Objective information in the empiricist view of von Weizsäcker

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October 14, 2015

Abstract

We analyze von Weizsäcker’s view regarding the concept of information in physics. In his view, information arises from the reduction of properties of a physical object to their logical descriptive propositions. The smallest element of a lattice of propositions is an atom of information which is considered as the essence of every physical identity including position space. von Weizsäcker calls this element, “ur”. Moreover, Biological evolution is described in terms of enhancement of the variety of forms. Form could be also reduced to descriptive logical propositions, thus to atoms of information. Therefore, information is the fundamental basis in von Weizsäcker’s plan for unifying all branches of Physics including Chemistry and Biology. Yet, there are inadequacies in his lines of reasoning, critically assessed in this paper.

1 Introduction

Carl Friedrich von Weizsäcker was a German philosopher and physicist whose main research activities were on nuclear fusion in the sun and other stars and on the creation of solar system. Yet, an impressive part of his works which is the subject of the present paper, includes his efforts for getting a unified

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description of all laws of physics under a theory called ur-theory. He introduced ur-theory in “Die Einheit der Natur” in 1971[1]. An improved version of the book entitled “the structure of physics” has been published in 1985 which was translated to English in 2006 [2]. This book is the fruit of years of efforts for obtaining a theory of unity of physics. In this book, information is the most fundamental concept underlying physics. The centrality of information in physics, however, was originally introduced by works on Boltzmann’s formulation of entropy in thermodynamics that was very similar to Shannon’s measure of information and Maxwell’s demon which resulted to great works on the role of information in physics. In the quantum area the concept of information was introduced by von Neumann, before the recent work of von Weizsäcker. Weizsäcker’s innovation is in using information as a central concept for unifying all branches of physics including Biology and chemistry which are also considered to be reducible to physics and in defining “ur”s as atoms of information. Thus, information is believed to be also a basic concept in the mentioned domains of natural science. The first part of the book is devoted to the plan of reconstruction of quantum theory which is the essence of ur-theory. In the second part of the book, the role of information in unifying Biological evolution with the Second Law of Thermodynamics is explained. In the last part of the book, von Weizsäcker talks about interpretations of quantum theory.

In this paper we present a survey on his views focusing on the concept of information. Since his philosophy has played a significant role on his view about natural sciences and his plan for reconstruction of physics, we begin with a short introduction about von Weizsäcker’s philosophical attitude, before entering and scrutinizing the main subject of his ideas, i.e., ur-theory. Concepts like experience, time and phenomenon have significant roles in his terminology. Therefore, we have devoted the second part of our paper to these concepts. In the third section, we explain his views about reconstruction of quantum theory which is associated with the development of ur-theory and its implications. In this regard, the role and significance of the concept of information become clear. In section 4, we investigate the same concept in Thermodynamics and Biology, in addition to von Weizsäcker’s view on the consistency of Biological evolution with the Second Law of Thermodynamics. Here, we assess the strength and coherence of his insight. In section 5, we present a critical analysis of ur-theory and show that the reduction of physical concepts to informational properties in the way von Weizsäcker describes has fundamental problems. The conclusion part is presented in the last section.
2 Experience, phenomenon and time

von Weizsäcker starts the first chapter of his book, "the structure of physics" by the basic statement "physics is based on experience". This statement has a central role in the conceptual structure of his theory. The first point in his theory is gaining knowledge about the realm of appearances of things or their phenomenological level. He is influenced by Kant in this viewpoint. The other point is the presumption of the concept of time as a primary and fundamental concept which is a prerequisite of experience in Kant’s view as well. Kant assumed time and space as two a priori features of experience, while they are not in themselves perceivable in experience. Indeed, time and space are two subjective concepts and every physical object corresponds to these subjective intuitions by the process of gaining knowledge about natural phenomena, where mind has a primary role here. Yet, we expect that each subject does conform to a real independently existed object. On the other hand, Kant believed that mind recognizes the thing not in itself, but through its appearances, thus, through perception [3].

In the same way, von Weizsäcker thinks that our knowledge of physics is possible based on the realm of appearances of physical entities (observables) and by means of perception. We construct our knowledge about an object using descriptions about their observables. Thus, necessarily we presume the existence of an object with all of its observables to construct knowledge about it. The object is matter and at the same time it has a form. However, von Weizsäcker goes a step further respecting Kant who is leaving aside space and excluding time as a precondition of experience. For, von Weizsäcker states that space is derivable from ur-theory and it is not a necessary precondition of experience.

According to von Weizsäcker, experience means learning from the past for the sake of future. The past, present and future tenses are thus prerequisites for experience [2, p.3]. Thus, experience is a temporal concept. Similar to Kant who introduced intuition and subjective prerequisites for empirical knowledge, which are known as Kant’s twelve categories, von Weizsäcker assumes time order as a necessary condition for empirical knowledge.

As mentioned earlier in Kant’s view, the object conforms to subject by gaining knowledge about natural phenomena, instead of that the subject conforms to the real independently existed objects. von Weizsäcker is apparently influenced by this viewpoint in constructing his ur-theory.

When one talks about an event in the past, thenceforth, (s)he considers it as a factual event. However, events pertaining to future have not actually occurred yet and are accounted as potentialities. In this regard, probability by its very nature is a temporal concept. This seems to mean that, one can
ascribe a probabilistic statement only for events pertaining to the future, while, we cannot talk about factually past occurred events with probabilistic propositions. Therefore, the concept of probability is intertwined with the concept of upcoming experiences. Hence, the concepts of time and probability are considered as prerequisites of empirical natural science. Regarding the importance of temporal experience in Weizsacker’s view and the distinction between past and future in temporal events, one should notice that, however, the meaning of “factually past occurred events” is completely vague in quantum mechanics. For example, let us assume that at $t = t_0$, we measure the spin component of a spin-$\frac{1}{2}$ particle along $z$-direction, $S_z$, and obtain $+\frac{\hbar}{2}$. Then, we perform a similar measurement along $x$-direction, $S_x$, at $t = t_1 > t_0$. What can we say about $S_z$ at $t_1$? It is a past occurred event with value $+\frac{\hbar}{2}$, but it is not factual in any sense at $t_1$. Any fact is a fact in quantum events, when we know it with certainty. Otherwise, it is an indeterminate phenomenon. So, our experience is limited to perceived facts at present, and past events are only important for making predictions about the future status of the system. At present, nothing can be said about the actual values obtained before for the system. Hence, our experiences at different times do not form a shared experience as a whole. For classical objects, also, there are situations in which one cannot talk about a past occurred event with certainty, because it might be measured with low precision. Past events, even if considered factual could be probabilistic.

The aforementioned lattice of propositions is established about properties which could be known by experience or by the realm of appearances of a given object. This is the basis for one of the main postulates of von Weizsäcker in establishing ur-theory, i.e., the existence of separable alternatives to which the next section is devoted.

3 Ur-theory

Ur-theory was a result of von Weizsäcker’s efforts towards establishing a unified theory of physics. Because physics is the most fundamental of all natural sciences including chemistry and Biology, such a theory should be capable of describing these domains of science as well. In his viewpoint, quantum theory among all theories of physics is the most fundamental and comprehensive one which could be the base for such a unified physical theory. The probabilistic nature of predictions of quantum theory, also, makes it general. One could assume quantum theory as a general theory of probability for its

\[1\] We will not use the adjective "empirical" before "science" throughout our work in this paper, for in von Weizsäcker’s view natural science is generally empirical.
statistical predictions and von Neumann’s abstract mathematical description of the theory can be viewed as a mathematical basis for a fundamental theory of physics [2, p.9].

von Weizsäcker considers quantum theory as possessing two levels. One is an abstract level which is limited to the mathematical framework of von Neumann, in which everything is described in Hilbert space without considering actual and classical concepts like position space, potentials, fields and particles. These concepts are pertaining to the second level, which von Weizsäcker calls the concrete level of the quantum theory. Then, he reconstructs an abstract representation of quantum theory using some postulates to establish his ur-theory [2, 4-9].

We previously said that in von Weizsäcker’s view, quantum theory is a general theory of probability. This theory helps us to analyze everything in terms of binary alternatives with yes/no answers which mean that there exist empirically decidable alternatives. This is the first and most significant postulate of ur-theory. These alternatives could be either possibilities of the occurrence of an event or propositions with which one describes a phenomenon which could be empirically tested. Indeed, what von Weizsäcker actually does is reducing physical observables to logical concepts of alternatives. When we want to gain empirical knowledge about something, we assume a number of logical alternatives about that object or event. Any repeatable experimental result is one of these alternatives. In this case, we say that observable properties are reduced to logical alternatives. However, this is possible only if one presupposes the existence of the object. This postulate is applicable in classical mechanics as well. One could divide every concept to smaller and smaller descriptive elements by means of binary alternatives until reaching the smallest indivisible part which is called by von Weizsäcker “ur”. Actually, this postulate follows the classical logic in which such an analysis is applicable for every perceivable property of an object. The only difference between classical and quantum mechanical logic in this regard is the selection of the corresponding lattice of propositions which is related to the definition and significance of information in each domain. One could deduce that for indivisible phenomena, two inseparable systems should be considered as a united whole. In other words, in these cases we are dealing with a non-classical phenomenon with a quantum mechanical nature. Here the word “phenomenon” is brought from Bohr as a result of his efforts for resolving the measurement problem and the effect of the measurement device on observed results. Bohr thought that the system and the measurement setup should be treated as one inseparable whole, known as phenomenon, considering that the underlying nature of interaction between the measuring setup and the system is in principle unknowable. Following this line
of thought, the lattice of propositions in classical mechanics is established about separable objects and in quantum mechanics, it is established about phenomena. Thus, the only difference between classical and quantum mechanical probabilities as mentioned earlier is in the selection of the lattice of propositions.

Therefore, the lattice of propositions is not exclusively applicable to separable events, but also to inseparable events. For instance, the entanglement between spatially separated quantum particles, results in a correlation between them in such a way that the information of one particle becomes dependent on the information of the other particle. This leads to an excess of information in quantum mechanics, relative to classical mechanics, because entanglement provides exact knowledge of one of the systems without any measurement performed on the other system. Similarly, one can mention the quantum uncertainty relation in which one cannot obtain sharp distributions for two incompatible observables in a simultaneous measurement. This means that complete and exact information about both incompatible observables is not accessible, simultaneously. In the plan of reconstruction of quantum theory, these points should be taken seriously. Taking these points into consideration, von Weizsäcker introduces his second postulate, namely the postulate of indeterminacy or postulate of expansion [2, p.77]:

To any two mutually exclusive final propositions $a_1$ and $a_2$ about an object, there is a final proposition about the same object which does not exclude either of the two. Two propositions $x$ and $y$ exclude one another if $p(x, y) = p(y, x) = 0$.

The quantum theoretical excess information is a result of this postulate. This is one of the necessary requirements of any theory of probability, as he denotes. In an expansion, no term possesses an absolute true value and as we mentioned earlier, probability is assumed as a temporal concept here, meaning that one can use probabilistic statements only for future events. Thus, in his opinion, time is the only concept amongst all of classical concepts that has a significant and fundamental role in the reconstruction of abstract quantum mechanics and is assumed by von Weizsacker as a realistic variable instead of being a parameter. In this regard, inspired from classical fundamental concept of time, he introduces the third postulate namely the postulate of “dynamics”. However, contrary to classical mechanics in the development of ur-theory, there are real distinctions between future and past modalities of time. This distinction reveals itself in the irreversibility of the measurement process and in the reduction of the wave function. Moreover, von Weizsacker tries to prove the Second Law of Thermodynamics using
Boltzmann’s H-theorem and through his definition of time. He believes that
time also reveals itself as a real physical entity in Thermodynamics. We leave
this point for further consideration in future.

As is apparent, two abstract prerequisites for experience are identifiable
in von Weizsäcker’s view. The first one is the concept of time that is de-
efined as the real distinction between the past and the potential future. The
second one is the existence of decidable alternatives. Each alternative can
be analyzed and divided into binary alternatives called “ur”s. This decidi-
ability is based on experience. One could plan experiments in which one
should choose an answer between two opposite results, i.e., yes and no. Step
by step, this analysis reaches an ultimate proposition with yes/no decisions.
This final irreducible alternative is called “ur”. Based on these premises,
von Weizsäcker establishes a lattice of logical binary propositions about ev-
ery observable property. This lattice has $2^k$ dimensions in Hilbert space.
If one uses classical information, i.e., Shannon information, this space pos-
sesses $k$ bits of information. Yet, according to the expansion postulate, in
quantum mechanics one could expand the given state space in terms of basis
states defined for incompatible observables. Consequently, one can assign
an unlimited number of bits of information to this $2^k$ dimensional lattice of
propositions. The ultimate binary alternative “ur” is the smallest part of the
lattice and the smallest element of physical information as well which pos-
sesses spinor characteristics, meaning that it has a two dimensional Hilbert
space and could be assumed as an atom of information with a substantial
role in the structure of physics. Indeed, every physical property which is
empirically knowable to us could be reduced to these atoms of information.
Definitely, von Weizsäcker asserts that one can construct all objective and
(non-abstract) concepts of quantum mechanics based on the concept of in-
formation and ur-theory. For instance, the three-dimensional position space
could be reduced to the concept of “ur” and its spinor space, accordingly.
The reasoning for this assertion is that the proper symmetry group of urs
is spinor’s symmetry group of SU(2). Taking advantage of the isomorphism
of this symmetry group with the symmetry group of rotation in three di-
imensional space (i.e., SO(3)), von Weizsacker deduced the three dimensional
position space from two dimensional Hilbert space of “ur”s. Moreover, he
was aiming to deduce all other quantum mechanical concepts like field and
particle using the substantial concept of atoms of information [10-12].
4 The role of information in Thermodynamics and Biological evolution

Evolution in this survey refers to the emergence of new forms in Biological systems during the history of earth. If entropy is a quantitative measure of irreversibility, information is the quantitative measure of evolution as well. Information refers to the amount of form, in other words the amount of Gestalt. Since Biological evolution is associated with increasing of variety of forms, the amount of information increases in this process. The amount of form is a property of an object and is defined by von Weizsäcker as the following [2, p.214]:

The more decisions can be made about an object, the more form one can recognize in it, in a general not necessarily spatial meaning of the word.

In other words, the amount of form is equivalent to the number of the possibilities for different descriptions of a given object. For example, a DNA molecule is described by various possibilities for the arrangement of its nucleotides, a spin-\(\frac{1}{2}\) particle is described by two possibilities for its spin components and \(N\) number of harmonic oscillators are described by \(2^N\) possibilities for their parity, etc.

On the other hand, Thermodynamic entropy is equivalent to the potential information. Therefore, information is a fundamental concept in both domains of Thermodynamics and Biology.

Because of the mentioned common characteristic of irreversibility in Thermodynamics and Biological evolution, these two domains of nature are assumed as one phenomenon occurring in two different levels. Here, however, one encounters the controversial problem of whether the Biological evolution occurs in accordance with the Second Law of Thermodynamics. However, von Weizsäcker’s answer is yes, Biological evolution doesn’t violate the Second Law of Thermodynamics. He believes that the mentioned problem arises from the fact that in text books of Thermodynamics, the increase of entropy is described as an increase of disorder. On the other hand, Biological evolution is associated with increasing of order. Accordingly, these two domains seem to be in contrast with each other. Nevertheless, one may consider order

\footnote{Parity (\(\Pi\)) is a unitary operator in quantum mechanics with two eigenvalues \(+1\) and \(-1\), defining in turn, even and odd parities for an arbitrary state-vector \(|\psi_i\rangle\). In a mathematical description, \(\Pi |\psi_i\rangle = \pm 1 |\psi_i\rangle\). As is obvious parity refers to the symmetry of the wave function under space coordinate inversion.}
or disorder as esthetical concepts, but not physical ones. To consider biological systems, one should have into account non-equilibrium thermodynamics in which the rate of dissipation of energy and time rate of entropy production is crucial.

Regardless of this point, von Weizsäcker believes that [2, p.215]:

It is usual to interpret entropy as a measure of disorder, and thereby thermodynamic irreversibility as an increase in disorder. Evolution, however, is understood as an increase in possible forms, and in that sense as order. Under these premises evolution must be perceived as a process proceeding against thermodynamic irreversibility. Here, exactly the opposite thesis is to be presented: Under suitable circumstances, an increase in entropy is identical to the growth of forms; evolution is a special case of the irreversibility of events."

Let us first see how von Weizsäcker defines information in these domains. Information has not an absolute definition. As he says: An “absolute” concept of information has no meaning; information exists only “under one concept,” more accurately, “relative on two semantic levels”[2, p.217]. We need at least two semantic levels for which information could be defined relatively. For instance, in Statistical Thermodynamics, information is quantified relative to macro-state and micro-state levels. The amount of information of a macro-state is related to the number of micro-states it contains. Therefore, we cannot talk about information of a macro-state without considering its corresponding micro-states. Determination of the micro and macro-states depends on the physical system (or the object) under study. For instance, DNA chain constitutes the macro-state and different arrangements of its nucleotides make its micro-states. Assuming that entropy is equivalent to information, von Weizsäcker explicitly states that entropy is a measure of form. The more information is there about an object, the greater is the number of forms (possible descriptions) of that object. Based on this argument, von Weizsäcker claims that assigning the increase of entropy to the increase of disorder is a linguistic mistake. As he believes [2, p.222]:

The concept of entropy is so general and abstract that the specification of a high a priori probability for a state rich in form also amounts to assigning a high entropy to it.

Therefore, the concept of information in Thermodynamics and Biology is somehow similar.
However, one may question what is the difference between that information which is the measure of irreversibility and that which is the measure of evolution? Their only difference is in the selection of the micro-state and macro-state levels. Additionally, there is a correspondence between entropy and the amount of Gestalt. So, any modeling of Thermodynamic irreversibility according to The Second Law regarding the increase of disorder is a linguistic mistake and should be revised.

In Thermodynamics, one only needs two corresponding levels of micro-state-macro-state to gain information from a system. But, in Biology, von Weizsäcker adds another level to the Thermodynamic semantic levels, called the morphological level. One measures the information of a macro-state with respect to the micro-states and entropy or information increases with the increase of the number of micro-states. In a similar way, in Biology information of a morphological state is evaluated with respect to its lower levels of macro and micro-states. Thus, von Weizsäcker concludes that the both above processes, i.e., Thermodynamic irreversibility and Biological evolution include the concept of information as a central notion, so that both of them are substantially related to information. Thus, they are identical in nature, but occur in different levels of natural processes.

von Weizsäcker proves this claim using two lines of verification. The first is a model that we analyze first. According to this model, if the first level (i.e., the micro-state) is illustrated as the atomic level and the second level or the macro-state is modeled by the molecular level, then the level of variety of forms in Biology – which includes a spectrum of Biological macro-molecules to a diversity of living systems is pertaining to the third level called the morphological level. In Thermodynamics, the quantification of information associated with a process needs only the first two semantic levels. While, in Biological evolution one needs the third level in addition to the first and second levels. For example, the bases in a DNA molecule make the atomic level, then the molecular level is the arrangement of bases in a part of the DNA molecule making, e.g., the gene which determines the color of eyes in a human body which constitutes the morphological level.

The clearest explanation is better to be quoted directly from von Weizsacker’s book [2, p.222]:

Restricting attention, as in the previous examples, to two semantic levels and one thereby defined concept of information, there follows from the structure of time only the Second Law: as time progresses, the actual information of the state present at that time will decrease with overwhelming probability, its potential information (entropy) increase. If one wants to express the de-
velopment of form by means of the concept of information at all, one must introduce (at least) three semantic levels, with three different measures of information then defined among them.

Consequently, Thermodynamic irreversibility is a special case of the Biological evolution, occurring at lower levels and both processes include the notion of information within their foundation.

The other line of verification, Weizsäcker talks about, is based on the Second Law of Thermodynamics. He uses the growth of a crystal as an illustration. This process is a good example of the increase of order in a system. Since it is a spontaneous process, von Weizsäcker deduces that it occurs with accordance to the second law and is associated with an increase of entropy. Thus, an increase of entropy is associated with an increase of order in the crystallization process. He finally concludes that information increases in this process, and the same occurs in Biological evolution, i.e., the increase of potential forms.

In a crystallization process, there are infinite possibilities for the generation of a final form which show the variety of arrangements in both molecular (macro-state) level and atomic (micro-state) level. By increasing these possibilities, the amount of information increases as well. This is analogous to what occurs in Biological evolution.

However, neither of the above arguments is flawless. First, he models the three levels of micro-state, macro-state and the level of variety of forms by atomic, molecular and morphological levels, respectively. Indeed he models the levels of energy distribution of particles which have a crucial role in Statistical Thermodynamics, with the variety of molecular forms produced by combination of atoms. It seems that the Thermodynamic level could be described by characterizing the particle’s level and its underlying classical laws. At the same time, atoms with appropriate energies combine with each other to form molecules which are the more organized forms relative to the atomic level. The Thermodynamic level including the assembly of atoms (or the molecular level) is assumed to be a more organized level than the atomic level in von Weizsäcker’s view. A higher level of organization occurs at the Biological level. While, the formation of molecules from atoms could be understood in terms of atomic levels of energy and the formation of molecular orbitals according to quantum mechanics, Thermodynamic process is not reducible to the dynamical-mechanical description. It seems that he wants to build a connection between micro-states (described by quantum mechanics) with the atomic level (which models the micro-states) on one hand, and the macro-state (described by Thermodynamics) with the molecular level (which models the macro-state) on the other hand in such a way that one
could reduce the Thermodynamic level to the dynamical-mechanical level. One could in principle establish molecular structures based on dynamical-mechanical rules. Yet, the Thermodynamics level is not reducible to these rules even in principle. Since, e.g., entropy is not a dynamical-mechanical notion. With a closer look, for gaining information about a macro-state one needs to consider the number of micro-states. So, the variety and multiplicity are characteristic features of the micro-level. For example, the mean value of energy in Thermodynamics is a measure of temperature and is being used to describe the macro-state. In this case, the micro-states are the individual particle’s energy levels.

In effect, the order of levels in Biological evolution according to von Weizsäcker’s model is as the following,

\[ \text{Atomic} \rightarrow \text{Molecular} \rightarrow \text{Morphological} \]

So, as is expected, the higher levels should be the more general levels and the lower levels should possess more variety and multiplicity. Every higher level should be considered as a macro-state with respect to its lower level. Therefore, the morphological level should be considered as a macro-state with respect to the molecular level, in the same way that the molecular level is a macro-state with respect to the atomic level (micro-state) and the amount of information in each case is evaluated with respect to attributes of these levels.

Yet, one should notice that the multiplicity of forms in Biological evolution appears at the morphological level. Then, the direction of the relation between these semantic levels changes. Because, the macro-state in Biology (corresponding to the morphological level) has more variety and multiplicity than its corresponding molecular level. This relationship is somehow similar to the relationship between the atomic and molecular levels. For, at the atomic level, the multiplicity of states (or, correspondingly, the abstract forms of knowledge) is again considerable. This is important, when the notion of information is taken into account. So, the true direction of levels changes to the following form:

\[ \text{Atomic} \rightarrow \text{Molecular} \leftrightarrow \text{Morphological} \]

The molecular level seems to have the less diversity with respect to both atomic and morphological levels. Consequently, to define information, the hierarchy of levels with respect to each other is not identical in irreversible processes and Biological evolution. Hence, the model doesn’t fulfill the real situation.

The second line of reasoning for unifying entropy and evolution is also not acceptable. Although, it is true that the process of formation of a crystal occurs in accordance with the Second Law of Thermodynamics, it is actually associated with an entropy decrease for the system and not increase as von
Weizsäcker assumes. Nevertheless, the decrease of entropy in this process is dominated by decreasing enthalpy and the crystallization occurs spontaneously.

Had we assumed that von Weizsäcker considered the whole entropy of the universe, this reasoning could still not be true [2, p.221]. Since, in the latter case, one cannot refer to the properties of the system and its states directly, as is usually requested for evaluating information.

5 A critical analysis of ur-theory

The work of von Weizsäcker in the difficult area of philosophy of science is an appreciable work, for it was a great challenge in unifying physics. It attracted much attention and resulted in branches of insights on the understanding of the concept of information in natural sciences up to the present time.

We saw through the three previous sections that von Weizsäcker considers information as a fundamental concept which is the basis for everything in physics. The physical object could be constructed from atoms of information. Furthermore, in the same line of reasoning the position space, forces and every physical observable could be reduced to an information basis. In addition, we saw that in Thermodynamics and Biological evolution, information identifies the amount of potential forms (and possibilities). The more the required number of propositions for describing an object, the more is its information and consequently, the more is its amount of Gestalt (form).

One may ask, however, what von Weizsäcker means by “form”? Following Aristotelian philosophy, he considers form as the essence of everything. Yet, form is a property of the object and knowable to us. This property is not separable from the object. Form, like any other property, should be analyzed by informational propositions with yes/no answers. The more propositions are required to describe an object, the more are its possible forms. Thus, form is the substance and information is the measure of substance. The ultimate alternative is called “ur” that is an atom of information. Here, the classical atomism is replaced by an abstract logical atomism. In the classical atomism, the division of an object to smaller parts takes place in the position space. Divisibility in terms of logical “ur”s is assumed by von Weizsäcker as a radical atomism which is an atomism based on the concept of information.

But, what is information? In addition to being a measure of form, information is what is understood [2, p.304]. This kind of definition mixes the subjective and objective notions of information all together. For example, the arrangement of nucleotides in the DNA molecular structure includes objective information about the future behavior of a living being independent
of whether it could be observed or not. “Understanding” in this case is the development of genotype to phenotype according to von Weizsäcker. This means that when a given form of a living being is changed in an evolution period to cause a transition from genotype to phenotype, a kind of understanding is also developed during this transition. This “understanding” is an attribute of the organism, itself, not dependent on perception of another conscious being.

This phenotype is an objectified semantic. On the other hand, we need at least two semantic levels of macro-state and micro-state to evaluate information. Thus, information has not an absolute definition, here. The alternatives or potentialities are not absolute but are defined relative to special semantic levels. The same situation holds for information. The definition of propositions or “ur”s is constrained by the restrictions of measurement instruments and limitations of human knowledge. Information in von Weizsäcker’s view is neither matter nor energy. But, it is another entity independent from both of them.

Semantic levels of information encounter us with concepts of mind and matter in von Weizsäcker’s philosophy, for which there is no fundamental duality in this view. Mind should be understood as a natural entity like matter, and human knowledge is a process occurring in Nature and belonging to it. So, knowledge is not independent of the matter stuff of the world. Information is both objective and subjective at the same time. The information about an object is objectively there, whether we know about it or not. However, it is knowable to us.

An object has a remarkable ontological aspect. Its observables are accidental or extrinsic properties and have no independent existence. Their existence depends on object’s existence. They are knowable to us and we analyze them by logical propositions. This logical aspect of knowledge which is based on perception, ultimately leads to a “ur”, i.e., the ultimate alternative of information. “Ur” is a logical concept and yet is not independently definable without assuming an object and its observables. Considering what von Weizsäcker says about the dependence of the decision of the lattice of propositions or the definition of “ur”s on the limitations of measurement instruments, “ur” is relatively an accidental concept.

It is admissible to ask how such a concept could be considered fundamental and substantial. Unfortunately, the definitions of an object and the atom of information called “ur” make a loop. One might consider the object and the atom of information as a whole, just like the system and the measuring instrument in quantum mechanics. Yet, there could be no “ur” when there is no object. Any proposition about an object depends per se on the nature of the object being considered. Then, its nature refers to proposition being
used. First, an object is presumed, then, its observable properties are defined through which one could gain knowledge about the object. Therefore, one analyzes these observables by binary alternatives which could be questions with equi-probable yes/no answers until reaching a final proposition. However, the final proposition (or a “ur”) depends on our previous decisions of propositions and is not distinguishable from them by itself. For example a proposition might be about up and down spin components of a quantum particle or about its massiveness. Such a proposition depends on the nature of the object being considered. So, information about an object is object-dependent. In another words, it is claimed that a “ur” is substantial. Yet, the nature of an object should be presumed, because without the definition of an object and characterizing its properties, the definition of a network of propositions which could ultimately lead to an atom of information “ur” is impossible. So, an irreducible element of subjectivism (i.e., the role of our minds in knowing and characterizing the matter stuff of the world including all objects and their properties) is introduced.

Regarding Kant’s view, the scientific knowledge refers to properties of physical objects as conceptualized by us. Our conceptions and our mental frameworks influence our scientific knowledge. For instance, we naturally have a Euclidean imagery of space. Our minds bear space and time as prerequisites of experience and our apprehension occur within this mental framework. This could be generalized to any logical method of gaining knowledge. However, limiting natural sciences to human subjectivism is a limitation to the creative and innovative apprehension of physical phenomena.

For example, one can notice that imaging a non-Euclidean geometry for space in Relativity Theory of Einstein could not be understood in terms of mental presupposition of special structures of space-time. So, Relativity Theory is a good example for how mind conforms to the external reality and that how physics does not match our mental framework. However, von Weizsäcker, trying to avoid the loop of subjective-objective information, declares that the process of cognition and gaining empirical knowledge is a process belonging to Nature itself. In his view form is the essence of every object and it is also the essence of mind. Nevertheless, if we accept this argument we expect that a physical explanation for the unity of mind and matter in terms of “ur”’s could be possible. No such underlying physics has been given yet. Furthermore, ur-theory does not explain how matter originates from the abstract logical concept of “ur”. From a different view, in von Weizsäcker’s opinion, experience is the cornerstone of physics. Experience is defined by him as the usage of data obtained from observation and measurements occurred in past for doing predictions about the future. Or as he says, experience means learning from the past for the sake of the future. However,
in some situations, we cannot know all properties of an object by experience (or through observation). In such instances how can one establish a lattice of propositions reducible to a final proposition or a “ur”? For example, consider the known problem of wave-particle duality in quantum mechanics. The quantum object has a particle-like behavior in some experimental conditions and behaves as a wave in other situations. Our experimental setups determine what we could observe for the object. Then our decisions influence the final “ur” proposition which can tell the object is a particle or wave. Each of these entities in turn has a completely different lattice of propositions. The proposition about the identity of being wave or particle in the logical reduction approach toward a “ur”, is unavoidably dependent upon our experimental conditions. So, according to ur-theory wave or particle should be assumed as a property of the whole experimental setup of a quantum object and not its nature by itself. But, what does ur-theory tell about an individual quantum object or its own nature? How can “ur” which is expected to be a fundamental and substantial entity depend on the external and empirical conditions of observation at the same time? The atom of information is context-dependent, just like the physical behavior of the object, itself. So, what is the fundamental preference of a “ur”? This leads to the conclusion that an atom of information has a dual character in its essence, corresponding to the dual character of a quantum object in different situations. Then, what is more fundamental, an object or its information? In this way, we will never know what a quantum object is and what its physical nature implies. The problem remains a problem and our knowledge of physics transforms to the knowledge of description of observations as it happened in the early quantum theory. Replacing objective atoms with “ur”’s does not solve any problem to help us obtaining a clearer picture of Nature and the behavior of its parts.

On the other hands, as is apparent from ur-theory, atoms of information are quantitative measures of a given object. It is evident that measures of the properties of a physical object could not be the essence of that object, especially if these measures only evaluate the extrinsic properties. This makes science be limited to merely perceptible levels of phenomena.

von Weizsäcker’s view which confines natural science to human perception and the realm of appearances of physical things (observable properties) is problematic. As Kant implies, the impossibility of substantive and priory knowledge independent of experience leads to the conclusion that the object must conform to the subject to make knowledge possible. Influenced by this view, von Weizsäcker introduces knowledge about an object by classifying observations in a logical subjective framework of mind and constructs a lattice of propositions or atoms of information. One should note that, how-
ever, there are theories in physics that have predictions proved empirically after they are predicted by the theory itself. For example, the existence of positrons was theoretically predicted by Dirac in quantum field theory. It was four years after this prediction that the particle was detected empirically by Carl Anderson. These kinds of theoretical predictions affirm that making correspondence between the predictions of theory with experience is not the mere way of gaining knowledge. Yet, in ur-theory, von Weizsäcker concentrates on the role of experience. The lattice of propositions about an object is constructed using the data obtained from experiments or former observations.

This way that confines our knowledge to perception and empirical incomes cannot resolve explanatory problems of quantum phenomena. In order to explain quantum weirdnesses (like wave-particle duality, nonlocal correlations, etc.) which are unexplainable by classical theories, using perception is not sufficient at all. Leaving aside material atomism and replacing it with informational atomism which is not more than a measure for manifesting forms of an object resolves no paradoxes. Moreover, it leads to new vague problems like: How could material objects be constructed from atoms of information? Or how could one explain subject-object association in natural events by an information-based view?

For information to be so fundamental and objective as von Weizsacker aimed to set it, we need a more abstract definition of this concept. Information needs to arise not from human logical roots. It should be independent of semantics and free of transmission aspects of communication. A step toward such concept was taken by Gornitz through introducing the objective concept of protyposis [13]:

Physics is more than an “extension of logics”, and, in physics information differs from destination, or meaning, or knowledge. Meaning always has a subjective aspect too, so meaning cannot be a basis for science and objectivity. If quantum information is to become the basis for science it must be conceived as absolute quantum information, free of meaning. It is denominated as “Protyposis” to avoid the connotation of information and meaning. Protyposis enables a fundamentally new understanding of matter which can be seen as “formed”, “condensed” or “designed” abstract quantum information.

This concept is believed to be a basis for derivation of Einsteinian structure of the non-Euclidian space-time [14].
Gornitz also offers an answer to our previously asked question by the concept of protyposis that “how could material objects be constructed from atoms of information?”\cite{15}:

If the protyposis should be connected with the established parts of physics, then, beside other requirements, the construction of relativistic particles from qubits has to be given. This means that irreducible representations of the Poincare-group must be constructed.

However, it is not clear how different aspects of reality, like material objects, energy, space-time, etc., could be obtained based on a unique and abstract concept of protyposis. How do these variety of concepts arise from such an abstract concept, without reference to any distinguishing agent necessary for making these distinctions meaningful? Could it predict new concepts or is it just a descriptive concept which provides a different language by which everything could be reduced to protyposis?

One of the other main problems of ur-theory is that when a lattice of propositions is constructed for an object, it should include all properties of that object. This means that all possible propositions that could be used for describing an object should be included in the logical lattice of propositions, so that the greater is the number of propositions, the greater is the number of forms that object possesses. Considering continuous variables, like $x$ and $p$, however, there is no complete set of propositions for describing the quantum state. This means that there are possibilities which could not be reduced to a final proposition in principle. So, a final proposition is not possible for an object and we are faced with an infinite number of elements of a lattice of information. Then, one cannot extract an object from informational basis. Yet, in von Weizsäcker’s view, the existence of a final proposition is a necessary condition for an object to actually exist\cite[2, p.77]{2}:

\begin{quote}
If a certain object actually exists, then a final proposition about it is always necessary.
\end{quote}

As von Weizsäcker claims, this statement is equivalent to saying that \cite[2, p.77]{2}:

\begin{quote}
Every object has at any time as property a probability distribution of all its properties.
\end{quote}

However, the problem is that the existence of a lattice of propositions is not always associated with the existence of a final proposition. In cases
which a final proposition does not exist for a system, von Weizsäcker says that such an object does not actually exist at all. This is in contradiction with situations described by continuous variables.

And at last, let’s see the role of information in Biology again. Biological evolution is associated with the increase of variety of forms and Biodiversity. If one asks why evolution takes place in this way, the answer is usually that this process occurs, because it is the more probable process. This answer is the same as the answer to the question of why Thermodynamic irreversibility occurs as the more probable process of increasing entropy. In static states, we can say the form of Biological systems could be described using a lattice of binary propositions. The final proposition is a “ur” with two equally likely answers. This shows that this lattice is basically symmetric. But a dynamic process like evolution—which occurs, because it is more likely to occur—could not be explained using the fully symmetric theory of information. In completely symmetric states, information reaches its maximum value and could not further increase. Therefore, diversity of forms does not occur as well. One may logically analyze a static system to reach a final proposition, but application of ur-theory to dynamic changes like evolution is paradoxical. Regarding information theory as a time-independent representation, ur-theory makes no distinction between states before and after evolution. Ur-theory is symmetric in the selection among several possibilities. It does not explain how such a selection among states which the system evolves toward them occurs. On the other hands, even if we accept that applying ur-theory to the dynamics of a quantum system has no problem, we have no unique mathematical model for the dynamics for a system under evolution which is different with a mechanical system. So, one have no answer according to ur-theory for biological evolution.

On the other hands, we know that there are cases in Nature for which such a symmetry is broken. For example two chiral molecules have a completely similar lattice of logical alternatives. But each final proposition is the opposite alternative of the other one. Yet, in nature, one of these cases uniquely occurs. For example, all amino acids which constitute natural proteins are right-handed and all tao neutrinos are left-handed. Almost all spiral oysters are right-handed. This break of symmetry is not understandable here, because left-handed and right-handed answers are equally probable according to ur-theory.

For continuous variables, however, no complete set of propositions exist. For instance, with a discrete variable like spin, we have in every direction a complete set of propositions given by up and down alternatives. For continuous variables like \( x \) and \( p \), the number of alternatives are not finite.

This is somehow similar to saying that for a continuous variable we have
analog information, while, for a discrete variable, every proposition contains a digital information. Analog information is innumerable and infinite, so it prevents us from constructing a lattice of propositions with definite limits [16].

6 Conclusions

Our analysis of ur-theory shows that replacing material atomism by logical informational atomism leaves quantum paradoxes unresolved, and yet is not successful in unifying Biology, Thermodynamics and Quantum Theory. Furthermore, it leads to additional obscurities like how logical elements of information could build material objects in a physical sense. “Ur”’s as atoms of information are dependent on human decisions and confined to instrumental limitations and could not be assumed substantial, as ur-theory implies. Another problem is about applying ur-theory to Biology, especially in resolving the problem of homo-chirality which bears a kind of symmetry breaking in nature. Even if we consider there is another universe which has opposite symmetries to ours, this doesn’t explain why this kind of symmetry breaking or chirality exists in our universe.

Acknowledgement The authors would like to thank the two anonymous referees for their valuable comments which led to improvement of our paper.

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