable of collective coherent excitations.

The success to date of the chemists' simplified idea that intensities, i.e., probabilities, are sufficient for a description is, in my opinion, not a sufficient proof that the ignored phase structure of the DNA double helix's overall wave (formed by the overlapping of the partial waves of numerous electrons) may not have additional information important for morphogenesis encoded in it, similarly to a photographic hologram. In everyday life, for example, we believe at first that we can obtain an essentially true-to-life image of objects or landscapes from a photograph. But a better understanding of optics teaches us that a large part of the information transmitted to us from the object by light is lost in conventional photography. We can only gain partial access to this by sophisticated methods of detection, such as holography (which also registers the phase relationships) now offers.

A minor personal experience of mine may serve to illustrate this situation. Quite a long time ago, I was looking down from the Empire State Building in New York City at the dense crowds of people in the streets below me. I was particularly fascinated by the way the masses of people poured out of the entrances to the subway stations, flowed through the streets, and then disappeared into other entrances at other points. I was just amusing myself by imagining how such complicated events could be approximated with increasing sophistication by systems of hydrodynamic equations, when I chanced to notice a man at an intersection who did not cross the street when the traffic light turned green, like the other people, but simply stood there. This was repeated several times, until a woman came over to him from the other side when the lights were green. The two embraced briefly, and then disappeared together into a cafe nearby. Nothing unusual about that! But at that moment, I realized that I would never be able to find a satisfactory explanation for what had happened, despite a detailed description of the course of events, since my limited insight cannot have any knowledge of, say, a previous telephone call to arrange the couple's rendezvous. Applied to biology, the telephone call that I could not perceive would correspond to undecoded information concealed in the phase relationships of the electrons' matter waves, or of modes of oscillation (perhaps of an electromagnetic nature) coupled to them. This might possibly provide points of contact with Sheldrake's "morphic fields." And that is the actual concern of my considerations, which I will now discuss in more detail in the last section, after these lengthy preparatory remarks.

5. A Bridge to Sheldrake's Morphic Fields

Since I am not familiar enough with Sheldrake's morphic fields, I do not feel able to discuss his ideas in much detail. However, I suspect that the vagueness of my own ideas about them, and my uncertainty about interpreting them correctly, also have something to do with Sheldrake's mainly qualitative arguments, on which he is still forced to rely, for lack of sufficient empirical clarification. This does not bother me, because it is typical of new beginnings.

Sheldrake seems to be convinced that a novel formative force is needed to explain the strange phenomena he describes, which, in particular, is supposed to have the peculiar characteristics of:

1. Controlling morphogenesis in a living organism;

2. Being able to affect its surroundings beyond the physical boundaries of a living creature, in such a manner that other living beings—mainly those of the same species, but also those of other species (e.g., dogs who live in close contact with the person to whom they relate)—can be influenced even over great distances, but in an individually specific manner (resonance);

3. Some sort of links between living beings and certain inanimate localities associated with them (e.g., homing pigeons and their home loft) exist or can be created, which enables them to find these.

Mechanisms of the cause and spatial mode of action of such formative forces are unknown as yet. Sheldrake therefore suspects that these exotic phenomena he describes will not be comprehensible within the framework of existing science, and postulates as a working hypothesis the existence of a "morphic field," or more generally, a "formative causation," referring to older traditions[18-20] for a description.

My considerations in the previous sections were intended to create a starting point for questioning critically, and possibly refuting, the exotic nature of his dynamic effects that Sheldrake suspects (and not their existence). To be more precise: I wish to investigate if and under what conditions Sheldrake's ideas have a chance in principle of being accepted on the terrain of present-day established modern natural sciences. On this point, I am not so pessimistic as most biologists who, like Friedrich Cramer in his contribution to this book, want to dump the baby out with the large quantity of "new age" bathwater that has accumulated today. I can fully understand the impulse to do so. But people draw the line between what they are just willing to believe, and what they consider utter nonsense, at different places. This limit is determined by subjective and objective factors. Objective confusion and accordingly justified unease is frequently created by the understandable temptation of the protagonists of new ideas to explain what is novel quite carelessly with terms and concepts that already have clear and well-understood meanings within established science. However, the scientist criticizing this should, for his part, also resist the temptation to declare it all nonsense because of this negligence. He should rather, to the best of his ability, try to translate back from the alleged phenomenon, which indeed often includes circular reasoning, to the originally observed facts, and begin with his own, supposedly more well-founded, considerations there. However, room should be made for the full intellectual scope of modern science in these "more well-founded" interpretations, and considerations should not be restricted to what seems immediately plausible to us from our macroscopic view.

It is certainly interesting and courageous of Sheldrake - in contrast to many "esoterics" - to make practical proposals[21] as to how his findings, which are (by his own account) not sufficiently supported empirically yet, can be checked by others, especially his critics. Since he himself does not have a suitable laboratory and funds at his disposal, he explicitly requests support by others. This book is intended to provide a constructive contribution to this. Sheldrake is familiar enough with the natural sciences to know how a scientifically well-founded set of measurements must be set up, and what the readings must look like, for them to be called a significant confirmation.

However, I should qualify this by adding that, even if his conjectures are not confirmed by the experiments he has proposed according to the usual scientific pattern, this need not mean a final refutation, in my view. For the special situation that an "objective" experiment requires by definition might perhaps damage or destroy his "morphic field." For quantum theory teaches us that every observation also causes an intervention in the "object" observed, after all. But, in the following discussion, I wish to exclude this loophole, which is always possible. Without further examination of the empirical facts, I will start with the optimistic assumption that Sheldrake's empirical claims have been confirmed experimentally, in a statistically significant fashion (with "a few standard deviations"), or that this proof can be provided in the future. In that case, we would certainly be faced with interesting "facts," which conventional science would have to attempt to interpret. Let me consider Sheldrake's morphic field and its various peculiarities under that premise.

First, the assumption that his fields are "exotic."

What Sheldrake finds particularly unconventional in his "morphic fields" is that they are supposedly not subject to strict mathematical laws, but can evolve. As a quantum-field theorist, I see no great obstacle in this. Such strictly defined laws of motion only occur for classical fields, such as the (classical) electromagnetic field, that obeys Maxwell's linear spatio-temporal partial differential equations, and the gravitational field, which obeys the nonlinear field equations of Einstein's General Theory of Relativity. There are indeed equations of motion in quantum field theory, but only for the space-time (x)-dependent field operators **O (x)**, which operate in a "potentiality space," an infinite-dimensional complex-valued vector space (a Hilbert space). Classical fields, M (x), can be derived from these if states are specified, namely as what are called "expectations" $M(x) = \langle Z | \mathbf{O}(x) | Z \rangle$ of these operators with respect to the states Z, or by forming "traces" M (x) = TRACE $[W_Z\, \mathbf{O}(x)]$ with the statistical operator W_Z of these states. This is not the place to go into more detail. For our orientation, it is only important to know that in this way, the associated classical fields M (x) are always a hybrid of a general operator field and a contingent state, which usually changes over time. By contrast to classical fields, a quantum-mechanical operator field is "genuinely creative"; it corresponds to a chain of destruction and creation processes.

Which quantum fields might play the role of Sheldrake's morphic fields?

In the material structure of matter, the electrons play a dominant role, since they are largely responsible for the spatial extension of the atoms, and the effective interaction between the atoms, due to their small mass. The much heavier atomic nuclei, which are made up of heavy baryons, in particular the nucleons, the proton and the neutron (which are almost 2,000 times heavier than the electron), play mainly the role of centers of attraction that compensate for the electrical charges of the electrons. Conceivable macroscopic quantum structures should therefore be due primarily to electron configurations. Because of the electrical charge of electrons, they have a long-range electrical dynamic effect (Coulumb interaction). In addition, any change in the spatial distribution of the electrons results secondarily in electromagnetic radiation, that is the generation of light quanta, of photons. Within a "body" (where heavy particles are present), electronic processes will therefore always be closely coupled to electromagnetic processes.

With regard to the ability of the morphic fields to control morphogenesis within organisms, the known quantum-mechanical collective phenomena of a magnetic type, as in ferro-magnets (magnetic spin waves), of an electrical type, as in superconductors (electrical currents of Cooper pairs of electrons), and of an electromagnetic type, as in the laser (light waves in various frequency ranges) might at first be considered as being possible candidates.

However, for information transfer outside of organisms, the only real candidate for the morphic field is the electrically neutral electromagnetic radiation field, because of the low concentration of heavy particles in the air. But the electromagnetic radiation field would have to have an extremely low energy, because it could not be detected with existing physical methods yet. Since the energy is proportional to the frequency

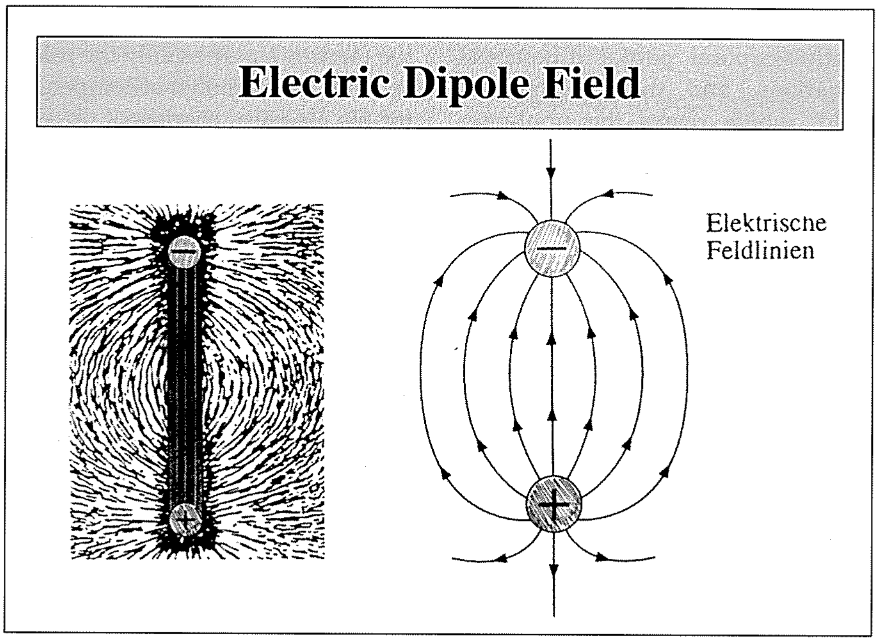

Figure 2: Electrical Field of Force

and the number of photons, this means that it could only involve sufficiently long-wave and weak (few photons) electromagnetic radiation.

Let us turn first to the possible physical processes within organisms. Studies of simple biological systems have in fact provided indications of the possible existence of such quantum-mechanical collective phenomena. However, these appear to be of a new type, based on the existence of molecular electric dipoles.

An electric dipole has a formal resemblance to a magnetic dipole. Magnetic dipoles are generated by the rotation of electrical charges. Thus, every electron with a single negative charge, in particular, has a certain magnetic moment, because of its intrinsic quantized angular momentum. It is, therefore, an elementary magnet. Elementary magnets lying close to one another try to align themselves in parallel, because of their interaction, if thermal agitation does not disrupt their alignment. Below the Curie temperature, this causes a strong magnetic polarization, as seen in ferromagnets.

An electric dipole is created if, in a system comprising a positive and a negative charge, such as a hydrogen atom, the two opposite charges are somewhat separated, like a dumbbell. Thus, the formation is electrically neutral (the negative charge compensates the positive one), but close by, an electrical field of force (see Fig. 2) turning back on itself is created (like in a bar magnet). There are many such "polar" molecules in which the positive center of charge of the atomic nucleus does not coincide with the negative center of charge of the electron shell, due to their asymmetric structure, so that they possess an electrical dipole moment, and are tiny electrets. The best-known example of a molecule with a relatively large electrical dipole moment is the water molecule (see Fig. 3). Much the same is true of ethyl alcohol, as well as of many molecules that occur in living organisms, in particular of DNA, enzymes, and proteins.

Electrets differ from their analogues, magnets, in two respects. Firstly, electrets can be aligned differently in space, like their magnetic counterparts (SU (2) symmetry degrees of freedom), but in contrast to them, their strength is not fixed (E (1) symmetry degree of freedom), since this depends on the distance between the opposite charges. This distance can be altered by external electrical fields. Secondly, if many small electrets were joined together, a sort of "ferro-electret" could be created; the interaction would be weaker in a side-by-side parallel alignment than in a head-to-tail parallel alignment. Therefore, fibre-type electrets form more easily than plane ferro-electrets. If the electrets were aligned successfully (breaking the SU (2) and E (1) symmetry), not only "electric spin waves" (by analogy to the magnetic Bloch spin waves) would occur (as low-energy Goldstone excitations), but also longitudinal waves: longitudinal oscillations along the dipole "fibres." But even in substances such as water, in which the molecule possesses a very large electric dipole moment, the ferro-electric state does not seem to be able to occur spontaneously, as in

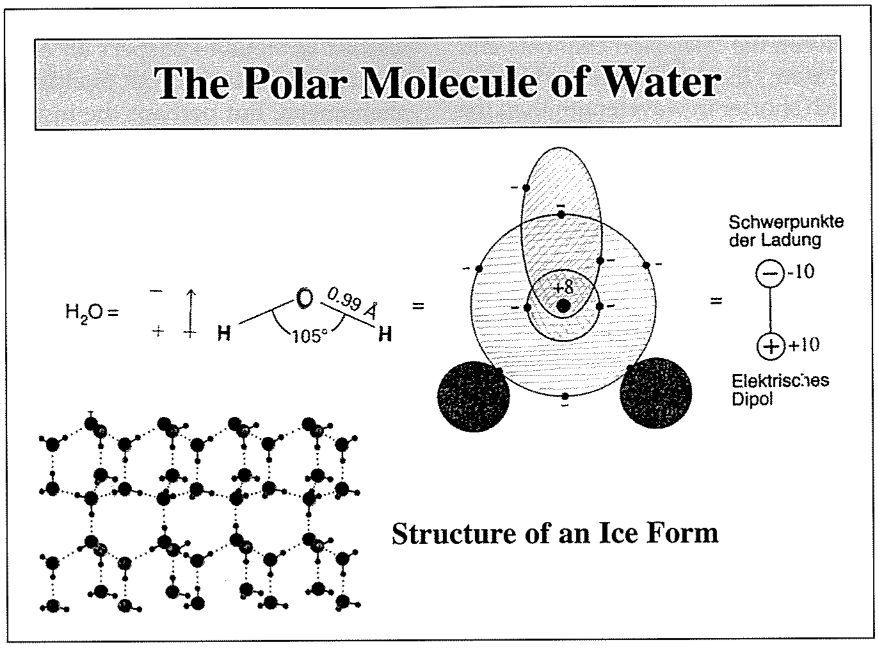

***Figure 3:** Water Molecule*

the magnetic case below the Curie temperature. However, it appears that this can be achieved in effect by a somewhat more sophisticated process. I would like to sketch this very briefly, despite its complexity, because it might provide an explanation for the mode of action of biological systems.

According to E. del Giudice and others,[17] the following general picture is obtained for a biological system:

The biological system consists, firstly, of a non-polar medium, in which the molecules do not possess an electric dipole moment, and which, being fed by metabolic processes, serve as a heat bath, as it were, of a definite, not too low, temperature. Secondly, it contains at least two bioactive components: the actual biomolecule and a substrate surrounding it, which is usually just water. Both of these components have a relatively large electric dipole moment. The biomolecule electrets align themselves along a one-dimensional fiber, due to the dipole interaction (breaking of the SU (2) rotational symmetry). Because of nonlinear interactions with the non-polar medium, bosonic electron pairs can congregate spatially at certain points of these "one-dimensional" fibers (breaking of the E (1) symmetry), and be excited into longitudinal oscillations along the fiber.[22, 23] Such local occurrences of symmetry breaking are known in physics as "solitons," and have been described. The electrical alternating current of the soliton oscillations induces a corresponding electromagnetic alternating field, which aligns the elementary electrets of the surrounding substrate (the water) and excites them to resonate. In this way, the rotational symmetry and the charge-spacing symmetry in the substrate are also "broken," causing corresponding low-energy Goldstone modes to occur in it (not only the two Bloch-equivalent spin-wave modes, but also an oscillation mode). Because of the finite size of organisms, the corresponding frequencies of the Goldstone modes are not zero, but of finite size. The symmetry breaking also results in a shielding of the Coulomb field, by the Anderson-Higgs-Kibble mechanism.[6, 24, 25] This makes a transition to what is called the "Fröhlich regime"[9] possible, in which the biological chain molecules resonate coherently with the water dipoles, and are supplied with energy by the surrounding non-polar heat bath. For this to function, a relatively high minimum temperature, at about the level of body temperature, is required. The biomolecules in the cell membranes, for example, oscillate at frequencies of about 10^{11}-10^{12} Hertz, that is to say, 100 to 1,000 Gigahertz. These frequencies are therefore in the range between the carrier frequencies of cellular radio telephones (2 GHz) and infrared radiation. Since the longitudinal oscillations in the biomolecule chains are linked to periodic charge displacements, electromagnetic waves of the same frequency are radiated. The process has a certain similarity to the superconducting state, but with spatially varying and oscillating charge densities, which is why radiation occurs. The wavelengths of the electromagnetic radiation field are in the centimeter-millimeter region in this case, and above the absorption band of water, of a few micrometers (5×10^{13} Hertz). So they can pass through and leave the aqueous organism largely unweakened. The energies of the photons of these waves amount to only a few hundredths of an electron volt, so that they can hardly be detected with present-day physical methods. Living organisms, on the other hand, due to their body's own extremely monochromatic vibration systems, might well achieve a sufficiently high sensitivity to photons to be able to perceive signals in this range. This resembles to some extent Sheldrake's morphic resonance. Their low energy could explain why this radiation has not been noticed yet. Contrary experience by Fritz-Albert Popp and his colleagues[26-28] seems to provide interesting starting points for an interpretation along these lines.

Let me cut short my more detailed description, which is probably difficult to follow in such brief form. All I wanted to do was demonstrate that these processes of quantum physics might in principle contain a fruitful potential for an explanation of Sheldrake's morphic fields. Further thorough investigations and critical discussions will be needed for this, no doubt.

According to these ideas, events within the living organism should be much more complicated than what is perceivable in their exterior environment. Externally, as far as I can judge, at most a weak electromagnetic radiation in the centimeter-millimeter range should occur (depending on the kind of biomolecule, perhaps down to tenths of millimeters and up to the decimetre range); in other words, in a wavelength band between the television channels and infrared. In this range, which is much shorter in wavelength than the cellular telephone channels (wavelength a few meters), fantastic amounts of information could be transmitted by amplitude and phase modulation, similarly to the transmission of the many independent telephone conversations. Because of the many, closely spaced low-frequency molecular lines (channels) there should be a sufficiently large bandwidth for this, as well. The various species-specific morphic fields would then presumably correspond to various forms of modulation of the carrier waves. These would thus be packaged in recognizable form in these carrier wave fields, as the individual telephone conversations are in the frequency band of radio telephony.

Since the centimeter and millimeter waves are only absorbed slightly by water and by air, the range of these waves at the Earth's surface could be very large, especially if we assume an extremely high sensitivity (detection of individual photons) of the living receiver systems. This could in principle make a long-range effect of the morphic fields understandable.

Of course, the assumption that electromagnetic radiation serves as the transmission system also means that such a conclusion calls for a physically possible, although technically difficult, verification. It should be possible to suppress these effects effectively by suitable shielding of the electromagnetic radiation field. Indeed, I would almost suspect that such investigations have already been carried out, since it always seemed obvious to suspect an electromagnetic cause to the Sheldrake phenomena. But perhaps the instrumentation obstacles are still too great. At any rate, there would be plenty to do for physicists here.

In conclusion, let me advise caution again. Perhaps the approach presented here is still too conventional. Since, in the final analysis, everything, truly everything is included and incorporated in the indivisible one potential reality, it should be possible to construct links of some other kind. These would, however, have less the character of a transmission of information between separate things vibrating at the same frequency (resonance), that is, of a communication as described here, but rather the character of a possible commonality or identification, a communion, such as associated with the Einstein-Rosen-Podolsky phenomenon (ERP). But then we would be confronted with the problem of how our consciousness at the level of the neo-cortex, which demands a "separation," a "congealing," a realization, or a more primitive system of perception, such as that of pigeons, could obtain such specific knowledge from this universal commonality to be able to react in a goal-directed fashion.

But all these are nothing much more than vague thoughts. Perhaps these speculations can provide fruitful incentives to further constructive and improved explanations, which demonstrate that they are appropriate by some unexpected observations, and lead to a deeper understanding of life and reality.

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"No man thoroughly understands a truth until he has contended against it."

– Ralph Waldo Emerson