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Article

When an Atom Becomes a Message—*Practicing Experiments on the Origins of Life*

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Abstract: Practicing experiments on the origins of life within the framework of quantum mechanics comes to face a task of distinguishing the descriptive spaces of the object between a space of physical states and a space of probability distributions. One candidate for accommodating both the physical and the probabilistic description in a mutually tolerable manner is to apply first-second person descriptions to the space of physical states while letting the space of probability distributions addressable in third person descriptions be accessible via first-second person descriptions. The mediator or messenger for accommodating these two types of description is the process of probability flow equilibration. The relative state formulation of quantum mechanics opens a possibility for the likelihood that a simple atom such as a carbon atom may carry a message for holding the process of probability flow equilibration. An experimental example demonstrating a carbon atom serving as a messenger is found in the running of the citric acid cycle in the absence of biological enzymes.

Keywords: branching; equilibration; internal measurement; message; probability; relative state

1. Introduction

One unique aspect of quantum mechanics is that the description of the quantum state and the description of its probability distribution are not congruent with each other. While the superposition of the quantum states is admissible, the similar addition of the probability distributions is not necessarily guaranteed. Suppose we tried a double-slit experiment with one slit closed and reported that the probability of the emitted atoms passing through the open slit and arriving at a designated small region

on the screen was 10%. Further suppose that we then opened the closed slit and closed the slit previously opened, and that we repeated the similar experiment with the report of the similar result of the arrival probability 10%. These reports of the experiments, when combined together, do not however conclude that the probability of the atoms arriving at the same final target region could be 20% when both the slits are open in the actual experiment. The uniqueness of the underlying quantum phenomena is in the observation that what looks mutually exclusive with respect to which slit is open is not literally mutually exclusive in the eye of the participating atom as a quantum. This observation comes to raise a serious tension when we practice third person descriptions in reporting the experimental results in a manner of being faithful to accepting the linguistic stipulation of the principle of the excluded middle.

In the classical realm of doing physics, on the other hand, the probability of an event is additive if the occurrence of each event is mutually exclusive with each other. The incongruence occurring between classical and quantum physics summarized by Bohr is as follows:

> "It is decisive to recognize that, however far the phenomena transcend the scope of classical physical explanation, the account of all evidence must be expressed in classical terms. The argument is simply that by the word 'experiment' we refer to a situation where we can tell others what we have done and what we have learned and that, therefore, the account of the experimental arrangement and of the results of the observations must be expressed in unambiguous language with suitable application of the terminology of classical physics." ([1], p. 209)

Practicing third person descriptions in an observational statement as employing our ordinary language is classical in appreciating the classical principle of the excluded middle [2]. Furthermore, if our standard practice of employing third person descriptions is inevitable even in reporting the experimental results concerned with quantum phenomena, any acceptable probabilistic description in quantum mechanics would have to be required to prepare on its own the ensemble of those individual probabilistic events each of which is mutually exclusive with each other.

One radical remedy for ameliorating the present impasse inherent in the incongruent dichotomy between the physical and the probabilistic description might be to dismiss the probabilistic character from the descriptive enterprise of quantum mechanics altogether as following Wheeler's suggestion indicated in the passage:

> "The kind of physics that goes on does not adjust itself to the available terminology; the terminology has to adjust itself in accordance with the kind of physics that goes on." ([3], p. 463)

Even if such a radical measure is not literally taken, the passage in the above would come to remind us the likelihood that any inconvenience occurring between the physical and the probabilistic description may be mitigated on the spot from the participatory perspective practiced in first-second person descriptions [4]. The expected role of first-second person descriptions here as the messages from within is to provide the probabilistic description with the ensemble of individual probabilistic events that could eventually be mutually exclusive. For the role of third person descriptions alone is no more than accepting mutually exclusive probabilistic events already prepared by whatever means provided externally.

As a matter of fact, practicing physics does not remain indifferent to first and second person descriptions. When we try to report the experimental findings in a scientific paper, the experimental arrangement and its protocol presented in the section of Materials and Methods of the paper is expressed in first person descriptions as in the form of "We put these two pieces together in the setup that we designed" and is performative in its effect [5]. The pieces pointed to by the physicist now assume the second person status. Setting the initial and boundary conditions applied to the time development of a quantum phenomenon under study is also performative on the part of the practicing physicist assuming the first person status, while those conditions put in the second person status are amenable to the performing physicist.

The pressing issue for us now turns out to be how one can mitigate the unwelcome tension occurring between the physical and the probabilistic description of the quantum phenomenon, which develops as following the deterministic equation of motion such as the Schrödinger equation of the wave function specified strictly in third person descriptions, in a mutually tolerable manner as incorporating first-second person descriptions also. In fact, as far as the laboratory experimentation is concerned, there has been no recorded violation of the deterministic equation of motion addressable in third person descriptions. At the same time, the Schrödinger equation of the wave function remains malleable enough to be susceptible to the initial and boundary conditions to be specified in first-second person descriptions.

One attempt for bridging over the chasm between the physical and the probabilistic description is the Wigner function [6,7]. It has been proposed as a candidate of the combined distribution in the phase space of both the position and the momentum coordinates of a quantum particle, expressed in terms of the wave function that serves as a representation of the physical state of the particle. In fact, the Wigner function in terms of the physical states is reduced to the probability distribution, which is merely marginal, with regard to the position of the particle when it is integrated over the momentum variable. Similarly, the Wigner function is also reduced to the marginal probability distribution of the momentum variable when it is integrated over the position variable. Nonetheless, the Wigner function by itself fails in reducing itself to a probability distribution since its functional value sometimes may happen to become negative depending upon the choice of the values of the position and momentum variables. No legitimate probability distribution is allowed to violate the condition of being non-negative. This aspect will, however, not be a disadvantage, but will rather be an advantage in the respect of keeping further room for appreciating the participation of first-second person descriptions.

2. Back to the Basics

The descriptive contrast between the physical state and its probability distribution is suggestive in focusing the unique role assumed by first-second person descriptions. It would certainly be legitimate to say that the theory of quantum mechanics based upon the notion of the quantum state is explicable in third person descriptions in the present tense. Nonetheless, the empirical test of the theory requires consultation with the relevant experiments which are methodologically grounded upon the presence of an ensemble of probabilistic events. This observation reminds us of the two distinct issues with regard to the occurrence of an ensemble of probabilistic events. One is for how to prepare the ensemble, and the other is for how to actualize an individual probabilistic event out of the ensemble. Both the acts of

preparation and actualization are performative and presume the participation of the agencies that are made descriptively accessible only through first-second person descriptions. Despite that, the standard practice of addressing quantum mechanics takes it for granted that the preparation of the ensemble of probabilistic events has already been completed and that the ensemble is accessible in third person descriptions.

Once the theoretical scheme of the unitary development of the quantum state such as the one in the form of the wave function developing as obeying the Schrödinger equation is adopted, Born's probability rule can apply as a means of assigning each quantum state its probability of occurrence as measured as the squared absolute value of the amplitude of the wave function [8]. This association of the squared absolute amplitude of the wave function to the probability of occurrence of an event specified by the state attributes of the wave function has actually been confirmed in countless physical systems even without allowing for a single instance of its violation.

A likely participation of the agencies accessible in first-second person descriptions may now become most keen when it happens to be the case that the state attributes specifying the quantum state would turn out to be variable, since the unitary development of the wave function accessible in third person descriptions to the global extent presumes the state attributes to remain invariable or equivalently maximally constrained [9]. A typical example of the variability of the state attributes is seen in the instance of the identity of a material unit to be transformed in the process. For instance, although each of the wave functions unique to a hydrogen molecule H_2 and an oxygen molecule O_2 has the distinctive state attribute specifying its own identity, the water molecule H_2O made out of the two molecules can assume another state attribute specifying its identity which qualitatively differs from either of the two identities of H_2 and O_2.

Needless to say, the state attributes of the wave function conceived from the global perspective sanctioned within the scheme of the unitary time development should remain invariant on the methodological ground since the variability of the state attributes is due to the local nature of the perspective to be taken. To say that the synthesis of a water molecule out of a hydrogen and oxygen molecule is an instance of the emergence of a new state attribute is due simply to taking the local perspective toward the global phenomenon being subject to the unitary development of the two molecules as keeping their state attributes invariant and also to marginalizing the global perspective. On the other hand, however, referring to the probability distribution requires both the perspectives, namely, the global and the local. The probability distribution assumes the occurrence of the conservation of probability amounting to unity to the global extent, while identifying each probabilistic event requires the local act of measurement as leaving behind the contrast between before and after the act of measurement as actual. While the physical description of the quantum state can remain understandably global, the probabilistic description has to assume the functional capability bridging over the chasm between the global and the local.

One undeniable advantage of the physical description of the quantum state is that the state can be specified by those attributes that are set to be memory-free without being bothered by the difference between before and after the act of specification. Because of the memory-free characteristic, the measurement of such a global state may turn out to be even gratuitous once the measurement apparatus is also taken as part of the global state. Nonetheless, once it loses a physical contact with the process of measurement, the proclaimed objectivity of the unitary development of the quantum state would be

jeopardized in an empirical sense. A proper appreciation of the empirical characteristic of the physical description would require accommodating the quantum state with the probabilistic description, rather than the other way around.

At this point enters the probabilistic event that can be memory-dependent. The probabilistic description comes to address two different kinds of probabilistic event. One is a control event for preparing an ensemble of probabilistic events so as to meet the conservation of probability to unity in a bottom-up manner, and the other is an event causing the subsequent control event. Although the occurrence of a control event can be seen as an instance of a many-to-one mapping in the sense of fulfilling the conservation of probability from within if the control event is taken as a target [10], it can also be viewed as an instance of a one-to-many mapping if the control event is taken as a causative factor [11]. Even if it is causative, the control event as a target is memory-dependent.

The actual cause for the control event is the inevitable mismatches between the preceding control events of a local nature which may violate the conservation of probability if left unattended. The occurrence of the mismatches is actually inevitable unless a global scheme for coordinating all of the participating local acts for the control events in a concurrent manner is available. Nonetheless, the mismatches should not be frozen into the record; otherwise the integrity of the probabilistic description would be lost from the empirical record. Measurement internal to each control event is thus memory-dependent in that the agency of the measurement can detect the discrepancy between the preceding acts by itself and the current sensing, and is also functional in removing the mismatches experienced even temporarily by all means at least until an unavoidable next cause for updating the control event will be experienced [12]. Unless an external agency intervenes, internal measurement conceived within the probabilistic description has to be both causative and functional, and even relational in relating the global to the local. A next question that may naturally come up is what does assume the role of such an internal agency that can exercise the two of the causative and functional competencies. We shall be required to revisit the actual practice of doing experiments in quantum mechanics in a more concrete manner in order to meet the challenge.

3. Negative Probability or Weak Measurement

Measurement conceived within the framework of laboratory experimentation is a physical process proceeding in phase space in general or in ordinary three-dimensional space more in particular. This constraining to phase space will generate further repercussions in the practice of quantum mechanics. In particular, in view of the fact that the basic quantity accessible to measurement in the laboratory is the probability distribution being reducible from the probability amplitude assigned to a physical state in phase space, it would be desirable to directly refer to the probability distribution in phase space. Measurement of a moving body or an energy quantum in phase space implies the issue of identifying the probability measure of finding what, where, in which direction, and how fast. However, a plain fact is that the probability distribution, if it is associated with the Wigner function, is not necessarily non-negative. The occurrence of a negative probability distribution conceivable from the mere expression of the Wigner function is due simply to the fact that the conjugate pair of the phase space coordinates, namely, the position and momentum coordinates of a quantum particle, cannot be measured and identified as such concurrently in a definitive manner. Nonetheless, a negative

probability distribution is hard to swallow in reality, especially in actual measurement unless the contextuality is explicitly specified even in the classical realm [13,14].

Once the notion of probability distribution in phase space is duly entertained, a natural consequence will be that its value at each phase point has to be non-negative. At the same time, the integration of the probability distribution over the entire phase space is conserved to unity. Furthermore, while quantum mechanics distinguishes between a mixture of mutually exclusive events and a pure coincidental event, the measurement of the probability distribution to be done by the physicist externally is about the mixture of mutually exclusive ones. This observation then raises a fundamental question on how one could accommodate the notion of a probability distribution with the occurrence of a pure coincidental event.

The issue underlying the distinction between a mixture of mutually exclusive events and a pure coincidental event will more sharply be focused upon if one pays attention to a simple case of weak measurement [15,16], while the issue of how to set the basis set to be applied to the measurement apparatus still remains to be settled [17]. For instance, when the atom in focus is spinning in any arbitrary direction like a silver atom carrying a spin one-half, the quantum state of the atom can be described as a coincidental combination of any two opposite directions. More specifically, the state of the atom spinning on the horizontal axis pointing to the right equals the fifty-fifty combination of the up-plus-down of the states spinning on the vertical axis. Likewise, spinning to the left equals the fifty-fifty combination of up-minus-down.

Then, suppose we apply a weak magnet to the traveling atoms initially spinning to the left on the horizontal axis to spread the beam vertically only slightly, and further apply a rather strong magnet to the vertically deflected beam leaving from the first weak magnet to spread it significantly again horizontally. The role of the second strong magnet is to split the flow of outgoing atoms from the first weak magnet into the two separate beams, in which one is for those moving toward left on the horizontal plane and the other toward right. The actual experiment reveals that the second strong magnet will send most of the atoms into the left-spinning beam if the atoms prepared initially are spinning almost completely to the left. However, some of the atoms end up in the right-spinning beam when the strengths of the first weak magnet and the second strong one are appropriately chosen [18]. This result, which may look counterintuitive at first sight, tells us that the first weak magnet does not completely separate the original left-spinning component into the up and the down components of the quantum state of the atom as leaving some room for the further interference between them to be kept survived internally for a while. Weak measurement ascribed to applying the weak magnet along the vertical direction allows for the occurrence of temporal changes in the on-going interference between the up and the down component so as to amplify the vertical deflection of the right-spinning beam coming out in the form of the post-selection as a consequence of applying the second strong magnet.

The fact is that while the external measurement of the spinning direction of the initial atoms was 100% left, the probability of detecting the atoms pointing to the left direction after the external measurement of the outcome from the weak measurement as applying to it the second strong magnet was less than 100%. Weak measurement is thus capable of varying the probability of a mutually exclusive event, especially with regard to whether the spin of the atom is directed toward either left or right in the end, as maneuvering the degree and the extent of the interference proceeding within a

coincidental event internally prior to the precipitation of mutually exclusive events. Weak interaction is in fact an instance of internal measurement [11].

Internal measurement in the realm of quantum mechanics is capable of forming and transforming what looks like a coincidental event from within. At issue here is how one can make a descriptive access to the occurrence of a coincidental event. In the standard framework of practicing quantum mechanics, the nature of a coincidental event under examination is imposed under the guise of the boundary conditions which are controlled by the physicists externally, upon the deterministic equation of motion such as the Schrödinger equation of the wave function. The deterministic development of the wave function by itself leaves the coincidental nature of an event intact. This external specification of a coincidental event is certainly accessible in third person descriptions in the present tense since the descriptive object is taken to stand alone out there from the outset.

However, once the issue of the transformation of a coincidental event is focused upon, the traditional deterministic scheme upon third person descriptions in the present tense could not meet the challenge since the descriptive object is not standing alone in stasis in itself. Insofar as the transformation is taken to be a natural event, it cannot be tenable for only the physicists sitting outside to exclusively manipulate the coincidental nature through updating the boundary conditions at will. We may require a descriptive scheme other than the one in the form of third person descriptions in the present tense.

One likely candidate for meeting the challenge may be first-second person descriptions in the present progressive and present perfect tense. As demonstrated in the case of weak measurement above, the transformation of the nature of a coincidental event can change the probability distributions of the consequential mutually exclusive events. This change is certainly quantum mechanical, but is not a consequence of the deterministic development following the quantum mechanical equation of motion under a fixed boundary condition. Changing the nature of a coincidental event can be associated with changes in the boundary conditions initiated by the materials themselves inside, but not by the physicists sitting outside, though the dichotomy between natural laws and their boundary conditions, the latter of which are controlled solely by the physicists, has been taken to be imperative also by them on the adopted methodological ground. Since forming and transforming the boundary conditions are performative on the part of whatever agency involved, invoking first-second person descriptions would become inevitable. Furthermore, since first-second person descriptions on the scene are in the present progressive tense, the transformation of the nature of a coincidental event is necessarily local. This local nature makes a sharp contrast to the global characteristic of the conservation of probability to unity that applies to the whole set of mutually exclusive events.

Relating the transformation of a coincidental event of the local nature to the conservation of probability applied to mutually exclusive events of the global character is however conceivable from the change of tense from the present progressive to the present perfect tense. Those events accessible in the present progressive tense come to precipitate the events to be registered in the present perfect tense, while the latter is to necessarily be updated in the present progressive tense subsequently. The inevitability of the update of the preceding perfect tense at a locale in the subsequent progressive tense at the same locale is due to the mitigation of conflicts between the preceding perfect tense at that locale and the subsequent influence in the progressive tense coming from and originating in the neighborhood

locales. Then, the constant reverberation of updating the present perfect tense in the present progressive tense in the supporting quantum mechanical system becomes inevitable.

The global record registered in the present perfect tense on the mutually exclusive events certainly satisfies the conservation of probability to unity. However, the action of the local update of the present perfect tense in the present progressive tense is done for the sake of fulfilling the conservation of probability since there is no material means for fulfilling the conservation of probability in a coincidental manner globally. That is to say, the measured probability distribution in phase space cannot be negative. The non-negativity of the measured probability distribution in phase space thus makes it natural to conceive of a dynamic scheme of preventing the occurrence of negative probability distribution by all means from being frozen in the completed record. At this point enters the distinction between the two movements. One is in the present progressive tense and the other is in the present perfect. What is stipulated empirically, however, is that the occurrence of negative probability distribution in phase space registered in the present perfect tense is prohibited. This may open a possibility for a negative probability distribution to be tolerated, even though only momentarily, to some extent in the present progressive tense as is the case with focusing upon the individual event of annihilation of a particle-antiparticle pair as far as the conservation of probability to the global extent is observed [19–21].

The occurrence of a negative probability due to application of weak measurements is in fact a derivative of modifying and transforming the existing quantum interferences to a nonlocal extent without destroying the interferences altogether. This observation comes to remind us that the act for the conservation of probability in a bottom-up manner would necessitate the participation of measurements to a wider extent even if they still remain local.

4. Probability Flow Equilibration

In principle, measurement is intrinsically local in phase space in that there are no material means to tell us what the whole material world would look like globally in a concurrent manner. Locality of measurement in phase space can now serve as a means of preventing the occurrence of a potential negative probability distribution in phase space as relating it to the measured non-negative one registered in the present perfect tense. What is specific to the local act of measurement is to introduce local Hilbert spaces corresponding to local quantum mechanical objects as naturalized constructs, supervening on the phase space, since measurement is always the projection of an object onto the measurement apparatus that is necessarily local in phase space. Every measurement apparatus, whether natural in its origin or fabricated by the physicist, is a device for projecting what is being measured onto a Hilbert space spanned by the basis set unique to the device itself. The device that is quantum mechanical in its material makeup with no exception is a physical means for preparing a Hilbert space supervening on phase space. Each quantum mechanical object belonging to a local Hilbert space serves as a means of measuring another object belonging to another local Hilbert space through the projection with the use of the correlation acting between the two [3,22].

One definitive consequence from this projection is that the probability distribution in each local Hilbert space is always non-negative. Non-negativity of the probability distribution in the Hilbert space is due simply to the completeness of the basis set characterizing the space. Each eigenvector

constituting the Hilbert space is mutually orthogonal and any vector in the space is decomposed into a unique linear combination of the component eigenvectors. The squared absolute value of the amplitude of each component determines the corresponding probability distribution that does not fail in being non-negative.

Non-negative probability distribution in a local Hilbert space assigned to each quantum mechanical object, supervening on the phase space, now comes to confront the conservation of probability in the whole phase space on which all of the possible local Hilbert spaces supervene. There must be some physical scheme substantiating the conservation of probability in the whole phase space as starting from non-negative probability distribution in each local Hilbert space supervening on the phase space. The Hilbert spaces supervening on the phase space are put under the constraint of making their local probability distributions always non-negative as adjusting the way of the supervening with each other. A decisive means for the adjustment is through modifying the extent of the correlation, that is to say, the interference, between the neighboring local Hilbert spaces. That is through the transactions of probability distributions between the neighboring different Hilbert spaces on the covering phase space so as to reach the global conservation of probability in a bottom up manner, or more specifically, through the local equilibration act for probability flow continuity between the adjacent local Hilbert spaces. Once the transactions of probability distributions toward the global conservation of probability in a bottom-up manner receive due attention they deserve, the momentary occurrence of the local flow of a negative probability can be tolerated since it is taken as a scalar quantity associated with a physical body involved in a vectorial movement. The momentary negativity of probability depends upon the perspective that the local moving detector takes.

The present local act of equilibration for probability flow continuity or probability flow equilibration in short however constantly reverberates in the participating local Hilbert spaces simply because there is no physical means to fulfill the condition of non-negative probability distributions in all over the Hilbert spaces supervening on the phase space all at once. Any local act for probability flow equilibration in a local Hilbert space comes to induce a subsequent act for probability flow equilibration in the neighborhood local Hilbert spaces supervening on the one and the same phase space. Probability flow equilibration is thus unique only to the interplay between the covering whole phase space and the local Hilbert spaces supervening on it. There is no likelihood of such probability flow equilibration either in the phase space or in each Hilbert space alone. It is the act of measurement of a necessarily local character that induces the mutual interferences between the phase space and the supervening local Hilbert spaces.

Probability flow equilibration now comes to the fore as an arbiter or mediator of negotiation between the global conservation of probability conceived merely as a theoretical construct and the actual physical process of a local character for implementing the construct in a bottom up manner. The contrast between the conservation of probability distribution in theory and probability flow equilibration in practice, however, may seem to contradict each other if both of them are referred to in the present tense. While the conservation of probability addressed in the present tense does not assume its violation in any sense of the words, probability flow equilibration admits in itself some platform upon which the conservation of probability distribution may be aimed at internally. When both are referred to in the present tense alone, the conservation of probability distribution is affirmed on the one hand, and denied on the other. Furthermore, the present conflicting dichotomy would simply have to be dismissed insofar as the law of

contradiction allowing for no possibility of affirming and denying the same object at the same time in the same present tense is duly observed. Both the conservation of probability distribution and probability flow equilibration cannot be referred to in the same present tense.

A legitimate alternative would have to be to employ different grammatical tenses when both the conservation of probability distributions and probability flow equilibration are referred to. In fact, probability flow equilibration can assume a momentary violation of probability flow continuity only from the local perspective, which may lack the consistency with the global conservation of probability distribution to be observed in the present tense. Because of the lack of the global consistency, such a momentary violation of the flow continuity cannot be observed as an objective fact. Nonetheless, the momentary violation can be tolerated in the present progressive tense addressable in second person descriptions, since the object moving in the second person status right in a process of its own making does not yet maintain the consistency to be found in the completed record addressable in third person descriptions. To be sure, the events registered in the present perfect tense as a completed effect precipitated from the movement in the present progressive tense would have to meet the global consistency insofar as the record can be referred to in third person descriptions in the present tense.

Probability flow equilibration is thus rather a necessary consequence of accommodating the two different types of space, phase space and Hilbert space, in a mutually tolerable manner. Phase space as a platform for displaying the contrast between the global and the local or between the outside and the inside can be conceived of even without being accompanied by the actual act of measurement. Unitary transformation as a quantum mechanical development in phase space certainly satisfies the global conservation of probability grounded upon its theoretical premise. In contrast, measurement is an activity of projecting an object onto a set of fundamental irreducible predicates unique to the measurement apparatus. Those fundamental predicates, whose representative examples are simply the numbers to be read out of the pointer of the measurement apparatus as practiced in physical sciences, are nonlocal as manifested in the nonlocality of measurement in quantum mechanics.

The nonlocality originating in each Hilbert space in turn may look local when viewed from the covering global phase space, and comes to invite interferences from the ordinary phase space as the platform for distinguishing the nonlocal from the global. While the notion of the conservation of probability legitimately comes from the phase space, its confirmation upon measurement extending all over the entire phase space all at once is untenable because of the locality of each Hilbert space embedded in the phase space. Insofar as one is determined to come to terms with the conservation of probability in measurement at least in the empirical sense, the activity of measurement in the Hilbert space itself would have to have the agential capacity for the sake of fulfilling the conservation of probability from within as supervening on the phase space. The interplay between the conservation of probability in phase space to the global extent and the implementation of each probabilistic event in a supervening each local Hilbert space in practice makes the local process of measurement in the latter agential. Although energy is a physical quantity to specify each Hilbert space, probability is a quantity that can address the transactions between those local Hilbert spaces of a natural origin supervening on the covering global phase space. That is probability flow equilibration. This recognition now opens a new inquiry into how the equilibration process is implemented in reality since the notion of probability distribution in quantum mechanics is not an irreducible basic, but is a theoretical derivative of

something more fundamental. At this point enters the issue of the relative state formulation of quantum mechanics [22].

5. The Relative State Formulation

Internal measurement can act upon and influence the degree and the extent of quantum interferences without destroying the interferences altogether as the experiments of weak measurement have revealed. Then, a subtlety of the relationship between internal and external measurement comes up to the surface.

For simplicity, suppose a quantum system S allows for only two distinct states $|A\rangle$ and $|B\rangle$ like in the case of an atom of a spin one-half. Here we will follow the conventional notation available to quantum mechanics such that each state is represented as an orthogonal unit vector in the corresponding Hilbert space H. The initial state of S denoted as $|init\rangle$ can be expressed generally as a linear superposition of the two states in the form of $|init\rangle = \alpha\,|A\rangle + \beta\,|B\rangle$ with $|\alpha|^2 + |\beta|^2 = 1$, in which α and β are complex numbers specifying the nature of the superposition. This specification comes from the theoretical premise on the part of external measurement which has not yet been committed to the actual measurement. Furthermore, when the observer O_{int} as another quantum mechanical system is introduced into the scheme, it can decisively identify the initial state as either $|A\rangle$ or $|B\rangle$ internally. The internal observer O_{int} can thus hold its quantum state $|O_{int}A\rangle$ as being relative to $|A\rangle$ when it observes $|A\rangle$, while it can hold its quantum state $|O_{int}B\rangle$ as being relative to $|B\rangle$ when it observes $|B\rangle$. The quantum states $|A\rangle$ and $|O_{int}A\rangle$ are correlated with each other in the sense that O_{int} measures the quantum state $|A\rangle$ internally as such. That implies that the occurrence of the quautum state $|A\rangle$ relative to another quantum state $|O_{int}A\rangle$ is equated to the measurement of $|A\rangle$ by the internal observer O_{int}. A similar correlation also applies to the pair $|B\rangle$ and $|O_{int}B\rangle$. Rather, the participation of the internal observer O_{int} is a necessary precondition for the occurrence of the relative states $|A\rangle$ and $|B\rangle$.

In contrast, the external observer O_{ext}, who pays its attention to the composite complex of the system S and the internal observer O_{int}, comes to regard the quantum state of the complex to be in $\alpha\,|A\rangle\,|O_{int}A\rangle + \beta\,|B\rangle\,|O_{int}B\rangle$, even prior to being committed to the actual measurement externally without specifying the explicit values of the complex amplitudes α and β [22].

The present scheme of relating the external observer to the composite complex of the system and the internal observer can further be explicated as referring to a chain of the chemical reactions $R_1 \rightarrow R_2 \rightarrow \ldots \rightarrow R_n$, where R_i (i = 1,2,...) denotes each intervening reactant. The presence of reactant R_1 is supported and identified by the whole reaction system except for the targeted reactant R_1, which is denoted as the internal observer O_1, as expressed in the conventional quantum-mechanical form of the state representation: $|R_1\rangle\,|O_1R_1\rangle$. However, this representation still remains incomplete in leaving another internal observer supporting and identifying the internal observer O_1 as such. Exactly at this point enters the reaction $R_1 \rightarrow R_2$, in which the newly emerging reactant R_2 assumes the role of supporting and identifying O_1 internally. That is to say, the internal observer O_1 synthesizes R_2 as a consequence of identifying R_1. The reaction $R_1 \rightarrow R_2$ is in fact a summary expression of the activity that the material support O_1 demonstrates a chemical affinity toward R_1 for transforming it into another reactant R_2. The occurrence of chemical affinities between the reactants is evidently a scheme of implementing the relative states in chemical reactions.

Likewise, the reactant R_2 requires another internal observer O_2 which can support and identify R_2 as such internally, in which the internal observer O_2 is the whole reaction system except for the targeted reactant R_2. The internal observer O_2 can thus be regarded as a transformation product from reshuffling the preceding support O_1. Basic to the reaction $R_1 \rightarrow R_2$ is the observation that the reaction is the operation of projecting the state vector $|R_1\rangle$ belonging to one Hilbert space onto another state vector $|R_2\rangle$ belonging to another Hilbert space.

A formal expression of the contribution of internal measurement for precipitating both the emerging reactant R_2 and the internal observer O_2 can be expressed as a mapping: $M_2 |R_1\rangle |O_1R_1\rangle = \alpha_2 |R_2\rangle |O_2R_2\rangle$ with $|\alpha_2| < 1$. Here the mapping operator M_2 represents a contribution of internal measurement required for supporting and identifying O_1 by the emerging reactant R_2, and a complex number α_2 represents the complex amplitude of the branching state R_2. Since the conservation of probability is maintained between before and after each branching, the squared absolute value of the amplitude will be unity only in the case that the outcome consists exclusively of a single branch, otherwise it would be less than unity. This sequence of internal measurement proceeds in a similar fashion as $M_{i+1} |R_i\rangle |O_iR_i\rangle = \alpha_{i+1} |R_{i+1}\rangle |O_{i+1}R_{i+1}\rangle$ with $|\alpha_{i+1}| < 1$ ($i=1,2,...$). Here the mapping M_{i+1} represents a contribution of internal measurement acting upon the internal observer O_i for precipitating both the emerging reactant R_{i+1} and the internal observer O_{i+1}.

A significance of the present sequence of internal measurement will be found when the reaction sequence happens to form a reaction cycle $R_1 \rightarrow \ldots \rightarrow R_n \rightarrow R_1$ as supplemented by the further scheme of $M_1 |R_n\rangle |O_nR_n\rangle = \alpha_1 |R_1\rangle |O_1R_1\rangle$ with $|\alpha_1| < 1$. The integration of internal measurement round the cycle now amounts to $M |R_1\rangle |O_1R_1\rangle = \alpha |R_1\rangle |O_1R_1\rangle$ with $M = M_1 \cdot M_n \cdot M_{n-1} \ldots M_2$; $\alpha = \alpha_2 \ldots \alpha_n \cdot \alpha_1$; $|\alpha| < 1$.

The complex amplitude α of the composite mapping M can thus be equated to the probability amplitude for holding the reaction cycle through internal measurement. The most durable event as being subject to frequent internal measurement turns out to be the one that can make the absolute value of the probability amplitude to be unity as depicted as $|\alpha| = 1$. And, the internal dynamics being responsible for varying the complex amplitude α eventually toward $|\alpha| = 1$ from within is through varying the extent of quantum interferences internally without destroying the interferences altogether as revealed in the occurrence of weak measurements. The factual robustness of the resultant reaction cycle comes to rest upon the chemical affinities that the reaction system would exhibit altogether. The reaction cycle lets each reactant in the cycle be fed upon by the reactant located in the immediate downstream. The probability amplitude of the reaction cycle that can approach unity is consistent with both conserving the probability to be unity and actualizing an event with its probability of occurrence to be unity.

In short, the relative state formulation sets the physical condition of novel cohesions acting between the relative states so that any reactant may come to require another reactant for its own sake of finding and recruiting its correlated partner with use of the intervening chemical affinities [23]. When the correlations between those related reactants eventually come to form a cycle, they can be stabilized in the resulting reaction cycle. The occurrence of a reaction cycle within the framework of the relative state formulation is a demonstration of the interplay between two different types of interaction. One is for the interaction running within each local Hilbert space that is strong, and the other is for the weaker interaction operating between different Hilbert spaces. Thus, weak interactions or measurements serve

as a factor for holding and influencing the interferences of the likely chemical bonds to eventually be formed or transformed in those reactants, whereas strong interactions or measurements for actualizing the bond making and breaking eventually collapse the intervening interferences.

Fixation of a reaction cycle is in fact due to the interplay of the two different kinds of dynamics. One is the branching-controlled dynamics of the quantum state, in which the squared absolute value of the amplitude of each branching wave function is equated to the probability of occurrence of the quantum state represented by the wave function when it is measured externally. Another one is the interference-modifying dynamics of internal origin varying the degree and the extent of the quantum interferences operating in the existing branching states. Of course, these two kinds of dynamics are not independent of each other. The branching-controlled dynamics of the quantum state is unquestionably under the constraint of the conservation of probability applied to all of the branching quantum states to be measured externally while no specification of how the branching would actually proceed is physically implemented. Despite that, the interference-modifying dynamics of internal origin can interfere with the branching-controlled dynamics from within. The interference-modifying dynamics can influence the branching-controlled dynamics and eventually let it dismiss those branches the amplitudes of whose wave functions happen to vanish as modifying the quantum interferences internally so as to meet the conservation of probability that is accessible externally.

Occurrence of a reaction cycle is just equivalent to raising a closure of internal measurement connected with single branches alone in a circular manner as a consequence of trimming off those irrelevant branches. When every upstream reactant is connected only to one kind of reactant of a different species in the immediate downstream while constituting a cycle as feeding upon the necessary resources available from its outside, the cycle holding itself can happen to appear with the probability of occurrence of unity. What is specific to the reaction cycle is that it is materially open while being closed functionally. The probabilistic dynamics imputed to internal measurement for the conservation of probability, which is equated to holding the unity of the reaction cycle, could eventually actualize the structure whose probability of occurrence asymptotically approaches unity. The unity of the reaction cycle is in the integration of both holding and actualizing the event whose probability of occurrence would approach unity exclusively on the quantum mechanical ground.

An essence of the underlying probabilistic dynamics is in the observation that the relative state formulation of quantum mechanics can incorporate into itself the capacity of influencing the interferences operating in the available relative states as facing the self referential complications. The intervention of self reference may inflict upon the material body in focus a disparity between before and after each act of self reference, and the legitimacy of such intervention rests upon the potential receptivity of the disparity on the part of the self-referring material body by itself. If the state of an object is admittedly defined in a crisp and perspicuous manner in advance, there would remain no chance for the likelihood that it may accept the disparity between before and after the act of self reference in the limit that the interval separating between before and after is made infinitesimally small. In this regard, the relative state is exceptional in that it constantly maintains room of some indefiniteness to further be specified. Each relative state requires at least two different relative states. One is the relative state to refer to, and the other is another relative state to be referred to. No relative state is irreducibly fundamental. This absence of irreducibility could make the self referential cycle of the relative states tolerable and receptive to experiencing the disparity between before and after the act

of self reference for the sake of holding the cycle itself. The identity of the reaction cycle resides within the dynamic tolerance in a manner of being invulnerable to the dynamic complications and discrepancies latent in the relative states between the acts of referring to and of being referred to.

The standard interpretation of quantum state in terms of Born's probability rule reveals that the probability amplitude is attributed to the amplitude of the wave function of a quantum state. Then, a difficulty may arise when the attributed probability happens to be negative. One likely strategy for circumventing this difficulty is to figure out the internal scheme of modifying the probability of occurrence of each probabilistic event in a self referential manner, that is to say, strictly within the framework of quantum mechanics. If the internal scheme of modifying the probability of occurrence so as to meet the conservation of probability is available, the likely occurrence of an event of a negative probability could be tolerated and interpreted positively in the respect that the conservation of probability is faithfully observed in the end.

A positive role of the relative state formulation of quantum mechanics is in providing us with a reliable scheme of modifying and revising Born's probability amplitudes as processing the quantum interferences between the available relative states. Although Born's rule has set up the pathway from a quantum state to its probability amplitude, the relative state formulation can also prepare the reversed pathway from the probability of occurrence of a quantum event to the relative quantum state to be actualized as maneuvering the intervening relative states. That is Bayesian in assigning a probability to the descriptive attribute of a state, whereas under the frequentist interpretation of probability, the empirical test of the presence of such a state can be done without assigning a probability to it. The Bayesian premise of assigning a probability to the descriptive state on the objective ground is equivalent to saying that the relative state is an attribute to be measured internally on the material ground.

One decisive implication of the relative state formulation is found in the likelihood of such an event whose probability of occurrence would approach unity as demonstrated in the likely occurrence of a reaction cycle. The reaction cycle is potential in actualizing the increase of its holding probability up to unity [24]. This observation however requires further qualifications since both the potentiality and the actuality cannot descriptively be accessible in the same present tense. If both are coincidentally coextensive, there would be no likelihood for distinguishing between the two in the same present tense. If both are indistinguishable, there would be no use of referring to both the potentiality and the actuality in a distinctive manner. This critical remark however applies only to the case that both are uncritically claimed to be descriptively accessible in the same present tense on a metaphysical ground in a manner being indifferent to its empirical confirmation.

In fact, although the actuality phrased in third person descriptions is accessible in the present perfect tense, the potentiality survives only in the present progressive tense. Furthermore, the present progressive tense presumes the participation of first-second person descriptions. For the progressive movement requires two agencies. The agency driving its own progressive movement is always relative to another agency that can sense the driving agency as such. Each of the actuality and the potentiality can recover its descriptive legitimacy if it is further qualified with the appropriate grammatical person and tense. An empirical confirmation on the mediation between the potentiality and the actuality would now require the material agency that can process the interplay between the present progressive and the present perfect tense. The material root of sense-perception is actually sought in the material agency

that can register experiences proceeding in the present progressive tense in its own perfect tense [25]. That will be an issue of what sort of material bodies could mediate between the two different grammatical tenses.

6. When an Atom Becomes a Message

When we address a physical phenomenon, the descriptive scheme to be undertaken takes it for granted that a linguistic symbol to be employed there refers to some aspect of the phenomenon. The referential capacity of the symbol is exclusively language-origin rather than being directly physical. The wave function in quantum mechanics, for instance, is a linguistic symbol to some aspect of a physical observable in the empirical domain. The interpreter of the symbol is the physicist. However, the referential capacity of a symbol is not limited to our human languages. Processing a symbol standing for something other than itself or the sign activity in short is ubiquitous in the biological realm [26]. This may suggest a plausible overview that the origin of the sign activity could have been coextensive with the origin of life, but it does not give us a dependable clue for how life could have originated. Insofar as the origin of the sign activity is an empirical phenomenon, it would be required to figure out the material process leading to the origin. A pressing agenda at this point is how the material process of something standing for something else could have emerged in the material world.

What is prerequisite to the present endeavor for addressing the origin is the occurrence of a physical observer who can recognize and interpret something standing for something else as such strictly on the material ground without accepting an anthropocentric intervention. Although the physical nature of such an observer strictly of a material origin would necessarily remain vague and indefinite on the verge of the origin of the sign activity, one condition must be fulfilled in any case. That is to hold the material identity of the observer to the extent that can be tolerated even in a primitive rough environment; otherwise our reference to it would lose its material support. The present requirement for the material identity then comes to induce a sort of conflicts between the material identity of the observer and the individual identity of a sign as something standing for something else, instead of the individual identity of the sign vehicle in isolation as a material body. The individual identity of a sign is already relational in itself.

When the observer experiencing the sign vehicle as an individual physical body assimilates it into its own body and holds it, the individual identity of the vehicle would merge with the identity of the observer and the distinctive nature of the sign carrying the capacity of representing other than itself would be lost in the end. If the sign as a physical body can really function in the observer, it would have to eventually leave the observer in due course in order to avoid the likelihood of merging its individual identity as a physical body into another material identity of the observer. If it constantly survives as processing the sign activity, the observer would be required to keep its own identity as exchanging the preceding material vehicle of a sign for the subsequent new one while preventing each material vehicle of a sign from staying there for an indefinite period of time.

The exchange of the sign vehicle by the observer is the necessary price to pay for the appraisal of the sign activity in which the individual identity of a sign assuming the capacity of standing for something other than itself is physically secured. Prerequisite to the occurrence of a sign activity is the

exchange of material. The empirical soundness of the present observation may thus be sought in the exchange of material to factually be guaranteed on an experimental ground.

One relevant experiment is the operation of the citric acid cycle in the absence of biological enzymes in the prebiotic conditions such as those simulating the hydrothermal circulation of seawater through hot vents on the primitive ocean floor. The citric acid cycle is the most fundamental metabolic cycle extracting energy for various biological functions through oxidation of simple carboxylic acid molecules such as pyruvate (CH_3–CO–COO–). Although the contemporary citric acid cycle is heavily armored with a huge complex of biological enzymes, there would have been no likelihood of expecting such enzymes in the prebiotic setting. We then utilized a flow reactor for examining the experimental likelihood of running the citric acid cycle in the reaction solution only of the eight different kinds of the major constituent carboxylic acid molecules including oxaloacetate, citrate, isocitrate, α-ketoglutarate, succinate, fumarate, malate and pyruvate as letting the solution shuttle between the hot (120 °C) and the cold (0 °C) regions in a repeated manner [27–29]. The citric acid cycle is the reaction cycle letting the carbon atoms flow though along the closed pathway in the direction of oxaloacetate → citrate → isocitrate → α-ketoglutarate → succinate → fumarate → malate → oxaloacetate as constantly switching the vehicle to ride on in this order.

The experimentally observed fact is that the two carbon atoms in the form of the acetyl group CH_3–CO– released from a pyruvate molecule and fed into the cycle at the pathway from four-carbon oxaloacetate to six-carbon citrate leave the cycle in the form of a carbon dioxide molecule one by one in the second and the fourth round of the cycle.

The fact that the carbon atoms constituting the citric acid cycle are totally alternated by the new ones until completing the fourth round of the cycle reveals that the identity of the reaction cycle survives the individual identity of each constituent carbon atom as a physical body. Despite that, each carbon atom in the cycle can be more than simply being a physical body as letting it be the carrier of a message about the future without invoking a metaphysical complication related to referring to the future in the present tense. It can refer to the future in the present as limiting its residence time inside the cycle. It is functionally decisive in serving as a sign for running the cycle in a lasting manner far beyond the limited residence time of each carbon atom staying inside the cycle as an identifiable physical body. Although the synthetic notion for integrating the past and the future in the present without being accompanied by supporting factual observations, such as life, information, dialectic synthesis and the transformation from potential to actual after Peirce, is metaphysical at best and cannot serve by itself as an analytical tool applied to the empirical domain directly, the carbon atom going round the cycle as carrying a message is physical in updating the present perfect tense in the present progressive tense [30].

A carbon atom in a citrate molecule in the upstream stands for the carbon atom to be found in an isocitrate molecule positioned in the immediate downstream. Thus, a carbon atom situated in the upstream is taken by the reaction cycle as a sign carrying by itself the message of going to be transferred into the immediate downstream. This observation is by no means an anthropocentric metaphor in terms of a human language. The agency being responsible for letting a carbon atom carry a message and for observing the message as such is the reaction cycle itself, and the occurrence of such a reaction cycle is due eventually to the experimental setup employed for simulating the hydrothermal circulation of seawater through hot vents.

As a matter of fact, the act of material exchange is agential of itself in changing the qualitative attribute of a material element through the changes in the tenses involved. The agential activity is on the ground that it is empirically testable, rather than simply being a matter of theoretical surmise. An essence of the interplay between a message, a messenger and information comes to derive from the very nature of a material agency processing the exchange of material. Information here is a synthetic consequence of the exchange of material. Put it differently, the material agency for taking a material for the carrier of a message provides a physical framework of analyzing what information is all about. The exchange of material is empirically agential in constantly updating the present perfect tense in the present progressive tense, while the integration of the past and the future in the present remains synthetic at most metaphysically.

The citric acid cycle in the absence of biological enzymes is actually an agency for separating the sign vehicle in the form of a carbon atom from what the carbon atom as the carrier of a message would imply. The decisive factor for letting the carbon atom as a physical body function also as the message carrier is a limited residence time allowed for the atom staying inside the reaction cycle. The incessant exchange of material is indispensable for the occurrence of a functional reaction cycle that is informational. What makes the reaction cycle informational is the exchange of material, rather than the other way around. Being informational is a synthetic consequence of the exchange of material that is agential in holding the identity of a material body processing the exchange. Furthermore, the factor being instrumental for taking advantage of the specific experimental or environmental conditions for the likelihood of the occurrence of a reaction cycle is the quantum mechanical nature of the participating atoms and molecules. The relative state formulation of quantum mechanics supplemented by the act for the conservation of probability from within can in fact be seen decisive at least in preparing a theoretical framework for upholding the reaction cycle as constantly exchanging the constituent atomic elements round the cycle with the new ones coming from the outside. The relative state formulation certainly provides the physical ground for actualizing a specific reaction cycle with the probability of occurrence approaching unity if the environmental conditions are appropriate.

7. Concluding Remarks

The likelihood of a functional matter in the form of a reaction cycle is sought in those atoms and molecules that can sense their outside. The capacity of sensing or measuring the outside is quite unique in being able to experience what has not yet been experienced. It goes beyond the scope of computable computation to be completed in finite steps with the recursive usages of the irreducible atomic operations that remain invariable, since experience by itself is not sure about whether it could eventually reduce to a recursive sequence of such irreducible atomic operations as echoed in Von Neumann's reservation:

> "By axiomatizing automata in this manner one has thrown half the problem out the window, and it may be the more important half. One has resigned oneself not to explain how these parts are made up of real things, specifically, how these parts are made up of actual elementary particles, or even of higher chemical molecules. One does not ask the most intriguing, exciting, and important question of why the molecules or aggregates which in nature really occur in these parts are the sort of things they are." ([31], p. 77)

The process leading up to the emergence of a functional matter as starting from a non-functional one may seem more informational rather than being merely computational [32]. While the ubiquity of computation as a universal regulative principle applied to integrating recursive operations is conceivable in an abstraction on a meta-level addressable in third person descriptions in the present tense [33], identifying the concrete nature of each recursive operation to appear on the empirical level is upon measurement punctuating the present progressive in the present perfect tense. Measurement in the empirical realm is by no means a derivative of computation in abstraction. Measurement would have to be prior when it comes to identifying what computation is all about.

Information entertained at least in the physical domain admits that the process of being informed is a temporal phenomenon. When we say we are more informed in time, information is taken as a factor for integrating the past and the future in the present. This integration is advantageous to information compared to physics per se since in the latter the distinction between the past and the future is not literally taken into account except for referring to the distinction between before and after the events. Nonetheless, information comes to face a formidable task of how to accommodate the distinction between the past and the future tense with the present tense especially with regard to the qualitative implications of each of the three tenses [34].

Although the extent of being informed can be evaluated as referring to the distinction between the past and the future while marginalizing the present, the distinction between the past and the future tense makes it inevitable to refer to what the present tense is all about. Both the assignments of making distinction and making integration of the past and the future tense are upon the one and the same shoulder of the present tense. While it can get rid of the stifling temporality accommodated into physics only in the form of distinguishing between before and after the events as dismissing the occurrence of a memory, information comes to face an almost insurmountable task of how to live with the integration of the past and the future in the present on a sound empirical basis. Integrating the past and the future in the present in theory alone, as demonstrated in an abstracted form of category theory in mathematics [35], is, however, synthetic at best metaphysically as refraining from referring to concrete empirical facts grounded upon the differences between the qualities of each of the three tenses.

One loophole that can escape from being entrapped by the malaise of the metaphysically helpless trichotomy of the past, present and future tense may be the appraisal of the dichotomy of the present perfect and the present progressive tense. A critical evaluation of integrating the past and the future in the present as demonstrated in the phenomena such as life, information, dialectic synthesis of thesis and anti-thesis, and the transformation from potential to actual and back is in turn to shed light on the duration addressable in the present progressive tense. While the integration of the past and the future in the present is metaphysical, the update of the present perfect tense in the progressive tense is physical in making matter functional. Exactly at this point, the role of an atom becoming the carrier of a message for holding the supporting reaction cycle should positively be appreciated. The atom as a message that is indispensable for holding the identity of a reaction cycle is informational and distinctive to the well-being of the cycle only in the present progressive mode, while the identity of the cycle properly survives in the present perfect mode at the expense of letting each individual atom as the carrier of a message survive in the cycle only over a limited time interval. Informational specification of the atom as the carrier of a message is thus a synthetic consequence of the occurrence

of a reaction cycle as an agency for reading the message latent in the physical carrier, rather than being merely a derivative of the quality of the atom that can stand alone.

The occurrence of a reaction cycle is both experimentally accessible and theoretically conceivable within the relative state formulation of quantum mechanics even without assuming biology in the beginning. Everett's relative-state interpretation has later been called many-world interpretation. Its germination was already implicit in the note added in proof of the 1957 paper. It goes like this:

> "In reply to a preprint of this article some correspondents have raised the question of the 'transition from possible to actual', arguing that in 'reality' there is—as our experience testifies—no such splitting of observers states, so that only one branch can ever actually exist. Since this point may occur to other readers the following is offered in explanation. The whole issue of the transition from 'possible' to 'actual' is taken care of in the theory in a very simple way—there is no such transition, nor is such a transition necessary for the theory to be in accord with our experience. From the viewpoint of the theory all elements of a superposition (all 'branches') are 'actual', none any more 'real' than the rest. It is unnecessary to suppose that all but one are somehow destroyed, since all the separate elements of a superposition individually obey the wave equation with complete indifference to the presence or absence ('actuality' or not) of any other elements. This total lack of effect of one branch on another also implies that no observer will ever be aware of any 'splitting' process. Arguments that the world picture presented by this theory is contradicted by experience, because we are unaware of any branching process, are like the criticism of the Copernican theory that the mobility of the earth as a real physical fact is incompatible with the common sense interpretation of nature because we feel no such motion. In both cases the argument fails when it is shown that the theory itself predicts that our experience will be what it in fact is. (In the Copernican case the addition of Newtonian physics was required to be able to show that the earth's inhabitants would be unaware of any motion of the earth.)." ([22], p. 462).

The defense by Everett in the above is however not satisfactory [36]. Despite that, the essence of the relative-state interpretation to be grounded upon on the empirical basis remains intact.

Basic to the structure of the relative state formulation is the recognition that the function of measurement is internal to matter. Internal measurement is a dynamic factor for accommodating the material interaction with the signaling interaction, which can incorporate into itself a physical precursor to the structure eventually culminating in the appearance of sensorimotor control in the full-blown biology. Functional matter in the form of a reaction cycle is thus suggestive in providing a prototype of biological activities including sense-perception and proto-metabolism, while being unmistakably physical in its makeup without presupposing what life is all about. This observation can provide us with a new perspective toward the origins of life and the emergence of the genetic code. In fact, each of the sign activity and the coded structure may be taken as a derivative of the underlying reaction cycles. These attributes are unique to the reaction cycles emerging with the probability of occurrence approaching unity.

Although physics is full of statistical laws that are certainly legitimate within the given contexts, this order-from-disorder principle is not entitled to dismiss the case of order-from-order in the material

world. A case in point is those physical events whose probability of occurrence approaches unity. The emergence of biology may certainly take advantage of the likelihood of such a non-statistical origin of order to be appreciated purely on a physical ground. The probabilistic nature of quantum mechanics is quite deterministic and self-constraining in providing us with the probabilistic pathway toward those events whose probability of occurrence would approach unity in the end. The order-from-order principle envisaged from the integration of both Born's probability rule and Everett's relative state formulation is Bayesian in that the enduring event as constantly transforming its tenses in time is an asymptote of the probabilistic event whose probability of occurrence would eventually approach unity.

References and Notes

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2. Although it could happen that a meta-level language may charge the validity of the principle of the excluded middle to be exercised on an object-level language, the principle would have to apply to the meta-level language in any case; otherwise the charge could not hold itself. Such a complication is unavoidable between any pair of a meta-level and an object-level language. Moreover, any theoretical thesis framed in an object-level language, even including those in theoretical physics, is inevitably metaphysical and is affirmed in the context of a certain meta-level language admitting the premise of accepting the object-level language in focus. One consequence of the metaphysical complication is that it could happen that an attempted theoretical model framed in an object-level language may positively be affirmed in one meta-level language and may negatively be criticized in another meta-level language. The outcome remains indecisive and equivocal insofar as one sticks to the dichotomy of an object-level and a meta-level language alone. There seems no likelihood for the settlement between those competing meta-level languages in sight if direct contact to experiences or experiments is lost. No metaphysics has the prerogative of subjugating all of the other contenders appearing solely on the meta-levels that can arbitrarily be conceived of. The advantage of doing empirical sciences, on the other hand, resides within their own capacity of getting rid of the unnecessary and unwelcome exchange between a meta-level and an object-level language, though limited in their expertise compared to metaphysics at large. They can concentrate only on the direct conference between a theoretical statement in terms of an object-level language without being bothered by the additional effort of explicating the supporting meta-level language in an explicit manner and an observational statement referring directly to the empirical objects and facts to be observed through experiences. Empirical science is in fact a strange, though powerful, metaphysical discipline in relativizing whatever metaphysical statements of an abstract nature framed theoretically there to observational statements carrying a concrete implication available directly from experiencing the empirical world.
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the past, present and future tense while marginalizing the metaphysical interventions. Information thus requires the integration of three different kinds of material support carrying each of the past, present and future in a qualitatively distinctive manner when it is applied in the physical domain empirically. In particular, the role of first-second person descriptions is in appreciating the participation of structural constraints of a local character called internal measurement into the development of a natural dynamics. On the other hand, physics on the externalist stance can remain non-informational in admitting that the difference between before and after the events is only quantitative as referring to a metric time. Symptomatic of the externalist stance in physics is external measurement admitting the identification of the state attributes to the global extent in a concurrent manner as perceived in the case of a Hermitian observable unique to a single Hilbert space in quantum mechanics. The present dismissal of informational attributes from the externalist stance is equivalent to accepting a maximum constraint of the external origin applied to dynamical laws operating there.

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12. The synthetic capacity unique to information is in integrating the past and the future in the present, though it may sound metaphysical in its outlook due to putting both the past and the future on the object level on the one hand and the present on the meta-level of description on the other hand. Accordingly, the control event of a local nature that is memory-dependent is informational in that the agency involved in internal measurement accommodates the past that is incorporated into the memory, with the future requiring further update of the control event, in the present. Emergence of the material agency for processing both causation from the context and control toward the context is not simply an issue to be proposed theoretically, but is an issue to be tested empirically in order to make it physical rather than being merely metaphysical.
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22. Everett, H. Relative state formulation of quantum mechanics. *Rev*. *Mod*. *Phys*. **1957**, *29*, 454–462.
23. Although this is not the place for explicating the ontological background in an exhaustive manner, the relative state formulation of quantum mechanics assumes at least one specific ontological stance implying that the process of measurement proceeding exclusively on the material ground is taken to be prior to the occurrence of something denoted by the symbol called the wave function or the state function. In short, the state in the relative-state formulation is grounded upon the cohesiveness qualifying and being latent in what is *being relative*. The cohesiveness upon *being relative* remains inaccessible to the standard ontology framed exclusively in third person descriptions in the present tense. Needless to say, the confirmation of the relative state formulation is definitely relative to the relevant empirical facts, rather than to the metaphysical statements of an ontological implication in one form or another.
24. In the standard scheme of stochastic process, there is a dichotomy between the probability distribution and the occurrence of individual probabilistic events or sample events though it would be quite seldom to pay a serious attention to the latter. In contrast, the scheme of Born's probability rule accompanied by Everett's relative state formulation comes to pay a legitimate attention to an individual event occurring with probability approaching unity when a reaction cycle happens to be focused upon. An individual event with the probability of occurrence of unity can be equated to the occurrence of an enduring event. An advantage of referring to Bayesian probabilities is that a probability can be assigned to an event to be deciphered in terms of the relative states accessible in first-second person descriptions, rather than directly to a state formally addressable in third person descriptions.
25. There would be neither sense-perception nor agency if everything in the empirical realm can be taken and retrieved from the record registered in the present perfect tense. The activity of punctuating the present progressive tense in the perfect tense has already been deprived within the record. For the agential capacity of punctuating the present progressive tense in the perfect tense has already been usurped there. The standard practice of doing physical sciences as referring to a metric time alone comes to dismiss the agential capacity of matter on the adopted methodological ground as letting itself be immune to the distinction of the different tenses. No agency survives in the record. Practicing empirical sciences solely upon the present perfect tense may unwittingly become a miserable victim of the stifling mechanistic methodology unless the constant update of the present perfect tense in the progressive tense is duly attended. The bacterial chemotaxis, for instance, may look quite mechanistic if only the record registered in the present perfect tense is

referred to. In contrast, once one pays a legitimate attention to the fact that sensing an attractant and moving toward the attractant is not concurrent, but is sequential, punctuating the act of sensing the outside for the occurrence of updating the tumbling motion of the bacterial body of its own may turn out agential.

26. Matsuno, K. Carbon atoms as prime messengers for the origins of life. In *Messages and Messengers—Angeletics as an Approach to the Phenomenology of Communication*; Capurro, R., Holgate, J., Eds.; Wilhelm Fink Verlag: Paderborn, Germany, 2011; pp. 303–325.
27. Matsuno, K.; Nemoto, A. Quantum as a heat engine—the physics of intensities unique to the origins of life. *Phys*. *Life Rev*. **2005**, *2*, 227–250.
28. Matsuno, K. Forming and maintaining a heat engine for quantum biology. *BioSystems* **2006**, *85*, 23–29.
29. Matsuno, K. Chemical evolution as a concrete scheme for naturalizing the relative-state of quantum mechanics. *BioSystems* **2012**, *109*, 159–168.
30. A most defensible or a fail-safe approach to the synthetic notion applied to the integration of the past and the future in the present has been the Kantian regulative principle as explored in the *Third Critique*, in which only the transcendental ego is solely responsible for maneuvering the reflective principle that is neither constitutive nor constructive directly in the empirical domain in the physical sense. In contrast, mechanistic movement explored on the part of nature remains intact in the *First Critique*. The integration of the past and the future in the present may sound incomprehensible if all of the three tenses are taken to be on the one and the same object-level language. One alternative for making it comprehensible would be to move the present tense from the object-level to the meta-level language. In essence, this has been what Kant actually adopted. Our attempt for shedding light on the role of an atom as a messenger for updating the present perfect tense in the present progressive tense, on the other hand, may be equated to a sort of naturalization of the Kantian regulative principle in the constructive context in a concrete empirical sense without relying upon the metaphysical dichotomy of an object-level and a meta-level language. Comprehension of the material origin of ongoing sense-perception, for instance, is rather straightforward in the respect of punctuating the present progressive tense in the perfect tense in sequence, while such comprehension would turn out to be extremely hard in the ordinary discourse limited only to third person descriptions in the present tense alone because of the abstract nature in the latter.
31. Von Neumann, J. *Theory of Self-reproducing Automata*; Burks, A.W., Ed.; University of Illinois Press: Urbana, IL, USA, 1966.
32. If a non-halting or non-computable computation, though which may sound like an oxymoron, is tolerable in a heuristic sense, it may open a possibility for approaching information through the recursive usages of irreducible atomic operations at least in the metaphysically tolerable context of integrating the past and the future in the present. The synthetic notion of information can arguably survive metaphysically, as with the case of life, dialectic synthesis, the transformation from potential to actual, and the like. Information upon computation as a research program may metaphysically be acceptable for those of us who take the epistemic perspective unique to us for granted. However, the present anthropocentric epistemic cut does not apply to the empirical cut of a natural origin such as the one separating between a functional matter and a non-functional one

as envisaged by von Neumann above on the verge of the origin of life. The empirical cut of a natural origin could have emerged even in the absence of the human observer possessing its own unique epistemic cut. Only after the empirical cut has been observed in the material world, it may become conceivable in an abstract manner to associate the cut with the epistemic cut uniquely of a human origin in one way or another.

33. Dodig-Crnkovic, G.; Müller, V.C. A dialogue concerning two world systems: Info-computational *vs*. Mechanistic. In *Information and Computation*; Dodig-Crnkovic, G., Burgin, M., Eds.; World Scientific: Singapore, 2011; pp. 149–184.
34. McTaggart, J.E. The unreality of time. *Mind* **1908**, *17*, 456–473.
35. Burgin, M. Information dynamics in a categorical setting. In *Information and Computation*; Dodig-Crnkovic, G., Burgin, M., Eds.; World Scientific: Singapore, 2011; pp. 35–78.
36. That the superposition of each individual wave function following the Schrödinger equation follows the same Schrödinger equation is due to the fact that the boundary conditions applied to each individual wave function are the same. Despite that, it is not the Schrödinger equation that determines its boundary conditions. To say that all elements of a superposition (all "branches") are "actual" is tantamount to saying that there must be some agency being responsible for setting and imposing the same boundary conditions upon each of all of them. Everett remained mute on what could assume that agency except for a theoretical physicist. Likewise, although the statement culminating in that all the separate elements of a superposition individually obey the wave equation with complete indifference to the presence or absence ("actuality" or not) of any other elements could survive only when the identity of the one and the same boundary conditions applied to each element is guaranteed on some grounds, no concrete scheme for guaranteeing the identity was provided. Rather, experimental evidence to the contrary demonstrating that different branches could interfere with each other through the scheme of weak measurements has been available more than half a century later than Everett's original formulation. Nonetheless, the main core of the relative-state interpretation remains invulnerable in stating that once the quantum states are approached in first-second person descriptions, the occurrence of the relative-state formulation could be invincible. The relative-state interpretation enables us to raise a crucial question of empirical significance as asking how a functional matter leading up to the stage of biology could arise from the material capacity of doing measurement under the guise of relative-states conceived from within the framework of quantum mechanics alone. The issue of the origin of a functional matter formulated in the scheme of the relative-state interpretation of quantum mechanics is empirically far more relevant than the issue of examining the appropriateness of the many-world interpretation, which may sound overly metaphysical, in terms physically or empirically accessible.