Cosmos and History: The Journal of Natural and Social Philosophy, vol. 18, no. 2, 2022

MATTER-INFORMATION EQUIVALENCE

George Edward Litchfield II

ABSTRACT: Information and matter are commonly viewed to be two separate entities, the former being abstract and the later corresponding to something concrete and physical. However, since the beginning of the Twenty-First Century, a paradigm shift has brought about a closer association between the two. While information can describe matter, matter carries and creates information. This essay attempts to show through two new paradigms, *Bit from Bit* and *Bit recognize Bit,* that in order for a description or measurement to apply to matter, that matter itself must be a description, or piece of information. Ultimately, it is information which composes objects of experience. In particular, the amount of information contained by an object is highly related to its surface area.

KEYWORDS: Philosophy; Zeno; Wheeler; Langan; Information; Matter; Bit

One of the central paradigms of the twenty-first century is the often mysterious idea that everything that exists is composed of information. In other words, we have this idea that the universe is a series of yeses and noes, and that binary logic is somehow an integral part of existence. To be honest, this notion was somewhat lost on me for a time. With a certain child-like innocence, I couldn't square the matter-information equivalence with the fact that matter is the thing that *carries* information. A coin is said to carry 1 bit of entropy (uncertainty resolving information), but how could a coin which carries information be itself information? After all, how do we define information in such a way that it can be said to be the fundamental substance of being? An ambitious task, to say the least.

The unit of information is known as the *bit or binary digit,* and is used to represent the answer to a single yes-or-no question. If something has more information, it has more bits, and thus requires more yes-or-no questions to describe it. Something which is unpredictable by nature requires more information to describe it than something that has predictable, regular patterns.

As physicist John Archibald Wheeler states, to say that all matter comes from information is to say that every *It* comes from *bits,*

> …from the apparatus-elicited answers to yes-or-no questions, binary choices, bits. It from bit symbolizes the idea that every item of the physical world has at bottom — a very deep bottom, in most instances — an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes-no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and that this is a *participatory universe.*

If matter can be identified with information, then Wheeler's vision of reality would be correct. In my mind, there is great philosophical evidence that Wheeler's vision is in fact correct. First, the wonder is not that from information arises matter (it from bit), but that from a given object or "it" arises a bit, a phenomenon we might call *Bit from It*! This deep piece of insight was first suggested in a *First Person Interview* with bar bouncing genius Christopher Michael Langan, who proposes that to observe the existence of something is itself a yes-or-no question, or piece of information, thus directly identifying existence with matter and information as a result of matter, or Bit from It.

Second, there is a something to be said about the paradox of the ancient Greek philosopher Zeno. Zeno proposed the following paradox:

> The argument is that a single grain of millet makes no sound upon falling, but a thousand grains make a sound. Hence a thousand nothings become something, an absurd conclusion.

What Zeno noticed can be used to succinctly tie together Langan's *Bit from It* and Wheeler's *It from Bit.* Essentially, we can view any object, which is composed of atoms, in the same way that Zeno viewed his Millet seed paradox. How can atoms, which we can't see, form an object like a human, which we can see and verify the "bit" of its existence? And if we can't see the atom, how do we verify that it even exist?

There's another problem, a rather big problem, and it pertains to the dinosaurs. How do we know the dinosaurs existed, if no one has seen a dinosaur? At the same time, how do we know that anything on a movie screen isn't real, even if we *have* seen it? You might recall reading a book called *Ender's Game* where the line between information on a screen and physical reality was blurred a bit. In other words, we have evidence that the dinosaurs existed from fossils, but we have no evidence to say that the *Star Wars* series did not actually occur.

Fossils, and *Bit from It,* identify information as a result of matter, but if we applied this to video games and movies, we would have to accept that these too have a material basis. *It from Bit*, meanwhile, supposes that every object in the physical world is composed of information, which makes it sound as though Wheeler supposes that we are on some kind of screen or hologram. But holograms as described by many science fiction films are only illusions; they have no mass, and therefore cannot be matter. Yet they carry messages and descriptions of physical things that are real, and thus are informational. A coin can be used to communicate a bit of information, but It from Bit would suggest that it is composed of the very thing that it communicates, namely bits. Substituting the two phrases in for one another, we arrive at the sophisticated phrase *Bit from Bit.*

Bit from Bit asserts that information can only come from information, that is, the bit that tells us that something exists can only be communicated if the thing is composed of bits. This circumvents the idea that there is some fundamental, indivisible particle that all things are composed of, and implies that atoms are indeed composed of yes or no indications, or information, indications which are indivisible with respect to their questions. Why does Bit from Bit seem like a rational compromise between the two phrases which compose it? A coin which communicates a bit of information is composed of information because it answers the question, "is there a coin on that table?" If there is no coin on the table (i.e. the coin doesn't exist), then there is no heads or tails indication.

Now, a coin, which is a physical "it", carries a bit represented by "heads or tails". But what about the observer, or receiver, of the information? A human is an observer ("it"), capable of recognizing the bit carried by the coin, in the same way it recognizes any other image stored by light. But we said that a coin is composed of information, namely the answer to the question "does the coin exist?" If the coin does not exist, then the message does not exist. But if the re ceiver does not exist, then it cannot recognize the message (heads or tails). Therefore, we have the idea of *Bit recognizes Bit*, that if you are not first and foremost composed of bits, then you cannot recognize or identify another bit.

How can we understand the "Bit recognize Bit" idea? Believe it or not, the best metaphor for understanding "bit recognize bit" is the human eye, which is functionally capable of both perceiving other objects and being perceived by other objects. Because of this, it takes an eye to recognize another eye. Without having eyes yourself, you can't directly observe whether someone else has eyes. This is exactly what the Bit recognizes Bit paradigm embodies. Without being made of bits yourself, you cannot recognize other bits. Thus, in a very real sense, bits are said hold a sort of *self aware* status, as they are constantly recognizing each other in new and exciting ways.

But we are still lacking a resolution to Zeno's paradox. How do we know that atom's exist if we can't see them, through a microscope or otherwise? And if we can't see each one individually, how do they form something that we can see? If we assume Bit from Bit, then we can "factor out" the first letter of each word, and we are left with the expression "B(It from It)". *It from It* is simply the idea that objects change over time into other objects, from a cook dicing up food to a complex oxidation reaction. It is exactly this change over time, not any kind of medieval alchemy mind you, that is not possible without the atomic theory, the periodic table, chemical reactions, mixtures and solutions, etc. In other words, if we neglect the existence of atoms, we cannot have change! And without *Bit from Bit,* we cannot have It from It, as suggested by the distributive expression above.

So the existence of atoms and the changes they describe is supported only within the framework of *Bit from Bit.* This makes sense intuitively, because if we *flip* a coin from heads to tails, we are not changing the fact that the coin itself exists, nor that it is communicating a bit of information. The same is true of atoms. In any chemical reaction, not only is mass conserved, but the number of moles of each atom must be balanced on each side of the reaction. The existence of the atoms has not changed, as supported by Bit from Bit, but their configuration has indeed.

In the same way that Bit from Bit supports It from It, we can derive *It recognizes It* from our Bit recognizes Bit paradigm, meaning that the bit's loosely defined self-aware status gives rise to the particular case of objects, like humans and animals, recognizing each other through signals sent and received. Going back to the human eye analogy, if it two people have eyes, then they see each other. Objects are able to recognize other objects, in other words, because they are composed of bits. The bits of one person indicate which elements are recognizable (communicable) to the other person, and vice versa. In the case of the human eye, the bit "has eyes" indicates whether or not a person can see another person. Always remember, If two people can see each other, then then they are both aware of the other person's stare, and there is undoubtably a connection of the soul.

In hat with Bit recognize Bit is the solution to another paradox, that of *particle-wave duality* as demonstrated by the double slit experiment. Given two slits, a photon or electron which is observed goes through one of the two slits, while light unobserved appears to go through *both slits* and creates an interference pattern. It is also important to note that the interference pattern disappears when one of the slits is closed, but returns when both slits are open. Open and closed. Observed and unobserved. It seems like these crucial bits of information are directly linked to the photon, and the answer to the question "is there interference?" Now, here's an interesting idea. We have the rules for how light behaves in the double slit experiment. Imagine if we explained these rules to someone with very little physics back ground, and asked them to, given 1) whether or not one slit was closed or both were open and 2) whether or not there was interference, to determine 3) whether or not there was an observer. If we did exactly this, then it would be true that the answer to the question "does an observer exist?" can only be determined *if both slits are open.* If one slit is closed, this information is irretrievable, and therefore the "slit configuration" bit (open or closed) recognizes the observer bit in the exact same a way that two eyes recognize each other through sight. In other words, if the slit is closed, we cannot determine if there is an observer, and if there is no observer, we cannot determine the state of the slit! Furthermore, because observation and interference are mutually exclusive events, we conclude that in the event there was an observer, there must logically not be an interference pattern. If there is not an observer, then the interference bit depends on the slit configuration. Particle-wave duality in a nutshell!

Now, all that's left to do is answer the question *how much?* How much information, how many bits, does a given object contain for a given region of space?

We will start by defining information in a way that is intrinsically related to the *volume* or region of space with which we want to concern ourselves, as well as a particular object composed of a uniform elemental mass, such as a coin. I want to assume that the object in question is composed of a single element, but an extension of this argument can be made for mixtures of elements and molecules. In fact, a single unit of volume will represent for our purposes a *yes-or-no question*, in particular the question "is there an atom in that unit of volume?" In a single unit of volume, we have 1 yes-or-no question, while in 2 units of volume we have 2 yes-or-no questions, and so forth. Given 2 units of volume, there are 4 *messages* total that can be communicate, since the combinations are YY, YN, NY, and NN, for a total of 4 bits.

For the given object, the number of moles N, one learns from a little chemistry, is related to the mass (M) of the object and the molar (atomic) mass (m) of the object, such that:

$$N = M/m$$
$$\longrightarrow N * m = M \qquad (1)$$

We also know that, since the material is made up of one element, the density "d" of the element is given by:

$$d = M / V \qquad (2)$$

Substituting equation 1 into 2 yields:

$$d = (N * m) / V$$
$$\longrightarrow \quad V = m * N / d \qquad (3)$$

The number of particles (atoms) "n" in a given system is given by

$$n = A * N$$

Where A is avogadro's number. Substituting into 3

$$V = m * (n / A) / d$$
$$\longrightarrow V = (m * n) / (A * d) = C * n \qquad (4)$$

Given this expression, we will define the *amount of information* carried by a single substance to be the number of combinations of particles in a given volume, or "V choose n", represented as **I = (V n)**. Let me explain why this is a fitting definition. Given two units of volume and 2 particles, the amount of information that can be communicate would be I = (2 2) = 1 bit. This means we can swap the particles' positions all we want, and still only communicate 1 thing, since one atom is not distinguishable from the other. If we have, say, 3 units of volume and 2 particles, then we would have I = (3 2) = 3 combinations, or pieces of information. If we do I = (3 1), we get 3 bits again. Ofcourse, the number of possible messages (the message space) generated for a given volume is 2 ^ V, but the number of particles effectively *limits* this value. So what does I = (V n) represent? It represents the *minimum* amount of information that can be used to completely describe a substance. In other words, instead asking "is there a particle in volume unit 1? Is there one in volume in unit 2? 3? 4? etc…" we ask the question, "given n particles, how many ways can I arrange them in a given space?" For example, for a 4-unit system with two particles, we could generate 2^4 = 16 bits of information, but instead, if we measure the number of particles and just count the number of arrangements in space, we only generate (4 2) = 6 bits of information, clearly much smaller.

Furthermore, we can substitute equation 4 into our definition of information, so that we get,

$$I = (V\ n) = ((m * n)/(A * d))\ n) = (C{*}n\ n) \quad (5)$$

This equation only applies for integer values of C, not a terrible drawback, especially since our goal is simply to understanding something about information and atoms. How else can we understand this equation? First, note that equation 4 gives us volume as a function of particles. If we differentiate equation 4 with respect to particles, we get something very interesting.

$$dV/dn = S(n) = C = [(m)/(A * d)] \quad (6)$$

Do you recognize this equation? The function S is the *surface area* of the substance. This equation says that the surface area of our substance will always be proportional to a constant C = m / (A *d). Increasing the number of particles increases the volume of the substance, but has *no effect on the surface area* of the substance given its uniform density and molar mass. Substituting into equation 5, we get,

$$I = (V\ n) = (Cn\ n) = (S^*n\ n) \qquad (7)$$

Equation 7 sells us that the amount of information in terms of combinations is *directly related to the surface area of the substance.* What we find is that the volume of the substance *does not matter* in this equations because it can be written in terms of the surface area. If we increase the surface area for a fixed number of particles, we ultimately increase the volume and the amount of information generated by the n particles. Moreover, equation 7 eliminates any worries we might have about the *state (solid, liquid, or gas)* of the object in question, and is highly related to the *entropy* of the object in question. Take water for example. For a n particle system of water, gaseous water vapor clearly takes up more surface area than solid water, and liquid water is somewhere in between. This is a direct consequence of our equation. Gases tend to more entropy, more disorder, more combinations, than solids, simply by virtue of the fact that they can take up more surface area than their solid and liquid counterparts. To be concrete, if we define *informational entropy* as the logarithm of the amount of information generated, then we have:

$$E = \log 2(\ I\ ) = \log 2\ (\ (Sn\ n)\ ) \qquad (8)$$

Equation 8 gives the number of yes-or-no question needed to be asked on average in order to *guess the element or substance.* It is less than the volume of the substance, as limited by the number of particles therein. If we consider any single particle, we find that,

$$E = \log 2\ (S) \qquad (9)$$

Now, here's where we turn the world upside down. By the process of abstraction commonly used in physics, *a particle can be anything!* We can consider anything from a flying saucer to a brick to a hydrogen molecule as a single particle of "molar mass" m and uniform density. This means that the amount of entropy contained in any particle of any size is related to *its surface area*. Game, set, and match.

As a consequence of equation 9, objects with more surface area contain more information than objects with a smaller surface area. Naturally, there is some sense that painting on a bigger canvas allows you to store more information than a smaller one. In fact, as you increase the symbols on the canvas, they become crowded quicker on the smaller canvas than the larger one, and thus the messages become blurred like graffitti. This crowding of symbols on a canvas is exactly the same process as adding particles to a particular volume.

Moreover, consider a box with a large fixed volume with a fixed number of gaseous particles. The particles inside this container will exhibit a low pressure, since there are fewer collisions with the sides of the container. Now, consider a scenario where we deform the box into a *cube* of the same volume. Because a cube has a minimum surface area for an box of any volume, the amount of collisions with the container, and thus the pressure, will increase. According to the ideal gas law,

$$P\,V = n\,R\,T \tag{10}$$

Since pressure increases, and the volume and the number of particles remain the same, the temperature of the system *must decrease,* if such a continuous deformation of a container is in-fact possible. This observation on some level coincides our notion of informational entropy and actual (physics) entropy. Because the temperature of the cube system is less than for the rectangle prism, the entropy as we know it from physics appears to decrease with informational entropy and surface area. In other words, as the amount of information a given object or volume contains decreases, so does its entropy, or even more intuitively, its *disorder or systemic unpredictability*.

As described by well-constructed and deep analogies, *Bit from Bit* might fill the explanatory gap that Wheeler refers to as the "very deep-bottom" behind objects we experience by literally identifying existence as a bit. Where the whole is made up of the same fundamental substance as the parts, Bit from Bit resolves

Zeno's paradox by creating a closed explanatory loop. Where does information come from? Objects. What are objects made of? Information. Furthermore, the *Bit recognize Bit* paradigm helps illuminate that certain bits are capable of recognizing each other, which could help explain or at least conceptualize particle-wave duality and conscious systems in general. Finally, the quantifiable amount of information an object contains is related to the surface area of the object, and can help explain why entropy decreases are so difficult to experimentally construct. When all is said and done, matter can be identified with information, and information must by necessity be the fundamental substance of reality.

glitchfield3@gmail.com

REFERENCES

"Christopher Michael Langan- First Person." Metro Goldwyn Mayer, 2001, www.youtube.com/watch?v=-ak5Lr3qkWo&t=1s

Huggett, Nick. "Zeno's Paradoxes." *Stanford Encyclopedia of Philosophy*, Stanford University, 11 June 2018, plato.stanford.edu/entries/paradox-zeno/

Thomas, Rachel. "It from Bit?" Plus.maths.org, 16 May 2016, plus.maths.org/content/it-bit