



Feature Article

A scientific rationale for consciousness

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Abstract. Consciousness is a concept that can be easily experimented but not easily defined. We show that the same observation applies to information, entropy and even energy. The best we can do is thus to generate and present “identity-cards” of these notions by listing their observable attributes with the help of mathematics, logics, information theory and thermodynamics. From a top-down approach starting from a view of reality based on a universal information field, emerges a ternary logical structure of consciousness that further generates, through meaning, a dualistic space-time continuum populated with an infinite number of “things”. The validity of our logical structure is backed by quotations from topmost scientists and by various mappings such as famous previous models used in philosophy and science. Implications in neurosciences are also briefly discussed.

Keywords. Consciousness, meaning, information, activity, matter, neurosciences.

INTRODUCTION

In a previous paper, a thought experiment arrived to the conclusion that consciousness has anteriority over energy and matter.¹ Such a statement should not be a surprise for Eastern civilizations but seems to be in conflict with the materialism prevailing in Western civilizations, due to the development of science since Galileo’s first attempts to replace qualitative philosophical statements by observations and quantitative argumentation. This is illustrated in the first of two lectures held by Galileo Galilei at the Accademia Fiorentina in 1588 in order to solve a literary controversy concerning the interpretation of Dante’s *Inferno*.² In these lessons Galileo took the opportunity to show how mathematics could support a model suggested by the architect Antonio Manetti and demonstrate that the model proposed by Alessandro Vellutello had parts that would have collapsed under their own weight. Shortly after he delivered his *Inferno* lectures, he also published a discourse on bodies in water, which refuted the Aristotelian explanation of why objects float in water.³

Galileo’s works thus paved the way to the intensive use of science and mathematics for giving rational explanations of natural phenomena. As evidenced by his work on the structure of Dante’s *inferno*, quantitative consid-

erations are of considerable help for settling between several philosophical controversies. Accordingly, the playwright Eugen Berthold Friedrich Brecht has put the following words in Galileo’s mouth: “One of the main reasons why the sciences are so poor is that they imagine they are so rich. It isn’t their job to throw open the door to infinite wisdom, but to put a limit to infinite error. Make your Notes”.⁴ Figure 1 shows an illustration of the current scientific paradigm initiated by Galileo, in which every phenomenon is assumed to occur in a 4D space-time continuum called Minkowski’s space referred to as M^4 space hereafter.

A widespread view is that it exists a pyramidal hierarchy for scientific knowledge that is based on eight fundamental disciplines: mathematics, physics, quantum mechanics, general relativity, electromagnetism, thermodynamics, chemistry and biology. In a previous paper, it has been advocated that such a pyramidal structure originating in the positivist thinking of the French philosopher Auguste Comte should be rejected and that a much better approach is to use group theory for revealing the fundamental links between these autonomous disciplines.^{5,6} Fitting consciousness in such a materialistic frame is generally perceived as a “hard problem”,⁷

while fitting free will of living beings may be referred to as the “hard question”,⁸ domains where qualitative arguments predominate over falsifiable quantitative statements. The aim of this paper is then to show what science has to say about consciousness, independently of philosophical descriptions characterized by a total lack of consensus among thinkers. We were motivated in our approach by some remarks made by topmost scientists about the role played by consciousness in our universe.

First, the importance of consciousness is obvious in quantum theory where the finite value of the quantum of action imposes that the observer always has an influence over what is observed. It is timely here to quote Werner Heisenberg, the father of matrix mechanics: “I think that modern physics has definitely decided in favor of Plato. In fact these smallest units of matter are not physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language (...). God is a mathematician”.⁹ One may also quote his enemy brother, Erwin Schrödinger, the father of wave mechanics: “As a matter of fact, I think that the material universe and consciousness are made out of the same stuff... But although I think that life may be the result of an accident, I do not think that of consciousness. Consciousness cannot be accounted in physical terms. For consciousness is absolutely fundamental. It cannot be accounted for in terms of anything else”.¹⁰ Two weeks later, the same journalist asked to their common mentor, Max Planck, this crucial question: “Do you think that consciousness can be explained in terms of matter and its laws? “. Planck’s reply was: “No, I regard consciousness as fundamental. I regard matter as derivative from consciousness. We cannot get behind consciousness. Everything that we talk about, everything that we regard as existing, postulates consciousness”.¹¹

Moving from physics to mathematics, it is worth quoting Eugene Wigner, the father of group theory applied in physics: “When the province of physical theory was extended to encompass microscopic phenomena, through the creation of quantum mechanics, the concept of consciousness came to the fore again: it was not possible to formulate the laws of quantum mechanics in a fully consistent way without reference to the consciousness. All that quantum mechanics purports to provide are probability connections between subsequent impressions (also called “apperceptions”) of the consciousness, and even though the dividing line between the observer, whose consciousness is being affected, and the observed physical object can be shifted towards the one or the other to a considerable degree, it cannot be eliminated. It may be premature to believe that the present philosophy of quantum mechanics will remain a permanent feature of future

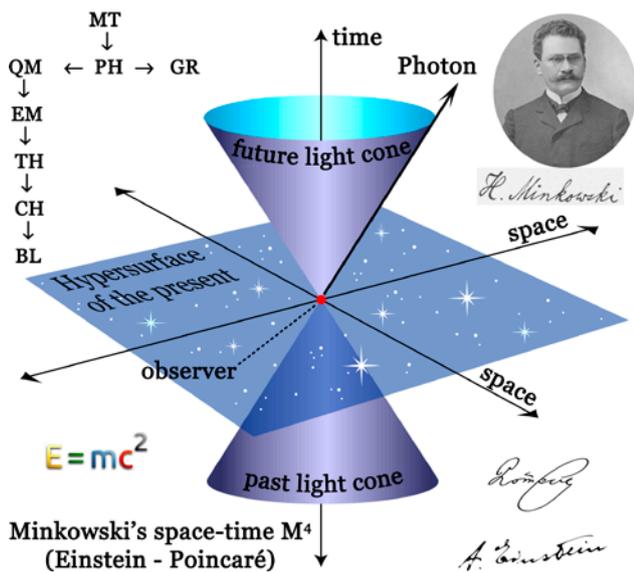


Figure 1. A picturing of the current materialistic paradigm in Western science. Reality is manifested in a 4D-continuum (x,y,z,ic-t) called Minkowski’s space, having inaccessible zones out of a light cone associated to a given observer. On the left, a schematic hierarchy for scientific disciplines shown here as the progression: mathematics (MT) → physics (PH) → quantum mechanics (QM) → electromagnetism (EM) → thermodynamics (TH) → chemistry (CH) → biology (BL). General relativity (GR, not illustrated here) is represented as a separate branch owing to the considerable difficulties met for merging this science with quantum mechanics.

physical theories; it will remain remarkable, in whatever way our future concepts may develop, that the very study of the external world led to the conclusion that the content of the consciousness is an ultimate reality".¹²

It should thus be obvious that putting consciousness at the source of any reality is definitively not the prerogative of an Eastern way of thinking. This means that science, the Western way of thinking, has also something to say on this subject. It would thus be very nice if both ways of thinking could lead to the same conclusion. This was demonstrated in a previous paper using a thought experiment and showing that consciousness cannot be the result of neural activity.¹ Here, we plan to develop the same idea using science's language. We will show that concepts of consciousness, analogic information with meaning, digital information lacking meaning and information activity may be defined out of any space-time framework. Consequently, information necessarily preexists any other concept such as entropy, energy or matter that could be viewed as a mere mapping from a virtual information field towards the observable M⁴ space-time framework. To keep the paper at a reasonable length, the problem of the physical nature of the information field will not be discussed here but treated in a third paper.¹³ Consequently, we will present here only a static version of consciousness based largely on thermodynamics. The scientific reason for such a choice is that thermodynamics aspects are universal and do not depend on mechanisms or physical implementation of the system. This is not true for dynamical aspects that are strongly implementation-dependent with mechanisms that are highly dependent on the physical structures used for storing and processing information.

Our methodology is inspired by David Bohm's model, addressing how the unfolding of an implicate order results in manifest order and structure as a result of the activity of a super-implicate order, which generates various levels of organization, structure, and meaning. According to Bohm, one finds at the root of capacities such as awareness, attention and understanding a pre-conscious "undivided state of flowing movement" – the actual and immediate activity of the holomovement. The nature of this movement can be discerned in a number of common experiences, such as listening to music. In such a model any transformation of consciousness must be a transformation of meaning, suggesting that everything, including ourselves, is a generalized kind of meaning.¹⁴ Quoting Bohm himself about such an approach: "As in the discussion of reason, it was shown how one level of thought will organize the next level. This can go on to produce a structure that may develop indefinitely with relatively closed loops of many kinds. This implies that con-

sciousness is organized through a generative order whose totality is in many ways similar to the totality of the generative and implicate order that organizes matter. It is now possible to look into the question of how consciousness and matter are related. One possibility is to regard them as two generative and implicate orders, like separate but parallel streams that interrelate in some way. Another possibility is that basically there is only one order, whose ground includes the holomovement and may go beyond. This order will unfold into the two orders of matter and mind, which depending on the context will have some kind of relative interdependence of function. Yet at a deeper level they are actually inseparable and interwoven, just as in the computer game the player and the screen are united by participation in common loops. In this view, mind and matter are two aspects of one whole and no more separable than are form and content".¹⁵

Finally, the scientist that has most investigated a consistent connection between physics and psychology is beyond any doubts Ernst Mach: "If psychical life is to be harmonized at all with the theories of physics, we are obliged, I reasoned, to conceive atoms as feeling (ensouled). The various dynamic phenomena of the atoms would then represent the physical processes, whilst the internal states connected therewith would be the phenomena of psychic life. If we accept in faith and seriousness the atomistic speculations of the physicists and of the early psychologists on the unity of the soul, I still see no other way of arriving at a tenable monistic conception."¹⁶

From such a survey of what have been said about consciousness by some greatest men in science, it should be clear that the consciousness-brain relationship should be understood as a unity and not as a duality between spirit and matter. A formal proof of the validity of such a statement has been given previously.¹ Now, it seems that time is ripe to go one step further and analyze at the light of the knowledge accumulated over the XXth century and over the first fifth of the XXIst century how such a monist view fits into modern science. Our philosophical position will thus be that it is possible to map brain activity onto computability with the immediate implication that consciousness should be external to the brain/brains for reasons listed below. We agree that postulating non-biology based brain/mind activity; is seriously disputable and we do not pretend to solve conclusively a debate that has agitated mankind during millenaries. Our aim is rather to allow the reader interested in the phenomenon of consciousness to deepen his own thoughts about the ontologic questioning: "What Is", by providing a safe scientific guideline to the complex bottom-up approach of reality, and a hint of the simple and powerful top-down avenue to the same.

A LOGICAL APPROACH TO CONSCIOUSNESS

As stated by David Bohm, one of the most striking attributes of consciousness is its ability to make order emerge from chaos. Consequently, logics should be at the very root of consciousness. It has been proven in 1913 by the American mathematician Henry Maurice Sheffer (1882-1964) that the Boolean algebra could be derived from the use of a single binary NAND logical operator (alternative denial) represented by the so-called Sheffer stroke (\uparrow).¹⁷ This remarkable property has the consequence that NAND gates are now crucial components of today's computers, for instance, through the use of flash memories. Accordingly, as all logical operations of binary logic may be encoded with just a single logical connector, high-performance computing processors may be readily developed. This immediately suggests basing consciousness on NAND operations.

Accordingly, let P and Q be two propositions that can be either true or false. The alternative denial operation is then defined as being such that $v(P\uparrow Q) = 1$ in all cases except when $v(P) = v(Q) = 1$, in which case $v(P\uparrow Q) = 0$. Consequently, if P stands for a proposition such as "I am", three primitive concepts immediately emerge:

- Negation: $\neg P = P\uparrow P$ that could be interpreted as "I am not"
- Tautology: $\top = (\neg P\uparrow P) = P\uparrow P\uparrow P$ meaning "I am who I am"
- Contradiction: $\perp = \neg\top = \top\uparrow\top = P\uparrow P\uparrow P\uparrow P\uparrow P$ or "I am who I am not".

Our claim is that we are facing the very basis of any kind of consciousness, in other words, its "identity card". Accordingly, the negation operation allows defining what is outside, the tautology what is inside, while the contradiction allows for the existence of incompleteness, that is to say the inevitable existence of undecidable propositions in any kind of coherent computing system using numbers.¹⁸ The other attributes of consciousness then logically follow as soon as the Sheffer stroke is applied to at least two different propositions P and Q. It is for instance possible to introduce the concept of causality through the use of an implication operator:

- Implication: $(P \Rightarrow Q) = P\uparrow(P\uparrow Q)$

Setting $P = Q$, one recovers the tautology under a new form $(P \Rightarrow P)$ that could be translated as "If Me, then Me". In fact, causality allows defining the existence of "time" seen as a never-ending succession of causes (P) and effects (Q). Irreversibility is very easily introduced at

such a level, by the mere fact that the truth table of the proposition $(P \Rightarrow Q)$ is different from the truth table of the reverse proposition $(Q \Rightarrow P)$. The implication allows also introducing the concept of "inhibition", another crucial attribute of consciousness:

- Inhibition: $(P \dashv Q) = (P \Rightarrow Q)\uparrow(P \Rightarrow Q) = [P\uparrow(P\uparrow Q)]\uparrow[P\uparrow(P\uparrow Q)]$

It is worth noticing that implication and inhibition are dual concepts, as it is possible to write: $(P \Rightarrow Q) = (P \dashv Q)\uparrow(P \dashv Q)$. Both operations refer to the same conditional statement "If ... then ..." and differ by the output: "go outside" for implication and "go inside" for inhibition. The existence of an active and expansive mode of action, or "Yang" mode using implication, as well as the existence of a complementary passive or contractive mode, or "Yin" mode using inhibition typical of Eastern philosophies, is thus logically deduced. From a neuronal standpoint, this implies the existence of two modes of autonomy: sympathetic or active, as well as parasympathetic or inhibitive. Alternation between awake state (active consciousness) and sleepy state (passive consciousness) is also described using this logical implication. The former explains the existence in the brain of a default mode network (DCN) associated to introspection, self-referencing, emotional regulation and mind wandering, all anti-correlated to the latter, a task control network (TCN) associated to top-down regulation of sensorimotor processing in control of oriented attention.¹⁹ It has thus been proved that shutting down the DCN was positively correlated with behavioral performance (implication), while reinforcing it interferes with task control, leading to degraded behavioral performance (inhibition).

Another attribute of consciousness is its ability to discriminate things. This is possible through the use of two other logical operators:

- Equivalence: $(P \Leftrightarrow Q) = [(P\uparrow P)\uparrow(Q\uparrow Q)]\uparrow(P\uparrow Q)$
- Incompatibility: $(P \oplus Q) = (P\uparrow P)\uparrow(Q\uparrow Q)\uparrow(P\uparrow Q)\uparrow(P\uparrow(Q\uparrow Q))\uparrow(P\uparrow Q)$

Translated into words, this gives "If Me then You and If You then Me" for equivalence the very basis for affinity or attraction and "If Me then not You and if You then not Me", the basis for repulsion. Such operations explain the structuration of groups of conscious beings into clans, parties, societies, religions, etc.

Finally, consciousness has also the ability to unite things (synthesis) according to a conjunction mode $(P \wedge Q) = (P\uparrow Q)\uparrow(P\uparrow Q)$ translating as "Me and You" or to

separate things (analysis) through a disjunction mode $(Q \vee P) = (P \uparrow P) \uparrow (Q \uparrow Q)$ translating as “Me or You”. Consequently, through synthesis conscious beings interact for sharing something independently of any kind of affinity, while through analysis, they gather for increasing diversity and wealth. These last two modes form the basis of any culture whether scientific, artistic or philosophic.

It is obviously quite amazing that all these fundamental attributes of consciousness derive from the existence of a single logical operation corresponding to the “alternative denial”. From a symbolic viewpoint, such a denial has been represented many times under the symbol of the Ouroboros, i.e. a dragon biting its tail, which clearly suggested by its circular shape, an exterior (negation), an interior (tautology) and an incompleteness (contradiction), owing to the self-referencing of the symbol where the beginning also corresponds to the end (Figure 2).

To conclude, this section on formal logics, it is worth noticing that consciousness may a priori proceed according to three different types of logics, depending on the meaning given to contradiction.

- The first logical mode is based on the allowance for the “*reductio ab absurdum*” proof, in which one

deduces from a contradiction $(\neg P \Rightarrow \perp)$ that P or $\neg\neg P$ are true statements (elimination of the double negation). Here we have the rational and coherent thinking mode typical of classical physics, based on Boolean algebra.²⁰

- The second logical mode rejects “*reductio ab absurdum*” proofs, by stating that contradictions are perfectly allowed, but that starting from a contradiction which is false by nature, one may deduce any kind of true propositions ($\perp \Rightarrow P$ explosion’s principle). Here we have the typical thinking mode of quantum physics stating that quantum objects may have contradictory descriptions such a wave/particle duality for instance. Mathematically speaking, this corresponds to intuitionistic logic characterized by the use of multi-valued Heyting algebra.²¹ Using intuitionistic logic, it may be shown that the double negation has an autonomous status that cannot be assimilated to an affirmation. On the other hand, it is always true that $\neg\neg\neg P = \neg P$. The explosion principle typical of Heyting algebra has physical consequences such as the existence of a big bang for inert matter explaining the observed diversity for matter. At a psychical level, the intuitionistic logic may clearly be associated to the unconscious mind, explaining why dreams are so difficult to interpret using the Boolean conscious active mode.

- The third logical mode corresponds to minimal logic that simply gives no special treatment to the contradiction.²² It follows that using minimal logic, there is no difference between the formula \perp and any other kind of formula F . This means that it is here possible to associate contradiction at any formula F , the negation becoming $P \Rightarrow F$. This is obviously the most amazing mode where nothing can be denied, as everything is true by essence. It is also the “Anything goes” apothegm of the philosopher Paul Feyerabend.²³ Here one may speak of oneness, i.e. the feeling of the deep unity of the universe. This is also the kind of logic depicted by the Ouroboros (Figure 2).



Figure 2. The mythical Ouroboros or snake biting its tail. Left : representation from a Greek manuscript, Codex Parisinus Graecus 2327, fol. 196, written in 1478 by Theodoros Pelecanos. Top right: representation from another Greek manuscript entitled Chrysopoeia of Cleopatra from Codex Marcianus Graecus 299 (Venice), written probably during the 11th century. Inside the Ouroboros, a text stating “Hen to Pan” translating as “All in One”. Bottom right: Zen’s enso (Japanese world meaning “circle”) is a circle that is hand-drawn in one or two uninhibited brushstrokes to express a moment when the mind is free to let the body create.

MEANING, INFORMATION, COMMUNICATION,
LANGUAGE

The above formulation leads to an identity card of consciousness, which is a mapping of its basic logical attributes. This is the only safe attitude when facing a concept that cannot be defined in an absolute manner. By experimenting consciousness, we meet the above attributes and by trying to go beyond that, we perform an act of faith that is out the scope of a scientific

approach. Moreover, as it is consciousness that gives the three possible meanings to contradiction, it should come first, before the two other concepts that are “meaning” and “information”.

Accordingly, with logical thinking, we are at the very root of scientific knowledge corresponding to Plato’s world of abstract ideas. The logical attributes of consciousness introduced above apply to any kind of proposition. Meaning is then the way chosen by consciousness for treating contradiction along 3 fundamental modes (rejection, acceptation or detachment). However, in order to make the connection with our observable physical world, we cannot stay at such an abstract level and we see in the information concept an obvious “fuel”. The idea is then to state that when consciousness meets information, a meaning emerges through application of its three modes and nine ways of reasoning. The notion of meaning may then be applied either internally for introspection (DCN mode of the brain) or externally to act and communicate (TCN mode). Figure 3 shows an illustration of our viewpoint.

As demonstrated by the Palo Alto school of thinking, it is absolutely impossible to “not communicate”.²⁴ Any silence or omission always carries a deep meaning suggesting that meaning is hierarchically superior to information. Now, “to communicate” means exchanging information through a language that may be digital or analogic. Information is thus not a primary attribute

of consciousness, but always a secondary attribute of it that can be non-reflexive (digital mode, TCN) or reflexive (analog mode, DCN).

Consequently, upon any information exchange, it is mandatory to consider two levels of language: the object-oriented language dealing with raw information, and a meta-language taking as object the language itself, thus dealing with more abstract structures. If the object-oriented language is perfectly suited for digital communication at a bit-level, it is however devoid of any meaning. Consequently, the role of the meta-language is to give meaning to the object-oriented language, thus placing analog communication above the digital one. Such a viewpoint is also in agreement with Gödel’s incompleteness theorems¹⁸ stating that languages able to close on their selves contain unavoidable contradictions (and if they don’t, they contain undecidable issues).

In order to decide of the truth of an object-oriented language L, it is thus mandatory to go at an upper ML (meta-language) level to find the resources needed for referring to all the expressions of L. In other words, the truth for L is located in ML and not in L. Similarly, the truth for ML will be located a still upper level MML and so on without ever ending. This shows that a language cannot contain an adequate true predicate for itself and truth cannot be defined at this level: it should be defined using a superior language.

It then transpires that any communication has always two aspects: the content (raw information) and the relation (meaning or interpreted information). As it is the relation that organizes the content, it follows that such a relation can only be a meta-communication. It should also be realized that, in any communication, the emitter may have more information at its disposal than the receiver, even if the receiver thinks that he has exactly the same amount of information (or vice-versa). It is then very dangerous to think that another party holds the same amount of information as oneself and will draw the same conclusions from a given communication.

The trouble with the analogic language is that a large amount of the elements constituting the morphology and the syntax of the digital language is missing and that it is the role of the translator to re-insert the missing elements. Consequently, upon translation of an analogic material into a digital one, it is mandatory to introduce the logical truth functions that are absent in the analogic communication mode. This is particularly true at the level of negation, which does not exist at all in minimal logic, heavily used in analogic communication modes. Any exchange of communication can thus be identified as symmetric or complementary depending on the fact that one considers similarities or differences.

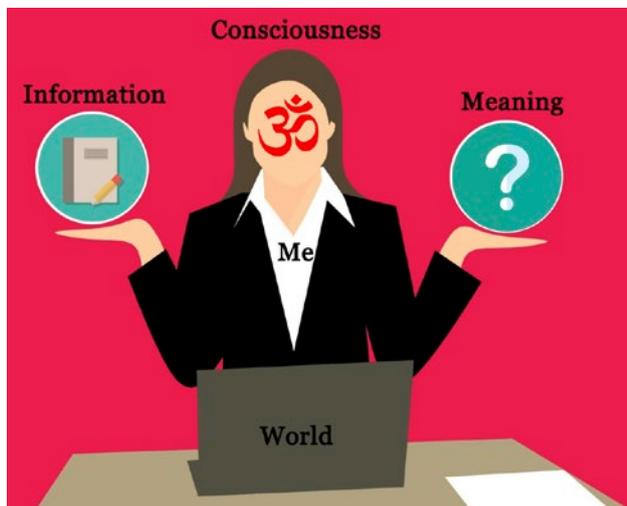


Figure 3. A pictorial representation of a conscious being (Me), represented here as a body and a Mind living in a material world, and using its consciousness to give meaning (?) to information represented by a pen and a book. Consciousness has been symbolized on the head of the conscious being by the mantra “Om”, the cosmic sound of Atman, identical in essence with Brahman, the Self, the only reality (in Hinduism).

Moreover, in any cognitive act, a clear distinction should be made between the fact of perceiving (raw information or object-oriented digital language) and the fact of understanding what has been perceived (information carrying meaning or analogic meta-language). This allows defining the meaning as information within a context. Alternatively, one may say that « *A bit of information is definable as a difference, which makes a difference* ». ²⁵ These two kinds of information may be easily confounded in the common language, despite the fact that raw and interpreted information do not act at the same level of communication.

INFORMATION ACTIVITY

Up to now consciousness appears as a primordial entity embedded in a kind of non-dual universal field filled with a “substance” named information, and has the ability to give meaning to the information stored in such a field through three logical modes and nine logical tools. Upon information exchange two levels of communication have been identified: digital language or analogic meta-language. The next step is then trying to define what could be an “object” in a world holding only information. Our postulate is that consciousness, focusing on a certain amount of information measured in bits, isolates within the non-dual field what we will call an “information pool”. Obviously, such an information pool would be first characterized by a certain number of binary digits (bits), the storing medium being the “stuff” evoked by E. Schrödinger in a 1931 interview and from which the illusion of matter could be created. ¹⁰

As consciousness is able to give meaning to a given information pool, it directly follows that some pools will be perceived by consciousness as holding highly meaningful groups of bits that could be used for building an “identity card” for the pool. Obviously, such highly meaningful bits will be eagerly kept within the pool and not transferred towards another pool, because such a transfer would cause an identity loss. Accordingly, the notion of “ego” is clearly introduced and identified.

Consequently, besides the information content, one should also introduce an information availability measuring the strength of each ego. Being a conscious information pool, each ego may exchange information with another ego that could hold less-meaningful bits, in which case the information availability will be high. At an upper level, ego may accept transferring its meaningful bits towards the universal information field, undergoing a dissolution process.

The notion of information availability thus introduces a fundamental “duality” within the non-dual information field. For instance, one may consider an information pool having low information availability. This basically means that the identity of such an information pool should be preserved during information exchanges. In such a case, one may speak of a static “volumetric” information pool. Alternatively, one may come across an information pool having high information availability. This means that we encounter in such a case a dynamic “radiating” information pool having no “volume” owing to the ease of transferring information. Such dynamic information transfers allow introducing the concept of “time” in order to characterize the “speed” of any information transfer and the associated bandwidth.

A space-time frame filled with matter and radiation thus emerges as a direct consequence of consciousness giving meaning to various pools of the information field. As consciousness has three modes of logical inference, we may identify three ways of perceiving space and time (figure 4) giving rise to three modes of apprehension of reality: by computing with numbers (wakefulness), by using symbols loaded with meaning (awareness) or by trying not to understand or describe by just living here and now (mindfulness).

On such a ground, it is possible to introduce a new concept, **information activity**, defined as the product of information content by information availability and characterizing the overall intensity of information transfers between information pools. Furthermore, this leads to a distinction between emitters that send information and receivers that accept information. But in order to behave as a potential information sender, the emitter has

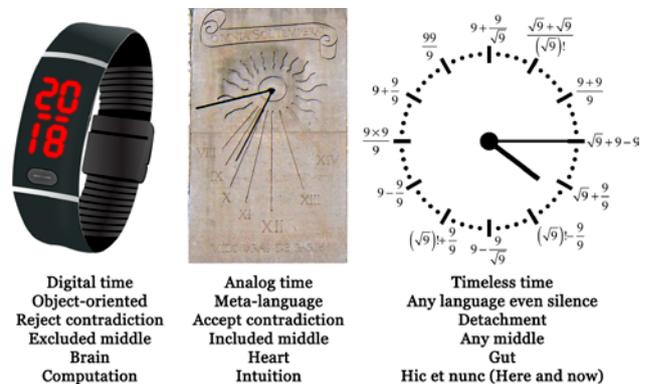


Figure 4. In our approach space and time are creation of consciousness and should be perceived along three different modalities according to the status given to the contradiction. The digital time is useful for a rational comprehension with the brain, the analog time for intuitive comprehension with the heart and the timeless time for immediate comprehension with the gut.

to handle both the emitted information and the context, the context being here defined as the amount of information not transmitted and kept by the emitter. This means that an emitter has a consciousness allowing it to discriminate between the information that should be emitted and the context that should not be emitted. It then logically follows that emitters should have necessarily higher information contents than receivers and that information should flow from pools having higher information contents towards pools having lower information content.

Moreover, if it happens that two pools of information have the same information content, there is neither emitter nor receiver and one may then be allowed to define a new single pool of information by adding the information contents of these two pools. In other words, information pools are thus doomed to always increase in size and should never decrease, leading to the logical conclusion that information content behave as the concept called entropy in thermodynamics. Such an identification of the information content with entropy is then in full accordance with the Shannon/von Neumann definition of entropy²⁶, giving further confidence in this interpretation.

Consequently, we meet here thermodynamics, a science sharing with consciousness the ability to deal with information at a meta-language level and with energy and matter at an object-oriented level. Staying at an information level, one may say that entropy measures the amount of digital information available on one hand,²⁶ while, on the other hand, complexity or thermodynamic depth²⁷ corresponds to the amount of information rejected at an analogic level. Alternatively, one may speak of digital information and analogic exformation that is treated by consciousness to define a context not transmitted during the communication.²⁸ It then becomes possible to reconcile the two conflicting interpretations of entropy. At a digital level of object-oriented language, one finds the Shannon-Von Neumann thermodynamic entropy, while at the analogic level of the meta-language, one meets the cybernetics negentropy of Wiener/Schrödinger.²⁹ A fundamental error is here to think that it is possible to obtain the meaning (cybernetics negentropy) by merely changing the sign of the amount of information (thermodynamics entropy).

It should also be clear that assimilating entropy to disorder and negentropy to order, as done in most thermodynamics textbooks, should be completely avoided. This is because there is no order or disorder at a digital level, such notions belonging to the analogic realm of consciousness observing things. At a digital level, information corresponds to what is unexpected, and there are

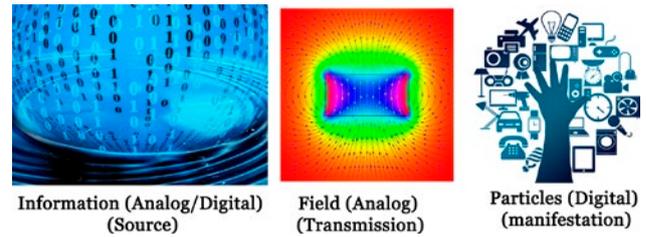


Figure 5. The three fundamental modes of perception of consciousness gives rise to the three basic models of reality: viewed as information at a primordial source level, viewed as fields during propagation and viewed as particles upon Manifestation as matter.

more unexpected things in a disordered situation than in an ordered one.²⁸ Moreover, it follows from Gödel's incompleteness theorems that it is impossible to know if there is order or disorder at a digital level. Order and disorder are thus clearly subjective notions located at the level of the digital meta-language and, as such, they have nothing to do with thermodynamics.

It follows that discriminating between pools of information according to their information contents allows distinguishing between potential emitters having high information contents and receivers having low information contents. However, it should be clear that, at this level, nothing is "observable". In other words, we are moving in a virtual world where everything is perceived as made of information. Here, it is worth quoting the great physicist John Archibald Wheeler: *"I think my life in physics is divided into three periods ... I thought at first that everything was made of particles In my second period everything was made of fields ... In this third, my impression is that everything is made of information"*.³⁰ Figure 5 shows a translation of Wheeler's statement. It is also worth noticing that David Bohm has also introduced in 1985 the notion of activity of meaning, a non-mechanical reality associated to enfoldment and unfoldment and quite close to the information activity concept discussed here.¹⁴

The next step is then to introduce fundamental coupling constants, the role of which is to set a limit between what can be observed (matter) and what cannot be observed (information, entropy and energy).

ENTROPY AND TEMPERATURE

The first constant has the role of giving physical meaning to the abstract notions of information content, information availability and information activity. As shown in figure 6, there is an identity in logical structure between communication and measurements in

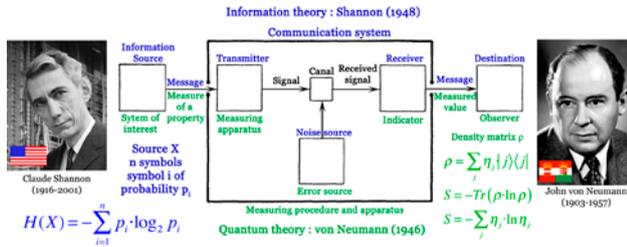


Figure 6. Similarity in logical structure between information theory and quantum theory meaning that information content for the mind should correspond to entropy for the body. Adapted from J. Rothstein (1951).³¹

quantum physics.³¹ This suggests generalizing the entropy concept used in statistical thermodynamics to the information theory.

Accordingly, the mathematician John von Neumann when asked by Claude Shannon to suggest a name for his newly discovered uncertainty function lucidly stated: “You should call it entropy, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name, so it already has a name. In the second place, and more important, no one really knows what entropy really is, so in a debate you will always have the advantage”.³²

It thus should be no surprise that a great confusion exists in science about the definition of entropy that merely reflects the great difficulty of defining consciousness. Such difficulties in definitions stem from the fact that entropy or consciousness cannot be defined explicitly as they are both primary concepts.

However, in the spirit of what has been done for introducing consciousness, the best way to introduce entropy to a material world is to describe its fundamental attributes.³³ Replacing the unobservable “information pool” by its visible counterpart, the “body” or the “soma” in Bohm’s language,¹⁴ it appears that entropy is a “stuff” that can be transferred, poured out, cumulated or distributed among bodies. Each body contains more or less entropy depending on its information content, the entropy of the whole system being equal to the sum of the entropies of its parts. Rubbing, grinding, heating or performing a chemical reaction, are examples of processes able to generate entropy. Entropy also has the property of being unable to cross thermally insulated walls, meaning that if it can be created, it is doomed to increase and never decrease in any isolated system. When entropy is poured into a body, this body becomes warmer, meaning that a body without entropy is absolutely cold. Any entropy increase also causes changes in volume, in shape, changes the state of aggregation as well as electric or magnetic properties. Finally, it is rath-

er easy to measure the amount of entropy in a body: for example, the volume loss of ice while melting is directly proportional to the amount of entropy added.

It follows from such an analogy that our first coupling constant should be an entropy. Now, knowing that entropy S measures also the information content, it comes that temperature T is readily assimilated to information availability, while information activity takes the figure of energy W through a fundamental relationship: $W = k_B \cdot T$ measured with a physical unit named “joule” (symbol J).

Such a unit is well adapted to the human body characterized by an average resting metabolic rate of $3611 \text{ J} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$,³⁴ corresponding to an average power of 105 watts ($1W = 1 \text{ J} \cdot \text{s}^{-1}$). A more convenient energy scale for discussing elementary phenomena in the visible universe is the zepto-joule (symbol zJ), with $1 \text{ zJ} = 10^{-21}$ joules. On such a scale, the universal entropy constant takes the value $k_B = 0.0138 \text{ zJ} \cdot \text{K}^{-1}$ also known as Boltzmann’s constant in memory of the Austrian physicist Ludwig Boltzmann, the father of statistical thermodynamics. Such a “quantum of entropy” allows discriminating between a non-observable world involving entropy changes such that $S < k_B$ and the visible universe where $S \geq k_B$.

ACTION AND FREQUENCY

Now, let us consider the situation where information sent by an emitter is captured by a receiver and then re-emitted without any loss towards the sender, restoring the initial situation. As the final state is the same than the initial one, the process may occur a second time and so on without interruption, leading to the concept of “vibration” characterized by the number of cycles performed per unit of time, i.e. by a frequency f . It should be obvious that activity and frequency have to be related in some way through a second universal coupling constant relating this aspect of the information world to the physical world. Such a coupling constant h is well known in physics under the name of “quantum of action” with a new relationship: $W = k_B \cdot T = h \cdot f$ where h is Planck’s constant, with $h = 663 \text{ zJ} \cdot \text{fs}$, (1 femto-second (fs) = 10^{-15} s). As for the quantum of entropy, the quantum of action L allows discriminating between a non-observable world involving action changes such that $L < h$ and the visible universe where $L \geq h$.

It is worth noticing that the fact that physical action L is quantified is a mere consequence of the quantification of information in bits. In other words, quantum physics, one of the most fundamental theories of modern science, emerges quite naturally from informa-

tion theory.³⁵ With such a link in hand, movement in the information world becomes what is called “kinetic energy” in the physical world, whereas structural information has his physical counterpart named “potential energy”. The first law of thermodynamics stating that the total energy should always be conserved stems from the fact that, once created, information can never be destroyed. Thus, at the scale of the whole universe, information exchanges are necessarily without losses.³⁶

Alternatively, Planck’s constant can also be interpreted as the multiplicative scale factor setting the scale of classical zero-point radiation appearing in classical electromagnetic theory, as relativistic classical electron theory with classical electromagnetic zero-point radiation gives many results in agreement with quantum theory.³⁶ Consequently, the identification made here would remain valid even if quantum mechanics was finally proved to be fundamentally wrong. Such an uncertainty in the validity of quantum theory stems from its well-recognized incompatibility with general relativity, another most important physical theory, *as both theories diverge on the evaluation of vacuum energy density by more than 120 orders of magnitude!!!*^{5, 37}.

LIGHT, MATTER AND ELECTROMAGNETISM

It should also be obvious that the distinction between static spatial-like information and dynamic time-like information cannot be a fundamental one as it is consciousness that gives meaning and identity to the various pools of bits. Consequently, a third universal constant should exist, intimately associating space with time. The basic postulate of equivalence between space and time stemming from the theory of relativity is thus logically introduced. By this definition, the third universal constant should be a speed $c = 299\,792\,458$ meters per second ($\text{m}\cdot\text{s}^{-1}$) giving an upper limit for the transfer of information between information pools. The fact that such a constant should not be infinite is here directly related to the fact that it belongs to the realm of the physical world where pools of information always have a finite number of bits. It then follows that two kinds of entities should exist in a physical universe: those able to propagate with the maximum allowed speed c , known as “photons”, and those propagating at speeds $v < c$, known as “matter”. In the second case, one may assign to a material object with an energy W , an inertial coefficient m or “mass”, linked to it by $\mathbf{m} = \mathbf{W}/c^2$.

As for the quantum of entropy or the quantum of action, the speed of light c allows discriminating between a non-observable world involving speeds v such

that $v > c$ and the visible universe (light cones) where $v \leq c$ (see figure 1).

At this stage we have in hand a possible justification for the observation of a physical universe where energy, the physical counterpart of information activity, could manifest itself through three kinds of variables (temperature, frequency and mass) corresponding to various kinds of information availability, linked through a fundamental equivalence relationship:

$$\mathbf{W} = \mathbf{k}_B \cdot \mathbf{T} = \mathbf{h} \cdot \mathbf{f} = \mathbf{m} \cdot \mathbf{c}^2.$$

However, such a picture applies to an observable universe having movement occurring in a single direction through translation. In order to be able to perform rotations, a 2D-spatial frame is required, requiring introduction of a fourth universal coupling constant e being a quantum of electrical charge with a physical unit named coulomb (symbol C) and such that $e = 0,106$ atto-coulombs (symbol aC), with $1 \text{ aC} = 10^{-18} \text{ C}$.

Associated to this new aspect of information activity, one should have a new variable measuring static information availability corresponding to the so-called electrical potential U (SI unit volt V or energy per coulomb) and leading to another fundamental equivalence relationship:

$$\mathbf{W} = \mathbf{k}_B \cdot \mathbf{T} = \mathbf{h} \cdot \mathbf{f} = \mathbf{m} \cdot \mathbf{c}^2 = \mathbf{e} \cdot \mathbf{U}.$$

Here, the reason for the quantification of electrical charge is that it is a fourth possible manifestation of the same stuff named information that is naturally quantified in bits. As for the quantum of entropy, the quantum of action or the speed of light, the quantum of charge e , allows discriminating between a non-observable world involving charges q such that $q < e$ and the visible universe where $q \geq e$.

Finally, one may combine translations with rotations to allow for spiral movements, requiring a fifth coupling constant related to the existence of magnetism. However, as electricity is linked to static rotations and magnetism to dynamic screw rotations, this new dynamic aspect of information availability $\mu_0 = 4\pi \cdot 10^{-7} \text{ H}\cdot\text{m}^{-1}$ corresponds to a magnetic inductance (SI unit henry H or $\text{V}\cdot\text{s}^2\cdot\text{C}^{-1}$) per unit length. This leads to yet another fundamental equivalence relationship:

$$\mathbf{W} = \mathbf{k}_B \cdot \mathbf{T} = \mathbf{h} \cdot \mathbf{f} = \mathbf{m} \cdot \mathbf{c}^2 = \mathbf{e} \cdot \mathbf{U} = (\mu_0 \cdot \mathbf{e} \cdot \mathbf{c}) \cdot \mathbf{I}$$

involving an electric current $I = dq/dt$, measuring the rate of variation in electric charge q with time t . Introduction of a magnetic permeability for empty space

means that such a medium should be considered as a “substance” having an electric permittivity $\epsilon_0 = 1/(\mu_0 \cdot c^2)$ corresponding to a capacitance (SI-unit farad F or $C \cdot V^{-1}$) per unit length.

WHAT IS ENERGY?

According to the present formulation, energy should be considered as the manifestation of information activity in M^4 space-time. As information activity is driven by consciousness through the meaning, energy and entropy should be considered as an attribute of a manifested consciousness. However, it is worth noticing that in the material M^4 world, energy is indeed a mongrel concept. This fuzzy nature of the energy concept was well perceived by the French mathematician Henri Poincaré: *“In every particular case we clearly see what energy is, and we can give it at least a provisory definition; but it is impossible to find a general definition of it. If we wish to enunciate the principle in all its generality and apply it to the universe, we see it vanish, so to speak, and nothing is left but this – there is something which remains constant”*.³⁹

Translated in our language, this means that energy as an attribute of consciousness may exist under an infinite number of different forms. As energy is the shadow of information activity and as information activity was defined as the product of information content by information availability, we have in hand a universal “recipe” for talking about energy in a manifest world. Each form of energy should then be considered as a product of a “coordinate” measuring the amount of something (a “thing” being, for consciousness, a pool of information with interesting conserved properties) by an associated “propensity” ruling spontaneous or natural transfers of such things between different parts of a thermodynamic system. Let us briefly demonstrate that all forms of energy known in M^4 comply with such a universal recipe.

A first coordinate could measure for instance the entropy content S of a body with an associated propensity corresponding to its temperature T , their product $dW = T \cdot dS$ being called “thermal energy”. The propensity is identified by stating that spontaneous evolution always occurs when entropy flows from a part with a high temperature towards another colder part, the reverse evolution needing another external form of energy. At thermal equilibrium, all temperatures have to be equalized to the same value, meaning that parts at similar temperatures do not exchange entropy anymore.

A second coordinate would measure the weight of a body, that is to say the product of its mass m by a char-

acteristic constant acceleration $g = G \cdot M/R^2$ provided by another bigger mass M of size R where $G = 66.7384 \text{ pJ} \cdot \text{kg}^{-2} \cdot \text{m}$ is Newton’s gravitational constant. To this coordinate, one may associate a propensity corresponding to altitude h , their product $dW = d(m \cdot g) \times h$ being called “gravitational energy”. Stating that spontaneous evolution always occurs when a part at high altitude moves towards a lower altitude identifies the propensity. At gravitational equilibrium, all altitudes have to be equalized to the same value meaning that parts at the same altitude do not move anymore. The reverse evolution consisting on moving from a low altitude towards a higher one cannot be spontaneous, needing the mobilization of another form of energy.

A third coordinate would measure the amount of momentum p of a body, that is to say the product of its mass m by its speed v ($p = m \cdot v$) associated to a propensity corresponding to its speed, their product $dW = v \cdot dp$ being called “kinetic energy”. The propensity is identified by stating that spontaneous evolution always occurs when a part of high speed changes towards a state of low speed, the reverse evolution needing another external form of energy. At kinetic equilibrium, all speeds have to be equalized to the same value, meaning no more exchange of momentum between parts moving at the same speeds.

A fourth coordinate would measure the amount of space (volume V) occupied by a body associated to a propensity corresponding to the pressure P inside the body, their product $dW = -P \cdot dV$ being called “mechanical energy”. The propensity is identified by stating that spontaneous evolution always occurs when a part of high pressure changes towards a state of low pressure, the reverse evolution requiring another external form of energy. At mechanical equilibrium, all pressures have to be equalized to the same value, meaning no more volume variations for parts having the same pressures.

A fifth coordinate would measure the amount of electrical charge Q at the surface of a body associated to a propensity corresponding to the electrical potential U , their product $dW = -U \cdot dQ$ being called “electrical energy”. The propensity is identified by stating that spontaneous evolution always occurs when a part of high electrical potential changes towards a state of lower electrical potential, the reverse evolution requiring another external form of energy. At electrical equilibrium, all potentials have to be equalized to the same value, meaning no more exchange of charge between parts at the same potential.

A sixth coordinate would measure the amount of electric flux $V \cdot D$ (where D stands for electric flux density measured in $C \cdot m^{-2}$) within a given volume V asso-

ciated to a propensity corresponding to the electric field E , their product $dW = E \cdot d(V \cdot D)$ being called “dielectric energy”. The propensity is identified by stating that spontaneous evolution always occurs when a region where the electrical field is high changes towards a state of lower electrical field, the reverse evolution requiring another external form of energy. At equilibrium, electrical field should be the same everywhere in the volume meaning no more exchange of electric polarization between different spatial regions.

A seventh coordinate would measure the amount of magnetic flux $V \cdot B$ (where B stands for the magnetic flux density measured in $\text{Wb} \cdot \text{m}^{-2}$) within a given volume V associated to a propensity corresponding to the magnetic field H , their product $dW = H \cdot d(V \cdot B)$ being called “magnetic energy”. The propensity is identified by stating that spontaneous evolution always occurs when a region of high magnetic field changes towards a state of lower magnetic field, the reverse evolution requiring another external form of energy. At magnetic equilibrium, magnetic field should be the same everywhere in the volume, meaning no more exchange of magnetization between different spatial regions.

An eighth coordinate would measure the amount of matter N within a given volume V associated to a propensity corresponding to the chemical potential μ , their product $dW = \mu \cdot dN$ being called “chemical energy”. The propensity is identified by stating that spontaneous evolution always occurs when a region of high chemical potential changes towards a state of lower chemical potential, the reverse evolution requiring another external form of energy. At chemical equilibrium, chemical potentials should be the same everywhere in the volume, meaning no more exchange of matter between different spatial regions.

As shown above and as stated by Poincaré, if the energy concept can be easily defined in a particular situation as the product of an energy coordinate by an energy propensity associated to such a coordinate, it is impossible to give it a definition covering all possible situations. The only thing that could be said about energy without going into details is that “*it exists something that remains constant during any evolution*”. Obviously, such a general definition corresponds more to a postulate than to a scientific statement derived from empirical evidence. Our scheme nicely relates this postulate to the existence of consciousness.

This suggests that energy could also be rigorously introduced in psychology and spirituality. For instance, Sigmund Freud was the first one to formulate a scientific theory of psychological facts by introducing the idea of the existence of a new form of energy called “mental

energy”. Accordingly, it was rather easy to introduce a coordinate measuring the amount of thoughts N coming from the “Id” with an associated propensity that Freud called “libido” acting as a kind of chemical potential that could be related for instance to glucose consumption within the brain⁴⁰ or to the amplitude of the 0.1 Hz component of heart rate variability.⁴¹ Within such a framework of thinking, knowledge of a total metabolic energy M could be divided by Boltzmann’s constant k_B to retrieve a “psychic temperature” $\psi = M/k_B$ as well as an associated mental energy $dW = \psi \cdot dN$. It is worth noticing that such an energetic approach of mental activity has been criticized and rather linked to a degree of controllability with mental fatigue associated to a lack of desire and not to a lack of energy.⁴² Here, it seems better to identify “desire” with information activity defined as explained above as the product of information content by information availability. The same holds for Qi or Prana that would better be viewed as information activity rather than “spiritual energy”. Again, such misuse of the term energy directly stems from the intrinsic vagueness of the concept.

The vagueness of the energy concept is also well illustrated by the fact that one may also consider only two kinds of energy: a first one describing the ability to change position of a body (kinetic energy) and a second one describing the ability to change the relative disposition of its constituting parts (potential energy). By contrast, entropy has a single meaning: measuring the information content in the world of consciousness and as the spreading of energy over all the accessible degrees of freedom in M^4 . The reason for the existence of the second law is then to distinguish between reproducible experiments in M^4 and non-reproducible ones that are “virtual”.⁴³

Accordingly, during mental activity, everything is possible, and the fact that an event is reproducible or not does not matter anymore. The fact that self-organized structures and diversity in M^4 stem from a flux of entropy⁴⁴ may also be logically related to an information flux in the information field of consciousness.

Finally, it is worth noticing that it is possible to avoid speaking about energy and entropy as two different entities in thermodynamics. It is the “free energy” concept or “chemical potential” defined as the total energy corrected of any entropy variation at a given temperature.⁴⁵ The trouble here is that the expression “free energy” may also be interpreted as the energy contained in the physical vacuum, i.e. as “zero point energy”.³⁷ A much better way is then to associate to each substance an “activity” variable, noted “ a ”, with the value $a = 1$ when the system contains only this substance (pure state) and the value $a = 0$ when the substance is com-

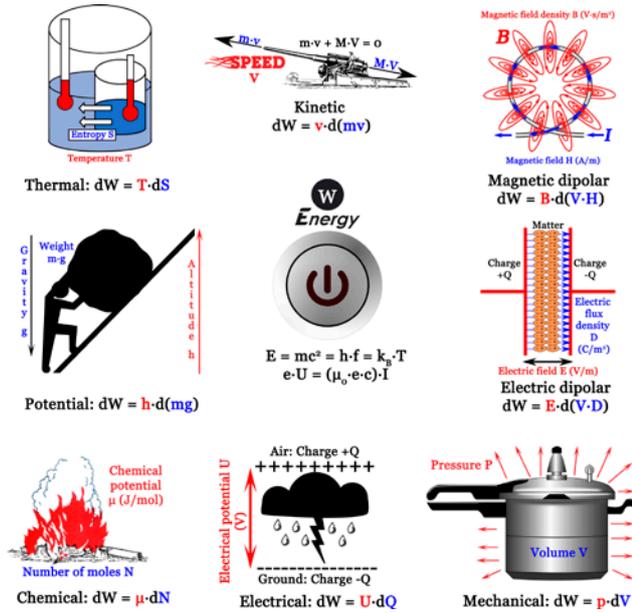


Figure 7. Eight common forms of energy in the observable M^4 space. In each case, energy corresponds to the product of a coordinate measuring an amount (highlighted in blue) by an associated propensity (highlighted in red) taking at equilibrium the same value everywhere in the system. Other forms of energy not represented here may also exist such as for instance interfacial energy $dW = \gamma \cdot dA$ where A is the coordinate measuring the amount of area and γ a propensity called surface tension. One may also cite elastic energy, $dW = x \cdot d(k \cdot x)$ where $k \cdot x$ is the coordinate measuring the amount of tension and x the propensity corresponding to a length. In fact it exists an infinite number of energy forms according to the meaning given by consciousness to the manifestation of information activity. One may thus even define a psychic energy, $dW = \psi \cdot dN$, where N is the coordinate measuring the amount of thoughts and ψ the associated propensity that could correspond to the intensity of desire for instance.

pletely missing in the system. Intermediate values ($0 < a < 1$) will thus describe any kind of mixture containing a given substance in variable amounts. Using such an “activity” concept avoids facing the troublesome energy/entropy duality, with just a single rule stating that exchanges of energy, entropy or matter always occur from spatial regions having a high activity, towards spatial regions having a low activity. This is a much satisfying alternative way of stating that energy should always be conserved (first law) and that entropy should always increase (second law). It then appears that the activity concept is not only a convenient way of giving a direction to any kind of evolution, but that thanks to its unified nature, it could also be considered as a more fundamental concept than energy or entropy considered separately. This is why activity has been put at the forefront and energy/entropy in the back in our previous paper.¹

DISCUSSION

In this paper we have proposed associating the concept of consciousness to the operation of a single alternative denial logical operator (\uparrow) acting on pools filled with information and giving meaning to them. Using the computer metaphor, pools with meaning then correspond to software, while pools devoid of meaning correspond to raw data. The ensemble of all information pools forms an information field that we may call “supra-consciousness”. At this level of minimal logic, there is no special treatment for the contradiction ($\perp = P\uparrow P\uparrow P\uparrow P\uparrow P\uparrow P$) that cannot be considered as the negation of a tautology ($\top = \neg P\uparrow P$). At a second level of intuitionistic logic (meta-consciousness), contradiction is viewed as the mother of any kind of truth ($\perp \Rightarrow P$), the negation having the property that $\neg\neg P = P$. At a third level of Boolean logic (rational consciousness), contradiction is used by consciousness to infer that something is true (if $\neg P \Rightarrow \perp$ then $\neg\neg P \Rightarrow \neg\perp = \top$).

Such a ternary approach of consciousness is by no means new and has already been explored by Ernst Mach by considering that Nature consists of the elements given by the senses.¹⁶ In other words, Mach was convinced that what we usually call sensations are the true elements - elements in the sense that no further resolution has yet been made of them - of the world. Then, the primitive man first takes out of them certain complexes of these elements that present themselves with a certain stability and are most important to him. Consequently, every physical concept is nothing but a certain definite connection of the sensory elements denoted by symbol A, B, C, \dots , and every physical fact rests therefore on such a connection. These elements are the simplest building stones of the physical world that we have yet been able to reach. In our approach such complexes of elements may be mapped with the notion of “information pool”. In his analysis, Mach was indeed obliged to introduce three kinds of complexes noted ABC (i.e. $\neg P = P\uparrow P =$ things out of the body), KLM ($\top = (\neg P\uparrow P) = P\uparrow P\uparrow P =$ the body) and $\alpha\beta\gamma$ for anything else ($\perp = \neg\top = \top\uparrow\top = P\uparrow P\uparrow P\uparrow P\uparrow P\uparrow P =$ the spirit). With these three complexes, one may for instance derive the existence of conscious I (ego) as $(KLM + \alpha\beta\gamma)$ facing an external world (ABC) made of things. But this is not the only possibility as one may have a pure spirit as $\alpha\beta\gamma$ facing a material world ($ABC + KLM$). A third combination could also be a material body (KLM) facing a spirit impregnating all things ($ABC + \alpha\beta\gamma =$ God). Finally, one could also envision a non-dual and non-local consciousness ($ABC + KLM + \alpha\beta\gamma =$ Atman). But, if Mach has derived such a scheme from its scientific empirical expe-

rience, we get the same result from the mathematical structure of logics based on propositions about the world linked into complexes through the Sheffer's stroke (\uparrow).

It was also deduced that space and time also have a triple interpretation (digital, analogic and both attributes) as well as physical reality (particles, fields and information). The fact that the time sensation is intimately associated to consciousness has already been analyzed in details by Ernst Mach¹⁶, and before him by Saint Augustine (time was a feature of consciousness named *animus*) and Plotinus (time is generated by the soul or psyche while eternity is the quality of the spirit or nous).⁴⁶ The evolution towards a ternary aspect of time was perceived in the Middle ages by Meister Eckart by adding the notion of *Nuâs*, the intersection of time and eternity. Eckart was thus talking of the *Nu* (=Now) in which time dissolves into eternity, a concept also identified by Sufi masters as *Ibn al-waqt* i.e. "son of the moment", free from the chains of past and future. The fact that time is a feature of the activity of consciousness was also well perceived in Hinduism (*ksana*) and Buddhism (*U-ji*). However different these spiritual ways may be, they all require three actions: focusing on the interior (internal analog time), body exercise to strengthen the will (external digital time) and some kind of regulation of breath (timeless time).

We have also introduced the concept of information activity in relation with the physical notions of entropy and energy with a fundamental relationship: $W = k_B \cdot T = h \cdot f = m \cdot c^2 = e \cdot U = (\mu_0 \cdot e \cdot c) \cdot I$. On the other hand Ernst Mach has clearly identified five basic elements for sensations: time-sensation related to consciousness, color-sensation and space-sensation related to the sight/touch pair, tone-sensation related to the ear/voice pair and matter-sensation related to the taste/smell pair.¹⁶ Following our approach an immediate mapping emerges: color/temperature (*T*) through Wien's displacement law, tone/frequency (*f*) through the existence of music, matter/mass (*m*) through the notions of atoms and molecules. Such a mapping leaves space-sensation mapped to the existence of static charges (electricity) and time-sensation mapped to the existence of moving charges (magnetism). Moreover, as movement needs specification of an inertial referential frame, a complete equivalence between electric and magnetic field and thus of space with time is expected. This is in agreement with the basic postulate of special relativity. This could be a quite convincing argument in favor of putting a single concept (information) at the source of Mach's five elemental-sensations associated to a physical world.

But one may also make a mapping with the five Platonic solids of antiquity: tetrahedron (fire/color-sensa-

tion), octahedron (air/tone-sensation), cube (earth/matter-sensation), icosahedron (water/space-sensation) and dodecahedron (ether/time-sensation). In such a symbolic language, the space/time equivalence could be mapped to the mathematical duality existing between dodecahedron and icosahedron. As cube and octahedron are also dual geometries, this also suggests another equivalence between tone (frequency) and matter (mass) in full agreement with quantum field theories based upon the equivalence $h \cdot f = m \cdot c^2$. Finally, the fact that the tetrahedron is its own dual could be mapped to the well-known fact that colors may be generated either by addition (unequal RGB-triples) or by subtraction (dual unequal CMJ-triples), the white-sensation (light) being produced by equal RGB-triples and the black-sensation (darkness) by equal CMJ-triples. Noticing that the wood grows from the earth and that the metal drops as meteorites from the sky (ether), we also have a mapping connection with the five Chinese elements.

Obviously, one could argue that such mappings are just coincidences occurring by chance. Such a position would in fact be the only reasonable conclusion in a bottom-up approach where the "big" is explained by the properties of the "small" holding the ultimate truth. However, in the top-down approach used here, where it is the big that is the ultimate reality that could be fragmented in a infinite number of ways into an infinite number of small illusory entities, these mapping based on mathematical ideas are just the glint of the profound unity and coherence of the information field holding supra-consciousness.

Going to neurosciences, it is satisfying to see that three kinds of consciousness states have also been identified: C0-consciousness for unconscious processing, C1-consciousness for having an information in the mind calling for an action on the outer world and C2-consciousness for introspection or meta-cognition.⁴⁷ A possible mapping would be to associate supra-consciousness (detachment from contradiction) to unconscious information monitoring C0, meta-consciousness (acceptation of contradiction) to introspective C2-consciousness and rational consciousness (reject of contradiction) to extrovert C1-consciousness. It is worth noting that three levels of consciousness (type I primary, type II oriented outwards and type III oriented inwards) was also developed by Jean-François Houssais⁴⁸ or by Philippe Guillemant (*anima*, me and self).⁴⁹ Referring to Block's concepts of A-consciousness (availability of information for use) and P-consciousness (perception of information),⁵⁰ it should be clear that here a fundamental ingredient is missing, explaining the considerable difficulties met by such a reduction from three modes to only two modes.⁵¹

Taking such a triple structure of consciousness for real then leads to the unavoidable conclusion that the current M^4 framework is too narrow and should be enlarged by adding at least two dimensions to it.

The need for such an enlargement from M^4 to a V^6 space, where the letter ‘V’ stands for Verity or Virtual, is already obvious in physics where general relativity is not compatible with quantum physics and is strongly suggested by the conformal invariance of Maxwell’s equations.⁵ This point will be fully developed in a third paper¹³. Another important point that has not been addressed here is the physical nature of the information field. Speaking of information without referring to the kind of memory used for storage is obviously not a tenable position from a scientific viewpoint.⁵² Taking for granted the metaphor of the computer, we know that memory is a crucial component for information processing. Here, we have proposed to link consciousness to an information field without referring to the kind of memory used for computing. In an annex to this paper, we have recapitulated the main technologies currently used for building memory devices for artificial intelligence design. In biology, we find neurons that can fire (spike of action potential or bit 1) or not (no spike or bit 0). These all-or-nothing pulses are the basic language of the brain supporting a brain-computer metaphor. Even, if there are good reasons for criticizing such a metaphor⁵³, all the standard arguments about why the brain might not be a computer are nevertheless rather weak nowadays.⁵⁴ Viewing consciousness as a “secretion” of neural activity, the problem appears to be awfully complex and unsolvable owing to Gödel’s incompleteness theorems¹⁸ stating that all consistent formal systems, that concern themselves with numbers, contain formulas about those very systems that are undecidable within the systems themselves. As self-reference is key for deriving meaning from elements that in themselves do not have meaning such as strings of bits, symbols, neuronal firing, etc., we are forced, in order to keep coherence, to kick consciousness out of neurons and brain activity as proposed here. It thus emerges in the brain a blind spot, something present but unable to be represented from within the system, which could be called the conscious “self”.⁵⁵ But, in contrast with Vukadinovic austere conclusion viewing consciousness as a nothingness having no independent existence apart from the brain, we argue that such a necessary blind spot is the door by which supra-consciousness enters the brain.)

Last but not least, our approach is closely related to Eastern traditions emphasizing that consciousness is the ultimate reality and that matter is just “maya” or illusion. Amazingly, such a nature consciousness was clearly per-

ceived by the great mathematician Henri Poincaré, in a paper written in 1906 and added to French editions of his book “Science and hypotheses”: “*One of the most surprising discoveries that physicists have announced in the last few years is that matter does not exist*”.⁵⁶ Recognition of this basic fact is also the reason why defining consciousness is generally perceived as a hard problem.⁷ As quoted by the cognitive neuroscientist Marcel Kinsbourne: “*What makes any problem hard is that something false but attractive stands in its way*”.⁸ Here the thing that is fundamentally wrong but nevertheless quite attractive is obviously the fact that matter and spacetime exists by itself.

CONCLUSION

To conclude, it should be recognized that from a scientific viewpoint based on the mathematical structure of logics that at least three levels of consciousness have to be distinguished in any discussion about such a concept that can be experimented :

- A rational consciousness giving an autonomous status to the logical operation of negation, to which no contradiction is possible since a double negation is equivalent to an assertion. Rational consciousness finds itself associated to digital information, object-oriented languages at the level of communication, or to thermodynamic entropy in the physical world.
- A meta-consciousness that admits the existence of contradiction, which allows for double negation to acquire an autonomous status different from the one of the assertion. Meta-consciousness is linked to analogic information, to meta-languages carrying meaning in communication, or to cybernetic entropy, also named negentropy, that we can relate to the existence of living systems.
- A supra-consciousness that does not attribute any specific status to contradiction, which amounts to making the operations of negation and implication equivalent. Supra-consciousness, for its part, transcends digital/analogic duality of information, for, at this level, only positive assertions linked by non-local causality chains exist.

The existence of supra-consciousness is usually ignored in neurosciences but was anticipated by top-most scientists: Max Planck (theory of quanta), Werner Heisenberg (matrix mechanics), Erwin Schrödinger (wave mechanics), Eugene Wigner (group theory), John A. Wheeler (cosmology), Henri Poincaré (theory of chaos), David Bohm (Aharonov-Bohm effect), Albert Einstein (theory of relativity) and Ernst Mach (theory of sensations). We have given here scientific arguments for

the necessity of using a top-down approach where consciousness generates space/time/matter/energy concepts from an universal stuff named information instead of the usual bottom-up scenario where space/time/matter/energy secretes consciousness as an emergent property of complex systems. It should be clear that our approach does not claim to be a kind of universal and transcendental truth that cannot be falsifiable by doing experiments. As shown in a third paper,¹³ it is perfectly possible within the proposed framework to formulate falsifiable assertions after considerations of dynamical aspects of information processing. To do this, we will have to introduce physical mechanisms allowing computing quantitative data that may be checked against well-designed experiments. It is our hope that the argumentation developed here will be of some help for performing well-designed experiments about the phenomenon of consciousness in a very next future.

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ANNEX

Here we describe for readers not familiar with technological aspects of information processing, the main techniques used to build artificial or natural memory devices. In the physical M^4 world, information is read or written on a material substrate that could be polycarbonate covered by aluminum for optical disks, a ferromagnetic material for tapes or hard-disks, silicon for

memory chips, or a metal-oxide semiconductor for flash memories. In all cases, one have to encode a succession of bits that can be zero (0) or one (1).

For optical compact disks, one uses lasers of different wavelengths: $\lambda = 780$ nm for CD, $\lambda = 650$ nm for DVD and $\lambda = 450$ nm for BluRay to read and write bits. Upon writing, the laser beam etches bumps (called pits) into the plastic surface, a bump representing the number 0 or leave a flat unburned area on the disc, called a land, representing the number 1 forming a continuous spiral of about 3–5 billion pits. The burned polycarbonate is then coated with an aluminum layer that reflects light. Upon reading, the laser flashes up onto the shiny side of the CD, with the lands reflecting the laser light straight back (bit 1), while the pits scattering it (no reflection or bit 0). For recordable compact disk (CD-R), there is a layer of dye between the protective polycarbonate and the reflective aluminum. For writing information, a high-power is used able to heat the disc in order making a tiny black spot on it. Upon reading, the laser light is completely absorbed by black spots (bit 0) while hitting unburned areas the laser light reflects straight back (bit 1). Such technologies cannot be used to manufacture rewritable compact disks (CD-RW). Instead of having a layer of dye, a CD-RW has a layer of metallic alloy AgInSbTe that can be crystalline and transparent to light (bit 1) or amorphous and opaque blocking light (bit 0). When a laser hits this material, tiny little areas can be changed back and forth between the crystalline and amorphous forms, allowing reading and writing information at will.

Ferromagnetic materials used in magnetic tapes, magnetic hard drives, and magnetic random access memory can also be used for information storage because they magnetic state can switched between two states using a magnetic field that is generated by electric currents. Here, a conductive layer forms a program/erase line for altering the logic value stored in the device. A bit one or a bit zero can be stored in the ferromagnetic region depending upon a direction and a magnitude of current flow through the conductive layer. By contrast memory chips use MOSFET transistors made of silicon to store information that is basically a three-terminal device with terminals named as Source, Gate, and Drain. Gate voltage controls the flow of current between source and drain. If gate voltage exceeds a particular threshold voltage, a current flows (bit 1) while below if gate voltage is below the threshold; there is no current (bit 0). The drawback is that as soon as the power is turned off, all the transistors revert to their original states—and the memory loses all the information it has stored. To overcome this problem, flash transistors have

been developed having a second gate (control gate) above the first one (floating gate). Oxide layers through which current cannot normally pass separate the two gates. In this state, the transistor is switched off storing a bit zero. But upon application of a positive voltage between the drain and control gate, electrons get pulled in a rush from source to drain. A few also manage to wriggle through the oxide layer by a process called tunneling and get stuck on the floating gate storing a bit one. The electrons will stay there indefinitely, even when the positive voltages are removed and whether there is power supplied to the circuit or not. Putting a negative voltage between the drain and the control gate repels the electrons back the way they came, clearing the floating gate and making the transistor store a zero again.