After the Transition "from It to Bit": Is This the Science Formerly Called Physics? *

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Abstract The fathers of the Scientific Revolution *intentionally* excluded mind from the *scientific* agenda: they wanted to (and did) build science based on the much more familiar, *spatial*, considerations, while the mind, they agreed, is of non-spatial nature. It seems that behind the attraction of "it from bit" lies a long suppressed in science but deep seated and probably scientifically fruitful desire to see something 'mental' emerge as the *principal* element in the structure of the Universe. Yet it would be *very naïve* to hope that the integration of the 'mental' into a scientific view can be accomplished in the historically familiar, incremental, manner, for example, by simply bringing "bits" into the focus. The scientific *common sense* suggests: to achieve such extraordinary goal requires an extraordinary scientific step, which I propose is the replacement of our numeric 'glasses' with new, non-numeric, 'glasses'. To this end, we have developed a fundamentally new—'informational', or structural—form of data representation, called "struct", intended to capture *previously inaccessible view of objects and processes*. It *might* be considered as a far-reaching generalization of the underlying idea of causal sets (in quantum gravity). The struct promises not only to serve as the *blueprint* for all "its", including space, but is supposed to elucidate the nature of the discovered in the last century ubiquitous discreteness. However, as never before in the history of science, the pragmatic question is this: Since it is the spatial considerations that for several millennia have fully guided the development of *mathematics* and physics, how many physicists are prepared *to start* the development of physics more or less anew, on top of such or similar informational structure (as opposed to the present 'safe' flirtations with the bits)?

One can best feel in dealing with living things how primitive physics still is.

Albert Einstein

1. Introduction: What is the nature of the basic conceptual foundations of modern physics?

In this section, I wish to draw your attention to the simple but overlooked fact that both physics and mathematics are built almost exclusively on the basis of spatial consideration, and this includes the way we treat time in physics. To this end, first of all, let us recall that the *concept of measurement*—which goes to the roots of our civilization—lies at the very foundation of physics. What is the origin of that concept? If we had to choose *one* prototypical concept of measurement, that would probably be the measurement of length. The central position it occupies in physics is a reflection of the historical fact that it was the *initial* form of spatial measurement, and again, spatial considerations have been driving the development of mathematics (and hence physics) for over four millennia. The

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In the essay, I use single quotation marks when appealing to a broader, metaphorical, meaning, while the double quotation marks refer to the *familiar* meaning of the phrase or serve the usual quoting function.

manifestation of this fact in modern applied mathematics is, for example, the central role of the vector space concept, while in modern physics, its central concept of field is absolutely unthinkable outside the spatial context.

One should also remember that the fundamental in mathematics and physics concepts of continuity and limit—whose motivations go back to two and a half millennia ago ($\sqrt{2}$) and received their main development in the 17^{th}–19^{th} centuries—have been driven entirely by the spatial considerations.

As to the last century, the two most prominent theories in physics, quantum mechanics and general relativity, where also guided by the spatial consideration: Hilbert vector space and Riemannian geometry (see also [1]).

Thus, despite an important role of "algebraic" considerations (e.g. group theory) in the physics of the last century, the most basic conceptual foundations of today's physics are undoubtedly of spatial origin. And even the group theoretic considerations in physics have a very distinct spatial flavor.

Here is the same general point expressed by Einstein [2]:

> it is characteristic of thought in physics, as of thought in natural science generally, that it endeavors in principle to make do with 'space-like' concepts *alone*, and strives to express with their aid all relations having the form of laws.

So the role of spatial considerations in shaping physics is not limited to the presence of various 'spatial' physical variables—e.g. length, velocity, acceleration, volume, density, etc.—but extends to *defining its very structure*. And in this connection, it is also useful to recall what Einstein said in his forward to "Concepts of Space: The History of Theories of Space In Physics" by Max Jammer:

> in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them.

But the main reason for the above discussion is to prepare you for the sobering thought that, *for the first time in the history of science*, the transition we are apparently faced with (to the information-based physics)—if indeed the informational reality is primary—*must* be non-incremental, or put simply, we will have to start more or less anew.

2. The unacceptable ambiguity of "information": Information as non-spatial structure

Our concept of "information" is so indiscriminant and ambiguous that a modern review of it concludes with the typical words: "The understanding of the core concept of 'information' … remains a highly contested area."[3] Still, even such conclusion is an understatement: we use this term quite frivolously, including "information warfare", "information age", "information storage", "information architecture", "information fatigue", "information transfer", "information retrieval", "information highway", "information explosion", "information gap". Unfortunately, this ambiguity of "information" has allowed its inappropriate use in more technical contexts, e.g. in information theory and physics, thus further exacerbating the situation.

Yet, despite this information euphoria, we have very little to show for it. Our billions of dollars worth search engines *do not 'understand' a single word* in what they search. As to the more sustained quest for AI, we also have hardly anything to show for it, except for the shuffling and renaming of its subfield, zillions of new terms, and various programs masquerading as "intelligent" ones. Incidentally, most programs are 'useful', but that doesn't imply they are "intelligent" [4].

However, I believe that, despite fueling the information euphoria, it was the advent of computers that, oddly enough, triggered a new powerful process of our 'liberation' from the tyranny of the 'physical' and, as I mentioned in the abstract, rejuvenated our long suppressed (certainly in science)

deep seated, and probably *scientifically fruitful* desire to see something 'mental'—the true source for understanding "information"—emerge as the principal element in the structure of the Universe. It is quite telling that this, scientifically fruitful, spirit of the present age is so strong that even physicists have fallen under its spell, although not without the help from the developments in quantum mechanics and cosmology. Unfortunately, some physicists are proceeding along the path of least resistance, the "it from bit" path. So the question is: Why has not all this 'information heat' been transformed into some 'light'? Or what has been missing in these attempts to tame the information?

I suggest that what has been missing is the common-sense scientific evaluation of the task, i.e. above all, the appreciation of the *unprecedented* nature of the task and of what it would take to accomplish it. This includes a full grasp of the *enormous gap between the mental/information and the spatial*, where, as we discussed in the last section, our present science—and especially its formal machinery—is built entirely on the spatial foundation. From this perspective, it should be intuitively clear that the "it from bit" path is *simply "too good to be true"*: there are no shortcuts and we need to look for *fundamentally new formal tools* not offered by the present mathematics. In fact, as I discuss below and as some scientists, including von Neumann [(i)], have maintained, there are serious reasons to expect that the integration of the 'mental' into a scientific view can only be accomplished with the *development of a radically different—non-numeric, or structural*—scientific language.

In light of this, instead of rehabilitating the term "information"—which I believe to be a superfluous one from the scientific and formal points of view—I suggest to informally associate the term with both "organization" and "structure". Indeed, in addition to "the loss of information" = "the increase in entropy", we have, for example, the following more relevant characterization of an information process [5]:

> the information process can be defined as a free movement of an invariant structure in the material carriers of various nature, and the information can then be thought of as this invariant structure circulating through the communication channels.

I would add (see below) that, besides the object structure, it is useful to associate "information" with the *organization* of the Universe via the ubiquitous classes of similarly structured objects/processes [(ii)].

Moreover, since 'information' is most likely our *last* scientific frontier, we have no choice but to *demand* from a candidate representational formalism, *even in its initial form*, the clarification of both the basic nature of the 'mental' in the Universe and the basic *underlying structure* of 'reality' itself. As suggested below, within our present (numeric) formalisms, in view of their intrinsic, point-based, structure, these issues cannot be adequately addressed. Quite naturally, to meet such unprecedented demands, instead of the vague appeals to "self-organization" and "top-down causation", nothing short of a fundamentally new scientific language will do.

And as far as the "bits"—the term introduced by Shannon—are concerned, they *encode*, rather than *represent* (see below), the *object structure* in a trivial way. Already in 1988 Gell-Mann was correctly asking Seth Lloyd: "But are the bits truly equal? . . . Some bits are more important than other. . . . But is there a mathematically precise way of quantifying the significance of a bit?" [6] To understand this issue, we will return to it at the very end of the next section, when we have a better idea about the proposed new conception of "structural representation".

3. On the proposed structural representation: ETS formalism

In contrast to the early developments in physics—when Galileo set the stage by directing attention to the laws describing those *points in space* (trajectory) that, for example, a thrown object passes at consecutive moments of time—today, we see *quite different* considerations, especially those related

to the evolution of the Universe, are beginning to play a decisive role. These evolutionary processes, such as the 'expansion' of space, the formation of atoms, molecules, stars, galaxies, and of biological organisms are all formative processes, and they probably dominate the much better known—but heading in the opposite direction—entropic processes. The main features of formative processes are *fundamentally* different from those of the *processes in dynamics that actually determined the development of physics, including its formal machinery*.

The known physical forces cannot account for the *structural regularity* of these formative processes as reflected in the observed *classes of similarly structured objects*, e.g. various classes of stars, galaxies, stones, trees. What is more, there are reasons to believe [7] that the ubiquitous in science numeric forms of 'data' representation, on which we have relied for several millennia, cannot adequately clarify the nature of such classes of processes. So the yet unrecognized in physics—but important to its informational turn—question is this: Which new, non-spatial, form(s) of 'data' representation will reveal the presently invisible and allow us to understand adequately the formative processes in Nature? Let us briefly address the issue in this, main, section.

Before proceeding, I suggest to approach this section not as that on physics *per se* but rather as a proposal for a new *non-numeric formal* language—representational formalism—for addressing the above formative processes, which are, most likely, informationally driven. However, as I mentioned at the end of the last section, we should expect this non-numeric form of data representation to reveal all physical processes in a completely new light, inaccessible under the numeric representation. Warning: The main difficulty for a scientifically mature reader is not to fall into the trap of the powerful habit of automatically *interpreting the information presented (of necessity) in the pictorial form in a "familiar" way, independent of the main text*.

First, **a representational formalism** is responsible for *the form of data representation*, i.e. it specifies the abstract entities for representing data, the data template. Such formalism is our scientific means of representing reality, the "spectacles" through which we see it: *all data is being collected and processed in that form*. This tem is not widely used in science, since s*o far we have had a single representational formalism*, the numeric formalism—including real and complex numbers, quaternions, octonions—and *only* some fields around computer science, especially around AI, have been experimenting with other representations.

Next, the term **structural representation** is used in science quite freely to designate some forms of 'representation', e.g. graphs (with nodes and edges), chemical structures, etc. Nonetheless, I will use this term as a general name for *the proposed formalism*, even though it has nothing in common with other, similarly labeled, 'representations'. The new formalism addresses *the formative*, or informational, side of reality as opposed to the spatial one. Its more technical name is the **ETS** (evolving transformations systems) formalism. This, fundamentally new in science, form of object/process representation is probably the first *event-based structural* generalization of natural numbers, as they are defined by the Peano axioms [(iii)]. These axioms rely on the concept of "successor operation" (see also Fig. 3), where a successor of a natural number is just the following number, while ETS formalism relies on the new informational concept of *structured 'successor' event*.

Thus, generalizing the *single and unstructured successor operation* in the Peano axioms to a *small finite set of structured events*—which are supposed to reveal, compared to a number, a new, structural, side of reality—we arrive at the basic intuitive idea of the proposed form of representation. As illustrated in Figure 1 [1] (see also Figs. 2 and 4), each such **primitive event**, or

[1] In this figure and its caption, to give at least *some* idea about the *formalities* involved, more detailed information is provided than is necessary for the essay.

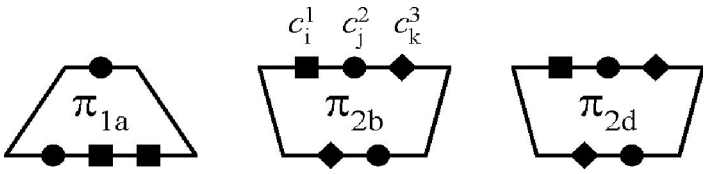


Figure 1: *Pictorial depiction* of three primitives. The first subscript in the primitive's name stands for the class of primitives sharing the same structure (and hence the same *overall shape*), e.g. π_{2b} and π_{2d}. The i**nitial** classes of processes are shown as *small solid shapes* on the top and the **terminal** classes of processes are those on the bottom of each primitive. The only labels of the individual processes shown in the figure, i.e. of the elements of these classes, are c_t^s $(s = 1, 2, 3)$ — the t^{th} process in the initial class C_s for primitive π_{2b}, where $b = < c_i^1 , c_j^2 , c_k^3 >$.

primitive transformation, or simply **primitive**,[2] should be thought of as a junction of fixed structure transforming the flow of one or several incoming, or "initial", processes into the outgoing, or "terminal", processes. (The concept of **process** is axiomatically built into the definition of a primitive and is an 'undefined' term.) From an applied point of view, the concept of primitive is supposed to be very transparent: it is *intended*[3] to be a mirror copy of the 'real thing'.

To contrast the numeric representation (Fig. 3) with the structural one, Figure 2 shows, with minimal explanation, examples of two small structs, the proposed new, *event-based, structural form of 'data representation'*. Although no 'time' is involved in its definition, a **struct** can be viewed as a 'temporal' stream of interconnected events of purely 'informational' nature and should be understood as such. Moreover, its novelty—compared with the conventional representational means—is directly related to its ability to capture an object's or process' *formative history*, or *formative structure*, i.e.

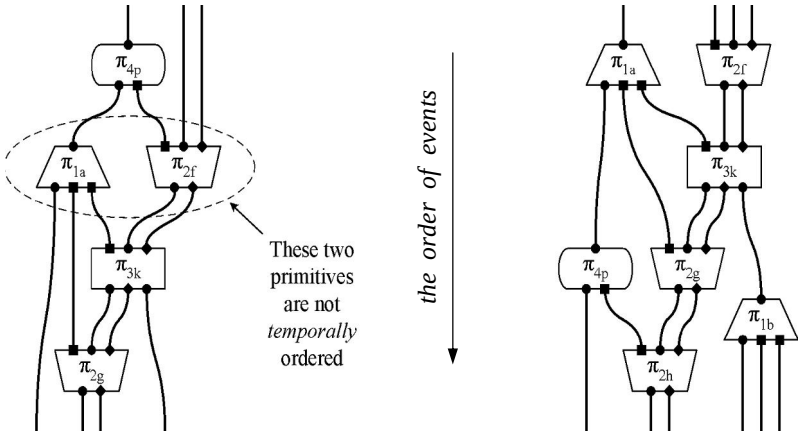


Figure 2: Pictorial depiction of two (short) structs. Note that each link between events must begin and end as the same 'kind'.

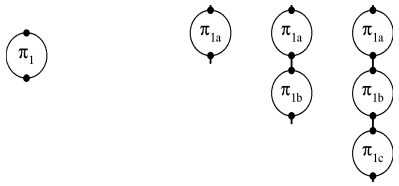


Figure 3: A single primitive (left) for the representation of natural numbers and the three structs corresponding to numbers 1, 2, 3. This could be interpreted as Peano representation.

[2] The adjective "primitive" and the corresponding noun emphasize that these form the *basic* set of events, in contrast to the 'higher level' events composed of several primitive events, which emerge at the *higher stages of representation*.

[3] Of course, such (main) assumption about the informational structure of actual events in Nature will have to be experimentally corroborated. However, what we know from particle physics and other scientific fields does support it.

the 'record' of how an object came to be what it is in a sequence of the corresponding formative events.[4] Formal definitions are somewhat intricate and can be found in [8], while an extended informal discussion, in [7]. Some non-physical illustrative examples can be found in [7, Sect. 2.9], [8, Sect. 8], [12–17], while the context of theoretical computer science is discussed in [9–11].

It was already accepted in the last century that the Universe is all about various "events". Yet the *basic question* that remains is this: *which kinds* of events, or what is the nature of these events? As we have learned in science, the only *satisfactory* scientific answer to such question can be provided by an appropriate *formalism* whose main postulates should be experimentally corroborated. It is precisely in this context that the *structure* of the above event—as a *particular kind of transformation* of several *fixed kinds* of initial processes into several *fixed kinds* of terminal processes—should be taken most seriously as the suggested answer to this basic question. Note that we are dealing here with a non-numeric and hence non-spatial concept. Also, following the logic of the numeric formalism, in this case, the event structure would be our *main guide to both the interpretation of reality and the development of the appropriate structural 'measurement' tools*, and the formalism will stand or fall based on the quality of such interpretation, or predictions. The latter is quite comparable to the way an organism makes predictions in its environment.

However, since this is historically *the first 'structural' formalism*, we must be prepared to learn *how to test structural* predictions about the nature of reality and how to 'combine' them with the numeric information. Thus, ETS formalism suggests that the underlying, i.e. informational and hence 'physical', reality can be faithfully viewed as the above streams of structured events. Note that the numeric formalisms could not have, in principle, made any *structural* claims about the underlying nature of events, since they rely on the unstructured, point-based, representation of events.

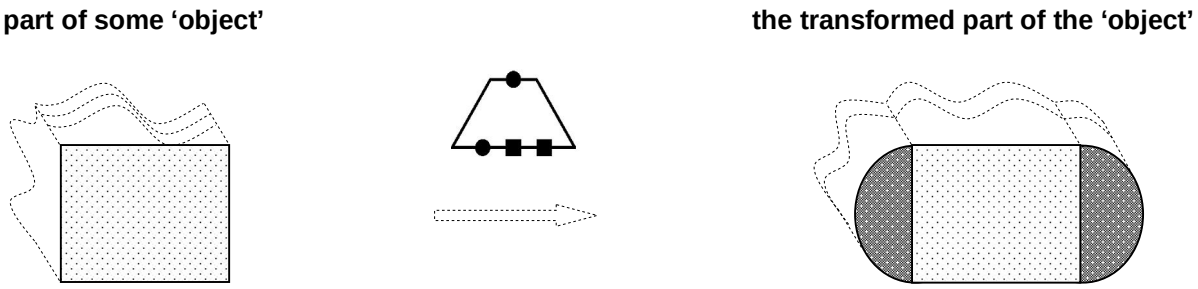


Figure 4: A stylized depiction of the (spatial) *application* of one of the four events depicted in Figure 2. The structure of this event, shown in the middle, is such that its application *transforms* a single particular 'part' of some object (shown on the left) into the tripart, two parts of which are structurally identical and the third is structurally the same as the input part. So the two solid circles in the event signify that the two, one input and one output, parts/processes are structurally identical (and should be treated as such by all other events). The shown shapes of the object's parts have no relation to the solid shapes in the event. (Note that the application of any other event from Fig. 2—to some other objects/parts—either *reduces* or *preserves* the number of object's parts, depending on the *number* of incoming and outgoing links.)

[4] Note that, in contrast to Nature, in case of an agent's representation, such formative events don't have to be the actual ones but are rather those to which the agent's 'mind' has access.)

What can we *initially* suggest about the relation between the proposed informational structure and the familiar to us spatial side reality? Again, all such discussions must be considered as tentative. However, there are reasons to interpret ETS event as an informational *blueprint for the corresponding physical event that transforms—according to the blueprint—the 'physical' entities to which it applies*, as schematically illustrated in Figure 4.

I will use the term **instantiation** when referring to a struct's spatial or any other 'physical' realization based on the blueprint provided by it. Thus, *what we can physically observe are the instantiations of the above events*. For example, let us consider an important physical process of the 'expanding' space as a consequence of the Big Bang, a process for which *no adequate* mathematical structure for its modeling exists. Indeed, it may turn out that the proper understanding of this process involves incremental space expansion via the spatial instantiation of the corresponding ETS events, where the current event links provide the spatial-region adjacency information with respect to the previously instantiated spatial regions associated with the 'predecessor' events for the current event. To facilitate the understanding of the latter and to get at least some *intuitive* feeling for the ETS representation (*and for that purpose only*), I present in the endnote (iv) a simple illustrative example from [7, Sect. 2.9].

Next, I would like to draw your attention to some key aspects of the ETS representation. First, as was mentioned, it is radically different from all known representations mainly because it is addressing the formative, rather than any apparent, structure. Second, ETS is expected to elucidate not only the nature of the discrete but also the nature of time: in fact, both the idea of the discrete and the idea of time are supposed to be embodied in the concept of struct.

Finally, considering the now popular in physics "bits"—and returning to the Gell-Mann's questions at the end of section 2—I draw your attention to the fact that each bit *by itself*, as its numeric counterpart, is not an autonomous formal entity, since it is not meaningful without the 'question' to which it provides a binary answer. This allows bits to be used as a binary *encoding* of an object but makes them inadequate as a scientific form of object / process *representation*, which is intended to be, as much as possible, independent of a spoken language. To appreciate this point, try to use bits (or even non-binary vectors) to encode an ETS event. Again, I emphasize: the key idea of the proposed representation is that the structure of the ETS event is supposed to be a 'mirror' copy of the structure of the corresponding actual (informational) event in Nature.

4. The proposed informational hypothesis about the organization of the Universe

Revisiting formative processes discussed at the beginning of section 3, we can now address the proposed **informational hypothesis** concerning the 'informational reality', or the basic form of organization of Nature, which has remained outside the focus of physics. Since any object in the Universe belongs to some class(es) of similarly structured objects, be it a star, a molecule, or an organism, we postulate that such *classes themselves are the basic units in the informational organization of Nature*. In other words, the Universe is *constituted* by the (evolving and interacting) collection of **classes** of similarly structured—in terms of their structs—processes. Moreover, all processes in a particular class share a *common generative structure defining that class*: the struct representing a member-process from a class is generated by the **class generating system** which non-deterministically constructs it.[(v)] For example, our Sun is a member of a particular class of stars, and its formation was (informationally) 'directed' by its class representation. In the present 'spatial' language, the Sun's formation was guided by the logic of the evolution of the entire solar system, but

the formation of the solar system is itself a process that belongs to some class of structurally similar processes in the Universe.

The above informational hypothesis is a generalization/extension of the biological organization and might be considered as a modern version of Plato's and Aristotle's views of Nature as the instantiation of Forms, which are actually the (Greek) root of the Latin verb *informare* = "to in·form". [vi]

The hypothesis is also the result of the long-term research work to understand and model the inductive processes in biological organisms. In fact, the proposed organization is supposed to explain why an organism *endowed* with the capability—inherent in the entire Universe—to construct the representations of some classes in its environment (e.g. of the class of snakes) is then able to recognize members of those classes not encountered previously (new snakes). It is most unlikely that such highly nontrivial *informational* capability could have evolved fully *on its own*, especially considering *the independence of the structure of (evolving) classes* in an organism's environment.

To come to grips with this hypothesis, it is also useful to ask yourself the following questions. Why do the *structures*, for example, of new stars (or rocks) usually resemble those of some earlier stars (rocks), and what does ensure this stability/regularity, without which the Universe would be incomprehensible?

5. Just a few implications for physics

To get at least some physical intuition, think of an elementary particle as 'specified' by an ETS struct, and compare this view (see also Fig. 6) with the view expressed by John Bell: "For me, it is so reasonable to assume that the photons in those [Aspect's et al.] experiments carry with them programs that have been correlated in advance, telling them how to behave." [18]

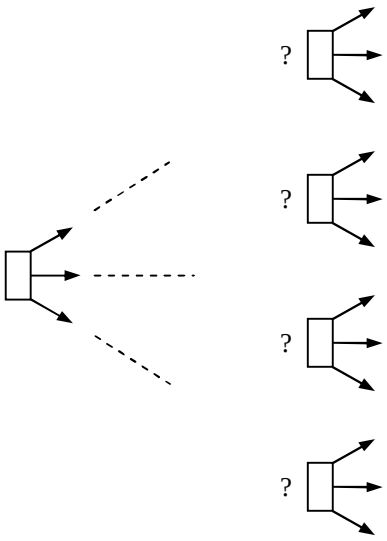


Figure 5: A schematic event-based version of the Huygens' view of light, which now removes the wave-particle mystery.

This brings up the *key* questions: How can we plan an experimental verification of the ETS formalism? And in particular, how do we approach the verification of the structure of (instantiated) events for photons, electrons, etc.?

Yet ETS does offer a very natural explanation of the mysterious "*wave-particle duality*" (Fig. 5) and of the even more mysterious *entanglement* (Fig. 6).

Moving on to the causal set approach to quantum gravity, it should be apparent that, compared to ETS, *the partially ordered set proposed as its discrete basis* makes hardly any *structural commitment* to either primary or informational nature of reality.

As to the *irreversibility* of all processes in Nature, since no event can be undone, it becomes a natural part of ETS formalism.

Finally, some of the other big questions are: How are the structs stored and retrieved in Nature, and what is the *physical* nature of *instantiated* events?

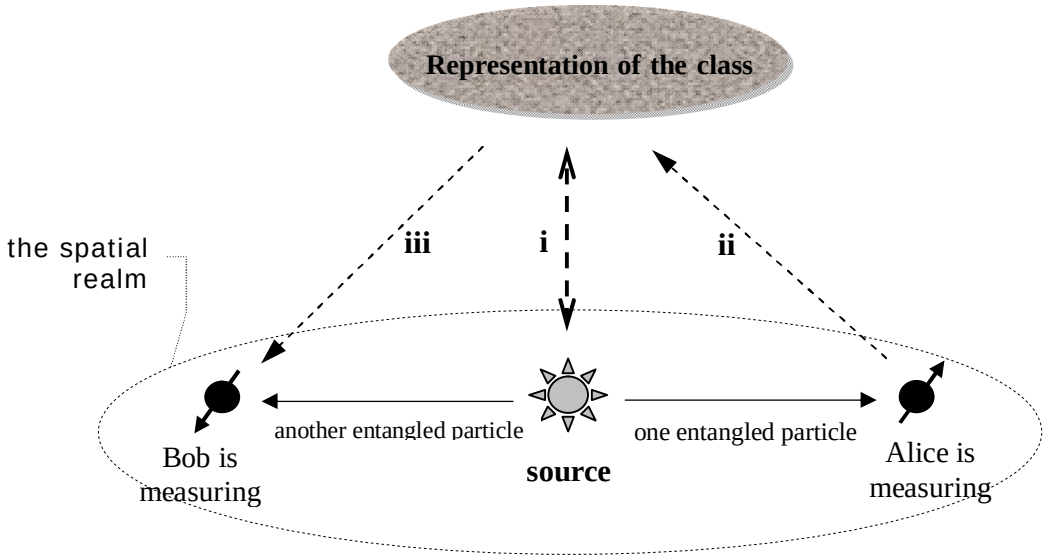


Figure 6: Possible mechanism behind the quantum entanglement. The dashed arrows and the roman numbers represent events and their temporal order: (**i**) generation of the class and the emission of particles from that class (**ii**) Alice is interacting with the particle and this modifies the (non-spatial) class representation, which, in turn, modifies the class members so that (**iii**) Bob is now dealing with the particle from the modified class.

6. Conclusion

The proposed structure of ETS events allows a *uniform treatment of all events in Nature*, including physical, chemical, biological, and mental events. If this structure will be experimentally corroborated, the scenario captured in the title of the essay is not that outlandish. However, *today*, the reality is such that a 'mature' scientist *is trained* to accept even the 11-dimensional space of M-theory much *more readily* than the ETS representation, even though the latter is incomparably simpler and more transparent than the former. This is to be expected, since in the latter case one would have to give up most of the *formal foundations* together with the prolonged professional training. But as we know, fortune does favor the bold.

Endnotes

(i) J. von Neumann, *The Computer and the Brain*, Yale University Press, 1958, p. 82: "the above remarks . . . prove that whatever the [formal language of the central nervous] system is, *it cannot fail to differ considerably from what we consciously and explicitly consider as mathematics*." [my emphasis]

(ii) This interpretation of "information" is fully consistent with the original meaning of the Latin verb *informare* (to inform), "the act of giving a form to something", which in turn goes back to the much earlier *Forms* of Plato. Thus I suggest that returning to the old question about the nature of Plato's Forms—i.e. by returning to the true origin of *informare*—we come near to the most fruitful interpretation of "information", which, unfortunately, is not well known.

(iii) According to *Peano axioms* (the most basic axiomatic system in mathematics) each natural number *n* has a unique "successor" ***S(n)***—defined via the successor operation ***S***—and all natural numbers are thus *inductively* constructed starting with 0. Note *the temporal nature* of this definition and hence of the natural numbers themselves. See for example, http://www.britannica.com/EBchecked/topic/447921/Peano-axioms

(iv) In Table E1 all (three) primitives for the present example are described. To simplify the drawings, various event links are not differentiated, i.e. they treated as identical. This example involves some group of two-

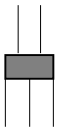
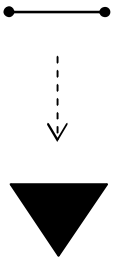
Basic events	**A spatial interpretation of the events**
	 the unique *initial* event: creation of a point; since this event initiates the generative process, it has no incoming links (I do not label this event)
 **P1**	 the expansion of a point into a segment**;** the right outgoing link in event P1 corresponds the newly created point and the left one, to the old
 **P2**	 the expansion of a segment into the triangle *by fixing one end of the segment and pivoting the other*; the middle outgoing link in this event corresponds to the newly created point, while the left and the right outgoing links correspond to the left and right ends of the original segment

Table E1: Observe the structure of the basic events involved. Since the top event is allowed to occur only once, at the very beginning, focus on the next two events. The incoming links of each of those events are associated with the points this event is acting on (input), while the outgoing links correspond to all the resulting points (output), which, in this example, *happen* to include the input ones. So when P1 or P2 is attached to any one of the three events, the input point(s) 'propagate' through this newly attached primitive and are 'open to business' again.

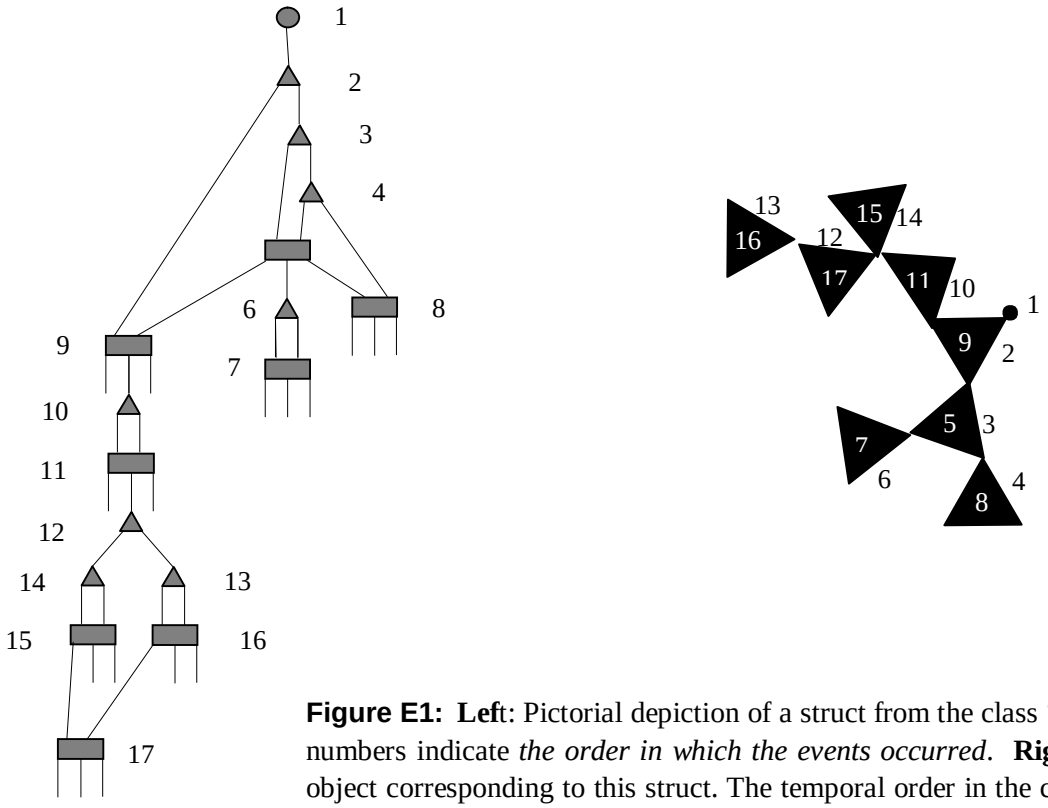


Figure E1: Left: Pictorial depiction of a struct from the class *Triangles*. The numbers indicate *the order in which the events occurred*. **Right:** the actual object corresponding to this struct. The temporal order in the construction of that object is indicated, where a number near a triangle's side indicates the number of the segment which was later expanded into that triangle.

dimensional figures that can be considered as located in a three-dimensional space (see the right side of Fig. E1).

Convince yourself that other 'representations' do not and cannot capture the same information as the struct on the left, i.e. the *formative structure*, hence the claim of the capability of the struct to address previously inaccessible side of reality, *if indeed this (informational) formative structure is critical.*

Which entity comes first: the object on the right or the struct on the left? There are reasons to believe that in order to explain the observed structural regularity of all classes, *the primacy of the informational class description* (see the next endnote) has to be assumed.

(v) **Class generating system**—the non-deterministic informational system responsible for generating class members—relies on the specification called **class representation** (a structural analogue of the equation), which 'algorithmically' specifies a *stepwise mode* of construction for the structs representing class members. Each step is specified by the set of *structural constraints* restricting the kinds of *struct segments* admissible at this step in the construction of the class element. The constraints are always flexible enough to allow *some* "environmental" events from other classes to participate constructively in this generating process, in which case such events become a part of the resulting struct; see [8, Part III].

(vi) In its modern version, Plato's Forms can be viewed as 'informational' *representations* of *classes* of objects/processes. Informally, think of a **class** as the set of all similarly structured—or a little more accurately, specified by the same generative, or informational, mechanism (see endnote v)—objects/processes. Actually, the *specification* of this generative (informational) mechanism is called **class representation**. A key point is that a class is specified/defined by the class representation, and I assume, does not exist without it.

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