The Game of the Biomousa: A View of Discovery and Creation*

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1 Introduction

No branch of science is explicitly devoted to studying world views and there are probably several reasons for this. First and foremost there is so little consensus within the same discipline, that very different and generally incompatible fragments of world views exist. On the other hand, there is a certain diffidence, perhaps even a taboo, about putting these fragments of world views, often the subject of enthusiastic discussions over coffee at scientific gatherings, into the form of a text. This diffidence is very marked amongst physicists because they know from experience how quickly, and for various reasons, such an attempt is dismissed as "unscientific" and "speculative". The world view fragment I would like to present here from the viewpoint of quantum mechanics should therefore be looked at in this light. It contains a number of aspects that are speculative and others that are directly based on recent experimental and theoretical data in quantum mechanics. Some parts are almost exclusively the result of the author's own personal beliefs.

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2 Quantum Mechanics and the Space View

Within the limited scope of this article it is not possible to discuss all aspects of the problems caused by quantum mechanics. We therefore refer the reader for a more detailed analysis to [1,2,3,4], were more explicit details of many aspects are contained as well as further references to other articles. Without fear of exaggeration, however, we can say that quantum mechanics differs from all previous physical theories in one very fundamental respect.

Until quantum mechanics was developed, a physical theory could, without causing too many problems, be regarded as a description of a part of reality that we can imagine. By this we mean the following: if we describe a classical physical entity using a classical theory, we can always "imagine" what happens to that physical entity and the description refers to what happens. For example, if we are describing a particle that is moving through space, we can "imagine" how this particle moves through space and classical mechanics describes what we have imagined. This no longer seems to be possible in the case of a quantum entity. Quantum mechanics gives us a number of rules that provide us with predictions about the chances of detecting a quantum entity in space; however, we are not able to imagine an object that is moving through space that is also compatible with the chances of detection offered by quantum mechanics.

Recently a lot of experimental and theoretical data has been gathered, which can be used to put forward a new view of the behaviour of a quantum entity. The aim of this article is to examine these data and to attempt to put forward a global view of reality that takes them into consideration. We shall call this global view the creation-discovery view. We shall be forced to abandon an old and profound preconception about the nature of reality if we adopt the creation-discovery view. This old preconception, which hinders our understanding of the micro-world, consists in believing that reality exists within space; we shall therefore refer to it as the space preconception.

Classical physics is also based on this intuition and there are various ways of describing the place occupied by a material entity in three-dimensional space. In the case of a rigid body, the position of the mass centre can be considered and the entity can then be described in a relative coordinate system with its origin in this mass centre. In the case of a liquid or gas, continuum mechanics is used, with the liquid or gas being described by means of a collection of points, present in that part of space where the mass density of the liquid or gas is different from zero. A wave, though often spread out, also has a place in our space. Whatever description of whatever entity may be considered in classical mechanics, the entity always has a place.

It does seem to be pre-scientifically a priori to assume that all material objects, both macroscopic and microscopic, are present at any given moment somewhere within our three-dimensional Euclidean space. Recent experimental and theoretical data have shown that it is very plausible to assume that quantum entities can find themselves in states, in which they are not present in space. According to the creation-discovery view, the view we would like to put forward here, space is no longer regarded as an all-encompassing setting. According to this view, detection of a quantum entity is not an "observation", but rather a "process", in which the detection apparatus "sucks" or "pulls" the quantum entity into space. This conflicts with our intuition since in our everyday reality every material entity has a place at any given moment.

In the creation-discovery view, we assume that the detection experiment contains an element of creation that partly creates the place "itself". This means that before the experiment, the quantum entity did not necessarily have a place and that the place is created by the experiment itself. An analogous process can be seen when determining the linear momentum (mass times velocity) of the quantum entity. The quantum entity has no particular momentum before the experiment that results in its momentum being created. Hence within this view, we no longer see space as an all-encompassing stage on which the whole drama of reality is enacted, but rather as a structure that we, as humans, have experienced, relying on our everyday experiences with the material macroscopic entities around us. We differentiate between the following two characteristics: 1. Every entity can be detected in space; space is therefore one of the structures through which we, as humans, encounter and create reality. 2. Every entity is present in space; space is therefore the stage on which everything real is enacted. The first characteristic is also valid for quantum entities, the second is not. In this way we adopt a new reality "statute" for space. Space as an "intermediate" meeting structure and not as an "all-encompassing" stage. Things make their place rather than simply have one. We can still find evidence in our everyday language of the change in meaning that the concept of space has undergone. We still say that space is the stage on which an event takes place. Events, since we still do not regard them as entities, can apparently still "find" their place in space, which means that they are not necessarily present in space before they have "found" that place.

To show why research in quantum mechanics has led us to the creation-discovery view, we shall briefly outline the latest findings in this discipline.

3 Is Schrödinger's Cat Dead or Alive or Neither?

If we want to use quantum mechanics as a universal theory and also use it to describe the entity comprising the measuring apparatus (a macroscopic entity) and the quantum entity, we find some very peculiar predictions. Schrödinger studied this problem in detail and we would therefore like to consider it from his cat's point of view [5]. Schrödinger devised the following mental experiment. Consider a room in which there is a radioactive source and a detector that can detect radioactive particles. There is also a glass bottle containing poison and a live cat in the same room. The detector is turned on for a period of time, during which it has a 1 in 2 chance of detecting a radioactive particle emitted by the source. If the detector detects a particle, a mechanism is activated that breaks the glass bottle, thereby releasing the poison and killing the cat. If the detector does not detect any particles, nothing happens and the cat lives. We can only learn the outcome of the experiment by opening the door of the room to see what has happened. If we make a quantum description, within orthodox quantum formalism, for the whole system (including the cat), the state of the cat (which we shall call p_{cat}) remains a "superposition state" of the two states "the cat is dead" (which we shall call p_{dead}) and "the cat is alive" (which we shall call p_{alive}) until the very last moment, i.e., when we open the door. To recapitulate,

$$p_{cat} = \frac{1}{\sqrt{2}}(p_{dead} + p_{alive}) \tag{1}$$

and this superposition state only ceases when we open the door to see what is happening. A considerable part of the basic problem of quantum formalism can be demonstrated by means of this example; we shall therefore examine it in detail. If we interpret the state, as it is described by the wave function of orthodox quantum mechanics, as a mathematical object that simply and solely describes our knowledge about the physical system, there is no problem with Schrödinger's cat. In fact, within this "perception of knowledge view" we can assume that the cat was already dead or was still alive before we opened the door, and that the quantum mechanical change in state only describes our cognisance of this fact. This "perception of knowledge view" also disposes of another problem: according to quantum formalism, while the door is being opened the superposition state $p_{cat} = \frac{1}{\sqrt{2}}(p_{dead} + p_{alive})$ "suddenly" changes into one of the component states p_{dead} or p_{alive}. This sudden change in state is known in quantum mechanical jargon as "the collapse of the wave function" and there is a natural explanation for it within the "perception of knowledge view". If the quantum wave function does in fact describe our knowledge of the situation, then this knowledge suddenly changes, as does this wave function, when we receive new information, such as when the door of the room is opened.

The "perception of knowledge view" therefore assumes that the wave function of quantum mechanics does not describe reality, which is independent of our knowledge of it, but rather it represents the cognition we have of this reality. It follows from this that, if the "perception of knowledge view" is right, an underlying reality must exist, which is not described by the wave function of quantum mechanics. In the example of the cat, this underlying theory provides a description of the cat's state, dead or alive, irrespective of whether we open the door to find this out. The "perception of knowledge view" therefore immediately gives rise to the hypothesis of the existence of a "hidden variable theory", which describes this underlying reality. And it is here that the problem with the "perception of knowledge view" arises. It can be demonstrated that the probability model of a theory, in which a "lack of knowledge" about an underlying reality is what causes the probability (called a hidden variable theory), always satisfies Kolmogorov's axioms. Kolmogorov's axioms (advanced by Kolmogorov in 1933) are those of classical probability theory, as already specified by Simon Laplace in the previous century. The quantum probability model does not satisfy Kolmogorov's axioms. John von Neumann was the first to prove a no-go theorem for the hidden variable theories [6]. The proof of the impossibility of reproducing quantum probabilities using a hidden variable theory was gradually perfected later [7]. Since the probability model of quantum mechanics does not satisfy these axioms, this theorem shows that the "perception of knowledge view" is not right. Recent experiments (concerning Bell inequalities) have confirmed that the "perception of knowledge view" is wrong.

It is now virtually a foregone conclusion that the wave function of quantum mechanics does not describe our knowledge of the system, but represents the actual state of the system, irrespective of whether we know this or not. However, if this is the case, then Schrödinger's cat creates a serious problem. Could it be that, before we open the door, the cat is in a superposition state, neither dead nor alive, and that this state is transformed into a state of being dead or alive by the door being opened? It does seem impossible to us that reality would react to our observations in this way. A reality where a state comes into existence because we take cognisance of it contradicts our everyday view of reality in so many respects that we can scarcely take the idea seriously. Nevertheless it seems to be an immutable consequence of orthodox quantum mechanics, applied to reality as a whole. Recently, with the emergence of the new formalisms, the fundamental concepts of which are much closer to reality, a completely different light has been shed on this problem.

4 New Formalisms and False Paradoxes

The paradox of Schrödinger's cat and many similar paradoxes of quantum mechanics are partly the reason why it is impossible to put forward a view of reality that is compatible with quantum mechanics. In fact, if the cat only lives or dies when we open the door, then only a subjective world view seems possible. There is a fundamental confusion between discovery and creation involved here. According to our everyday perception of reality, we believe that the cat is already dead or alive before the door is opened, and that finding a dead or a living cat is only a "discovery" of a reality that already existed. The application of quantum mechanics to this situation forces us to interpret this discovery as a "creation". The theoretical advances made in research in quantum mechanics, and more specifically the development of new quantum formalisms, have resolved paradoxical situations such as that of Schrödinger's cat. The conclusion is that orthodox quantum mechanics is not a universal theory, but rather a formalism that is only valid under limited circumstances. Since these findings lie partly at the origin of the development of the creation-discovery view, they will be discussed briefly.

These new formalisms are very general. A very general formulation of the new formalisms is that of Charles Randall and David Foulis [8] and a more physical formulation is that of Piron and Aerts [9, 10, 11]. An entity S is described by means of the collection of its states. A state describes the reality of the entity S. No specific mathematical structure is imposed a priori on the collection of states, as is the case in quantum mechanics (a Hilbert space) and in classical mechanics (a phase space). Furthermore, it is assumed that experiments are carried out on the entity S and the collection of relevant experiments is explicitly examined. Once again no mathematical structure is fixed a priori for the collection of these experiments, as is the case in quantum mechanics and classical mechanics. It is merely assumed that when an entity S is in a particular state and an experiment is carried out, a result is achieved with a certain probability. The original state is hereby changed into a new state. In this way the measurement process can be described in general terms. If no measurement is made, the entity S is still in a particular state, which then changes as time goes on. This dynamic change is described by the Schrödinger equation in the case of quantum mechanics, and by Newton's equations in the case of classical mechanics.

In this new general description it is very possible, even natural, to discern special experiments. Hence the concept of "classical experiment" is introduced: an experiment devised in such a way that there is always a predetermined result for every state of the entity S. A classical experiment is therefore an experiment where the result is fixed with certainty, even before the experiment is carried out. Generally speaking, the collection of relevant experiments will include some classical experiments and some non-classical experiments. It is possible to prove a theorem in which the classical part of the description of an entity is kept separate [12, 13]. The collection of all states can then be described as the union of a collection of classical mixtures, where every classical mixture still contains a collection of microstates that are non-classical. If quantum mechanical axioms are formulated based on this general situation, it can be demonstrated that the collection of states within one classical mixture can be represented by a Hilbert space. The collection of all of the states of the entity is then described by means of an infinite collection of Hilbert spaces, one for each classical mixture. Orthodox quantum mechanics emerges here as a limiting case, in which not a single classical measurement exists, and the representation then gives rise to one Hilbert space. Classical mechanics is the other limiting case, in which only classical measurements exist, and the representation then gives rise to a phase space description. The general situation of an arbitrary physical entity is neither pure quantum nor pure classical and can only be described by means of a collection of various Hilbert spaces. If the measurement process is viewed within this general framework, the problem of Schrödinger's cat disappears. Opening the door is a classical measurement that does not change the state of the cat in any way, and it can be described in this way within this general formalism. The quantum collapse occurs when the radioactive particle is detected by the detector, and this process is non-classical, even in the description within the general formalism.

It's not only the paradox of Schrödinger's cat that is resolved within this general formalism. It is also possible to regard quantum mechanics and classical mechanics as two special cases of a more general theory. This general theory is "quantum-like" but causes no paradoxes for the measurement process because the measuring apparatus is described within the same formalism as a classical entity and the entity to be measured as a quantum entity. In conclusion we can state that the measurement paradox is due to the structural limitations of the orthodox quantum formalism.

5 The Einstein-Podolsky-Rosen Paradox and the Quantum-Classical Relationship

The perpetual existence of the superposition states, which caused paradox of Schrödinger's cat (the superposition state of the living and the dead cat), was used by Einstein, Podolsky and Rosen to formulate a much more subtle paradoxical situation. Einstein, Podolsky and Rosen considered the situation of two separated entities S_1 and S_2 and the composite entity S composed of these two separated entities. They demonstrated that it is always possible to put the composite entity S into a state such that measurement of one of the component entities determines the state of the other component entity. In a situation involving separated entities, this is a prediction of quantum mechanics that conflicts with the "separated" concept itself. In fact, in the case of separated entities, the state of one of the entities is not determined by what is done with the other entity, a fact confirmed by the experiments that we can carry out on separated entities.

Once again if we look at this situation from the point of view of the new formalisms, the paradox can be explained. If we consider the situation of two separated entities, it is possible to prove that the entity S, which is composed of the two separated entities S_1 and S_2, never satisfies the axioms of orthodox quantum mechanics, not even if classical experiments are conducted, as was the case in the measurement paradox [10, 11, 14]. There are two axioms in orthodox quantum mechanics (known as "weak modularity" and "the covering law" in the jargon), which are never satisfied for the situation involving an entity S composed of two separated quantum entities S_1 and S_2. The shortcoming of orthodox quantum mechanics identified here goes much deeper structurally than the one discussed earlier in connection with the measurement problem. In the latter case it is possible to put forward a solution where one Hilbert space in orthodox quantum mechanics is replaced by a collection of Hilbert spaces. This solution is manageable within the framework of the Hilbert space formalism. The inability of orthodox quantum mechanics to describe separated entities lies in the vector space structure of the Hilbert space itself. The two "bad axioms" are the axioms that give rise to the vector space structure of the Hilbert space and if we remove these axioms in order to describe separated entities, we have to construct a completely new mathematical structure for the state space. This, however, is what recent findings tell us to do and it is the only way to free quantum formalism from EPR-type paradoxes in connection with the description of separated entities. Work is under way on this within the new formalisms.

It is a serious mathematical step to abandon the vector space structure for the collection of states but recent new findings have confirmed the necessity of such a step. The possibility of examining both classical entities and quantum entities from the viewpoint of the general formalism resolves the measurement paradoxes. However, the possibilities as regards description remain polarised between classical and quantum or generally a mixture of both. Very recently we began to explore intermediate regions (between classical and quantum; the so-called mesoscopic region) from the viewpoint of this general formalism. Once again the same two axioms seem to make a description of intermediate regions impossible [15, 16]. If we formulate a theory without these two axioms, we can describe quantum, classical, a mixture of both, and also intermediate mesoscopic entities, which are neither quantum nor classical. This approach would enable us to describe a continuous transition from quantum to classical.

In conclusion we can state that orthodox quantum formalism has several fundamental shortcomings, which have now been identified. By resolving these paradoxes, quantum mechanics (more specifically the "quantum-like" generalised formalisms) is freed from the subjective predictions that were an immutable part of the orthodox theory.

6 The New Experiments

It is evident to us from experiments that Schrödinger's cat does not live or die because we open the door and that the state of one of the two separated entities is not determined by what is done with the other entity. We have been able to explain these paradoxical predictions of orthodox quantum mechanics as being the result of a structural shortcoming of the mathematical formalism. However, it is not at all evident from experiments what these special quantum effects, connected with these superposition states, where they do exist, actually mean. Some physicists have gone so far as to insinuate that perhaps certain superposition states in question do not exist at all and are just mathematical artefacts of the theory. Recent experiments have shown, however, that it is actually possible to prepare quantum entities in these superposition states. We shall briefly mention a few aspects of these experimental results.

In experiments with very low-energy neutron beams, Helmut Rauch and his group succeeded in putting one neutron within a silicon crystal into a superposition state of two states located far apart [17, 18]. In the experiment, the silicon crystal has a diameter of over five centimetres and the two component states are states of a neutron that is located within cubes A and B with edges measuring one millionth of a centimetre. Location A of one component state, which we shall call p_A, is over three centimetres away from location B of the other component state, p_B. The neutron was prepared by Rauch in a superposition state p_{sup} of these two component states, in other words $p_{sup} = \frac{1}{\sqrt{2}}(p_A + p_B)$. If the neutron is in state p_{sup} and detection is initiated in one of the two areas A or B, there is a 1 in 2 chance of detecting the neutron in area A and a 1 in 2 chance of detecting it in area B. Rauch and his group succeeded in verifying that the neutron was in a superposition state p_{sup} because they conducted additional experiments on the neutron in this state. One of the most fascinating of these additional experiments involved rotating the spin of the neutron. Using a magnetic field located in area A, Rauch rotated the spin of the neutron in the superposition state p_{sup}. The result of a precession over an angle of n degrees through the magnetic field in area A on the component state p_A results in an actual rotation of $\frac{n}{2}$ degrees, as predicted by means of the superposition principle. A simultaneous rotation over n degrees of the other component state p_B, using a magnetic field in area B, also results in the spin of the neutron in the superposition state rotating $\frac{n}{2}$ degrees. Rauch conducted all kinds of additional experiments, which all correspond with the quantum description of one neutron in the superposition state of the two component states located far apart [19]. These experiments, and many others, prove the existence of the superposition states in question, and the question we can now ask ourselves is whether we can draw conclusions from these experiments concerning the physical meaning of the superposition state. Before answering this question, we would like to discuss another problem of quantum mechanics that is closely linked with the possibility of suggesting a physical meaning for the superposition states.

7 The Origin of Quantum Probabilities

We have already mentioned that the "perception of knowledge view" is not right and we have also explained how it offered a natural solution for the situation of Schrödinger's cat. The "perception of knowledge view" did more than provide a solution for Schrödinger's cat; it also presented a simple "classical" explanation for the existence of quantum probabilities. In fact let us argue once more from the point of view of the "perception of knowledge view", where the underlying reality is not described by the wave function, but by a hidden variable theory. In this situation quantum probability is the natural result of our lack of knowledge about this underlying reality. This is also how classical probability is explained, so it should come as no surprise to us that the aforementioned theorem exists, in which theorem it is proved that every hidden variable theory gives rise to a probability model that satisfies Kolmogorov's axioms. Kolmogorov did, after all, formulate his axioms for the classical probability theory. Since the probability model of quantum mechanics does not satisfy Kolmogorov's axioms, with the result that the "perception of knowledge view" cannot be sustained, we have to look for a new non-classical explanation for the origin of quantum probability. Quantum probability is not the result of our lack of knowledge about a deeper reality, as is the case with classical probability.

It is sometimes suggested that these quantum probabilities are intrinsically part of nature, and we then talk about "ontological probabilities". No-one seems to be able to "understand" this kind of probability, however; hence it has never gone beyond a vague abstract concept of "ontological probabilities". There is a third possibility, though, and we would like to illustrate this by means of an example.

Suppose that we are considering the following experiment: "We take a walnut from a basket and we crack the walnut in order to eat it." Let us elaborate on the way in which we crack the walnut. We do not use nutcrackers, but simply take it between both hands and squeeze as hard as we can and see what happens. Anyone who has ever cracked walnuts in this way knows that various things can happen. The first occurrence we want to identify is when the walnut turns out to be mouldy. (1) If a cracked walnut is mouldy, we do not eat it.

Let us now suppose that there are N walnuts in the basket. This means that for a given nut, which we shall refer to as H_k, there are two possible outcomes of our experiment, which we shall refer to as E_1: we crack the nut and eat it, and E_2: we crack the nut and do not eat it. Suppose that of the N nuts in the basket, M are mouldy. The probability that our experiment will result in E_1 for a nut H_k is $\frac{N-M}{N}$, and the probability that our experiment will result in E_2 for the nut H_k is $\frac{M}{N}$. This probability is the result of our lack of knowledge about the complete reality of the nut. In fact, before we start cracking the nut H_k, it is either mouldy or not. If we could gain this knowledge without having to crack the nut, we could eliminate the probability arising from this lack of knowledge by only considering the nuts that are not mouldy. Classical Kolmogorovian probability theory is based on this assumption about the nature of the probability that exists.

Anyone who has experience of cracking walnuts knows that other things can happen too. Sometimes we destroy the nut by breaking it, so that it becomes mixed up with the broken shell. If that happens, we generally make a quick assessment of how serious the situation is and decide whether it is worthwhile separating the nut from the shell. If it is not worthwhile we do not eat the nut. Hence there are a further two possible outcomes of our experiment: E_3, which corresponds to a "badly cracked nut", in which case we do not eat the nut, and E_4, which corresponds to a "well-cracked nut", in which case we do eat the nut. We can again state that for a given nut H_k, the two outcomes are possible and each outcome will occur with a certain degree of probability. We sense right away, however, that this type of probability is different to the previous type because it depends on the way in which the nut is cracked. Unlike the previous case, where M walnuts are mouldy and $N - M$ walnuts are not mouldy, we cannot divide the nuts in the basket "beforehand" into those that will be "well cracked" and those that will be "badly cracked". This kind of division does not exist because it is created by the cracking experiment itself. We have here a good example of how part of reality is created by the measurement itself, namely the cracking of the walnuts.

The most interesting aspect is that the mathematical structure of the probability model needed to describe the probabilities that ensue from cracking the walnuts well or badly is different from the mathematical structure of the probability model needed to describe the probabilities that ensue from the walnuts being mouldy or not mouldy. More particularly:
-The probability structure that describes the indeterminism that is the result of a lack of knowledge about a more complete reality of the occurrence in question is a classical Kolmogorovian probability model (this situation fits within the "perception of knowledge view").
-The probability structure that describes the indeterminism that is the result of the fact that while the measurement is being carried out a new part of reality is created, which did not exist before the measurement was carried out, is a quantum-like probability model.

We cannot demonstrate these two statements within the scope of this article but we can refer the reader to the articles in which these statements are proved and illustrated by means of examples [1, 20, 21, 22].

It can also be proved that every quantum mechanical entity can be obtained by means of a model, where the cause of the quantum probability is a lack of knowledge about the interaction of the measuring apparatus with the quantum entity during the measurement experiment, in the course of which a new part of reality is created that did not exist before the measurement was carried out [11, 21, 22]. This is the explanation for quantum probability we would like to advance.

8 Discovery and Creation: The Role of Space

Let us assume that we have been able to remove all of the mouldy nuts from the basket, leaving only nuts that are not mouldy. In the jargon of physics, we shall say that each individual nut is in a pure state, with regard to the property of being mouldy or not. In the original situation, when the mouldy nuts were still present in the basket, an individual nut was in a mixed state of mouldy and not mouldy, with weights $\frac{M}{N}$ and $\frac{N-M}{N}$. In the situation under consideration, we have a basket of walnuts that are not mouldy and with reference to this we would like to introduce the concept of "potential". With regard to being mouldy or not mouldy, we could claim for each walnut that it was mouldy or not mouldy before the experiment. With regard to being "well cracked" or "badly cracked", we cannot describe the walnut as such before cracking is measured. What we can claim is that each walnut is potentially well cracked (and is then eaten) or potentially badly cracked (and is not eaten).

No-one has any difficulty understanding the example of the walnut. Our proposition is that we should try to understand quantum probability in the same way. The only difference is that the measurements in quantum mechanics, where the second type of probability is introduced (due to the fact that a new part of reality is created during the measurement), are measurements for which such a creation is difficult to imagine. For example, the detection of a quantum entity is just such a measurement: whereas we would intuitively like to consider detection as the "determination of position", a position that already existed before we began the measurement to determine it, we have to learn to accept that detection of a quantum entity contains an element of creation of the position of this entity during the process of detection. Walnuts are potentially "well cracked" or "badly cracked" and quantum entities are potentially within or outside a particular area of space. The experiment that consists in finding the quantum entity within this area of space or not finding it within this area, takes place after the measuring apparatus needed to detect this has been set up in the laboratory, and the interaction of the quantum entity with this measuring apparatus has begun. Before that the quantum entity is potentially present and potentially not present within this area of space.

Note that this explanation for quantum measurements forces us to look at the concept of "space" in a new way. If a quantum entity, in a superposition state, is only potentially present within an area of space, we can no longer regard space as the stage for reality as a whole. Rather space is a structure that has developed along with the classical relationships between macroscopic physical entities. These macroscopic physical entities are always present within space because space is simply a structure in which they are always present, but this is not the case for quantum entities. In a normal state a quantum entity is not present within space; it can only be pulled in by a detection experiment. This process of pulling into space is associated with the second type of probability (as with the cracking of the walnuts) because the place of the quantum entity is partly created during the process of detection. The neutron in the Rauch experiment is not within space. It can be detected in two different areas of space, A and B, but the fact that this always occurs in these two areas is due to the fact that a detection experiment pulls the neutron into one of these two areas.

The experiments concerning the Einstein-Podolsky-Rosen paradox can also be easily understood within this discovery-creation view. Involved here are two quantum entities S_1 and S_2, which can be prepared in a superposition state p_{sup} of two component states p_{12} and p_{21}. The component state p_{12} is a state where entity S_1 is present within an area of space A_1 and the other entity S_2 is present within an area of space A_2, while component state p_{21} is a state where entity S_2 is present within area A_1 and entity S_1 is present within area A_2. These two areas A_1 and A_2 are located far apart (12 metres in the case of the photon experiments) and measurements are carried out within areas A_1 and A_2. These measurements produce results that would seem very contradictory if we were to interpret the situation from the viewpoint of a "perception of knowledge view" or "hidden variable theory", where we would assume that the two entities S_1 and S_2 are already present within areas A_1 and A_2 before the measurement is carried out, and we only have a lack of knowledge about exactly where the entities are. With the creation-discovery view, where we assume that the detection measurement involves an essential creation of place, and hence that before the measurement is carried out the two entities S_1 and S_2 are not already present within areas A_1 and A_2, there is no problem interpreting the measurement results. The violation of Bell inequalities is even a natural phenomenon in this creation-discovery view, which can be perfectly imitated by means of macroscopic physical entities [1, 22].

9 The Creation Process: The Biomousa

We would like to try to extend the findings concerning the non-spatial character of quantum entities, and the way in which this is explained in the creation-discovery view, to reality as a whole. Hence we can distinguish different layers of reality: pre-material layers, the material layer, the biological layer, the social layer and the cultural layer. Note, however, that this is a greatly simplified representation. The localisation process of quantum entities is the bridge between the pre-material and the material layer of reality, and that is the way in which the material entities are rooted in the pre-material layer. Similarly, every layer is rooted in the previous layer (biological in material, social and cultural in biological) and a similar structuring process describes the "existence" of the entities over the layers. In the creation-discovery view, the entities in the cultural layer (languages, communications systems, works of art, theories, and so on) are not simply regarded as human creations, but also as new entities for a nascent reality. Things have always happened in this way: what we now call matter was once a vague and rather insubstantial structure. When neutrons, protons and electrons were busy deciding whether to organise themselves into atoms, atoms were world views. When atoms organised themselves into macroscopic matter, this macroscopic matter was a world view. When cells organised themselves into plants, animals and humans, these entities were world views. World views are precursors of reality.

This classification of reality into different layers contains an explicit idealisation because the different layers are not really separated. The material layer is the most important one for our present way of life. It is made up of the organisation of atoms. This organisation is so complex that the atoms, as individual entities, no longer fit into the most fundamental aspects of this reality. According to quantum mechanics, the atoms, and even the initial structures in which atoms started developing material reality, are not in space in most of the cases. The biological layer is the layer of living matter. It is not a fundamental new layer, but rather a choice in favour of the power of perpetuation of macromolecules, which have organised themselves into self-replicating organisms, with the DNA molecule as the basic module. The social layer is the layer where living organisms interact with one another and try out new perpetuating entities: the hunt as the entity that provided food for everyone, the table as the entity where people eat together, and the house as the entity where people live together. The cultural or intellectual layer is the latest and most fragile achievement. In this layer world views provide fresh impetus for developing greater perpetuating entities. Cultural products and the creations of the human mind exist in this layer and are seeking the space, the world view, in which they belong. Individuals who travel between two cultures will not necessarily be present in the reality of a culture, just as quantum entities that travel between two macroscopic entities are not necessarily present in the reality of these macroscopic entities, a reality that we situate within space.

Long ago only pre-material quantum entities existed in a pre-material layer. They organised themselves into matter and space as a meeting place for this matter was created. The same creation process that began in the pre-material layer is now fully under way in the cultural and intellectual layer, and new small phases constantly appear. We shall call this creation process "the Biomousa" ("Biomousa" or "muse of life").

10 Entropy and Creation: Boltzmann and Statistical Mechanics

According to the second law of thermodynamics, the entropy of a closed system cannot decrease. It is often maintained that entropy is a measure of the disorder of a system and if this is so, the second law of thermodynamics seems to be at odds with the idea of a creation process that produces entities with a great power of perpetuation. We would like to examine how this situation arises within the creation-discovery view. First let us clarify the concept of entropy. There appear to be two layers of reality where entropy plays a fundamental part and we shall see that this is no coincidence.

Originally entropy was introduced in the material layer of reality. Ludwig Boltzmann was fascinated by the idea that matter is made up of a vast number of atoms. At the end of the nineteenth century, when Ludwig Boltzmann developed his theory, atomic theory had not yet been proved and was far from being generally accepted. Boltzmann believed in the existence of atoms but many important physicists did not share his view. In his search Boltzmann tried to understand some important, and at the time very topical, problems, using this theory as his starting point. The industrial revolution in the nineteenth century had created tremendous interest in the steam engine, more specifically physicists and engineers were working intensively on the problem of converting heat into mechanical work. It was known that mechanical energy could easily be converted into heat, for example by friction, but the reverse process did not seem so simple. Cold water can be mixed with hot water to obtain lukewarm water, but what about the other way round? What were the laws of nature that stood in the way?

The introduction of the concept of entropy shed some light on the subject. Let us consider an example: a drop of hot water has a certain entropy, which we shall call $S(hot)$, and a drop of cold water also has a certain entropy, which we shall call $S(cold)$. If we consider two drops of water, one hot and one cold, then these two drops of water have an entropy $S(hot + cold)$, which is the sum of the original entropies, $S(hot + cold) = S(hot) + S(cold)$. If we mix the drop of hot water and the drop of cold water, thereby obtaining two drops of lukewarm water, then the entropy of these two drops of lukewarm water, $S(lukewarm)$, is much higher than the sum $S(cold) + S(hot)$. By mixing hot and cold water we have increased the entropy, and this is an irreversible process. This principle is expressed in the second law of thermodynamics: in every physical process for a closed system entropy remains constant or increases. This principle explains why heat can only partially be converted into mechanical work; the concept of entropy was therefore vital for what Boltzmann was trying to understand.

Let us consider for a moment what a drop of water is according to atomic theory, in which Boltzmann firmly believed. The molecules contained in a drop of cold water can occur in many different configurations. They dance about and vibrate and their configuration changes constantly. All of these configurations would look different if we could observe them at microscopic level, but with the naked eye they all appear alike, i.e., like a drop of cold water. When we speak of a drop of cold water, then we are referring to an entity that has many different states at microscopic level, without this changing its macroscopic aspect in any way. Boltzmann's discovery was that entropy is a measure of this indeterminacy at microscopic level.

The entropy of a drop of water is the logarithm of the number of "microscopic" states that macroscopically give rise to an identical drop of water, multiplied by a constant k, which is known as Boltzmann's constant. Can we understand this effect of increasing the possible microscopic states of a mixture? Let us try with the help of an example. Let us assume that we have some red balls and some yellow balls that we can put into compartments. To make the experiment more specific, let us consider a case where we have three different compartments in which we can place the red balls. Only one ball can fit into each compartment and this can result in $2^3 = 8$ different configurations. Let us list the possibilities: $(,,), (,,r), (,r,), (r,,), (,r,r), (r,,r), (r,r,), (r,r,r)$, where $(,r,)$ means "first compartment empty", "second compartment occupied", and "third compartment empty". In general, if n compartments are available, this gives us 2^n different configurations. Where $n = 2$, this gives $2^2 = 4$ configurations; where $n = 3$, this gives $2^3 = 8$ configurations, which are listed above; and where $n = 4$, we have $2^4 = 16$ different configurations. It can be seen that if we allow n to increase, we quickly reach a very large number of configurations. For example, $n = 25$ gives us $2^{25} = 33,554,432$ configurations and $n = 100$ gives us $2^{100} = 126,750,600,000,000,000,000,000,000,000$ configurations, which is a huge number. Let us now assume that we also have yellow balls that can be put into compartments too. For three compartments, this gives eight different configurations once again: $(,,), (,,y), (,y,), (y,,), (,y,y), (y,,y), (y,y,), (y,y,y)$. Now let us look at the two entities together, in other words on one side red balls and on the other yellow balls that can be put into compartments. In the case of two times three compartments, the number of configurations possible is $2^6 = 64$. We shall not list them all but instead we shall give an example: $(\ ,y, \ ,r, \ ,r)$, a configuration that is the combination of $(\ ,y, \ )$ and $(r, \ ,r)$. In this case the yellow balls were not mixed with the red. If we now consider mixtures, then $(r, \ ,y, \ ,y,r)$ is also a possible configuration. How many mixture configurations of this kind are there? Each of the six compartments can either be occupied or not occupied by a red ball or a yellow ball. This gives $3^6 = 729$ configurations, which is much more than the 64 non-mixed configurations. This difference between mixed and non-mixed configurations becomes much greater as the number of compartments increases.

Why do drops not separate out? Boltzmann's line of reasoning went as follows: given that no preferred microstates exist and that the chance that a certain mixture will move towards a particular microstate owing to arbitrary external influences is therefore the same for every microstate, very improbable states will virtually never occur. Let us look at our example again. If every microstate has the same chance of being realised, then this corresponds in our case to 1 chance in 729. The chance of changing into a non-mixed configuration is then 64 in $729 = 0.087$, less than one chance in ten. In our example this still amounts to a good chance and in fact in the case of red and yellow balls that are divided between 6 compartments, there will be a fairly probable chance of finding a non-mixed configuration, i.e., only yellow balls in the three left-hand compartments and only red balls in the three right-hand compartments. Let us now try to make our example a bit more realistic in comparison with the actual situation of mixtures of matter. For n compartments, the chance of finding a non-mixed configuration (only yellow balls in the $n/2$ left-hand compartments and only red balls in the $n/2$ right-hand compartments) is $\frac{2^n}{3^n} = (2/3)^n$. This chance becomes very small as n increases because the limit as n approaches infinity of this variable is nil.

The number of molecules in a sample of matter may be estimated at about 10^{24} and the number of microstates of this enormous accumulation of molecules, which give rise to the same macrostate, is very large. If we are describing the sample of matter by means of classical statistical mechanics, as was the case in Boltzmann's day, we have to replace the concept of "number of microstates" with "volume in phase space". The scope of this article does not allow us to put forward an exact calculation because we would have to introduce the concept of phase space. Nevertheless, we would like to further discuss a highly simplified (and strictly speaking mistaken) view, where we would simply present the sample of matter as an accumulation of individual molecules and only the number of these molecules would be used in the calculation of the entropy. We therefore assume that the sample of matter consists of 10^{24} spaces, each one of which can be filled by a molecule. To find out what the chance is of a mixed situation changing into a non-mixed situation, we have to calculate (2/3) to the power 10^{24}. The chance is something like 1 divided by 10 to the power 10^{23}, which is an extremely small chance. Let us develop this example further in order to get an idea of how small this chance really is. Assume that every nanosecond (1/109 seconds) a new configuration of 10^{24} compartments is filled with red and yellow balls, which more or less corresponds to the frequency with which these kinds of changes in configuration could take place for real molecules. For each change in configuration the chance of a non-mixed configuration is 1 divided by 10 to the power 10^{23}. Using probability theory, we can then calculate how many changes in configuration have to take place for there to be more than a 1 in 2 chance of finding a non-mixed configuration at least once. This produces a figure of 0.7 times 10 to the power 10 to the power 23. If we assume that a change in configuration occurs every nanosecond, then we have to wait 0.7 times 10 to the power 10 to the power 23 nanoseconds in order to have more than a 1 in 2 chance of finding a non-mixed configuration at least once. The age of the universe is estimated to be 10 billion years, which is 10 to the power 26 nanoseconds. We would therefore have to wait 10 to the power 10 to the power 22 lifetimes of the universe. This is unimaginable and actually boils down to the fact that the realisation of a non-mixed configuration is so improbable that it will never happen, not even at the level of the age of the universe. The chance of changing from a mixed situation to a non-mixed situation is therefore unimaginably small. The same holds for a mixture of two drops of water, one cold and one hot. The configuration of two drops of water divided up into a cold drop and a hot drop exists, but is so improbable that a spontaneous change to such a state never occurs.

Boltzmann's reasoning is the subject of great debate because it is an attempt to explain the irreversibility of certain macroscopic processes starting from reversible microscopic processes. Although this is a very important issue and debate is still raging, we shall see that the problem of irreversibility manifests itself in a much more crucial way in the creation-discovery view. We would just like to note that Boltzmann's reasoning perhaps does not prove irreversibility, but it does enable us to understand why there is a spontaneous conservation of or increase in entropy before a change occurs in a closed system. The fact that structures we know "go to ruin", attacked by "the ravages of time", is an expression of this reasoning. The pyramids of Cheops are silting up because the configuration of stone crystals, built over three thousand years ago by the Egyptians, has a lower entropy than normal desert rock. Mountain ranges are eroded by rain because a sharp mountain peak has a lower entropy than a flat wasteland of rocks and mud. When you go for a walk along the beach, you will never see the sea and wind form a sandcastle as if by magic because a sandcastle has a much lower entropy than a pile of sand. Sugar never spontaneously separates from the coffee in a cup of sweet coffee because the coffee and sugar mixture has a much higher entropy than coffee and sugar separately. If we watch a film in reverse and see how a cigarette "unsmokes" itself, and how our best friend dives out of the swimming pool onto the diving board, and how eggs jump out of the pan and back into their shell, then we are flouting the second law of thermodynamics.

All entities of the construction process that are fixed in a particular layer of reality are struggling against this second law of thermodynamics. A table has a much lower entropy than a random collection of pieces of wood and iron, and that is the reason why tables do not come into being spontaneously. A hunt, as a social entity, has a much lower entropy than the random actions of a group of people, and that is why a hunt does not arise spontaneously. A book has a much lower entropy than a random collection of sheets of paper, and in turn a sheet of paper has a much lower entropy than a random sample of wood pulp, and that is why no books come into being spontaneously. Living beings (plants, animal and humans) are entities that offer "resistance" to the second law of thermodynamics. The way in which molecules are organised within living matter corresponds to a local decrease in entropy. What is the driving force behind this struggle against the second law of thermodynamics? Do we understand this second law enough to be able to formulate a response to this question? To clarify this point, we would now like to study the other layer of reality where the concept of entropy has had success.

11 Shannon and Information Theory

As already mentioned, entropy is introduced in the material layer of reality. In 1948 Claude Shannon published a article in which he laid the foundation of information theory [23]. Like Boltzmann in his day, Shannon was interested in an important and topical problem: how can information be efficiently transmitted? In his article he introduces the concept of information content of a message. The length of a message is certainly related to the information content of the message, but it is also evident that messages of different lengths can have the same information content, for example, the same message in different languages. The reason for this is that there is often redundancy, which makes the message much longer than its information content, so that the information content actually depends on what are considered to be permitted messages of a given length. If all the permitted messages of a given length are known and are numbered, there is no redundancy in this numeration and the size of the code number can be regarded as a measure of the actual information content. Hence Shannon defines the information content of a given message as the logarithm of the number of permitted messages. The information content of a message is usually given in bits. A bit is a binary digit. The idea is that the message is translated into a binary alphabet with two symbols 0 and 1 and its length is then measured. If the text I am writing now has an information content of $10,000$ bits, that means that if I were to translate the same text into machine language, using only 0 and 1, I would need a string of $10,000$ characters to set it down, and this string would be chosen from a possible $2^{10,000}$ of these strings of $10,000$ characters.

Can we identify the second law of thermodynamics in this cultural layer of reality? The amount of information in a text is entered by Shannon and corresponds to the entropy of a material substance. The microstates for the material layer are determined by the states of the molecules that make up the sample of matter in question, and the entropy is the logarithm of the number of microstates. In the case of the cultural layer, the entropy of a text is determined by the amount of information needed to store this text.

What would be analogous in the cultural layer with mixing matter in the material layer? We propose the following: suppose that two people want to write a text together, in other words a joint text, and to make the analogy clear, suppose that one of the two people writes in red ink and the other in yellow ink. A non-mixed text is one in which one person has written the first half and the other person the second half. Suppose that we digitise the text and that there are n spaces available. In a randomly mixed text, every space can be empty, or can contain either a red character or a yellow character. This gives 3^n different possible configurations. In 2^n of these configurations, the first half of the text is written by one person and the second half by the other person. Where a text of n bits is written jointly, the chance of a non-mixed text being spontaneously created in this way is $(2/3)^n$, the same chance of finding a non-mixed configuration in our earlier example of the red and yellow balls that can be put into n compartments. This chance again becomes very small when n is large. Let us look at an example. The text that is being created here takes up $10,000$ bits in memory. If this text were to be written by two people, the chance of a non-mixed text is $(2/3)^{10,000} = (1/10)^{18,031}$ (a decimal point followed by $18,030$ noughts followed by a 1). We can also express this differently: if a text of $10,000$ bits is written and stored by two people, so that the red letters of the first person are still distinguishable from the yellow letters of the second person, this will need a memory of $10,000$ bits multiplied by $log3/log2 = 1.58$, which is equal to $15,800$ bits. In general we can say that a text of n bits jointly written by k people will need a memory of $nx(log(k + 1)/log2)$ bits. For a group of 10 people jointly writing the text, this gives $3.45n$ bits. This example helps us understand what the analogy is with the second law of thermodynamics. Texts are seldom jointly written in such a way that all possible configurations are equally probable. In general, tasks are divided and different sections are written by separate people. Our example, although it clarifies the situation, is therefore a bit unrealistic. Conversations take place in a much more mixed way. The chance that a conversation between several people will deteriorate into a succession of monologues by separate individuals is actually very small. We can generalise this to collaboration on any cultural product and conclude that it is very improbable that such a collaboration would deteriorate into individual actions by the various participants.

Here we encounter the deeper meaning of the second law of thermodynamics. With regard to this we would now like to illustrate the fecundity of our layers perception and our creation-discovery view. In the cultural layer of reality it is abundantly clear that the second law of thermodynamics, as we have illustrated it, is a marked idealisation of a much more profound principle, which is well-known to philosophers, and which we may express as follows: "The whole is greater than the sum of its parts".

12 Creation and Perpetuation in Different Layers

Every microstate of an entity S, composed of two non-mixed entities S_1 and S_2, is a product state, determined by a microstate of S_1 and a microstate of S_2. This is the reason why the entropy of this entity S, composed of two non-mixed entities S_1 and S_2, is given by the sum of the entropy of S_1 and the entropy of S_2. The entropy of a mixture S of two entities S_1 and S_2 is higher than the sum of the entropy of S_1 and the entropy of S_2 on account of the fact that the mixture S has microstates, those which describe a mixture and which are not a product of microstates of S_1 and S_2. The mixture S is actually a new entity that does not simply consist of S_1 and S_2, and this explains the fact that S has states that are not product states of states of S_1 and S_2. The increase in entropy for a mixture is a result of the increase in microstates for this mixture.

When two quantum entities come together new states of non-separated entities are created. These new states are represented by the functions that cannot be reduced to waves in three-dimensional space; these are the non-local states. This phenomenon is very well described and predicted by the quantum formalism and has now been confirmed by experiment. In this case, however, we shall not discuss a mixture. With a quantum entity in a non-product state, the subentities lose their individuality. The whole cannot be regarded as the combination of its parts and this fact underlies the many paradoxical quantum effects. This phenomenon is also found in other layers: a jointly created cultural product is not a collection of small basic cultural products. The fact that entropy as a concept can be successfully used in two layers is no coincidence and is associated with the special phase in which the creation process of the biomousa takes place in these two layers. This is the phase we call the "building phase" in the next section of this article. Broad interpretations of the nature of reality, which are often derived from the second law of thermodynamics, are therefore highly over-simplified. For example, the interpretation that the phenomenon of mixtures not spontaneously separating would predestine the whole of reality to evolve towards greater disorder and less order is a local conclusion that is also related to the special phase in which this second law manifests itself, and hence does not constitute a truth in other layers of reality. We should mention that the popular interpretation of entropy as a measure of disorder needs to be refined a great deal. Entropy is a measure of the number of microstates that give rise to the same macrostate and hence it is a measure of the information content of this macrostate. The fact that a situation where there are more microstates corresponds to a situation where there is more disorder is related to the specific phase in which the creation process takes place, and to the various layers that are being compared, and is not a general fact. If, for example, we consider the process of spontaneous crystallisation of a supercooled substance, entropy increases if the process takes place under adiabatic conditions. Using ideas about order and disorder in everyday life, it is difficult to maintain that the crystal is more disorderly than the supercooled substance. The interpretation of entropy as a measure of disorder can be salvaged in this example by assuming that the order we want to consider is made up of two parts: one of a configuration nature and the other of a thermal nature. The configuration-type order produced by crystallisation of the substance is lost because of an increase in disorder, which is caused by the potential energy released (latent heat) being spread over the vibration modes of the crystal. In this way "disorder" has to be related to both the distribution of the particles in space and the distribution of the energy over the energy levels. This is a very sophisticated way of looking at matter, however, which also depends on the theory that is being used. Another situation where it is clear that disorder and entropy are two different concepts is in the analysis of the behaviour of gravitational systems. Here too we find spontaneous spatial structuring, which means increased spatial organisation, even in the case of a closed gravitational system. Only when the process is looked at in phase space, thus introducing a completely abstract notion of order, can entropy still be regarded as a measure of disorder [24].

If we acknowledge that sandcastles are not spontaneously created, we must also acknowledge that people make sandcastles. How should we interpret this? We can now clarify this point. The calculation of the entropy of a sandcastle primarily has to do with how we interpret the sandcastle and what we mean by "spontaneously". We are surprised at the creation of the sandcastle only if we look for the creativity required to create it in the material layer. If by "spontaneously" we mean "by using creativity in the material layer", then the sandcastle is formed simply as a result of the movement of grains of sand, as small material entities, making use of the random forces that prevail between these grains of sand. If we interpret "spontaneously" as "what happens on a beach where people are sunbathing", it is much more probable that a sandcastle will be created. People are therefore needed to make a sandcastle. But now we have only shifted the question because why are these people there? In order to fit this question into the creation-discovery view, we would first like to examine in more detail the analogy between the two layers in which we identified the entropy law.

In the material layer of reality we would like to characterise three organisation levels of atoms and molecules or ions more generally. A crystal (a solid substance) is an explicitly organised form. All of the particles remain in their "place" in the same state and can only exert influence and move locally. This produces a very coherent but rigid form of organisation, which, however, has and requires minimum energy. Various types of structure are possible in this organisational form. A liquid is a more implicitly organised form. Forces hold the particles together but each particle can still move individually to a certain extent. There is no coherence between the particles, only attraction. A gas is an accumulation of virtually free particles that only hit upon each other. The biomousa, however, has not chosen any of these three options. It was not interested in the complete dissociation and excessive vagueness of a gas, or in the wetness and perfect malleability of a liquid, and certainly not in the still, fixed rigidity of a crystal. What kind of backbone does the biomousa have? This question will help us unveil the mystery. There is a fourth way of organising matter. Let us elaborate on this.

The molecule can be regarded as the seed of the crystal. Starting from this molecule there seem to be various ways of building larger structures. We have already discussed one of these ways in detail: that of the crystal. This comprises a constantly recurring pattern of basic structures. Once the periodicity has been established, there is no limit to the size of the crystal. This crystalline mode is averse to any form of creativity. The crystal is like wallpaper with a pattern that is repeated in all directions. Wallpaper is not regarded as an example of creativity in our cultural layer and the biomousa also took the same view in prehistoric times. Although it was fascinated for a time by the creation of the basic molecule, the way of the crystal was not its way. The fourth way is choosing to make creative use of molecules. Complex organic macromolecules are works of art, made by the biomousa, in which every atom and every group of atoms plays a unique and individual part, quite unlike the part played by another group, as in the case of the crystal. The fourth way leads to living matter. It is in fact these molecules that form the basis of the material of living matter. And this is the way that the biomousa has chosen, seeking the power of perpetuation through creativity. The material forms of living beings, the single-cell organisms, plants, animals and humans, are the creations of the biomousa in the material layer of reality. This way immediately takes us away from reductionist territory. A macromolecule is not a collection of interacting atoms, just as an atom is not a collection of interacting prematerial particles. A macromolecule is a structure, a construction: it is greater than the sum of its parts. It has new states, which are not product states and which cannot therefore be regarded as a configuration of atoms.

Now that we have analysed the various forms of organisation within the material layer, let us return to the cultural layer. The basic entities of the most recent layer of reality are the "cultural products" in the broadest sense of the term. An entity is situated in the cultural layer because a meaning is associated with this entity; the possibility therefore exists of "covering" this entity with "symbols" (by introducing symbols in the cultural layer of reality). Symbols originated from sounds and gestures, probably mainly intended as a pure means of communication between humans and animals originally. They gradually became more and more complex and have created their own entities, which are all cultural products. Old material and social entities, such as the table and the hunt and the house, were vested with "meaning", but the "force field" of the meaning has also created really new cultural entities: texts, theories, works of art, cultures, and so on. In this sense we could regard "meaning" as the principal "force field" of this cultural layer of reality. All cultural products are immersed in this force field but entities in the previous layers of reality do not feel this force [25].

Let us pick up the trail of the biomousa once again. We want to think about texts as cultural products and we compare them to material entities. They are made up of words, which we can compare to molecules. The atoms are the letters and letters joined up to make a word are molecules. Words can join up to form sentences, equivalent to chemical bonding to form larger molecules. We can construct texts made up of the same sentence or a collection of sentences repeated over and over. This is a crystal text. This is a crystal text. This is a crystal text. This is a crystal text. This is a crystal text. This is a crystal text. This is a crystal text. This is a crystal text. And so on. These kinds of texts are crystals. If through some process or other, for example an error in the software of our word processing program, the words or letters of these sentences got mixed up, then we get texts that are liquids and gases. Thsi la s cr is yext tat. i le s cr axt ysts i taTh. We would not normally identify these kinds of constructions as being texts. Why not? No "meaning" can be established or passed on because all of the combinations of letters do not result in words, and all of the combinations of words do not result in sentences, and all of the combinations of sentences do not result in texts. Only those combinations of letters that are arranged in accordance with the "force field" of the "meaning" form words, and only those combinations of words that are arranged in accordance with the force field of the meaning form sentences and texts. Once again, meaningful sentences are not a collection of words. They are constructions and structures, which contain new states, which cannot be reduced to the configuration of the words. Shannon's entropy theory does not explore the layer of meaningful sentences.

The same argument applies to material entities. Only those combinations of atoms that are arranged in accordance with quantum mechanical forces result in molecules, larger molecules, and crystals or living matter. And it is only these forms of organisation that support the quantum mechanical force field, and communicate through it, by means of photons. Liquids and gases do not take part in this game, and if we cannot allow random combinations of letters and words to be regarded as sentences or texts, then we should also conclude that liquids and gases cannot be regarded as real matter. They do not take part in the original creativity game. Liquids and gases have only acquired a material aspect by means of the large number of molecules that we find in them at our macroscopic level because disorder is reduced by this large number of molecules and they have become usable "matter" again for the creation of living matter. Crystals and living matter are real matter. Crystals correspond to texts made up of recurring sentences, whose meaning is no greater than the meaning of just one of these sentences. Meaning remains at a local level and cannot really expand. The way of the biomousa, used by the macromolecules, allows the force field of meaning to expand and create living matter. This living matter corresponds to our texts, which we regard as real and valuable cultural products.

13 The Different Tongues of the Biomousa

We would now like to try to identify the different phases of the journey of the biomousa and we are aware that only a broad outline is possible. The contents of this section therefore have to be regarded as an attempt, using broad metaphors, to speculate in very general terms about the nature of the biomousa.

Suppose that we start with the existence of a collection of basic entities. In the material layer these are the atoms, and for part of the cultural layer they are the letters and words that make up the language. The letters and words of the language are of course only the basic entities for a particular part of the cultural layer, while atoms are the basic entities for all entities in the material layer. For the sake of simplicity, we shall confine ourselves to that part of the cultural layer that relies on language.

One particular phase, which we shall call the *building phase*, is chiefly a construction based on combinations of the basic entities in particular structures. In general there are many possibilities but some will be found to be "better" than others. The building phase in the material layer consists in constructing large quantities of different kinds of matter, all made up of the fundamental building blocks, i.e., molecules. The building phase of the language part of the cultural layer consists in constructing large quantities of different texts, all made up of the same basic entities, i.e., words. This building phase is explosive and partly destroys the old structures and the old order. The less systematically structures are created, the more these structures obey a kind of second law of thermodynamics. In fact, if molecules are simply thrown together any old how, there is little chance of living matter being produced. If words are simply written down in any old order, there is very little chance that a meaningful text will emerge. We would like to mention that in reality this process does not take place in the simplified manner we describe here. Meaning grows when texts are present. Space and spatial forces grow when mixtures of elementary particles are present. Disorder increases, while the entropy view of the mixtures and the increase in disorder provide a good description of this phase.

The second phase, which we shall call the *development phase*, consists in creating functionally oriented aspects, which have more to do with mutual interaction and interaction with the outside world. Some combinations of basic elements are clearly able to interact with their environment more and better than others. Our ancestors searched for caves to live in and, although a cave as a pure material object is highly improbable, its perpetuation is ensured in the form of a house. The cave "clicked" in some way or other with the needs of our ancestors. The model of the cave lead to them constructing house-like buildings themselves. In the cultural layer it is likewise communication that will select the texts as being significant. The development phase is still an explosive phase, like the building phase, but it introduces the element of selection, which tempers the constant tendency towards an increase in disorder. In fact, some texts will be preferred to others and in this new classification, the most disorderly texts will have less chance of survival.

We shall call the next phase the *structuring phase*. The new area is structured. Newly created entities are given a place. This phase corresponds to arranging and structuring particular texts and communications. Cultural elements are assigned a place and the concept of space is introduced. Two very important aspects of the previous phases, creation, which is so essential for exploring all possibilities, and the optimisation of perpetuation and of perpetuation techniques, which often involve copying, or a creative form equivalent to copying, are partly split off and the concept of motion in structured space emerges. Entities can move in space without losing their individuality. Moving is copying oneself in a "stable" way and is reversible over time. This structuring phase is well under way in the cultural layer of our reality. People are constantly engaged in assigning cultural products their place and in defining the space in which they can move. If we return for a moment to the material layer, we can see that the structuring phase is already complete here. All material entities are well arranged in space and can move within it and interact with one another. Space as a stage has become separated from time and has produced an illusion of "reversibility". Our way of thinking about the universe is determined by space to such an extent that we also see time evolving within this space. But this is wrong of course. We can now understand better why pre-material entities are not present in this space. Space is the stable structure, seeking equilibrium between perpetuation and its need for structure, between creativity and its need for exploration. Creation then partly converted itself into "motion". Just as the matter of the ink used to write the letters of a text on a sheet of paper is not present in the cultural space that is now forming in our cultural layer, so too are quantum entities not present in space.

We shall call the fourth phase the *potentiality phase*. This phase clearly starts building a bridge to another layer of reality. The structuring phase introduced a lot of new and perpetuable structures. These structures have a very low entropy compared to the basic elements but they are highly perpetuable and hence they exist. The benefit of modules is discovered, especially in connection with perpetuation. Modules are larger elements than the original fundamental building blocks, which can be used uniformly and which can easily be copied and hence increase perpetuation. All our modern electronic equipment is based on this modular principle. Mathematical theorems are also modules, however, as are large biochemical molecules and genes. Modules are the first attempts to choose new fundamental building blocks and thereby forget the old ones and incorporate them into an automatic reproductive process that has enormous power of perpetuation and, at the same time, a stable structure. That is why the creation of modules is the first step towards a new layer of reality. In general, however, a new layer is not just created immediately since this is not the purpose but rather the ultimate result of the choice of modules. Why do we call this phase the potentiality phase? With the introduction of modules, the interaction with the space extensively created in the previous phase implodes again. A module possesses a special property in that it contains a lot of potential reality in itself, reality that only becomes existent when the module takes up its place. DNA is a good example of an unbelievably complex module because it has the potential to allow a whole living being to grow, if it ends up in the right place. It is an implosion of external reality because this living being has the potential to remember and pass on information and hence support the building blocks of the new cultural layer. Plants, animals and humans have developed a very complex game, which we call sex, to ensure that DNA always ends up in the right place. Why do we not regard DNA as the basic element of a first new layer of reality? We could do this, though how we define these layers is of course arbitrary to some extent. Nevertheless we choose not to call this a new layer because it lacks one essential characteristic of a separate layer. Genes have not explored the universe. They have not seen the stars! They have not expanded their space to infinity. However, the stored potentiality, i.e., the plants, animals and humans in material forms, has set to work to reach the stars. To this end, man, and man alone, had to take a new step. He started to digitise his experiences, he introduced concepts or modules of experiences. He began to ensure the perpetuation of these concepts by inventing writing among other things. And his knowledge, which is the power behind this new cultural layer of reality, began to spread out over the universe. We shall call the next phase the *bridging phase*. New basic elements are introduced in this phase. These basic elements are separate from the previous basic elements yet are grafted onto them. Initially these basic elements are still modules but then steps are taken to digitise all of the important entities. The new layer of reality now becomes a quantised layer. And we have returned to a building phase.

We can now understand what automation means. The introduction of modules to increase perpetuation implies the introduction of automation. Prototypes are in fact forms of modules too. Real creativity swims ahead of this automation, as it were, like foam on the crest of a wave, and takes place on the edge of the new layer forming. We also believe that every layer goes in search of its past and wants to grasp it again in its entirety. The previous layers did this because, as we know, the four fundamental forces in nature (Gravitation, electromagnetism, weak interactions and strong interactions) bind all matter and energy in the universe. If we consider the modern quantised view of interaction between entities by means of a force, this interaction is nothing more than the interaction of a force particle: in the case of gravity, the graviton, in the case of electromagnetism, the photon, in the case of weak interactions, the boson, and in the case of strong interactions, the gluon. And in the case of the cognitive force field in which we live, the word.

The highly speculative view we are putting forward here identifies man as the vehicle for the most recent force of nature, the cognitive force, and as the foundation of the new layer of reality, the cultural layer.

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