INFORMATION, NUMBERS, TIME, LIFE, ETHICS

By Lorraine Ford

1. INTRODUCTION

The sense of the word information meaning "knowledge communicated" comes from the mid-15th century, and still today the two primary senses of the word information in dictionaries are "knowledge communicated" and "knowledge gained", where the meaning of the word "knowledge" includes the idea of perception and awareness[1].

By contrast, in 1948 when Claude Shannon considered "How is an information source to be described mathematically, and how much information in bits per second is produced in a given source", he defined information as a quantity, and gave it a rigorous mathematical formulation [2]. Yet more than sixty years later the 2013 Foundational Questions Institute essay contest is still asking "What IS Information?"[3]. One might conclude from the persistence of this question that, when it comes to understanding the foundations of physical reality, Shannon's conception of bits of information and all subsequent similar conceptions of information are incapable of delivering the goods.

What IS capable of "delivering the goods" is a conception of information based on the former sense of the word. In this essay I discuss why information at the foundations of reality should be understood in the former sense of the word, i.e. as subjective experience, and why represented and coded information i.e. Shannon-type information is a secondary concept. I discuss the nature and content of information, and how numbers, time and ethics fit into the picture and relate to the nature of information.

2. DOES INFORMATION COME IN BITS?

A single binary digit (or bit) is a part of a code consisting of strings of zeroes and ones, which can be physically represented by the hardware of a computer, or even by symbols on a piece of paper. Data to be input to a computer (words, letters, numbers and/or symbols) must be encoded into strings of bits which are formatted so that a computer program can "recognise" them and perform logical operations on them.

But without the context of the computer program, or knowledge of the codes and formats used, the strings of bits aren't much use to anybody: bits are not information (in the original sense of the word) in and of themselves [4]. Also, the numeric results of any calculation done to analyse a string of such bits can only be said to represent information about relationships in general, but not about information in the particular, not about what a specific string of bits is intended to represent.

A string of zeros and ones could represent other things apart from numbers or letters of the alphabet: it could represent the answers to a series of questions, the results of a series of coin tosses, or something else. But without knowing what category of information the string represents, without the set of questions, without the knowledge that it represents the results of a series of

coin tosses, or without a codebook showing the correspondence between particular strings and particular letters or numbers, a string of bits can only represent incomplete or partial information: as explained above a string of bits is not information in and of itself, and it's only by virtue of its context and convention that a string of bits can be said to represent information.

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> *"the bit is the smallest possible chunk of information. The universe is made of bits. Every molecule, atom, and elementary particle registers bits of information. Every interaction between those pieces of the universe processes that information by altering those bits." Physicist Seth Lloyd [5]*
>
> *"Information is quantified in bits, or binary digits, exemplified by a coin toss. The coin is either heads or tails, and determining which amounts to acquiring precisely one bit of information…quantum mechanics says that the states of matter are fundamentally discrete rather than continuous, so they form a countable set. It is then possible to work out (approximately) how many bits of information any given volume of the universe contains by virtue of quantum discreteness" Physicist Paul Davies [6]*

The "bit" that physicists Seth Lloyd and Paul Davies refer to appears to correspond to e.g. an electron "jumping" from one quantum state to another quantum state; a "bit" seems to mean e.g. an electron jumping from one atomic orbital to another, where the atomic orbital is characterised by a set of numbers representing the energy, orbital angular momentum, magnetic moment, and spin of an electron. So a "bit" doesn't seem to be a more fundamental category of information than the energy, orbital angular momentum, magnetic moment, or spin of an electron. Far from being fundamental, the concept of a "bit" seems to somehow embody a relationship between these other categories of information about matter, but it is not clear that reality in fact "sees" a "bit" rather than these other categories of information. There doesn't seem to be enough grounds for making a "bit" the basis of an explanatory scheme or a theory of reality.

The notable feature of the above type of "bit" is that it represents a jump i.e. a discontinuous transition from one state of matter to another state, e.g. from one set of numbers representing e.g. energy, orbital angular momentum, magnetic moment, and spin of an electron to another set. But surely, to label this discontinuity a foundational "bit" is to give up on the search for the origin of the discontinuity which really does seem to represent something foundational about reality.

3. WHAT IS INFORMATION?

3.1 INFORMATION IS SUBJECTIVE EXPERIENCE

Unfortunately, the term "information" has been applied to physical objects, bits, which can only ever REPRESENT information. This inappropriate terminology has made understanding the concept of information more difficult.

Information is the thing that is represented; it is not the representation of the thing. In everyday life, it can be difficult to distinguish information from represented information because the two are usually so closely associated almost every minute of the day: the words/symbols in the online newspaper on the computer screen REPRESENT information, but this representation is closely tied to actual information i.e. the subjective experience of information when the online newspaper is read.

I contend that all information in suitably integrated physical objects [7], at all levels of reality from particles to living things, is subjective experience. Seemingly, the inappropriate use of the word

information mentioned above has come about because science and society have, even to this day, shied away from facing up to the subjective nature of information.

The key point is that information doesn't just exist, it is APPREHENDED. That is, information doesn't objectively exist at all: it only exists via subjective apprehension i.e. information is derived from subjective relationship to the rest of reality.

Information is apprehended at the foundations of reality, but this is not to say that plant cells and people apprehend information in the same way that particles do. And this is not to anthropomorphize particles; this is only to suggest that living things, being made out of particles, apprehend information in the same way that particles do; although, clearly, there is a much more complex network of information and summary information in living things. This apprehended information is what we describe as "subjective experience". There is nothing mystical about subjective experience.

3.2 REPRESENTED INFORMATION

The difference between information and represented information is somewhat like the difference between subject and object. Egyptian hieroglyphics like those on the Rosetta Stone are objects that have long been regarded as information [8]. But actually, these hieroglyphics, and the Egyptian demotic and Ancient Greek text on the Rosetta Stone, have only ever been tokens of information, they have only ever represented information. What these hieroglyphics represent is subjective information: i.e. the subjective experience of the stone's creators; and now that hieroglyphics can be decoded, the subjective experience of those who can read them.

If information were objective, there could be no argument as to its nature, because seemingly everyone would agree about every objective item of information. However, physical representations of words and symbols, i.e. written words, spoken words, braille, are the closest thing we have to objective information (for those who speak the same language). This is not to say that there are no objects, only that there is no objective information. From the point of view of a subject, all of the rest of reality represents information: not just hieroglyphics inscribed in stone, but trees, people, cars, clouds, sounds.

Physicist John Archibald Wheeler pointed out that law of nature equations written on pieces of paper "can't fly". He said, "You see, these equations can't fly. But our universe flies. We're still missing the single, simple ingredient that makes it all fly." [9]. It's the same for all physically represented information whether on a piece of paper or on a computer disk: they are objects. What lives, what flies, are subjects.

3.3 "THE PHYSICAL" IS INFORMATION

> *"Information is physical. Information is not a disembodied abstract entity; it is always tied to a physical representation. It is represented by engraving on a stone tablet, a spin, a charge, a hole in a punched card, a mark on paper, or some other equivalent." Physicist Rolf Landauer [10]*

Physicist Rolf Landauer identifies what seem to be 2 types of things: massy, bulky physical matter and information about physical matter, and says they are the one thing. And he's right. Not only is there no evidence of one arising from the other, but you can get into all sorts of philosophical absurdities if you try to consider how one might arise from or relate to the other. In addition to this, the use of Ockham's Razor would seem to suggest that one of them would have to be superfluous to requirements.

But contrary to what Rolf Landauer said, I contend that it's more productive to reverse what he said: what we call "the physical" is actually just information from the point of view of a subject. However it is simpler sometimes to just refer to "physical" reality.

3.4 TYPES OF INFORMATION

Research into quantum mechanics and the use of quantum computers has served to highlight an important feature of reality: information in reality comes in two distinct types, necessitating two different mathematical representations and treatments. One type of information is information relating to current physical outcomes (which in living things seems to also includes experience in the present of stored representations of past physical outcomes).The other type of information is information which can only be described as information about multiple potential future outcomes: it is information that seemingly implies both potential physical outcomes and potential time. This is further discussed in sections 6 and 7 below.

4. WHAT IS THE CONTENT OF INFORMATION?

> *"Categories play a central role in perception, learning, communication and thinking. Categorization is used to group objects together into classes, based on similarities. These classes are called categories or concepts" [11]*
>
> *"the brain is wired to put in order all the categories of objects and actions that we see…It has long been thought that each category of object or action humans see — people, animals, vehicles, household appliances and movements — is represented in a separate region of the visual cortex…researchers found that these categories are actually represented in…the brain" [12]*
>
> *"Categorization is accordingly not about exactly the same output occurring whenever there is exactly the same input. Categories are kinds, and categorization occurs when the same output occurs with the same kind of input, rather than the exact same input. And a different output occurs with a different kind of input." [13]*

Recent papers in the fields of computer science, neuroscience, and cognitive science highlight the fact that human beings, and no doubt other living things, perceive information in categories. I.e. part of the content of information is categories. But is this just a feature of living things, or does it reflect a general principle: does information at the foundations of reality come in categories?

But what are the candidates for information categories? If laws of nature were just a type of loose mathematical description that we humans imposed on reality, then one wouldn't expect that they would hold up and allow us to work out how send a rocket to the moon. But what has "held up" is not necessarily particular laws of nature, which may or may not be entirely correct (e.g. Einstein's equations superseded Newton's, and Einstein's equations may themselves be superseded one day). What has held up is the form of the equation as a way of looking at reality: symbols to represent (what I would call) categories of information e.g. mass, charge; other symbols to represent (what I would call) relationships between these information categories (+,-,x,÷); and "=". Seemingly there are no other candidates for categories of information at the foundations of reality but things like mass, charge and spin.

> *"If you want to learn about nature, to appreciate nature, it is necessary to understand the language that she speaks in. She offers her information only in one form; we are not so unhumble as to demand that she change before we pay any attention." Physicist Richard Feynman [14]*

The language that nature "speaks in" is represented by law of nature equations. These equations represent the content of information at the foundations of reality, and a currently existing information network that interconnects all of reality. They are seemingly constructed out of the following 3 types of things:

1. Types of things like mass and charge which we can represent with single letter symbols, and which we can measure – these are information categories;
2. Types of things that we can represent with the symbols "+,-,x,÷": these symbols represent the types of relationships that can interconnect information categories; they are NOT Platonic objects , they are non-measurable constituents of physical reality whose existence can only be inferred;
3. The type of thing that we represent by "=": it is NOT a Platonic object, it is a non-measurable constituent of physical reality whose existence can only be inferred.

A set of one or more law of nature equations constructed out of the above 3 types of things could never evolve automatically or accidentally or randomly: they are a logical "dead end" in themselves. For laws of nature to "evolve", it is necessary to have a mechanism for creating new categories of information out of the currently existing law of nature structural elements. This hypothesized "creation" of new information categories and new information structures would of necessity be a principal feature of the nature of reality. It seems to be clear that the evolution of complex life requires the evolution of new categories of information, and this in turn requires the construction of new categories interconnected to currently existing reality.

5. NUMBERS ARE INFORMATION TOO

> *"What is it that breathes fire into the equations and makes a universe for them to describe? The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe." Physicist Stephen Hawking [15]*

In the above section I argue that reality must have an underlying currently existing non-Platonic physical/information structure: this is what we represent with law of nature equations. But this physical structure, represented by these law of nature equations, is like a generality: you need the particularity of numbers to create particular physical reality – particular numeric values for mass, charge, momentum etc. In one sense, numbers breathe "fire into the equations", thereby creating "a universe" where "the model" law of nature equations are the essential infrastructure.

Numbers are used to quantify categories of information: Fast, but HOW fast? (for the category velocity); big but HOW big? (for the categories mass and/or length). Numbers are information too. But in the face of claims that numbers are abstract objects [16], or "natural numbers can be represented by classes of equivalent sets" or "the number 3 is represented as sss0, where s is the 'successor' function" [17], the numbers that are found when nature is measured require an explanation.

Some numbers associated with categories of information found in nature may be derived solely from relationships between categories: if 4 categories of physical information are interconnected in a law of nature relationship, and numbers have been obtained from measurement of 3 of the categories, then the fourth number might be understood as being due to the ratios, products, sums or differences etc. indicated by the other 3 categories' relationship to the 4^{th} category.

Some numbers must derive from the measurement unit used: if the unit of measuring distance is a stick called "a metre", then the number quantifying "how far to the supermarket" depends on the particular measurement stick used: the number obtained is equivalent to counting sticks.

But the above qualifications about numbers found when nature is measured don't define or explain numbers, they merely bear on the discussion. There are still the questions of what, absolutely, is a number? And is a number really what is found when nature is measured?

Picture a banana on a table in front of you. If you represent the information category "banana" as "b", 3 bananas might be represented as "b+b+b", where "+", a symbol whose use in law of nature equations seemingly indicates that it represents something essential about the nature of reality, seemingly represents something like combining the bananas as one unit. But to go from 3 bananas to the number 3, you would have to "take away the bananas" i.e. "(b+b+b)÷b". I.e. the number 3 represents a construction where the underlying infrastructure is hidden: any category of information could be similarly hidden in the underlying infrastructure of the number 3. I'm contending that the number "3" is not the outcome of a calculation: "3" is a symbol representing a preserved, currently existing, but hidden, physical information category relationship.

When we utilize the number 3, e.g. in a calculation, then at some level it clearly exists in physical reality as an information category relationship. But numbers found when a particular category of fundamental information is measured seem to have a unit; they don't seem to be dimensionless numbers. The unit seems to suggest a natural granularity to be found in numbers associated with categories of information.

If "d = (a+b)÷c" could be said to represent a law of nature, and if "d = (b+b+b)÷b" says that information category "d" = 3 units (e.g. change in position or momentum equals 3 units), then the input of a new number to the system such as might occur with quantum decoherence might be represented by something like the following: "(d=(a+b)÷c) AND (d=3)". There are further implications: that the creation of "d = (b+b+b)÷b" seems to be the equivalent of creating a new temporary law of nature; and that this number input to the system will have effects on the system due to law of nature relationships, and this number and its numeric effects are what is found when nature is measured.

6. TIME

> *"Is there a short and fast program that can compute the precise history of our universe…? There is no physical evidence against this possibility. So let us start searching!" Computer scientist Jürgen Schmidhuber [18]*

> *"everything in the universe is made of bits. Not chunks of stuff, but chunks of information — ones and zeros. … Atoms and electrons are bits. Atomic collisions are "ops." Machine language is the laws of physics. The universe is a quantum computer." Physicist Seth Lloyd [19]*

Currently, it's not unusual to envisage physical reality as the output of a giant computer or to envisage physical reality itself as a giant computer. In the former case, the output of the computer program would be a physical reality that showed law of nature relationships when measured, so the computer program itself would be different to the laws of nature. In the latter case, the computer program would consist of the laws of nature. In either case, the computation implied by the word computer means that there must be another whole layer of furiously active reality with its own complex structure underlying every physical outcome we observe.

But in the absence of any signs or evidence that a processing and calculating activity, as we know and understand it, is actually taking place, laws of nature must be considered to merely represent static relationships: although laws of nature look like mathematical equations, there are no calculations whatsoever occurring. This means that the system is static or almost static: the

numbers don't change, or don't change much. In order for the system to effectively move forward in time, what is required is the constant injection of newly created numbers (arising from quantum indeterminacy, and associated with categories of information like particle position, momentum, particle spin, particle orbital angular momentum etc). Physicist Seth Lloyd puts it this way:

> *"quantum mechanics, via decoherence, is constantly injecting new bits of information into the world" Physicist Seth Lloyd [20]*

These "bits of information", i.e. these numbers associated with particular existing categories of information, are seemingly not just zeroes and ones. The numbers in effect spread throughout the system by virtue of law of nature relationships:

> *"The way in which the universe computes is governed by the laws of physics" physicist Seth Lloyd [20]*

But there are no computations or calculations as we know them going on: the numbers effect the entire system not via calculations but via existing static information category relationships i.e. laws of nature.

"Quantum indeterminacy" represents information about possible futures. The decoherence that injects new numbers into the system is a one-way process that seemingly also creates time. Without time and new numbers, reality is static. The activity of creating new numbers is the "unfolding of time":

> *"The most important property of time is that it unfolds… You can predict the statistics of what is likely to happen but not the unique actual physical outcome, which unfolds in an unpredictable way as time progresses" physicist George Ellis [21]*

> *"The activity of time is the process which generates the future out of the present" physicist Lee Smolin [22]*

7. LIFE AND ETHICS

> *"the universe is a system where the very specific details and structures in it are created when quantum bits de-cohere - choose one path out of multiple possibilities" physicist Seth Lloyd [19]*

The above section would suggest that somehow, numbers are being generated out of "quantum indeterminacy". These numbers relate to particular categories of information like particle spin or relative spatial location. These numbers can be considered to be the result of "random choice" or subjective choice, but in any case, whatever it is is a necessary aspect or feature of reality. Either "random choice" is a feature of reality or subjective choice is a feature of reality. Not just a feature of reality, but a crucially important pillar of reality: it is part of the essential nature of reality.

> *"Are our futures determined already? Are our experiences of willing, choosing, imagining, and inventing all illusions because the future is already written? Or are they true and real and in fact deep hints as to the nature of reality? Is it already fixed what kind of life my child will have or how bad global warming will be, or does what we choose to do really matter?" physicist Lee Smolin [23]*

Physicists (and others) have to ask themselves "what is the physical (i.e. information) structure of our universe?" Do we live in a universe with no subjective information, or equivalently, where from the point of view of a subject there is only one physical outcome possible for each next moment in

time thereby rendering choice impossible? Or alternatively, do we live in a world where from the point of view of a subject more than one physical outcome is possible for each next moment in time AND where a subject can non randomly choose/create physical outcomes? These are questions about the fundamental structure of information in the universe.

If we live in a universe where the former is the structure of reality, then all the intellectual and philosophical gymnastics, all the cunning reasoning, can never alter the fact that our system of awards and punishment is a complete sham, built on fine but ultimately empty words and self-deception. The basis of ethics and morality is subjectivity, NOT intellectual rationalisations. Our ethics derives from the fact that we are subjects: we feel i.e. we understand subjectivity. The scope of morality is other subjects i.e. atoms, molecules, cells, living things - but not chairs or computers because they are not subjects, i.e. not information integrated objects.

We have physics at the level of the particle, and physics at the level of the cosmos, but the bit in the middle where living things reside is also the domain of physics. Whatever the final shape a physical theory of information takes, you can be sure that what physicists say about information and the nature of reality will affect the attitudes of very many people: is the future “already written” or “does what we choose to do really matter?”

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