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Chemical Affinity as Material Agency for Naturalizing Contextual Meaning

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Abstract: Chemical affinity involves the integration of two different types of interaction. One is the interaction operating between a pair of reactants while forming a chemical bond, and the other is the prior interaction between those reactants when they identify a reaction partner. The context of the environments under which chemical reactions proceed is identified by the interaction of the participating chemical reactants themselves unless the material process of internal measurement is substituted by theoretical artifacts in the form of imposed boundary conditions, as in the case, for example, of thermal equilibrium. The identification-interaction specific to each local participant serves as a preparation for the making of chemical bonds. The identification-interaction is intrinsically selective in precipitating those chemical bonds that are synthesized most rapidly among possible reactions. Once meta-stable products appear that mediate chemical syntheses and their partial decompositions without totally decomposing, those products would become selective because of their ongoing participation in the identification-interaction. One important natural example must have been the origin and evolution of life on Earth.

Keywords: chemical affinity; computation; covalent bond; cross-hierarchy exchange; internalism; measurement; meta-stable products; narrative forms; non-covalent bond; semiosis; time

1. Introduction

Chemical affinity assumes a unique role in a wide variety of material organizations in the physical world. Although it is a type of interaction, chemical affinity is different from the interactions entertained in physics. The difference rests upon the perspective we take. In physics, given a system of many particles, it is customary to view their interactions as occurring simultaneously with the presence of the particles themselves. Unless further qualifications are explicitly made, the physicist assumes an externalist, and idealist, stance, enabling the perspective that, once a system of interacting particles is present, reactions are simply taken for granted at the same time all over the system as a foregone conclusion. Interactions are taken to automatically follow the simultaneous coexistence of these particles. The unity of each particle, once admitted as such, is maintained throughout on methodological grounds unless it is acted upon from the outside. In contrast, the chemical affinities entertained in chemistry are the focus of the chemist when considering a limited local set of particular reacting individual atoms and molecules. The chemical affinities unique to a reacting molecule are unaffected by chemicals residing over beyond its limited immediate perceptual horizon, while physics has methodological prerogative of assuming an unlimited perceptual horizon even on the part of interacting atoms and molecules. The chemist sits, as it were, on the shoulder of a reacting molecule, sharing with that molecule the assessing of affinities as between being potential and actual. That is an example of what we call the internalist stance [1,2].

Our present focus on chemical affinity in relation to the issue of information is signified by at least two aspects. One is to emphasize that a reacting molecule can serve as an agent of being informed about which molecules in the neighborhood it will react with. Another aspect is to inform the chemist of what sort of new products would eventually be synthesized. The usage of the term information here is exclusively synthetic, and chemical affinity could assume the role of an active and synthetic agency hopefully reaching up to what is called information on strictly material grounds. In order to clarify the role of chemical affinity in light of information, a simple pedagogical example may be helpful here.

Let us imagine, for instance, a tight box filled with the inert gas, argon, which is further contaminated by three other particles, namely, a hydrogen molecule, an oxygen molecule and a sulfur atom. The chemical affinity latent and potential in the hydrogen molecule is such that it can make either a water molecule when colliding with the oxygen molecule or a hydrogen sulfide molecule when colliding with the sulfur atom. These three particles in the gas prior to making a chemical bond, e.g., a covalent bond, between them can act upon and be acted upon each other through electrostatic interactions or their modifications, including Lennard-Jones or van der Waals interactions, which a physicist could also perceive. Those affinities, due only to electrostatic attractions prior to the stage of forming a chemical bond, do not specify the upcoming bond-making. They are not specific enough to forebode which bond, either that of a water molecule or of a hydrogen sulfide molecule, will actually be made. The covalent-bond to be made by way of sharing orbital electrons between the interacting particles is thus selective in forming the bond out of possible ones that were potential at the prior stage involving only physical affinities. Even though the sulfur atom would produce faint electrostatic attractions toward the hydrogen molecule separated from it by a sizable distance in the gas, it would remain idled if the oxygen molecule comes first in recruiting and sharing the hydrogen's electrons.

Underlying, and preceding the formation of a chemical bond is necessarily the mutual identification of the participating particles.

The hydrogen molecule in the gas differs in stability from the hydrogen atoms in the synthesized water molecule. We will consider that once a material unit, such as the water molecule, has formed, it would become plausible to associate it with another term—the “self”—since the agency forming and preserving this unit in a natural setting is just the unit itself, which would be immanent in the situation prior to being actually realized.

The natural descriptive means for expressing the presence of a self would be through first person descriptions as an indispensable narrative form. However, first person descriptions by themselves cannot serve as a dependable means for framing definitive statements in the empirical sciences because of the equivocality due to the plurality of possible reports. Despite that, first person descriptions cannot be dismissed simply by decree since the participation of local agencies in forming and maintaining the organizing units is the rule and not the exception empirically, even though their reports become fuzzified as they change over time. We believe that if one could reach a relatively stable organizing unit by tracking the flow of first person descriptions, this might provide us with an opportunity to access the identity of a unity—a self—that is implicit within third person descriptions. Its presumed descriptive stability would emerge indirectly from the temporal plurality of first person reports made under its influence. This could be the essence of what the internalist stance might deliver.

Bond making in chemistry is an internalist enterprise in the sense that this action is grounded in the inescapable fact that an internal agency must be capable of distinguishing between being potential or stressed for making an einselection and actual or being only temporarily relieved as a consequence of implementing an einselection [3]. Furthermore, this distinction is actually embodied in how limited resources, such as an orbital electron to be shared in a covalent bond, or a local space to be occupied by each ionic atom for an ionic bond, will necessarily be allocated internally. Only those bonds surviving local resource limitations can be made accessible to third person observations and descriptions. A descriptive author, as it were, sitting on the shoulder of a surviving chemical compound, would be entitled to contribute a report about the emergent supporting material vehicle even in third person descriptions after the fact.

A methodological advantage of focusing upon chemical affinity while addressing the development of material organizations, including biological ones, would be constructed by allowing potential and actual affinities both to be considered, as well as by allowing switching over to those actual affinities when their descriptions in an objective sense might be required. A positive aspect of the present methodology will be seen in tracing the development of an organizing unit while it repeats the actual bond-making accompanied by subsequent bond-breaking. A case in point would be the synthesis of meta-stable products in material evolution under far from thermal equilibrium conditions.

2. Synthesizing and Decomposing Meta-Stable Products

Chemical reactions in thermal equilibrium are exceptional in assuming that every forward reaction is exactly counter-balanced with its reversed reaction. This is the principle of detailed balance. A characteristic quantitative value specifying the equilibrium reactions is constructed as the equilibrium constant, expressed in terms only of the difference of the Gibbs free energy between the reactants and

the products and the equilibrium temperature of the reaction solution. The equilibrium constant determines the relative ratio of population densities between reactants and products in thermal equilibrium, in which no development of further products is possible.

In contrast, however, if the stipulation of thermal equilibrium is lifted, the principle of detailed balance between initial reactants and final products no longer holds. There would be no stipulation enforcing each bond-making reaction to be exactly counter-balanced with its reversed bond-breaking reaction, even though bond-breaking reactions may be unavoidable, as revealed in instances of photolysis, hydrolysis or thermal decompositions. Now the possibility arises that a product might remain as meta-stable in the sense of preserving some of the chemical bonds formed at the preceding, preparatory stage, even while some other previously synthesized bonds would eventually be broken. This meta-stable product can thus enter into a succeeding stage of forming further chemical bonds involving surviving bonds carried over from the preceding stage, and then rearranging them.

The occurrence of meta-stable products processing bond-making and bond-breaking opens the likelihood that a meta-stable product could serve as material support for processing further exchanges of material. Specific to this material support is that, while processing the exchange of material, it survives by pulling in and feeding upon the material flows available from the readily-accessible neighborhood by mediating the potential chemical affinities latent in its support into actual chemical bonds. At the same time, this support also continually suffers partial decomposition. The identity of the support, or framework, for processing the exchange of material is thus sought *in the material flow ITSELF*, rather than in particles moving within that flow. Significant in this scheme of material exchange processing is simply that the operation of chemical affinity repeatedly transforms from potential to actual and back without relying upon, for example, something like a full-blown background function of biological metabolism. Furthermore, the likelihood of the emergence of this kind of material support for the processing of material exchanges could provide biological evolution with a scheme of proto-metabolism already feasible at the level of chemistry.

Experimental evidence for such a material support that became important to biology at an evolutionary stage prior to its onset is available from observations on the operation of the citric acid cycle in the absence of biological enzymes [4]. A rough sketch of the experiment is that the reaction solution, including all of the major carboxylic acids up to tri-carboxylic acids, is repeatedly circulated between a hot (120 °C) and a cold (0 °C) region, as in the case of seawater circulating around the vicinity of hydrothermal vents on the ocean floor. The reaction solution is kept away from thermal equilibrium by maintaining a temperature gradient. The carboxylic acid molecules we focused upon include pyruvate as the carbon source, oxaloacetate, citrate, isocitrate, α -ketoglutarate, succinate, fumarate and malate. We did not supply aconitate from the outside, since it is a dehydration product of citrate, and isocitrate is a hydration product of aconitate once the cycle is operating. The objective of the experiment is to see whether the two carbon atoms supplied from pyruvate in the form of the acetyl group $\text{CH}_3\text{-CO-}$ as a complex of a methyl group, $\text{CH}_3\text{-}$, and a carbonyl group, -CO- , could further transform their chemical bonds and then leave the cycle in the form of carbon dioxide, CO_2 , in the absence of biological enzymes [5]. The general perspective was that biology organizes but does not generate chemical activities.

If the cycle is operative, an oxaloacetate molecule fed with the acetyl group $\text{CH}_3\text{-CO-}$ from pyruvate is transformed into a citrate molecule, modifying the supplied acetyl group into a complex of a methyl group and a carboxylic group $\text{-CH}_2\text{-COO-}$. The newly formed complex $\text{-CH}_2\text{-COO-}$ remains as is until the citrate molecule is transformed into succinate via isocitrate and α -ketoglutarate. The complex group $\text{-CH}_2\text{-COO-}$ in the succinate is further transformed into the complex of a carbonyl group and a carboxylic group, -CO-COO- , when the succinate molecule is transformed into oxaloacetate via fumarate and malate. The release of a carbon dioxide molecule, CO_2 , from the carboxylic group of the complex -CO-COO- toward the outside of the cycle is made only after the transformed oxaloacetate enters the second round of transformation, and is transformed into another citrate molecule when fed with the acetyl group from pyruvate as in the first round. The effect of releasing the carbon dioxide molecule from the cycle is to find the pathway from isocitrate to α -ketoglutarate in the second round of transformation. Another carbon atom in the carbonyl group -CO- in the complex, -CO-COO- , found in the oxaloacetate at the end of the first round is released in the form of a carbon dioxide molecule in the pathway from α -ketoglutarate to succinate in the fourth round after being further transformed into the carbon atom in another carboxylic group [6].

This experiment revealed that when there is no pyruvate in the reaction solution, the cycle does not emerge, even though all of the seven carboxylic acids (oxaloacetate, citrate, isocitrate, α -ketoglutarate, succinate, fumarate and malate) are present initially. Pyruvate is thus vital to running the cycle as the source of carbon atoms taken up by the cyclic material support, though the carbon atoms taken in eventually break away from that support and are released in the form of carbon dioxide. Importantly from our perspective, when one of the seven carboxylic acids, such as α -ketoglutarate, is missing in the initiating preparation with pyruvate present, the cycle does not emerge initially, but gradually comes to synthesize the missing carboxylic acid from within as the reaction solution repeatedly passes through the temperature gradient. This emergence of a bond-making that was initially missing shows that the material support running the cycle is immanent in the presence of given initiating and boundary conditions [3,7].

The meta-stable unit in the above example is the citric acid cycle itself. Being the material support processing the exchange of material, it is clearly a physical phenomenon. However, it needs to be understood in reference to its hierarchical nature [8]. The hierarchical relations here would be:

[temperature gradient [citric acid cycle [organic compounds]]].

These hierarchical relations once registered in the finished record are unquestionably approachable in third person descriptions. In fact, a material unit processing the exchange of its constituent particles does not exist at the same hierarchical level as those particles. If these particles are regarded as being fundamental units, as would be common in physics, then the material unit processing the exchange of the particles would tend to be understood simply in terms of these particles. However, such a reduction of a higher level into a lower would ignore the identity of the material unit at the higher level. Its level of description transcends the level where the particles have their meaning in the system. Addressing the higher level properly, thus avoiding entrapment by reduction to the lower level, requires that we pay attention to the uniqueness of the higher level itself, as such [9]. That is, we should acknowledge the class identity of any material unit which remains unmodified by the exchanges of its constituent material particles of the same kind, just as we recognize it, for example, in the living cell. Such an

acknowledgement of the class identity in a third person description is due necessarily to referring to the consequence of the activity of the material unit assuming first person status. Once the citric acid cycle is set into operation, the cycle has its own identity even though the constituent carboxylic acid molecules are exchanged with similar individuals. We must also recognize that the identity of the citric acid cycle is founded in the class identity of the carboxylic acid molecules, as a class, rather than in their individual identities.

Furthermore, the onset of the cyclic material support that processes the exchange of material particles reveals a characteristic aspect of the actualization of chemical affinity. That is the act of maintaining material flow continuity in the face of resource limitation. The citric acid cycle feeds upon the carbon source in the form of the acetyl group within the pyruvate molecules. This feeding-upon activity is due to the chemical affinity involved in making and transforming chemical bonds that occurs between an acetyl group and an oxaloacetate molecule in the cycle in such a way that the oxaloacetate molecule transforms into a citrate molecule by incorporating the acetyl group while modifying it further into a complex of a methyl group and a carbonyl group. The total effect of this feeding-upon activity is to balance the carbon flow leaving the cycle. The agency involved in manipulating the carbon flows entering and leaving the cycle is the cycle itself. The continuity of carbon flows entering and leaving the cycle, which can be confirmed externally by the biochemist, is a consequence of the act of balancing the inflow to the outflow, as performed by the cycle. The observed material flow continuity results from the material act for balancing the inflow to the outflow by the material support itself while processing the exchange of material. That is material flow equilibration [1].

Important to the balancing by material flow equilibration is a natural capacity of detecting class identities among the material elements that come to constitute an organized unity in the form of a reaction cycle. The cycle processes the exchanges of these material elements, even though those elements would recover their individual identities if the affinity to the class identity were to be nullified. The causation involved in preserving class identity is finalistic, while causation involving the individual identity of an element at its own scale would be efficient.

Note that measurement proceeding under conditions of resource limitation, such as the constraint of energy conservation, is necessarily cross-hierarchical and finalistic, since such a constraint is about class properties only. We note further that quantum mechanics would be inherently at home with the act of internal measurement once the “relative-state” interpretation of Everett is adopted [10]. This relative-state interpretation conforms with Bohr’s Copenhagen interpretation as far as actual laboratory observations are concerned; and, Born’s probability amplitude of the wave function applies to both equally as well. However the difference between the two interpretations becomes apparent once we consider the origin of the measurement apparatus. While the Copenhagen interpretation takes it for granted that the physicist is responsible for measurements, the relative-state interpretation conceives of the occurrence of any quantum state relative to any other to be a measurement. The natural occurrence of chemical affinities if it were to be framed in the relative-state interpretation would seem to be an instance of final causation proceeding under resource limitations.

Material flow equilibration assuming the first person status is finalistic in entailing and filling the deficiency, or the presence of absence [11], as constantly precipitating and leaving further deficiencies to be ameliorated down the road. To put it differently, processing the deficiency of the resource is

accessible only to first person descriptions, and not to third person descriptions because of the difficulty in identifying what is absent in foresight definitively in a positive context.

The material flow equilibration of chemical affinities that occurs in the citric acid cycle is due to the actions of making and transforming covalent bonds among the carbon atoms. However, the precipitation of class identity from the constituent material elements is not limited to the chemical affinity involved in maneuvering the covalent bonds. A case could likely be made that non-covalent bonds are instrumental in precipitating the class identity among the participating material elements. A representative example of this is the transcription-translation scheme of gene regulation networks in biology.

3. Processing Transcription-Factor Molecules

Biology is grounded upon the maintenance of the class identity of a molecular organization in the face of vicissitudes of the constituent molecular subunits. For instance, consider a biological system such as a human egg cell containing about 30,000 genes encoding proteins, of which roughly 3000 encode protein transcription factors which regulate RNA transcriptions. Transcription factors determine when genes will be turned on and off by orchestrating a network of transcription sequences. At issue is how it is possible for an individual transcription-factor molecule to adequately regulate the expression of each of about ten genes on average in successive developmental processes.

One clue to this is found in the observation that typical genomes contain extensive non-coding, regulatory regions, and that these regions can act as enhancers, silencers, insulators, and promoters of the genes. If the expression of each gene is regulated by a combination of many different transcription factors, the resulting combinatorial control must be competent to form a consensus among the participating transcription factors in regard to whether or not the targeted gene will be expressed, as well as how and when. At this point we encounter the issue of time [12].

Addressing the nature of the flow of time in developmental processes can be made explicit by considering the input-output relationship between transcription-factor concentrations and the rate of protein production from downstream genes. Although noise latent in the transcription factor molecules is random and rapid due to the stochastic nature of each biochemical reaction involved, this does not imply that a similar randomness and rapidity would also affect the rate of protein production downstream. This is an issue that must be settled experimentally. One relevant experimental model reveals that fluctuations in the output of the protein molecules occur far more slowly than those of the input level of the transcription-factor molecules [13,14]. The characteristic time scaling the output level is at least a few orders of magnitude greater than that for the input level. This experiment suggests that there must be some robust scheme of generating slower fluctuations as a temporal phenomenon, whereby an underlying regulatory organization at a higher level serves as a standard to which time passing in the form of fluctuations is referable.

In fact, there is a scheme for “materializing” the flow of time on the ground that time can remain as a temporal record even while continually passing away. The binding interaction between transcription-factors and a DNA molecule being transcribed is rather weak due to the fact that the underlying van der Waals forces implement a binding energy on the order of only 1 kJ/mol or less. This non-covalent binding can easily be detached because it is subject to thermal fluctuations in the

ambient. However, if there are a sufficient amount of transcription-factor molecules available in the neighborhood, the detached binding site can easily be reoccupied by another transcription-factor molecule of the same kind located nearby. The consequence is maintenance of the identity of the binding site—that is to say, the functional unity of the site—in an effectively uninterrupted manner, even though the individual transcription-factor molecules continually touch and go.

The identity of a binding site relates to the class property of the participating transcription-factor molecules. The magnitudes of the relatively slow fluctuations of the protein molecules expressed in the output of the transcription-translation process can be viewed as representing the flow of time that is characteristic of the class identity of the binding between the transcription-factor molecules and the DNA molecules being transcribed. The functional unity of the binding site underpinning the class identity of the individual transcription-translation molecules may help to suppress the rapid fluctuations associated with the input molecules that are being rapidly exchanged. In short, these touch-and-go acrobatics would be expressing the class identities of the transcription-factors, a characteristic found throughout in biology. The output of proteins is thus a process at a larger scale—a higher level [8,9]—than the changes in transcription factors.

The stability of the class identity maintained despite the vicissitudes of the constituent material elements that has been observed empirically, and even experimentally in some cases, raises the question of how it might be possible to make access to it theoretically, or at least descriptively. This issue can be more sharply focused in light of the Church–Turing thesis from the field of computation.

4. Going beyond the Church-Turing Thesis

When we can discern the signs of class identity among individual material elements, the computational approach, culminating in the Church–Turing thesis, becomes of interest. If we follow the tradition of pure logic, any meaningful statement of finite length written using a finite alphabet can be assigned a specific natural number to distinguish it from all possible other such statements. Then proving a target statement when starting from a premise statement reduces to mapping natural numbers to other natural numbers since each meaningful statement can be assigned a distinctive natural number. The Church–Turing thesis is the assertion that all universal digital machines are equivalent with respect to the class of computational functions that map natural numbers to other natural numbers. Consequently, insofar as one accepts the Church–Turing thesis, it becomes attractive to use computation in describing a world that is imagined as proceeding by way of the recursive usage of simple atomic operations. These can then be represented as arithmetic operations. Once identity is the object to be discerned, a “computational takeover” could be attempted by way of discovering class identities as starting from individual material elements. Even though some have argued against the validity of the computational perspective (e.g., [15]), this is not the view of the majority of mathematical logicians [16].

However, any proposed computational takeover of the descriptive enterprise would actually produce nothing more than methodological artifacts [17]. The descriptive enterprise requires the assumption of invariable objects to be described. This could be neatly accomplished simply by using third person descriptions.

So long as one sticks faithfully to third person descriptions, there would be no chance of confronting or challenging computational “takeovers”. Everything “out there”—being taken to be

invariable—can be described in terms of the irreducible fundamental predicates that an author decides to choose beforehand. In this enterprise it would be methodologically prohibited for additional, *de novo*, irreducible predicates to emerge while an object was being described. Although the emergence *de novo* of a class identity among material elements initially specified by their individual identities alone would be plausible as an empirical phenomenon, it would not be accessible in third person descriptions presupposing individual identities. If, for example, one were to remain within arithmetic operations, it would not be possible to reach algebraic operations from initial premises limited only to arithmetic operations. Although both operations are at home with the notion of infinities, the class property of infinity differs between arithmetic and algebraic operations. Algebraic operations would not appear during the process of arithmetic operations no matter how long we might await them while observing arithmetic operations.

These considerations, however, do not necessarily lead to the conclusion that descriptive efforts would necessarily be insufficient when variable empirical phenomena happen to be chosen as objects. First person descriptions confronting the agency of the first-person status would leave the issue of computational takeover undecided. Once we switch seriously to first person descriptions, some of the difficulties met with in third person descriptions could be reduced or even obviated, unless first person descriptions are unnecessarily elevated to the status of a stand-alone oracle (cf., [18]). Being responsible for grounding first person descriptions, a material agency assuming first-person status would require the necessary material resources to survive in the empirical world. Such a material agency could do what third person descriptions cannot describe, such as a cross-hierarchical integration. A material unit such as the potential citric acid cycle concretizing a class identity that was latent in its individual constituent elements would be an example of such an enterprise.

At issue here is whether the citric acid cycle would emerge as either oxidative or reductive during evolution. The cycle is oxidative when it oxidizes reduced carbon complexes such as pyruvate, releasing both carbon dioxide and the energy that cells can utilize for synthesizing ATP. Conversely, the cycle would be reductive when it reduces carbon dioxide and synthesizes various intermediary metabolites such as pyruvate and amino acids. This reversed cycle is operative in some bacteria, where it synthesizes carbon compounds [19]. The decisive factor in determining which form of the cycle, oxidative or reductive, would be fixed during evolution would have depended upon the mix of resources available locally. The potential reductive cycle would not survive if only reduced carbon complexes were available in the neighborhood. Likewise, the liminal oxidative cycle would not survive if only carbon dioxide molecules were available. We here take the internalist view that it would be the nascent cycle itself, assuming first-person status, that would determine which cycle, oxidative or reductive, could become fixed in evolution. There would be no prior guarantee of success. Risk-taking cross-hierarchical emergence and the ability to intake the necessary resources are two sides of the same coin for a potential material agency having first-person status in a particular locale.

When we allow judgments of the past in light of present interpretations, as epitomized by Whiggery in the political arena, first person reports become subjugated to domination by third person descriptions. However, this distorted view of the past would not contribute to survival in the current material world since the present allows no guarantees of success. Temporal continuity occurring during the present moment, when viewed as if from the past, could on the other hand function as a gift

presented to possible risk-taking endeavors from the first person perspective. Of course, it would not be the case that every risk-taking effort would be entitled to this gift. This consideration reminds us of the difference between the notion of time as embodied in first person reports and the one taken for granted in third person descriptions. The latter construction of time is exclusively appropriated by descriptive authorship assuming the third person status. In contrast, time in first person descriptions is something the agency of the first-person status is striving for in the sense that its own survival is prerequisite to experiencing time. Here we will again examine the nature of time more empirically.

5. The Material Aspect of Time

An enigmatic aspect of time is revealed in the observation that, while passing away constantly, it always remains as time (c.f., [5,20]). Time integrates these two incompatible attributes by both embodying change and remaining invariable. One promising strategy for understanding these incompatible characteristics without getting entrapped in philosophical rambling would be to refer to historical evidences that resulted from examining the problem empirically.

A case in point is the water clock. Its oldest physical evidence was found among the relics excavated from the period of the reign of Amenhotep III in the eighteenth Egyptian dynasty about 3500 years ago. This is a device that measures the elapse of time accompanying the accumulation of water flowing down into a small measuring-cylinder through a tiny hole in the bottom of a huge tank filled with water. If the water level of the tank remains practically constant by adding water to the tank to compensate for the outflow, the instrumentation integrating the invariable water level of the tank and the accumulation of water in the measuring-cylinder can be established. Time as referred to in this scheme is represented by the accumulated amount of water in the cylinder. The relationship between the invariable level of water in the tank and the continuing accumulation of water in the cylinder is indifferent to whether the passing duration is being measured in this way or not.

Another historical example revealing this aspect of time is a pendulum clock invented roughly 350 years ago. Curiously, Galilei, as a key figure in grounding the basic idea of the pendulum clock, relied instead upon the water clock while conducting the free-fall experiment of a bronze ball rolling down a tilted wooden gutter lined with parchment. In fact, the difference between the water clock and the pendulum clock is significant. The pendulum clock as a fixed material configuration expresses the invariant cyclic motion alone, and is not concerned with any material change or unidirectional movement. It does not integrate both the invariant reference and the variable unidirectional movement as does the water clock. Any scheme of letting the pendulum clock being an integral part of the time phenomenon would require an additional component harnessing a unidirectional movement to the cyclic motion. Here the additional component could be a physicist comparing the cyclic motion to some change occurring outside pendulum's activity. That might involve applying the notion of the natural numbers to counting the repetitions of the cyclic motion. This "read-into" character of the unidirectional movement would remain unchanged even if the pendulum clock here was replaced by a more sophisticated harmonic oscillator such as an atomic clock.

Unique to the set of the natural numbers is its invariable class property as a category, wherein each natural number is distinguishable from all others through arithmetic operations. By repeatedly adding a unity to a natural number, one obtains a monotonically increasing sequence of natural numbers that

the physicist could associate with unidirectional motion. This unidirectional movement maintains conformity with the invariant class property of the natural numbers as a category. This is the time which the physicist is at home with, as embodied in Ptolemy's sidereal time and in Newton's absolute time; it is also anthropocentric in grounding itself in a category unique to humans. The category of the natural numbers enables humans to count. Physical time is thus a chimerical integration of both the synthetic capacity of the natural number category and the individual identity of a material body involved in an invariant cyclic motion.

Anthropocentric time is not limited to physical time. It is also, on philosophical grounds, applicable to Kantian time—a framework of an *a priori* sensuous intuition involved in integrating sense perceptions by the transcendental ego. This transcendental ego is nothing other than the pronoun referring to each of us as human beings. An advantage of having anthropocentric time that includes both physical and transcendental time is that it can be elevated into something more than merely a representation of something else. In this regard, anthropocentric time differs from naturalized time grounded upon the processes of exchanging materials. An irony here is that the nervous system of a human during time perception appreciating anthropocentric time is very busy in feeding upon ATP and releasing ADP as a form of ongoing material exchanges proceeding in naturalized time. Naturalized time is, in fact, a direct representation of the unidirectional movement of material flow. For some purposes naturalized time would by no means be at a disadvantage compared to its anthropocentric counterpart.

Naturalized time includes an immensely large variety of the unidirectional material flows underpinning processes of material exchanges. The synthetic capacity latent in naturalized time as found in biology can be identified as inhering in the chemical affinities of the participating material bodies. Conversely, the synthetic capacity latent in physical time as an anthropocentric construct would be limited only to the natural numbers, as revealed in the predominance of decoherence of a quantum system when it is allowed to interact with its environment only incoherently [3]. The set of the natural numbers mediating physical time cannot without difficulty meet the synthetic challenge of mapping an arbitrary subset of the natural numbers onto a particular natural number. There is no one-to-one correspondence between the set of the natural numbers and its power set that covers all of the possible subsets of the initial set of natural numbers. As well, there is no computable program that, after examining the code of an arbitrary chosen program, can determine whether that program is computable and halts in finite steps.

Introducing a new type of non-recursive function, such as making a decision or einselection by a single step, that cannot be reduced to a simple tally of pre-given atomic operations compiled with their recursive usage alone would go beyond the standard scope of computation framed within the Church–Turing thesis. In contrast, the synthetic capacity latent in the chemical affinities of a material support that processes material exchanges, such as the citric acid cycle, is much more than just a tally of the elements themselves. Its synthetic capacity is more than just a subset of the material elements constituting that support.

Both anthropocentric time and naturalized time can serve as basic tools for measuring events occurring in the material world, but their synthetic capacities are markedly different. The difference can be made explicit by referring to the relationship between a material support and a subset of its elements. This will be the issue of the relationship between a context and its contextualized elements.

6. Contextual Meaning

Context is a concept for acquiring conceptual access to an object consisting of more than a single irreducible element. A prototype might be thought to be available in set-theory as developed in mathematics. Given a set of physical elements, a subset can easily be derived. Once the contrast between a set and a subset has been conceived, it may seem reasonable for an empirical scientist to apply the notion of subset to an object of interest in the empirical world. However, the relationship between a set and a subset would be arbitrary, insofar as a subset remains a theoretical artifact. There is no definite criterion concerning how to discern a subset beforehand. Upon realizing this, the empiricist would be forced back to the starting point.

Once we consider the dynamics of physical elements given in a set, the set itself would constitute the context in reference to which each element can be identified during the passage of time. The time involved here would be physical time, in which the identity of each physical element of the relevant clock would be preserved. Because of this stipulation of physical time, any synthetic development of the context would be obviated on methodological grounds. The synthetic capacity of physical time is limited to that possible in the category of natural numbers. There would be no room left for new syntheses to emerge out of a given set of physical elements in physical time. The status of the context would remain fixed as that which a physicist will have declared from the outside, where it would be the object of third person descriptions.

Being confined to third person descriptions renders the description of an external object feasible in terms only of pre-existing elements and their recursive atomic operations. Moreover, third person descriptions make it possible to assume that an object will remain unchanged during the period of description. That would be an observation in the anthropocentric time characteristic of the discourse of the describing author. Physical time as referred to in third person descriptions of empirical records would judge the past in light of the present. In this case the context is anthropocentric, whether we like it or not.

In contrast, when switching to naturalized time, a completely different perspective emerges. A material support processing the exchange of material, whose activity underlies the occurrence of naturalized time, is an organizing unit continually involved in the exchange of constituent material elements. This organizing unit consists of a subset of the material elements temporarily involved in it. Characteristic of this organization is that each element can readily enter into it and leave it behind. Given a set of the material elements, there is a very tangible relationship between an organized subset of these elements and the elements themselves. Consider at this point the relationship between a set of elements and another set of all possible subsets of the original set—*i.e.*, the power set of the original set. From the formal point of view, there is no one-to-one correspondence between a set and its power set, somewhat analogously to the contrast between the natural numbers and the real numbers. The absence of a one-to-one correspondence here makes computational access from a set to its power set untenable. There can be no unique correspondence between a member of a countable set and a member of its power set, which is uncountable. There is no unique relationship between the natural numbers and the real numbers, as demonstrated by the Cantorian diagonal argument. The power set is far more condensed than the set in its density. That is to say, the cardinality of the power set is greater than that of the set.

However, the other side of the coin is that even if computational access to the power set from a set is not available in anthropocentric time, the relationship between a power set and the set could open a possibility for new synthesis and emergence once we are set free from the artificial stipulations of computation, which must be supposed to eventually halt in any case. One agency relating a set to its power set would be chemical affinity, as demonstrated in the emergence and sustenance of a material support that processes material exchanges, as in the example discussed above. The context of this material support is natural in the sense that it is not a theoretical artifact imposed externally. So we would be concerned with naturalized time. The contextual basis of naturalized time here is the presence of the material support processing the exchanges of material.

While the computational approach is quite powerful in specifying constraints, recursive operations on a finite set of elementary processes would still encounter the halting problem. It remains unsettled whether a given task of computation could eventually halt. If it does not halt, there could be no effect of such an enterprise. In contrast, chemical affinity has the capacity of being involved in *de novo* synthesis in a way completely different from the artificial pathway of the recursive processes of computation.

7. Concluding Remarks

It has been customary to associate contextual meaning with the concept of information, in the sense that meaning arises as a result of being informed. However, this may be a hasty conclusion. A context is specific to and depends in the first place upon how the notion of time is conceived. If time is taken to be an anthropocentric construct, as with physical time, it will involve anthropocentric artifacts that produce the conditions under which time is tallied. To suppose that meaningful information is “out there”, as in third person descriptions, would be a misapprehension. Third person descriptions basically align with anthropocentric time, whose synthetic capacity is limited to what would be possible within the category of the natural numbers. There would be no chance for the emergence of a new meaningful implication during the course of a development embedded in anthropocentric time. If any meaningful information appearing in the context is noted in third person descriptions, it must have been arranged for by the descriptive author from the outset, even if not apparent to the author at first. One attempt for overcoming this impasse might be expected by taking a semiotic perspective. However, this approach is still premature.

Peircean semiotics treats of three primary correlates—object, sign and interpretant—while also incorporating the three categories of Firstness, Secondness and Thirdness. One cannot expect any simple correspondence between the three correlates and the three categories. The correlates are implicitly deployed in first person descriptions in the sense that an interpretant, as the agency involved in interpreting a sign, can assume first-person status. Partial access to the interpretant in third person descriptions is conceivable in terms of the three categories, in which Firstness is about vagueness or potentiality, Secondness is about actualization through interaction, and Thirdness is about developing habit from action. One possibility in this direction would be to appreciate the possible occurrence of interpretance in any Firstness that may be latent in Thirdness. This would involve a metaphysical exercise. However, a serious issue would still remain. When such a third person description is attempted using anthropocentric time, there would be no chance of having an actual agency with

first-person status. The only agency acceptable in third person descriptions is that of the descriptive author itself. Even worse, if anthropocentric time were to be abandoned, Peircean semiotics would face a serious difficulty in conceiving of non-anthropocentric time based only in its own theoretical framework.

This difficulty is synonymous with the one met when either justifying or refuting the continuum hypothesis in mathematics, which states that there is no set whose cardinality or size lies strictly between that of a set (e.g., the natural numbers) and that of its power set (*i.e.*, the real numbers). Given this gap between a set and its power set, anchoring the emergence of a material support that processes material exchanges, as described above, on a sound theoretical basis would be extremely difficult from the computational perspective relying upon recursive operations alone. The likelihood of the appearance of such a material support can be better grounded upon the occurrence of naturally formed classes of material elements.

The possibility of naturalizing contextual meaning empirically in the frame of naturalized time may provide us with a new opportunity for re-examining the theoretical background underpinning the information concept, semiotics, and even set theory in mathematics.

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