The Play of Mind in Emptiness

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The world emerges in the play of mind in emptiness.
ancient teaching

This year FQXi essay contest asks what is more fundamental, information or `material' objects – or in the terms of the famous catchphrase authored by the late visionary J. A. Wheeler, it is *It from Bit or Bit from It?* As a last-moment entrant I had the opportunity to skim some of the early submissions and saw that, while most leaned toward the *it from bit* vision, surprisingly few gave a good analysis of what information is, presumably motivated by certainty that our deeply intuitive notions arising from our immediate experience should suffice. Several contestants espoused a provocative under the circumstances view that, in physics, information is superfluous. I would like to defend the position that information lies not only in the heart of Life but also is at core of `reality' studied by physics. Despite the central role information plays in shaping reality, *It* is more fundamental than *Bit*, the latter being just the reflection of the former. Once reflected though, *bits* are absorbed into *It* and become the integral part of the emerging reality which in turn is reflected again, and again, in a recursive loop, where the results of the previous iteration are plugged in as the input for the next. In this view, reality is continuously emerging anew in the interplay of the current *It* with the stochastically arriving series of *bits*.

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I would like to start with the question of what is information, but rather than relying on the definition provided by Shannon in Information Theory that mainly concerns with signal processing and forms of advanced data analysis, I would like to begin closer to the origins, which warrants a brief excursion into the natural world in order to see how information is experienced by living things on this planet, and what it means for humans in our daily lives. It is in these first-hand experiences where our deep-seated notions originate.

We have intimate knowledge of what information means and are aware that not just humans but all living creatures receive, process, store and output information. In fact Life could be defined as a process of active information exchange between the living lings and their environment. What constitutes information for each creature, be it bacterium, protozoan, plant, animal or insect, depends entirely on what its sensors or senses can deliver. A single cell organism gets information by the means of various receptors studding its cell wall, while multicellular organisms evolved specialized sensor organs. Even though the underlying reality is the same for all, each kind of

creature perceives the world through its own set of narrow bands on various spectra of available information, the precise characteristics of which are shaped by evolution and dictated by the specific needs essential for each species survival.

When trying to imagine what sort of world various creatures perceive, we can be certain that all sense gravity, temperature and pressure and capture from their environment molecules essential for their growth and relevant for survival. To appreciate the variety in the ability of nature to obtain information about the world it is good to be reminded that insects and birds see ultraviolet; snakes infrared; bats and dolphins use echolocation; dogs brighten their world with a rich olfactory palette; platypus, catfish and sharks sense electromagnetic fields. Even plants have specialized cells to sensor light, pressure, temperature; not only do they `know' up from down but can also `hear' the sound and `smell' the air!

This richness in variety of nature's ability to capture various kinds of information out there makes us realize that we know of *It* only through *bits* our senses can deliver; and that, while these bits form the very basis of our knowledge about the world, the information we derive from them remains necessarily restricted by the limitations inherent in our senses and sensors. What else may be out there? Even when we fully realize our limitations, all too often in our discussions of the nature of reality we cannot help but remain biased by our intimate and familiar, accustomed, vision of the world.

To take this point out of the realm of abstract knowledge and put it right where it belongs – and that would be involving our brains' limbic systems – I would like to take a moment to tell you about a friend who, as it turned out soon after we met, had a severe form of red–green color blindness, a not uncommon variant among males. Trying to imagine how he experienced the world I questioned him extensively. And so, as he was explaining to me how, in order to see roses on a bush, he had to actively look for differences in texture between the foliage and the flowers, a funny thought occurred to me which I did not divulge to him for obvious reasons. I thought *hmm* I have green eyes and wear bright-red lipstick. What if it were the other way around – and framed by cheeks with a greenish, sickly hue to boot? Most people would gasp but he would still find me attractive!

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In science, we built our towers of knowledge from the bottom up, starting with collections of disjoint facts, or *bits*, which are essentially *reflections* of various aspect of objects, events or *things* – the *It* in question -- and then, through a series of recursive steps in which raw data is successively distilled, we come to a point where we no longer need to store all the pertaining *bits* in memory, having found the way to recreate them on demand following an organizing principle discovered in the process. When faced with new to us, thus far ununderstood aspects of reality, our initial approach is top-down, from the height of the edifice of knowledge we have already built. When the *thing* does not yield easily to our examination, we are forced to get all the way down to the

level of the sensors at our disposal and look for the ways to improve them and to augment their ranges. In doing so, however, it is still worth keeping in mind that no matter how much information we can amass directly or indirectly, through reasoning or aided by means of our most advanced technology, it will still remain just a subset of all the information to be had out there. Can we always get what we need? How would we determine what may it be? Can a yes-or-no question be asked about what we do not know?

This brings us to the provocative idea espoused by J. A. Wheeler in his celebrated thesis on quantum theory where he compares the workings of the universe with a computer and says: *Every 'it'—every particle, every field of force, even the space-time continuum itself—derives its function, its meaning, its very existence entirely—even if in some contextsindirectly—from the apparatus-elicited answers to yes-or-no questions, binary choices, bits.*

At first glance the idea strikes me as both limiting and impractical. It is limiting because it presupposes an *a priori* knowledge about both the universe at large and every specific thing in it – which appears to preclude the emergence of novelty of any kind (and we would not like that, because it is our inherent thirst for novelty that keeps humans so fascinated and deeply engaged in life). It is impractical, because going down a binary-tree list of questions presumably stored in a database implies that *everything there's to know* about the universe – each and every bit of it – would end up having to be stored (which is a bad idea on both empirical and theoretical grounds). And then what if the right question gets never asked?

In his thesis Wheel conjectured that ours is a *participatory* universe. Despite its immediate appeal, the anthropic principle, in the context of which Wheeler presented the idea, implies that a high level of consciousness, as exhibited by humans, is required to be able to sense, process and respond to information, in other words *to participate.* Who knows, maybe his main intension was to provoke a deeper discussion into the nature of reality? It is also likely he was influenced by the state of knowledge at the time of writing. Today we are certain that not just humans but all living things `participate', each in its own way. From here it is natural to infer that it must also hold true for *each and every thing in existence*. Why, even a jagged rock rising from the surface of a lifeless planet absorbs sun's energy during the day, stores it, and then radiates as heat into its environment at night. How is this not a participation in the universe?

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Several entrants in this year contest expressed the idea that information is superfluous in physics. This suggests that they derive their notion of information from the advanced Shannon's theories, far removed from the grosser level where physics generally operates, – which makes them difficult to apply, especially in areas still mainly concerned with capturing and processing raw data. And so before we continue our discussion I would

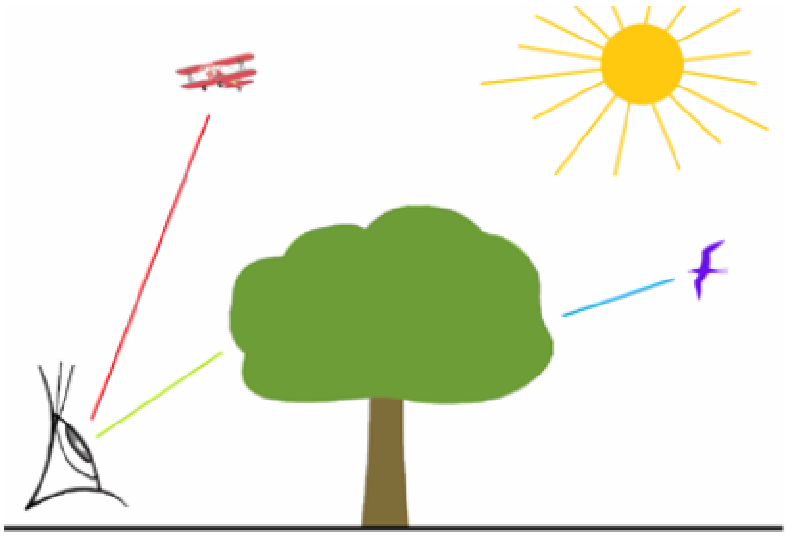
like you to consider a simpler and more informal view of information, loosely based on the following points:

* The only way to know *It* is through *bits* captured by our sensors.
* Bits are *reflections* of various aspects of things.
* Every single *thing* in existence *participates*, i.e. it receives information, processes it and outputs in turn.
* No matter what kind of info we can get and how much of it we may amass it will always remain only a subset of all available (or not) information out there.

In the context of this view, physics has always dealt with information, even when *It* and *Bit* were still one and the same in our minds. I would like to advance an idea that physics entered Information Age long before Shannon and the arrival of computers, perhaps without us fully realizing it. The revolution in our minds began when we stopped taking the *bits* we get for granted and realized that what *seems* may not be what *is*. Not in the least part this was prompted by our recent discovery of the limitations inherent in the medium that brought us information about the world at large; and that was light and its finite speed.

Light has always been our primary source of information and we often use two concepts interchangeably. Thus physics' involvement with *information per se* began with the arrival of Special Relativity. Consider that SR is primarily the theory of *relativity of information*, for it states in effect that the apparent sequence of observed events – or the order in which the *bits of input* are received – as seen by one observer, may not be the same from the point of view of another observer.

With this in mind, on the simple example of visible light as the carrier of information in the macro world of both Classical Physics and Relativity, let us try and sort out *bits* from *its* and see what *participation* in Wheeler's terms may entail. Consider the following diagram:



Here *It* is the whole thing: the sun, the plane, the tree and the bird – each equally *participating* in making the snapshot of reality. Sunrays bounce off the things' *surfaces* and are reflected in *all directions*. The *participation* here consists in receiving white light and reflecting it in some color: the bird blue, tree green, plane red. So what is meant by information here is limited only to the shape and color of things and their position in space, while the rest of information, like what kind of a bird or a tree it is, or where the plane is headed, or how much they weigh, or their histories, is ignored.

In this diagram visible light is the medium that transmits information about all the *participants* into the *milieu*, be it space or spacetime. The reflections the participants *put out* into the milieu herald their presence to other participants, regardless of whether this output may eventually become someone's input or not. Here the observer does not see the bird, because the tree between them prevents the information in the form of blue light reflected off the bird from reaching his eyes; and so while he remains oblivious of it, this of course does not mean that the bird is not there. It is also worth noting one important characteristic of the *medium of information* here: the light falling on either the bird or the plane does not divert them from their course.

With this in mind we can define *participation* as a process in which some *input* is captured from the environment and, transformed, *put out* back into the *milieu*, where it merges with the information already present. Thus we can break down the process into the following components:

1. **source** of information (i.e. something that emits energy or reflects it)
2. **output (**or reflection) itself
3. **medium** that carries or transmits the information throughout the milieu
4. **perceiver** of the output (or observer, which here is the surface of an object)
5. **input** the perceiver gets, which is *always* just a subset of the output in (2)
6. **processing** of the input (here, visible light) by the perceiver
7. **act of participation itself**, i.e. the result of the process in (6) *put out* into the milieu by the perceiver (the tree output green light)
    - here the **perceiver** becomes a bona fide **source** in turn
8. **the cycle is completed and repeated again from 1.**
    - This suggests that information flows not linearly but fractally

I intentionally restricted the discussion to a small segment of the spectrum of electromagnetic radiation and said nothing about gravity, mass, momentum, etc. – all other types of information that *each and every thing* continuously receives as input, stores and outputs back into the milieu, transformed. The same principle applies to all types of `participation in the universe', including those of a more complex type (ex. a tree leaf, while reflecting the green portion of light that fell on its surface, absorbs other bands of energy and uses some of it in turn to generate ATP).

The crucial aspect of the `participatory scheme' above is that output, or *new information*, is always generated at the *boundary* that separates *two different environments*. Nature offers many examples of this. In our diagram the boundary is the surfaces of objects and that is where the information about their presence is generated in the form of the reflected light. Looking around we may notice that the most interesting stuff seems to always happen where two opposites meet: land and sea, water and air, hot and cold, fast and slow. Thus Life is believed to have originated in foamy surfs at the boundary where land meets the sea; ice forms intricate florid patterns on the inside of a window pane separating warm air in the room from the bitter cold outside; fast moving air currents collide with slow moving water forming ripples and waves; surface tension at the boundary between water and air shapes droplets into spheres; etc. etc.

The recursive loop of the `participatory scheme' above implies that reality is a local phenomenon, perpetually generated anew, emerging as the result of exchange of information between all participants. While this view fully supports Wheeler's thesis that reality is created by participating observers of the universe, it suggests a far more democratic universe than implied by the context of his participatory anthropic principle (hopefully such a universe will find its place among the *many worlds* of yet another provocative interpretation of reality offered by Wheeler).

This view also supports Wheeler's idea that the universe operates like a computer, although it seems at odds with the linear flow of information driven by `the apparatus-elicited answers to yes-or-no questions' but rather suggests Wolfram's cellular automaton. I find it comforting that this view is also in line with the ancient Buddhist definition of reality that states, *The world emerges in the play of mind in emptiness*. Translated into modern terms, it says, reality is generated in the interplay of information with space. We know what *Bit* is. This suggests that *It* is space.

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Having sorted out *Bit* from *It* in the macro world, it is time to address the other Wheeler's famous catchphrase. *Whence the Quantum?*

Our initial attempt to break down the quantum setup into participants, milieu, medium and input->output, promptly ends in failure. There are no *things* in Quantum and no *boundaries* separating any two different environments. Instead the spacetime is infused with various fields that tend to taper off gradually making *Quantum It* appear rather fuzzy. Conspicuously absent is the *medium* that would transmit the information about the events without disturbing them in the process. There is no light – or rather here light itself is the object under the examination, which reduces the setup to `particles' bouncing off each other in the manner of billiard balls. In terms of our participatory scheme, here the input, the perceiver of this input, its output in turn, and the observer (sensor) – all are one and the same. It is a little wonder that it has been hard to tell a quantum *bit* from *it!*

Then we find out that `particles' do not quite behave like billiard balls should. This logically implicates the *milieu*, suggesting that Quantum milieu must differ somehow from both space and spacetime. As for what this difference may be, the clues point to extra dimensions, the possibility of which is however firmly denied on the grounds that there is no evidence of this, the first objection being *how come we do not see it?* – which brings to mind the pains humanity went through before accepting that Earth indeed was round.

The situation appears hopeless. Grappling in the dark physics is reduced to entertaining bizarre ideas that *It* exists in a superimposed state of all possibilities, including the mutually exclusive ones, until the observer takes a peak and, in doing so, *actualizes* the event. Better yet, an event can be actualized retroactively, as proposed by Wheeler – again! – by switching sensors in the setup in just the right moment. In real life, openly professing the belief that you can make things happen by mere looking at them is enough to land you in a psychiatric ward. Not so in sciences – and not just physics – where expanding on the idea, in a learned manner, may earn you a Ph.D. instead.

Members of the lay public huddling outside the temple of science willingly suspend their disbelief, some shaking heads, some muttering *gee.* But can this be? We are compelled to ask: W*hat* constitutes this incredible in its effects *quantum observation?* We return to the setup and, upon a closer examination of the measuring process, quickly realize that it is not quite like billiards! A better analogy comes to mind. It's more like being charged with the task of observing flies while blindfolded and with a swatter for the sensor.

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As the popular Russian expression goes, `let us try and keep flies separate from hamburgers'. Now is a good time to be reminded that *It* is the unknown delivered to our senses, and sensors, via *bits;* and that whatever information we are getting is always only a subset of what is to be head out there. This naturally draws our attention to the sensors at our disposal and invites the following questions: What sort of interactions can we possibly detect within the constraints of our current knowledge? What other types of information may be lurking out there? What sort of sensors would we need? — What are we looking for?—Can a yes-or-no question get us the coveted answer?

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In the macro world of relativity and classical physics, it is customary to depict the flow of information as a line of cause and effect — and whether this line is straight or curved does not matter. What matters is that there are two points on it and time flows in between in a fixed direction. In such a setup all relevant variables are known and accounted for, even though it is understood that in reality no two events ever stand apart in a vacuum but are continuously bathed in the sea of *bits*, large and small,

significant and seemingly irrelevant, incoming *each in its own time* from all directions at once. These bits are the consequences, or effects, of other events, both large and small, near and far.

This view suggests that each participating event, or a process, while drawing input from the same local pool of *bits*, has its own version of the order of events that generated these *bits;* and that it may differ, slightly or substantially, from the order as seen by the other participating processes, or event, *including the ones that interact directly with each other*.

This view is at odds with the flow of information represented in a shape of a neat cone. The recursive loop of the `participatory scheme' suggests that information is continuously generated by the events, large and small, near and far; and that each event, or process, *sees its own thread of causality*; and together these threads weave the beads of events into the intricate tapestry of reality.

In the macro world, we measure *time of a process* in terns of another process – say, x cycles of process X complete in *y* cycles of process Y, which is fine as long as X and Y run independently from each other. But here is the catch: each well-defined process, especially of a more complex type, requires a certain set of bits *in order to run to completion*. The necessary bits may come not just from one or two but several distinct processes that must complete, *each in its own time*, in order to generate those bits. In this scheme, the *time of a process* cannot be easily defined in terms of a measure of cycles of the underlying processes that supply the required input.

If information arrives in the shape of a fractal wave, instead of a neat cone of causality, then the front of this wave, at the boundary of *now* separating future from the past, contains many small and smaller yet events which, having already completed, *repeatedly* herald of larger events to come. They do it through means of similarity in their patterns with the events of which they inform. This implies that information about the future may arrive *beforehand* in the form of smaller and seemingly unrelated events. This notion is reflected in what people have traditionally called `omens'.

This brings forth another question. What is *now?* Where does it hide in this perpetual flux of bits zipping through various processes? And where does nature *store* information, and how? May I suggest that perhaps information is stored at the heart of idling processes *waiting* to run. They are waiting because they need to get their *bits* in a row, so to speak. *Hence the Quantum.*