Information: what do you mean?
On the formative element of our universe

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Abstract

Information is considered as a fundamental building block of reality, along with matter and energy. Yet the word information is often employed as a container term that represents many different modalities ranging from information constituting a physical parameter to the daily transmission of the news in human culture. Information is particularly known from the description of nature at its micro-level and from computer science (bits an qbits), but also is essential in understanding the evolution of macrostructures in the Universe. The interactions of subatomic waves/particles subsequent to the Big Bang, guided by feedback loops and backward causation, created a dynamic network of quantum information, that finally enabled the formation of highly complex macromolecular structures and first life. Parallel innovations in biophysical complexity occurred, expressed in quantum states that can be brought in superposition, after an "intelligent" search and selection process in nature, aiming at a future path. Therefore, both the becoming and future of the Universe can be viewed as an unfolding as well as a continuous measurement and creation of basic information. A collective memory of nature or a universal consciousness is considered as a prerequisite for the origin of life and further evolution of intelligence.

Current information theory implies that information can both be described as a physical entity, bearing an entropic element, in which the impact of information is inversely related to the probability that it will occur (Type 1 information), versus the concept that information reflects the certainty of a message and is directly related to its probability and meaning (Type 2 information). This dual aspect of information reflects the perspectives of sender and receiver in the transmission process and resembles wave/particle duality in which (proto)-consciousness can be instrumental in transition of the Type 1 to the Type 2 information aspects. It is shown that basic information is largely hidden from us, due to observation-induced perturbation of this intrinsic information.

Information may be transmitted in very different ways and at very different levels. In the living cell this may constitute chemical and electrical signals, but also specific spatial perturbations, for instance, in the 3-dimensional structure of proteins. At the level of human communication, vibration patterns can be expressed in electromagnetic waves in the form of light, sound, music, as well as in images and stories (transmitted by radio, telephone, internet and TV, for example). Such information is transferred to the brain through specifically tailored sensory organs that accommodate complex patterns of wave activity, that subsequently are converted to neural activities in a cyclic workspace of the nervous system. The emergence of human information, knowledge and understanding, in itself, can be seen as a creative force in the physical universe, which can influence the generation of complexity of Nature in all domains. A new information paradigm has been

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proposed that represents a new integral science of information, on a physical and metaphysical basis: it seems easier to describe matter and energy in terms of information than vice versa. Consequently, information can be used as a common language across scientific disciplines.

Contents:

"*A basic idea in communication theory is that information can be treated very much like a physical quantity such as mass or energy*"

Claude Shannon

"*Without matter, there is nothing; without energy matter is inert; and without information, matter and energy are disorganized, hence useless*"

Anthony Oettinger

"*I believe that consciousness is, essentially, the way information feels when being processed*"

Max Tegmark

1. Introduction: Interrelation of Matter, Energy and Information

Our world, as we sense and experience it, can be perceived as consisting of three building blocks: matter (in all its modalities), energy (in all its forms) and information (in all its variants), see Fig. 1. Information is particularly known from the description of nature at its micro-level of elementary particles and from computer science (bits an qbits), but is also essential in understanding the higher complexity of living organisms as well as the macrostructures such as planets, and galaxies of the Universe. For instance the so-called "Big Bang" and the events that followed, appear to constitute a fine tuned expansion process, in the framework of a very specific set of interrelated physical laws and constants, as it has been unveiled by humans 13.5 billion years later (see for excellent reviews: Davies, 2007, Greene, 2004, Linde, 2003, Görnitz, 2012). In this sense the evolution of our universe can be seen as a dynamic flow of unfolding information and creation of new information.

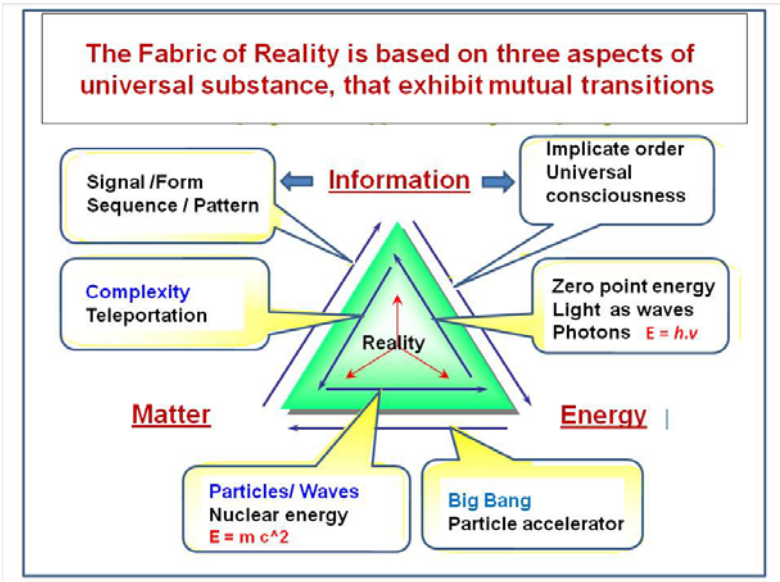


Fig. 1: The fundamental building blocks of Nature: the triad of energy/matter/information

This essay is based on the thesis that information is as fundamental as matter and energy in the fabric of reality, in other words: information is physical. Information may even represent a modality of physics that preceded the manifestation of matter (Wheeler 1990, Zeilinger, 2000). But how are these three building blocks interrelated? Can information be reduced to energy and vice versa, can energy and matter be defined as modalities of information? Matter and energy were once considered two separate and distinct elements, until Einstein proved they were inter-convertible as indicated in the $E = m c^2$ equation. One may wonder: where the item of information is in this famous equation (see Fig. 2). Some see information as a modality of energy and interestingly the constant c in the equation, according to Einstein, was not only indicating the maximal speed of light but at the same time was meant as the maximal speed of information transfer (see Seife, 2006). Umpleby, 2004, published a paper titled *Physical Relationships among Matter, Energy and Information*, which attempts to connect the three concepts. Using Einstein's established mass-energy equivalence formula, the relationship between the frequency of photon energy, which is observed in the photoelectric effect, displayed a maximum rate at which any system can compute, being 2×10^{47} bits/second/gram. Reversely, it has been recently experimentally shown that information can be converted to free energy, using non-equilibrium feedback manipulation of Brownian particles on the basis of information on its location. Such a particle can be driven to a higher energy level by the information gained by measurement of its location (Toyabe et al, 2010). Görnitz et al, 2012, derived

an extension of the mass/energy equation in which quantum information in Qbits can be directly related to mass and energy. Quantum information is defined here as *absolute information*, in principle, being free of meaning, (so called protyposis), and it was proposed that matter is formed, condensed or can be designed from such abstract information. Information as being more fundamental than matter and energy was earlier proposed by John Wheeler, 199o (it from a bit !), and by Anton Zeilinger, 2000/1999. The latter author demonstrated that sending of complete information on an elementary particle over a large distance (teleportation) results in the formation of that particular particle in material form and concluded that information is a *primary* element in nature.

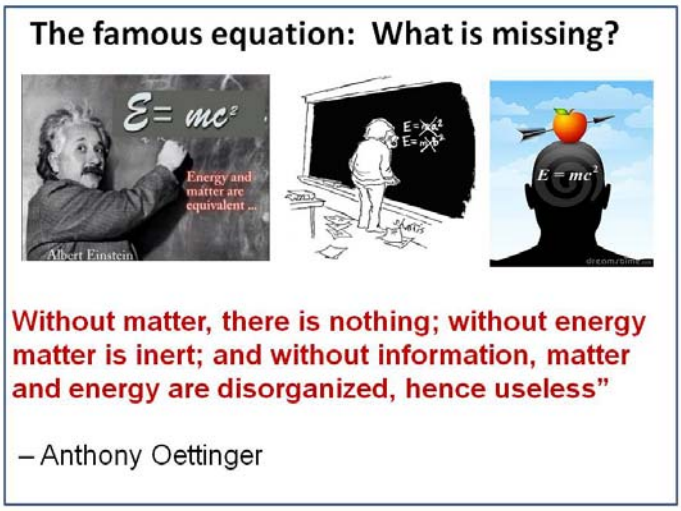


Fig. 2: Relating energy to matter, but where is the aspect of information?
Information and evolution

The interactions of subatomic waves/particles, subsequent to the so called Big Bang, created a dynamic network of quantum information, that finally also enabled the formation of highly complex macromolecular structures. The history of these particular wave/particle interactions, are supposed to be stored in an all pervading quantum field, as it was inherited from the initial information matrix (Zizzi, 2006). Each step in the unfolding evolution implied an inherent potential for change and, ultimately, also the ability to generate biological life. The creation of first life was facilitated by processes such as self-organization and autocatalysis, as well as synergistic and symbiotic processes (see Kauffman, 1993, Margoulus, 1998), providing an ever growing, novel, information framework. Further complexity and sophistication in biological evolution was partly realized by genetic mutation, and chromosomal reorganization, combined with the selection pressure of the environment. Most of the abovementioned evolutionary phenomena have in common that they are based on "copying of information". Obvious time constraints in the creation of very complex cellular components such as membranes, organelles and functional proteins, renders it likely that in the evolution process nature employed quantum mechanical principles such as superposition and entanglement of wave information as well as backward causation. These modalities were used in the process of creating higher complexity towards proto-conscious first life and self-supporting and replicating life forms, see also section 8). In the ongoing process of higher complexification, the humanoid brain evolved, among others, leading to self-consciousness and social awareness (Fig. 3), as central elements in the cultural evolution in the past 5000 years. Our present world with its mass media and Internet is almost dominated by an overwhelming flow of information, that for some means inspiration and for others is rather threatening, since the control of information quality as

well as the freedom of its distribution is of great concern. Therefore, we should always consider the following questions: where is the real information in the data, where is the hard knowledge in the information, but also: where is the very wisdom in the presented knowledge ! (see Fig. 3).

The reader will notice that in the foregoing the term information is used in very different contexts (information in physical, biological and cultural settings), that requires a clear definition of what we mean by it, what forms it can take and even how it can be manipulated in our world of societal and scientific metaphors.

Fig. 3: Evolution of the universe, pictured as a progressive unfolding of information from the micro to macro level (left) and in time, from the "Big Bang" to living organisms (right).

2. The fundamental character of information

What Is Information? It arises through interaction!

Extending the notion of environment or the external world, the following notions of information were given by Gershenson (2010):

Notion 1: *Information* is anything that an agent can sense, detect, observe, perceive, infer or anticipate. This notion is in accordance with Wiener (see later), where information is seen as a just-so arrangement, a defined structure, as opposed to randomness and it can be measured in bits.

Notion 2: *An agent* is a description of an entity that acts on its environment. Note that agents and their environments are also information, as the can be perceived by other agents. An agent can be an electron, an atom, a molecule, a cell, a human, a computer program, a market, an institution, a society, a city, a country or a planet. Each of these can be described as acting on their environment, simply because they interact with it.

Notion 3: *The environment* of an agent consists of all the information interacting with it.

Notion 4: *The ratio of living information* of an agent is the amount of active information produced by itself over the amount of active information produced by its environment.

Information therefore seems inherently relative to the agent perceiving it. Athough, information can exist in theory "out there", independently of an agent, for practical purposes, it can be only spoken about once an agent perceives / interacts with it. This implies that the real meaning of the information will be given by the agent in the act of perceiving and evaluating the particular information, and, among others determines how the agent responds to it. Thus note that perceived information is different from *the meaning* that an agent gives to it. Consequently, meaning is an active product of the interaction between information and the agent perceiving it.

Is Information Physical?

In physics, *physical information* refers generally to the information that is contained in a physical system. Its usage in quantum mechanics (i.e. quantum information) is important, for example in the concept of quantum entanglement in order to describe effectively direct or causal relationships between apparently distinct or spatially separated particles.

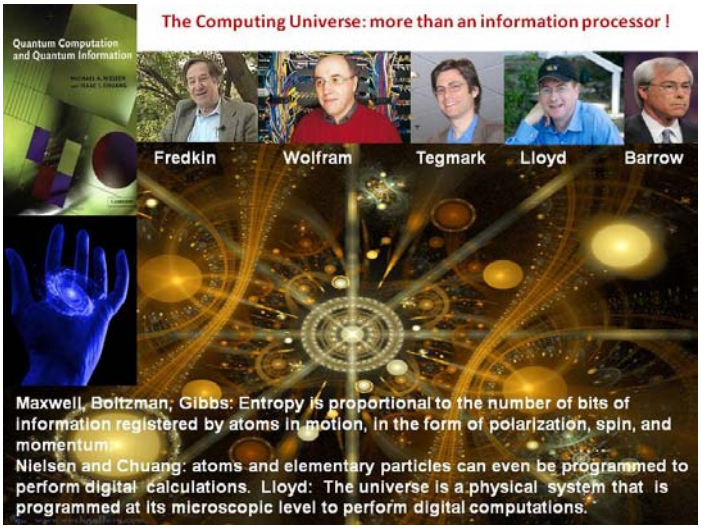


Fig. 4: Physical information and digital character of the Universe, and proponents of the concept of a mathematical Universe (upper part).

Quantum theory states that the energy levels that electrons can occupy in an atom, are "quantized", so that the energy that is absorbed or emitted during transitions between these different energy levels can only take on (discrete) multiples of some minimal value. So energy is not absorbed or emitted on a continuous sliding scale, but can only change in discrete steps. Particles at the atomic level should therefore not be seen as refractory entities, but rather as elements that are able to exchange energy in an ongoing process of quantum communication, albeit in discrete steps. In this communication process, light waves (photons) are crucially important. On the scale of the micro-universe, the resulting network of elementary particles has the ability to store information through perturbation of modalities such as position, spin, charge and polarization on the basis of an incredible number of possible combinations of these parameters.

If information is constantly produced due to particle encounters, where exactly is this information localized ? It seems implicitly enclosed in the particles themselves! According to the famous physicists Maxwell, Boltzmann and later on Gibbs, entropy is proportional to the number of bits of information registered by atoms in motion in the form of polarization, spin and momentum. This seem to imply that individual elementary particles such as electrons and the related atom constructions are not entirely identical but rather contain implicit information related to their individual history of physical encounters. Such a collection of information can perhaps be more easily envisioned, realizing that particles can be represented in wave form and may undergo superposition, meaning that they can integrate wave information. Nielsen and Chuang (2010) in their book, even concluded that that atoms and elementary particles can be programmed to perform digital calculations. In line with that, Lloyd, 2006 sees the universe as a physical system that, at its microscopic level is programmed to perform digital computations (Fig. 4). Implicit in this concept is, that through entanglement and resonance these wave/particles form an active information matrix that constantly unfolds and creates new information collected in an all pervading data/knowledge field (see also section 8). From the very beginning of our universe this field acted as a dynamic source of change and experience (the latter used here as a metaphor, such as proposed by Whitehead (1933, book) as the most fundamental creative element of the Universe)

In a very useful book in this regard with the title: "Decoding the Universe", Charles Seife (2006) explains:

"*What is it that gathers information about the atom and disseminates it into the surrounding environment: it is nature itself that is constantly making measurement on everything. The particles of light and air are nature's probes or measuring devices. By observing an object you are simply receiving the information that has already be deposited on those particles. Even if you would remove the earth atmosphere and our sun distant photon's from distant stars are bombarding our planet. The universe is teeming with cosmic rays that are composed of photons that were born shortly the big bang. Even without any of those photons, nature would be able to collect information since it creates its own particles at every point of space: on the smallest scales, particles are constantly winkling in and out of existence in the quantum vacuum or zero-point energy field. They appear, gather information, disseminate it into the environment and disappear into nothingness from whence they came. These evanescent are the so called vacuum fluctuations occurring throughout the universe, and make it impossible to shield an object completely from Nature's measurements.*"

The latter vacuum domain is also called the zero-point energy field (ZPE) and is considered a likely candidate for collective memory of nature, by some interpreted as a sort of universal consciousness (see for instance Laszlo, 20007, Mitchell and Staretz, 2011, Meijer, 2012 and 2013, (see also section 9). According to quantum theory, such interactions between particles (for example, between photons and electrons) can be also described as wave interferences, producing novel vibration patterns in the form of superpositions. In even greater detail: matter, at its most basic level, may exists as a system of vibration patterns in a web of mutual relations, as more recently hypothesized in the String/M theories.

The different faces of information

Information itself may be loosely defined as "that which can distinguish one thing from another. It was earlier defined also as “the difference that makes the difference”. The information embodied by a thing can thus be said to be the identity of the particular thing itself, that is, all of its properties, all that makes it distinct from other (real or potential) things. It is a complete description of the thing, but in a sense that can be separated from any particular language.

When clarifying the subject of information, care should be taken to distinguish between the following specific cases (taken from Wikipedia, 2011):

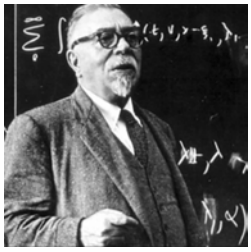
- The phrase **instance of information** refers to the specific instantiation of information (identity, form, essence) that is associated with the being of *a particular example* of a thing. (This allows for the reference to separate instances of information that happen to share identical patterns.)
- A **holder of information** is a variable or mutable instance that can have different forms at different times (or in different situations).
- A **piece of information** is a particular fact about a thing's identity or properties, i.e., a portion of its instance.
- A **pattern of information** (or *form*) is the pattern or content of an instance or piece of information. Many separate pieces of information may share the same form. We can say that those pieces are *perfectly correlated* or say that they are *copies* of each other, as in copies of a book.
- An **embodiment of information** is the thing whose essence is a given instance of information.
- A **representation of information** is an encoding of some pattern of information within some other pattern or instance.
- An **interpretation of information** is a decoding of a pattern of information as being a representation of another specific pattern or fact.
- A **subject of information** is the thing that is identified or described by a given instance or piece of information. (Most generally, a thing that is a subject of information could be either abstract or concrete; either mathematical or physical.)
- An **amount of information** is a quantification of *how large* a given instance, piece, or pattern of information is, or how much of a given system's information content (its instance) has a given attribute, such as being known or unknown. Amounts of information are most naturally characterized in logarithmic units.

The above usages are clearly all conceptually distinct from each other. However, many people insist on “overloading“ the word "information" (by itself) to denote (or connote) several of these concepts simultaneously.

The way the word information is commonly used can refer to both the "facts" in themselves and the transmission of the “facts”, as is treated in the following.

3. Information according to the opposing theories of Wiener and Shannon.

Information according to Wiener


Norbert Wiener

The double notions of information as both facts and communication are inherent in one of the foundations of information theory: *cybernetics* introduced by Norbert Wiener (1948). The cybernetic theory was derived from the new findings in the 1930s and 1940s regarding the role of bioelectric signals in biological systems, including the human being. The full title was: *Cybernetics or Control and Communication in the Animal and the Machine.* Cybernetics was thus attached to biology from the beginning. Wiener introduced the concepts: amount of information, entropy, feedback and background noise as essential characteristics of how the human brain functions.

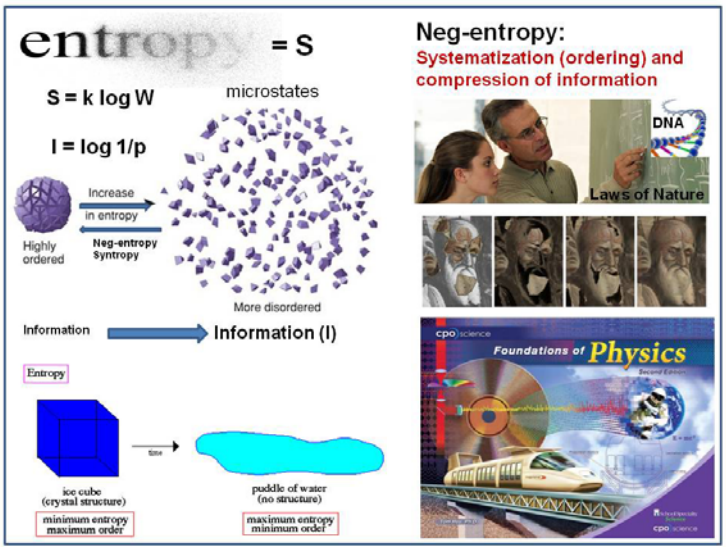


Fig. 5: The concepts of entropy and neg-entropy, in relation to information. S= Entropy; k= Planck constant; W=number of microstates (indicating disorder) ; I= Information content or impact; p= probability that information arise.

From Wiener (1948): "*The notion of the amount of information attaches itself very naturally to a classical notion in statistical mechanics: that of entropy. Just as the amount of information in a system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization (Fig. 5).* Wiener coined the label of a whole new science: *We have decided to call the entire field of control and communication theory, whether in machine of animal by the name Cybernetics, which we form from the Greek steersman.* He also declared his philosophical heritage: *If I were to choose a patron for cybernetics... I should have to choose Leibnitz.*

What is information and how is it measured? Wiener defines it as a probability: *One of the simplest, most unitary forms of information is the recording of choice between two equally probable simple alternatives, one or the other is bound to happen - a choice, for example, between heads and tails in the tossing of a coin. We shall call a single choice of this sort a decision. If we then ask for the amount of information in the perfectly precise measurement of a quantity known to lie between A and B, which may, as a priori probability, lie anywhere in this range, we shall see that if we put A =*

0 and B = 1, and represent the quantity in the binary scale (0 or 1), then the number of choices made and the consequent amount of information is infinite.

Wiener described the amount of information mathematically as an integral, i.e. an area of probability measurements: (1) *I = log p, in which p= probability.* Wiener says the formula means: *The quantity that we here define as amount of information is the negative of the quantity usually defined as entropy in similar situations.* Wiener`s view of information is thus explicitly that it contains a structure that has a meaning. It was also called formative information. (see Gregersen, in Davies and Gregersen, 2010). *It will be seen that, according to Wiener the processes which lose information are, as we should expect, closely analogous to the processes which gain entropy (disorder).* By Wiener the concept of information is, from its very conception attached to issues of decisions, communication and control.. System theorists build further on this concept and see information as something that is used by a mechanism or organism, (a system which is seen as a "black box"), for steering the system towards a predefined goal. The goal is compared with the actual performance and signals are sent back to the sender if the performance deviates from the norm. This concept of negative feedback has proven to be a powerful tool in most control mechanisms, relays etc. Interestingly, quantum physicist Schrodinger, 1959, in his influential book "What is life" earlier coined this type of information as neg-entropy.

Information according to Shannon

Claude Shannon

The other scientist connected with information theory is Claude Shannon. He was a contemporary of Wiener and as an AT&T mathematician he was primarily interested in the limitations of a channel in transferring signals and the cost of information transfer via a telephone line. He developed a mathematical theory for such communication in *The Mathematical Theory of Communication*, (Shannon & Weaver 1959). Shannon defines information as a purely quantitative measure of communicative exchanges (see Fig. 6).

Weaver (in Shannon & Weaver 1959), links Shannon`s mathematical theory to the second law of thermodynamics and states that it is the entropy of the underlying stochastic process in the information source that determines the rate of information generation: *The quantity which uniquely meets the natural requirements that one sets up for "information" turns out to be exactly that which is known in thermodynamics as entropy. This concept of information was later substantiated by Bekenstein, 2003 and Hawking, 2010.* Shannon indeed defined the amount of information as the negative of the logarithm of a sum of probabilities: the impact of information is inversely proportional to the probability that the information arises.

Equation (2): I = log 1/p in which I = information content and p = probability. Note that 1/p in fact stands for uncertainty or disorder: the larger the probability the smaller is the extent of order or likelihood of occurrence. It resembles the well-known Boltzman equation for Entropy: S= k. log M, in which S= amount of Entropy (disorder), k= the Planck constant and M the number of microstates (measure of disorder).

The formula (2) for I is in fact the opposite of Wiener`s equation (1). It is there because the amount of information according to Wiener is equal to neg-entropy (order) and that of Shannon to amount of entropy (disorder).

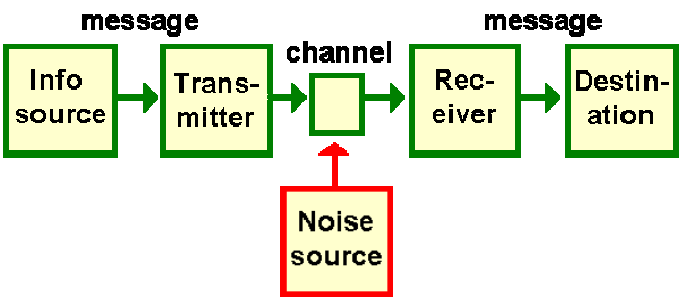


Fig. 6: Scheme on transmission of information from the famous article of Shannon

For an information theorist, at least based on Shannon, it does not matter whether we are communicating a fact, a judgement or just nonsense. Everything we transmit over a telephone line is "information". The message "I feel fine" is information, but "ff eeI efni" is an equal amount of information. Shannon is said to have been unhappy with the word "information" in his theory. He was advised to use the word "entropy" instead, but entropy was a concept too difficult to communicate so he remained with the word. Since his theory concerns only transmission of signals, Langefors (1977) suggested that a better term for Shannon's information theory would therefore perhaps be "signal transmission theory". But Shannon`s "information" is not even a signal:

If one is confronted with a very elementary situation where he has to choose one of two alternative messages, then it is arbitrarily said that the information, associated with this situation, is unity. Note that it is misleading (although often convenient) to say that one or the other message conveys unit information. The concept of information applies not to the individual messages (as the concept of meaning would), but rather to the situation as a whole, the unit information indicating that in this situation one has a freedom of choice, in selecting a message, which it is convenient to regard as a standard or unit amount.

The contradictions in the current information theories further explained

Weaver, explaining Shannon`s theory in the same book: *Information is a measure of ones freedom of choice in selecting a message. The greater this freedom of choice, the greater the information, the greater is the uncertainty that the message actually selected, is some particular one. Greater freedom of choice, greater uncertainty greater information go hand in hand.*

Thus there is one large, and often confusing, difference between Shannon and Wiener. Whereas Wiener sees information as negative entropy, i.e. a "*structured piece of the world*", Shannon`s information is the same as (positive) entropy. As pointed out above, this makes Shannon's "information" the opposite of Wiener`s definition of "*information.*" How can something be interpreted as both positive entropy and negative entropy at the same time? The confusion is unfortunately fuelled by other authors. The systems theorist James G. Miller, 1978, writes in Living Systems: It was noted by Wiener and by Shannon that the statistical measure for the negative of entropy is the same as that for information….. Yet, as pointed out by Seife (2006): "*Information is flowing from the sender to the recipient of a message and each has a different role in the transaction. It is really "good" for a source of message to have high entropy since it means that the source is unpredictable and it is uncertain what the message is going to say ahead of time. If you already knew it would not give you any new information! But once the message is received it is essential to reduce the uncertainty and derive meaning. Sometimes you will hear people say that*

information is negative entropy. This arises because people are accustomed to analyze different things. Some are looking at the sender and the unpredictability of a potential message and others are looking at the receiver and the uncertainties about the answer to the question. In truth, both are looking at the same thing: sender and receiver are just two sides of the coin."

In conclusion: Shannon's information deals only with the technical aspect of the transmission of information and not with its meaning, i.e. it neglects the semantic aspect of communication. The amount of information required to describe a process, system, object or agent determines its complexity. According to our current knowledge, during the evolution of our universe, there has been a shift from simple information towards more complex information (the information of an atom is less complex than that of a molecule, than that of a cell, than that of a multi-cellular organism, etc.). Interestingly, this "arrow of complexity in evolution can guide us to explore general laws of nature. Of note, since information is relative to the agents perceiving it, information will potentially be transformed as different agents perceive it. Another way of stating this law is the following: information will potentially be transformed by interacting with other information. Information may propagate as fast as possible. However, only some information manages to propagate at all. In other words, we can assume that different information has a different "ability" to propagate, also depending on its environment. The "fitter" information, i.e. that which manages to persist and propagate faster and more effectively, will prevail over other information. Note the similarity with the meme concept (a meme is an infectious piece of information, see Heylighen, 2006, Meijer, 2007).

In relation to information, there is no agreed notion of life, which reflects the difficulty of defining this concept. Gregersen, 2010 explains: "Many researchers have put forward properties that characterize important aspects of life. Autopoiesis is perhaps the most salient one, which notes that living systems are self-producing. Yet, it has been argued that autopoiesis is a necessary but not sufficient property for life. The relevance of autonomy and individuality for life have also been highlighted. These approaches are not unproblematic, since no living system is completely autonomous. This follows from the fact that all living systems are open. For example, we have some degree of autonomy, but we are still dependent on food, water, oxygen, sunlight, bacteria living in our gut, etc. This does not mean that we should abandon the notion of autonomy in life. However, we need to abandon the sharp distinction between life and non-life, as different degrees of autonomy escalate gradually, from the systems we considered as non-living to the ones we consider as living. In other words, life has to be a fuzzy concept. Under the present framework, living and non-living systems are both information. Rather than a yes/no definition, we can speak about a "life ratio"

A central question remains: can the abovementioned two modalities of information be reconciled ? In this respect the present author proposes the following: Type 1 information is seen as registered physical information (expressed in Bits and/or Qbits), reflecting the basic data that is an intrinsic property of matter and arises through interaction of elementary particles, as well as their more complex aggregates. Type 1 information is related to (not equal to) increased entropy. Type 2 information is created by systematic collection, compression and selection of information in relation to life processes aiming at autonomy, survival, and reproduction. It encompasses aspects of awareness and intention towards the environment, aiming at survival (proto-consciousness). In higher organisms this may include experienced awareness and self-reflection, providing full consciousness. Type 2 information therefore encompasses a decrease of entropy (neg-entropy) and bears the feature of significance and meaning.

In spite of this dual character, Type 1 and Type 2 information can be seen as complimentary aspects of the unity of information as a building block of nature, in the same way as wave/particle duality in quantum physics. If a wave state is measured and the particular data somehow registered, collapse occurs to the particle form. In this process information and entropy is lost since the collapse implies a transition from multiple possibilities to a single possibility. This already may have occurred in primitive (proto-conscious) life systems, in the integration of endogenous and exogenous (environmental) information, necessary for survival. One mechanism of collapse is observation, registration and interpretation by conscious systems. In a similar sense, the conversion of Type 1 information to Type 2 information, can be viewed upon as an active (proto)-consciousness mediated transition of states, clarifying the well known relation between intelligence and the creation of information as it is well known from our daily life. The latter includes the cultural (artistic and scientific) efforts of describing the representations of, as well as the fabric of reality (see also Duncan, 2010).

4. Information is partly hidden: we can only observe a limited part of reality

The verb "to inform", as employed in the common daily language, is originally related to the expression "to model according to a form". As mentioned earlier, "to inform" derives from the Latin term " in-formare", that indeed means "to give a form". Aristotle wrote: "Information" (*translated in current terminology*) is a truly more primitive fundamental activity than energy and matter. Thus he seemed to imply that information does not have an immediate meaning, such as the world "knowledge", but rather it encompasses a modality that precedes every physical form (Meijer, 2012).

Once there is a form, the potential information can become expressed through one of its possible manifestations. The totality of all forms can then be regarded as (the*) space*, and can be viewed upon as a *"know-dimension*". A form is intrinsically capable of movement (and hence of re- and de-formation as well as recombination). Series of such events may have created first manifestations of life and subsequently a spectrum of different life forms. The ability of a life form to control its own abilities can be defined as *(proto) consciousness*. This "awareness" of the surroundings enabled life forms to probe the immediate environment and also to experience time (according to sequence and relative motion of forms). Such data were crucial in the framework of maintenance, security and survival (see also section 9). The interpretation of a shapes in the environment, or forms of sensed energy, can be envisioned as individual information that provided primitive entities with such (proto)-consciousness. Perhaps the most important of all this is that consciousness, in more sophisticated forms, colored perceptions and directed manifestation of organisms by actively generating and selecting meaningful representations of the outer world. This in turn created self-awareness of the own life form, in relation to both the external and bodily environment.

Information concepts have been examined, apart from the earlier mentioned Wiener (1948) and Shannon (1948), also by von Neumann (1963) in well known contributions and, more recently, by Frieden (2004). This generated useful theories to physics, to computation and to communications technologies. Information is hypothesized to be comprised of dual aspects, similar to the dual aspects of light: wave and particle. Wheeler (1990) stated that information is truly fundamental and exhibits two basic aspects: physical and phenomenal. Both aspects seem essential in the further understanding of consciousness.

According to Frieden, (2004): "In information theory, a clear difference should be made between intrinsic (bound) information [B I] and observed information [O I]. Intrinsic information is defined as the most complete information that describes an object known as *Fisher information*. In the process of observation, for instance by a human being, an incomplete picture is obtained due to the inherent limitation of the observer (Fig. 6, for example, remember the uncertainty principle in quantum physics).

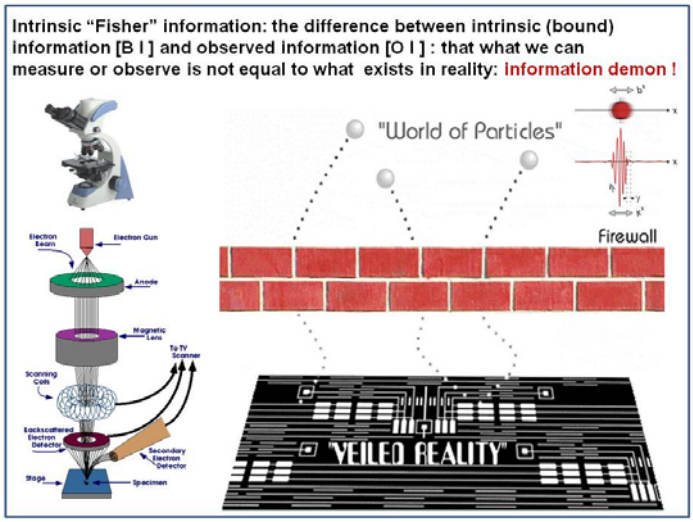


Fig. 7: The veiled reality pictured as a firewall: the quantum wave world is hidden from us

In the process of observation, photons play a crucial role: they probe (illuminate) the object (the source of information) and act as a communication carrier in the chosen communication channel or information flowing route (for instance a telescope or a microscope, see Fig. 7). Observation of such information can subsequently lead to mathematical description and finally to the formulation of laws of nature. Important in this aspect is the role of the particular probe particle (for instance a photon). In the process of probing the object, the probe particle interacts with the object and perturbs its intrinsic information. Nature therefore seems to play a "knowledge acquisition game" in which it adds a certain level of random noise to the data (this was called "*the information demon",* Leff and Rex, 1990 and2003).

According to Frieden: [B I] minus [O I] varies between infinite and zero, depending of the quality of the information (transmission) channel between object and observer as well as on that of the "measurement" with regard to sensory detection, perception and interpretation by the observer. This difference also indicates the ability to communicate the perceived observation, in a consistent form, to the external world (for example to the scientific community). Measurements are in principle imperfect" ([B I] – [O I] > 0). This difference can also be seen as a measure of complexity or, from the standpoint of the observer, as the relative inability to know perfectly. Thermodynamically bound information is a measure of disorder: [B I] has the intrinsic tendency to decrease (called entropy) and to spread across larger space (dissipation). *[B I] is also a measure of value in the sense that it can be expressed in Bits or in Qbits* (see Frieden, 2004*)*

As treated above, if the information is fully observed and transmitted, it may be compared with the result of teleporting a particle: by sending complete information on the particular particle over a long distance a real particle (in material form) is created at the given distance (Zeilinger, 1999, and

2000). This shows the *fundamental* property of information: it precedes matter or, in other words, information [B I] *produces* matter. As mentioned before, this concept of intrinsic information [B I] has been earlier called "*Fisher information*" (see the review of Frieden, 2004).

[B I] may also be used to envision the phenomenon of entanglement of paired particles with opposite quantum mechanical spin over large distances: a measurement of the spin of one of the single particles immediately influences the spin of the other paired particle, irrespective of the distance between them (Bell, 1966). This is due to the fact that they share some form of intrinsic information that *for observers* represents a hidden variable, instead of being due to classical signal transduction between the particles. Thus, the observed particle contains, what Bohm calls, "*active information*" about the unobserved particle (Bohm, 1980, Bohm and Hiley, 1987).

In other words, humans with their evolutionary developed brain, can only see "reality" through a "firewall" (see Fig.7) that only permits a sort of selective filtration of information, see Jahn and Dunne (2007 and 2004). Therefore it is of utmost importance to identify the nature of these inborn filters, to develop mental abilities to inactivate them at least to some extent and and/or to create technology to potentially circumvent them. This may eventually be a feasible task: Spinoza (1677/1995) claimed that intelligence will ultimately learn to fully comprehend reality! Although the truth at the micro-level may be directly hidden for us, it can, in principle, be inferred despite this "information demon": we may in various ways penetrate into this i*ntrinsic* information level. In this sense the universe will cooperate with intelligence. The goal in this cooperation is survival and consequently to reverse the destructive effect of the second law of thermodynamics.

Science is concerned with the ability to make predictions that can be tested empirically. For example observing an interaction of particles through studying interference patterns in quantum systems, yields relevant information. Particle interactions can be seen as a form of information propagation and in fact, each particle is basically a bundle of information fully describing its current state, in other words: the wave function of a particle contains various modalities of information about the particle. The spatial part of the wave function contains information about the probability of localizing the particle in a given spot. The spin part has information about the probability of identifying it pointing one way or another, clearly the property of spin should be seen as a category of information rather than one of energy. This is also true for potential entanglement, that provides information of a paired particle, irrespective of their distance. Quantum information, however, is different from classical information since it cannot be established without its state becoming the measured value. Such states measured as a qubit are known as basis states or basis vectors".

5. Information as related to Neg-entropy and Syntropy: Order or Chaos ?

Neg-entropy

Ordered systems, such as our universe in the beginning, are supposed to expire in less ordered systems (increase of disorder or entropy increases, according to the principles of thermodynamics). A greater disorder implies that more information is needed to describe the system. An increase in entropy, consequently, means an implicit increase in information. Yet, in our part of the universe, contrary to the second law of thermodynamics, also a *decrease* in entropy is seen. This produces an increase of ordered complexity such as life forms, as was already described by Schrödinger, 1959. As mentioned earlier, this so called *neg-entropy* is associated with a virtual reduction of information., since, in a systematic manner, information is compressed (formative information). For example, the compression of information in formulating the laws of nature can be seen as an example of such a neg-entropic process. Presently, more and more of such information is generated and shared in the non-local information store that we call the internet. In this global process, interestingly, information density is increasing, despite the much larger area over which it is distributed.

Syntropy

The famous mathematician Fantappié already in 1944 formulated the *Unitary Theory of the Physical and Biological World*, and started from the consideration that half of the solutions of the fundamental equations of the universe had been rejected by physicists. Vannini and Di Corpo, 2011 explained it starting from the Klein-Gordon energy/momentum/mass equation of special relativity: $E^2 = m^2c^4 + p^2c^2$. In this equation E is energy, m mass, c the constant of the speed of light and p the momentum. This equation is quadratic and has two solutions, one positive (+E) and one negative (-E). Physicists had always rejected the negative solution since in the variable p there is time and in the negative solution time flows backward, from the future to the past. Einstein proposed to put $p = 0$, since the speed of bodies, compared to the speed of light, is very low and can be neglected. In this way the energy/momentum/mass equation simplifies into the famous $E = mc2$. Fantappié however believed that mathematics has a principle of reality, and that we cannot take in consideration only the part of the formulas that suits us. Fantappiè decided to study the properties of both solutions, the positive and the negative solution and he found that the first solution describes energy that diverges from a point, from a source, as for example the light from a light bulb, whereas the negative solution describes energy that diverges from a point, backwards in time.
Consequently in our observable world we appear to move forward in time, but in connection with a domain, hidden for us, experience the negative solution as converging forces. Fantappié named this tendency syntropy (from Greek *syn*=converging, *tropos*=tendency), in order to distinguish it from the law of entropy which is derived from the abovementioned positive solution.

Starting from this past-future duality, another mathematician, the New Zealander Chris King has developed a model of consciousness in which free will would arise from our being immersed in a dual stream of information travelling in opposite directions of time: on the one hand information from the past in the form of memories and experiences, on the other hand information from the future in the form of emotions (King, 2003 and 2011).

The syntropy model strikingly coincides with the ideas of Teilhard de Chardin: life, rather than being caused, would be guided by attractors which already exist in the future. His theory assumes

that, in the future, there is a human-attractor towards which we are converging and evolving. This in contrast to a random biological evolution as dictated by Darwin's classical theory. The formation of new complex structures would be driven by attractors that guide macro-evolution processes towards more advanced complex structures through the mechanism of attractors that may retroact from the future.

In 1928 Paul Dirac tried to get rid of the unwanted negative solution by applying the energy/momentum/mass equation to the study of electrons, turning them into relativistic objects. But, also in this case, the dual solution emerged in the form of electrons (e^-) and antiparticles (e^+). The antiparticle of the electron, initially named neg-electron, was experimentally observed in 1932 by Carl Anderson in cosmic rays and named *positron*. Anderson became the first person who proved empirically the existence of the negative energy solution. Consequently, the negative solution was no longer an impossible mathematical absurdity, but it was an empirically shown phenomenon. Dirac's equation predicts a universe made of matter which moves forwards in time and antimatter which moves backwards in time. According to Wheeler's and Feynman's electrodynamics, emitters coincide with retarded fields, which propagate into the future, while absorbers coincide with advanced fields, which propagate backward in time. This time-symmetric model leads to predictions identical with those of conventional electrodynamics. For this reason it is impossible to distinguish between time symmetric results and conventional results (Wheeler & Feynman, 1949). In the 1970s Szent-Gyorgyi (Nobel prize, 1937) concluded that in living systems there was wide evidence of the existence of the law of syntropy, even though he never managed to infer it from the laws of physics. While entropy seems a universal law which leads towards the disintegration of all types of organization, syntropy reflects an opposite law that attracts living systems towards a more harmonic organization (Szent-Gyorgyi, 1977). Ilya Prigogine, winner in 1977 of the Nobel prize for chemistry, introduced in his book "The New Alliance", a new type of thermodynamics, the "thermodynamics of dissipative systems", typical of living systems. Prigogine stated that this new type of thermodynamics cannot be reduced to the rules or thermodynamics (Prigogine, 1979). Recently, Henry-Couannier, 2012, in a paper on: "Negative Energies and Time Reversal in Quantum Field Theory" reviewed the theoretical and phenomenological status of negative energies is in Quantum Field Theory, leading to the conclusion that hopefully their rehabilitation might be completed in a modified general relativistic model.

Thus, the concept of *syntropy,* at first sight*,* seems related to *neg-entropy* (absence of entropy by), but as treated above it is rather based on a reversed flow of information from future, by which a converging information process is obtained that opposes the information-diverging processes of entropy: increased chaos is compensated for by ordered, life-conferring information flow (Vannnini and DiCorpo, 2011

How to express physical information

What is the basic entity to describe information? Entropy, if considered as information is measured in bits. The total quantity of bits is related to the total degrees of freedom of matter/energy. For a given energy in a given volume, there is an upper limit to the density of information (the so called Bekenstein bound), suggesting that matter itself cannot be subdivided infinitely many times and there must be an ultimate level of fundamental particles. Bekenstein, in his overview "A Tale of Two Entropies", highlighted a connection between the world of information theory and classical physics. As mentioned above, this connection was first described by the earlier mentioned Shannon (1959), who introduced a measure of information content, known as Shannon entropy. As an

objective measure of the quantity of information, Shannon entropy has obtained a central position, for example, the design of modern communication instruments and data storage devices, are based on Shannon entropy. As, mentioned above, Shannon entropy deals with an intuitive link between measures of uncertainty and information: the greater our uncertainty about the outcome of an experiment, the more one may gain from actually performing it. In fact, Shannon information represents a parameter indicating the expected information gain, even before we perform an experiment, and also an average gain following multiple repetitions. In this concept, the higher the deviation from uniform probabilities the more information is available. The central idea in this context is that information is a physical entity (it is encoded into configurations of energy and matter). Consequently physics, in fact, consists out of information, for instance by statistically indicating the amount of information imparted by prior conditions ("prior knowledge") at a given measurement.

Modern physics now considers the bit (binary digit) - the binary choice - as the ultimate fundamental entity. John Wheeler (1990), expressed this idea as “it-from-bit”, and implied that the basis of the physical universe -the “it” of an atom or subatomic particle - is not matter, nor energy, but a bit of information. Consequently, the entire universe should be seen as a cosmic processor of information. If elementary particles interact, they are exchanging bits or, in other words, they transmit quantum states. The universe can thereby also compute its own destiny. For instance, Lloyd (2006) postulated that there are content-holding structures in the universe, that posses "content" of whether they are "here or there”. At the same time, there are other cosmic structures that can read that content and may identify it to be non-random. They then use this information to recognize patterns and quantify how much information is in a particular channel. It is important to note here that information does not exist by itself, because it depends on an intrinsic system that is able to decode the “message” and can register the "sender" and "receiver".

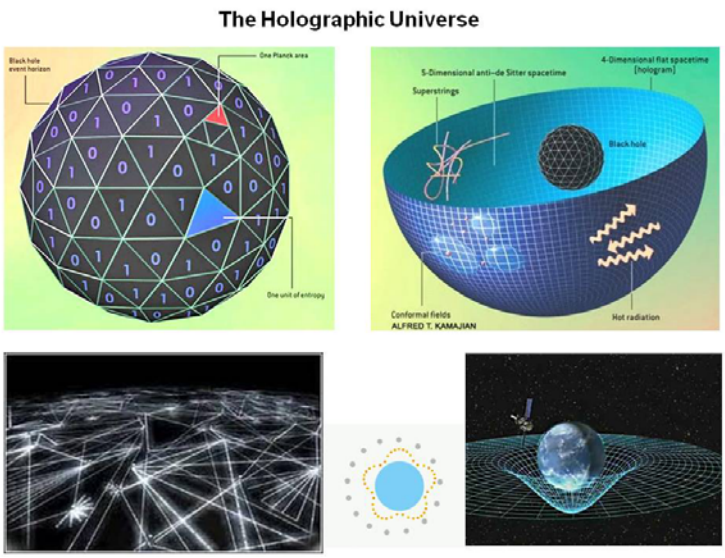


Fig. 8: Schematic representation of the holographic structure of a black hole (upper left) and the olographic universe (upper right), in which the implicit information, expressed in bits, is holographically projected on a virtual screen, also enabling an entropic description of gravity, as opposed to the classical deformation of space/time (right below).

Shannon's efforts to find a way to quantify the information contained in transmitted messages, led, as mentioned above, to a formula with the same form as that of Boltzmann. In his article

"*Information in the Holographic Universe"*, (Fig. 8). Bekenstein, 2003, concluded that: "Thermodynamic entropy and Shannon entropy are conceptually equivalent: the number of arrangements that are counted by Boltzmann entropy reflects the amount of Shannon information one would need to implement any particular arrangement of matter and energy." At first sight there seems to be a clear difference between the thermodynamic entropy and Shannon's entropy of information: the former is expressed in units of energy divided by temperature, the latter in essentially expressed in dimensionless "bits" of information, but this apparent difference is entirely a matter of convention.

Conclusion:

The expanding Universe can, in this view, be considered as the outcome of an entropic force which in its turn gives rise to the accumulation of information that provided biological evolution with a life conferring potential. Closely related to this is an intrinsic property of this system: the universe, in spite of the ongoing entropic processes, at the same time, is increasing order in relation to creation and further development of intelligence. This aspect is not only inevitably connected to its ultimate destination on the cosmic scale (see Barrow and Tipler, 1986), but it is also fundamental for the organization of life on the micro-level. As stated earlier, this phenomenon was called *neg-entropy*, and can be viewed upon as the compression of active information, such as the formulation of the laws of nature or the coding of information for the proteome in DNA/RNA.

6. Why a Science Philosophy of Information?

The philosophy of information (PI) is the area of research that studies conceptual issues arising at the intersection of computer science, information science, information technology, and philosophy.

According to Floridi (2010 b) this discipline includes:

1. the critical investigation of the conceptual nature and basic principles of information, including its dynamics, utilization and sciences
2. the elaboration and application of information-theoretic and computational methodologies to philosophical problems.

The philosophy of information (PI) has evolved from the philosophy of Artificial Intelligence, logic of information, cybernetics, social theory, ethics and the study of language and information.

But again, just what is information in this respect? According to Beavers (2012): The term is undoubtedly vague and still an important part of the modern linguistic landscape. We live in the "information age," we read "information" in the papers, we can gather "information" on, say, the salt gradients of the currents in the Pacific Ocean, and we can talk about the amount of "information" that can be delivered over a wireless connection. Yet, as several philosophers have pointed out, we can scarcely say precisely what the term means. Given that it is also used differently across different fields of study (biology, communications, computer science, economics, mathematics, etc.), it is a hallmark of the philosophy of information to undertake this clarifying task, if the term "information" is to be informative at all.

The expression: philosophy of information was coined in the 1990s by the abovementioned Luciano Floridi, who elaborated a unified and coherent, conceptual frame for the whole. Floridi (2010a) identified five different kinds of information: *mathematical, semantic, physical, biological and economic, but this list is obviously not definitive.* According to Floridi, four kinds of mutually compatible phenomena are commonly referred to as "information":

- Information about something (e.g. a train timetable)
- Information as something (e.g. DNA, or fingerprints)
- Information for something (e.g. algorithms or instructions)
- Information in something (e.g. a pattern or a constraint).

The author stipulated: "the word "information" is commonly used so metaphorically or so abstractly that the meaning is quite unclear. Information is in fact a polymorphic phenomenon and a poly-semantic concept so, and it can be associated with several explanations, depending on the level of abstraction adopted and the cluster of requirements and desiderata orientating a theory. The abovementioned Claude E. Shannon, for instance, was very cautious: "The word 'information' has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. *It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field*. (italics added)" (Shannon, 1948). Thus, following Shannon and Weaver, 1959, supported a tripartite analysis of information in terms of (1) technical problems concerning the quantification of information and dealt with by Shannon's theory; (2) semantic problems relating to meaning and truth; and (3) what he called "influential" problems concerning the impact and effectiveness of information on human behavior, which he thought had to play an equally important role. And these are only two early examples of the problems raised by any analysis of information".

Floridi, also mentioned eighteen problems in information science that are in need of solution there by setting the agenda for future development in this research area while connecting it to previous work. The questions are discussed in Floridi, 2011a and are worthwhile to be cited here:

1. What is information?
2. What are the dynamics of information?
3. Is a grand unified theory of information possible?
4. How can data acquire their meaning?
5. How can meaningful data acquire their truth value?
6. Can information explain truth?
7. Can information explain meaning?
8. Can (forms of) cognition be fully and satisfactorily analyzed in terms of (forms of) in-formation processing at some level of abstraction?
9. Can (forms of) natural intelligence be fully and satisfactorily analysed in terms of (formsof) information processing at some level of abstraction?
10. Can (forms of) natural intelligence by fully and satisfactorily implemented non- biologically?
11. Can an informational approach solve the mind-body problem?
12. How can information be assessed? If information cannot be transcended but can only be checked against further information … what does this tell us about our knowledge of the world?
13. Could epistemology be based on a theory of information?
14. Is science reducible to information modelling?
15. What is the ontological status of information?

16. Can information be naturalized?
17. Can nature be informationalized?
18. Does computer ethics have a philosophical foundation?

Information-theoretic and computational methods, concepts, tools and techniques have already been developed and applied in many philosophical areas:

- to extend our understanding of the cognitive and linguistic abilities of humans and animals and the possibility of artificial forms of intelligence (e.g. in the philosophy of AI; in information-theoretic semantics; in information-theoretic epistemology and in dynamic semantics);
- to analyze inferential and computational processes (e.g. in the philosophy of computing; in the philosophy of computer science; in information-flow logic; in situation logic; in dynamic logic and in various modal logics);
- to explain the organizational principles of life and agency (e.g. in the philosophy of artificial life; in cybernetics and in the philosophy of automata; in decision and game theory);
- to devise new approaches to modeling physical and conceptual systems (e.g. in formal ontology; in the theory of information systems; in the philosophy of virtual reality);
- to formulate the methodology of scientific knowledge (e.g. in model-based philosophy of science; in computational methodologies in philosophy of science);
- to investigate ethical problems (in computer and information ethics and in artificial ethics), aesthetic issues (in digital multimedia/hypermedia theory, in hypertext theory and in literary criticism) as well as in psychological, anthropological and social phenomena characterizing the information society and human behavior in digital environments(cyber-philosophy).

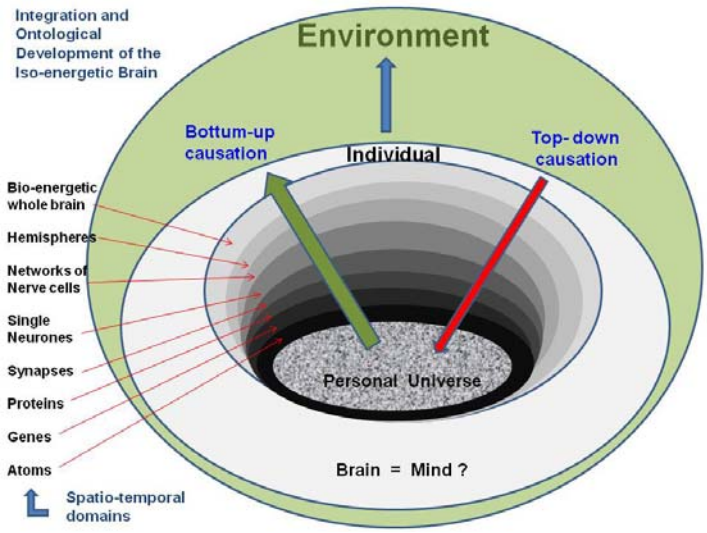


Fig. 9: A representation of a multi-layered organization structure of the human brain, encompassing top-down and bottom-up information transfer on the basis of an evolved personal universe (world view), in recurrent interaction with the environment and universal mind (From Meijer and Korf, 2013).

Modeling of physical and conceptual systems in relation to organizational principles of life, was recently performed for cognitive brain function on the basis of an iso-energetic and bi-cyclic information model of mind-brain relationships.(Meijer and Korf, 2013). The Fig. 9 shows the levels of organization of the brain, largely based on the concepts of Searle and Kauffman. The lowest

levels of complexity range from elementary particles (photons, quanta), via atoms and protein molecules, whereas the higher levels are composed of individual neurons, neuronal networks, individual or personal brain. According to QM mind theories the (individual) mind is directly connected to the whole universe, via quantum fields interacting with the "personal universe". This spatial-temporal organization is created through bottom-up ontological processes (bottom-up causation) and is also subject to top-down causation (Bohm and Hiley, 1987), through interaction with a supposed general knowledge field (Meijer and Korf, 2013).

Current Paradoxes of Information

Beavers (2012), illustrated various kinds of philosophical problems that the philosophy of information confronts by examining three paradoxes that have received much attention in the literature. I cite: "The inverse relationship principle mentioned above, that the informativeness of a piece of information increases as its probability decreases, may seem intuitive at first glance, but as it stands, it leads to two problems with counter-intuitive outcomes. The first was framed by Hintikka (1970) which he named the "scandal of deduction." The second was identified by Bar-Hillell and Carnap (1952) and is accordingly called the Bar-Hillell--Carnap Paradox. The third involves Weiner's (1950) conflation of meaning with information and appears in Dretske (1981). Consider again the inverse relationship principle: the probability that a given (correct) conclusion or answer will follow from a logic or math problem defined in a formal language is 100 percent. It is therefore, according to the inverse relationship principle, maximally uninformative. Yet, as Hintikka noted, "in what other sense, then, does deductive reasoning give us new information? Isn't it perfectly obvious there is some of such sense, for what point would there otherwise be to logic and mathematics?" The Bar-Hillell-Carnap Paradox notes that since the less probable a piece of information is the more informative it is, and since contradictions are maximally improbable, they are the most informative, leading to another counter-intuitive conclusion. Appealing to Norbert Wiener's equation of "amounts of meaning" with "amounts of information" (Wiener, 1948), Dretske noted a similar issue that challenges the inverse relationship principle. Any adequate theory of semantic information must somehow account for these paradoxes. Dretske does so by sharply distinguishing between meaning and information, which offers some help with the last paradox. Floridi (2011a) suggested that the absence of truth as a criterion for in-formativeness in standard theories of semantic information lies at the root of the problem. He suggests "a theory of strongly semantic information," which provides the definition of semantic information as "well-formed, meaningful, and truthful data," mentioned above. This seems to deal adequately with the first and second paradox, since taking truth into account means that "semantic information about a situation presents an actual possibility that is inconsistent with at least one but not all other possibilities". This view renders a contradiction impossible where truth is concerned and a tautology vacuous because it eliminates any possibility of false-hood. Thus, both are uninformative (see for the above references Beaver, 2012).

Preference for using information as a fundamental parameter

A potential benefit of using information as a basic descriptor for our world, is that the concept is well studied and formal methods have already been developed, as well as its philosophical implications have been discussed. Thus, there is no need to develop a new formalism, since information theory is well established. One can borrow this formalism and interpret it in a new way. Finally, information can be used to describe other formalisms: not only particles and waves, but also systems, networks, agents, automata, and computers can be seen as information. In other words, it can contain other descriptions of the world, potentially exploiting their own formalisms. Information, therefore is an inclusive formalism. This is not to suggest that describing the world as information is more suitable than physics to describe physical phenomena, or better than chemistry to describe chemical phenomena. It would be redundant to describe particles as information if we are studying only particles. Rather, the suggested approach is meant only for the cases when the physical approach is not sufficient, i.e. across scales, constituting an alternative worth exploring to describe evolution.

7. Information from a quantum physics perspective

Classical versus Quantum information

According to Wikipedia, 2012, “The instance of information that is contained in a physical system is generally considered to specify that system's "true" *state*. In many practical situations, a system's true state may be largely unknown, but a realist would insist that a physical system regardless always has, in principle, a true state of some sort—whether classical or quantum.

When discussing the information that is contained in physical systems according to modern quantum physics, we must distinguish between classical information and quantum information. Quantum information specifies the complete quantum state vector (or equivalently, wave function) of a system, whereas classical information, roughly speaking, only picks out a definite (pure) quantum state if we are already given a pre-specified set of distinguishable (orthogonal) quantum states to choose from; such a set forms a basis for the vector space of all the possible pure quantum states (see pure state). Quantum information could thus be expressed by providing (1) a choice of a basis such that the actual quantum state (See Fig. 10) is equal to one of the basis vectors, together with (2) the classical information specifying which of these basis vectors is the actual one. However, the quantum information by itself does not include a specification of the basis, indeed, an uncountable number of different bases will include any given state vector. Note that the amount of classical information in a quantum system gives the maximum amount of information that can actually be measured and extracted from that quantum system for use by external classical (decoherent) systems, since only basis states are operationally distinguishable from each other. The impossibility of differentiating between non-orthogonal states is a fundamental principle of quantum mechanics equivalent to Heisenberg's uncertainty principle.

As indicated above, digital information is, in general, expressed in bits which may have the value “0” or “1”(yes/no). In computers, bits are represented as the physical states of a certain physical system. It is obvious that a physical bit can only be either “0” or “1”, that is, if it is represented by a classical system. Yet, with the possibility of characterizing individual quantum particles in much greater detail, the question arises which new phenomena may occur when we use such quantum systems to represent information, assuming that their propagation and processing is determined by

the laws of quantum physics. One interesting aspect comes up when we consider the qubit or quantum bit. In contrast to a classical bit, a qubit is not restricted to the states “0” or “1”, but it can also be in a superposition of “0” and “1”. This means that the value of the bit is not exactly defined. If it is measured, one gets randomly the answer “0” or “1”. Although in this way certainty is lost, a major advantage of a qubit is that the superposition can exist in many different forms, and consequently a qubit has the potential to represent much more information than the classical bit and renders extremely high calculation capacity.

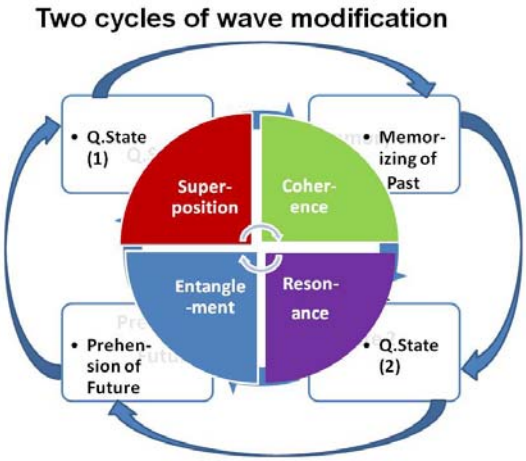


Fig.10 : The choice aspect of consciousness, as the resultant of two induced quantum states in the quantum brain, as realized by wave resonance, superposition, coherence and entanglement, enabling memorizing the past and prehension of future events.

Von Neumann (1963) introduced an "ontological" quantum physics approached information theory as a knowledge-based discipline, which brought the role of the observer and the measurement instrument in the operation of the system. Stapp, 2009 described Von Neumann's view of quantum theory through a simple definition: "*the state of the universe is an objective compendium of subjective knowings*". This statement implies that the state of the universe can be seen as represented by a wave function which is a superposition of all the wave functions that conscious beings can collapse through observations. In this sense it is a sum of subjective acts, although collectively an objective one. Thus the physical aspect of Nature (the Schrödinger equation) can be viewed upon as a compendium of subjective knowledge. Of note: the conscious act of asking questions on the very nature of reality may drive the actual transition from one state to another, i.e. the evolution of the universe.

Quantum information in a final context

Potentially, all information that is ultimately available about the state of the universe could in the far future be collected and compressed by an advanced intelligence, producing a final knowledge register to be used as a recipe for the construction of next version of our universe. In other words: this ultimate syntropic type of information could be made suitable for black hole-mediated transmission into an adjacent space/time domain, in order to create a follow-up universe of our present one (the so called cyclic model of our universe, see for cosmological projections: Vidal

(2010), Vaas (2004), Heylighen (2010), Zizzi (2006) and Penrose, 2010). In this sense, intelligent life may be inevitable for the future evolution of our type of universe (cf. the "Strong Anthropic Principle", (see Linde, (2003) and for the final destiny of intelligence, (Barrow and Tipler, 1986 and Tipler, 1995): "*all events in nature belong to a particular form of different codified energy transformations, so that the total energy cannot be created or destroyed*". Alternatively, scientific observations made throughout the history of our universe may, through a process of backward causation can, in principle, lead to adaptation of the fundamental laws of nature, in spite of the fact that they were often assumed to be fixed from the beginning (see Wheeler, 1987). Observations made throughout the entire duration of the universe, in this way, can contribute to fashioning the form of the laws in the first split second after the Big Bang, when they were still significantly malleable. Thus the potential for future life acted like an attractor, drawing the emerging laws towards a bio-friendly region in the parameter space (see Davies, 2003 and 2007).

8. The Universe as created through a process of unfolding information

From the birth of our universe to its supposed end, information will continuously flow, for example, in the process of biological and cultural/scientific evolution. This is not a time-linear event but should rather be seen as a chain of feed-back loops, in which existing information is processed and new information is generated and integrated. With regard to evolution, feed-back of information on the state of the whole, including that of the stable intermediates, of life forms is required to create and functionally integrate the particular building blocks of the entities that constitute the ongoing processes of higher complexification. This feed-back leads to perturbation of these basic processes that in turn can, but not always will, result in a to a higher level of functionality of the whole. This cyclic flow of information, for example can lead to efficient adaption of cells and organisms in evolutionary processes.

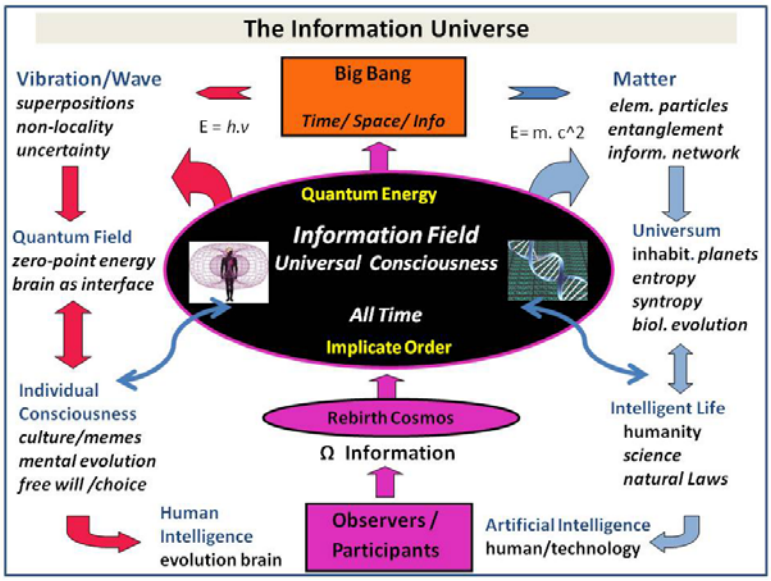


Fig. 11: An example of including a universal information field in an integrated scheme, depicting our Universe as a circular flow of information with its material (right part of the figure) and mental (left) aspects, in which for these aspects a non-dual and complimentary matter/mind modality is assumed. This concept assumes a holographic quantum information field (universal consciousness), that is regarded as a fundamental component of our universe and gradually further develops, among others through feed-back

processes and interaction with individual consciousness, in which humans and other intelligent life forms play crucial roles in observation of and participation in the cosmos. A circular model of the universe is proposed (more extensive treatment of the concept can be found in ref. Meijer, 2012).

Yet, a basic perception of nature as a whole is only possible if a collective memory is available, which argues for some kind of universal knowledge domain. In principle, consciousness can be perceived as processing of and integration of information (Tononi and Koch, 2008). These authors stated that their theory also implies that consciousness is not an all-or-none property but is graded: specifically, it increases in proportion to a system's repertoire of available states. In fact, any physical system with some capacity for integrated information would have some degree of experience, irrespective of the stuff of which it is made, and independent of its ability to report, thereby suggesting a pan-psychic mode. *Consequently, since consciousness is observed in literally all the aspects of evolution, consciousness should have a universal character and must be present at each level of the cosmos.*

Three aspects should be differentiated here: the gradual unfolding of the primary information that was present a priori at the start of our universe, and along with that, new information that should arises in the ongoing process of universal entropy and converging information, potentially induced by attractors. The interference of the latter two modalities of information, can be viewed upon as a holographic process, in which these two types of information, interacting in a two-dimensional space, are converted to a three-dimensional image. The universe as a holographic projection was earlier proposed by David Bohm, (1980) and later on worked out by Bekenstein, 2003, 't Hooft, 2001 and Hawking, 2010, among others. In a hologram, each sub-part contains the information of the total holographic picture. It is the unfolding (a priori) information that is the basis of this holistic aspect and forms the fundamental binding element in the universal information matrix (Fig. 11). This may give rise to evolution: the creation of form both in its material and mental modalities (as exemplified in Fig. 11). In our brain the latter aspect is reflected in our thoughts, sensory and extra-sensory percepts, memes, metaphors, concepts, models etc.

One central feature of quantum mechanics is the existence of informational but non-causal relations between elements of systems. These relations are non-causal insofar as they are modulated instantaneously over any distance and do not involve the transfer of energy between the parts of the system. In conclusion: the above mentioned information matrix pervades all non-living and living elements of the universe and can be called a knowledge domain or a universal information field that may be structured as a holographic system (Meijer, 2012).

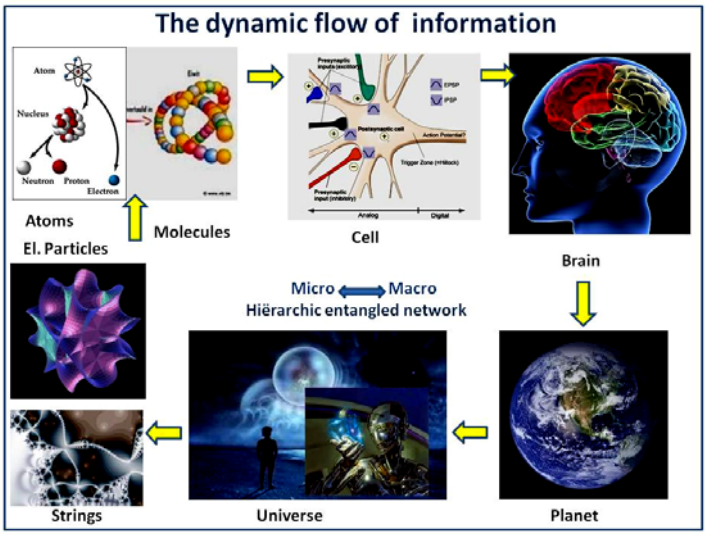


Fig. 12: The dynamic flow of information in our Universe, pictured as starting with vibration of strings (lower part, inset left) in a 12- dimensional space, leading to elementary particles and atoms that form molecules as a basis for living cells such as neurons that on their turn, with other cell types, form our brain as a part of the human organism. Humans inhabit planet Earth, as a part of our galaxy and universe, in a process of participation by natural and artificial intelligence. The Universe, of which the basic elements on the macro scale, are constantly reprogrammed in order to provide a holographic self-consistency (lower part, left).

But how is information organized and integrated in nature? Although a reductionist scheme on the dynamic flow of information in nature from the micro- to the macro scale, as pictured in Fig. 12, seems intellectually satisfactory, such a scheme evidently lacks the aspect of integration and consistency that enable nature to act as a whole at the different levels indicated. The unfolding and creation of information, as well as the processing of it, can be pictured as an act of composing of symphonic music: in addition to the interpretation by the maker and the musicians, it obtains significance through the subjective emotion of the listener. Unfolding can also be pictured as the growth of a huge tree from an extremely small seed (a priori information) that unfolds during maturing. During the growth of the tree, intrinsic (morphogenetic) information is used and new information is collected from the environment, resulting in steadily rising complexity as well as modulation of the basic recipe, resulting in the manifestation of life and survival. This phenomenon is often "explained" by, so called, "emergent" processes in which completely new properties are claimed to arise spontaneously from building blocks that themselves do not display that particular property. However, as mentioned above, the physical background and validity of the emergent concept is presently debated. Alternatively, the induction of novel complexity in time can be seen as a process of "backward causation".

Two different mechanisms may play a role here: Firstly, such a time-reversed causation may entail a feed-back of information from a future condition of higher complexity (see also section 7). This can be related to the observer effect in quantum physics in which the wave information collapses to particle information by the act of conscious observation, but only after the observer chooses to read and interpret the interference pattern (see the delayed choice model of Wheeler, 1990). An observer effect can even be envisioned to occur in observing the boundaries of our Universe through a telescope and thereby looking back in time to the Universe in its starting conditions. The observer may, in this manner, even perturb events at the time of birth of our universe (see Wheeler, 1990). Thus the present observation may influence the past in a retro-causal manner. In information

terminology, one could say that such backward causation is to make a time-reversed copy of a future event.

Backward causation may also be understood in relation to the so called transactional interpretation of quantum physics: collapse of the wave function and the experimentally observed time delays and "feeling the future aspects" may be due to the sending of an advanced wave (into the future) and simultaneously an offer wave (into the past) that then are accommodated by the best fitting future and past events (see Cramer, 1998 and 2005): the handshake effect). The produced answer waves, subsequently, are returned to the present and mixed in order to create the state of the particular wave function. Each quantum event in the present time thereby entails specific but not directly observable information from the future (Fig. 13).

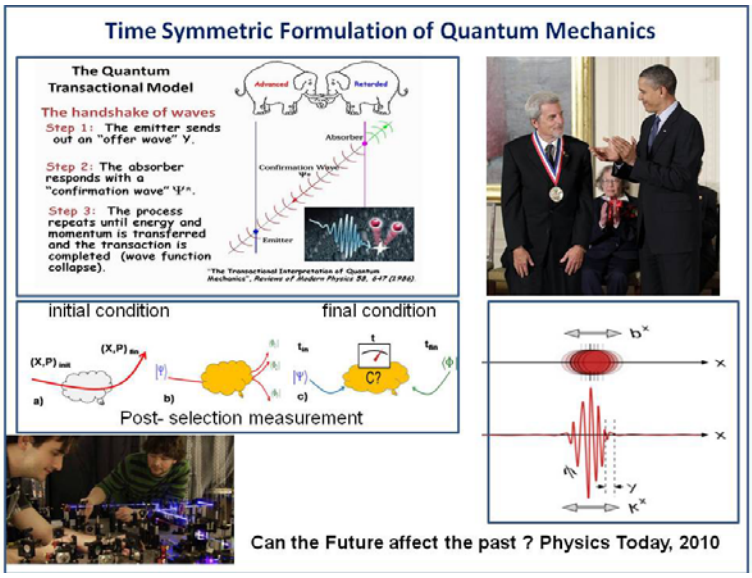


Fig 13: Weak measurement of wave function (middle left), that prevents wave collapse (right below) supporting" time symmetric" quantum physics, as postulated by Aharonov, the scientist that received a major price from the president(upper right inset), supporting the transactional interpretation of quantum physics by Cramer(upper left).

Aharonov's team and various collaborating groups (see Aharonov, 2010), studied whether the future events can influence the past, by sophisticated quantum physics technology. Aharonov concluded that a particle's past does not contain enough information to fully predict its fate, but he wondered, if the information is not in its past, where could it be? After all, something must regulate the particle's behavior. In 1964, Aharonov, then in New York, proposed a new framework called time-symmetric quantum mechanics. Recent series of quantum experiments in about 15 other laboratories around the world seem to actually confirm the notion that the future can influence results that happened before those measurements were even made.

Generally the protocol included three steps: a "pre-selection" measurement carried out on a group of particles; an intermediate measurement; and a final, "post-selection" step, in which researchers picked out a subset of those particles on which to perform a third, related measurement. To find evidence of backward causality, information flowing from the future to the past, the effects of, so called, weak measurements were studied. Weak measurements involve the same equipment and techniques as traditional ones but do not disturb the quantum properties in play. Usual (strong) measurements would immediately collapse the wave functions in superposition to a definite state.

The results in the various cooperating groups were amazing: repeated post-selection measurement of the weak type changed the pre-selection state, clearly revealing an aspect of non-locality (Fig. 13). Thus, according to Aharonov and associated research teams, it appears that the universe might have a destiny that interacts with the past, in order to bring the present into view, in line with the earlier mentioned theories of Wheeler and Fantappie. This highlights the notion that matter should be seen as a "frozen" (collapsed) aspect of wave information, each particle is in fact material point information in a quantum field and living organisms are complex compositions of billions if such wave/particle modalities. This idea is very much in line with the idea that, on the deepest micro-level, nature can be described as vibrational energy, in the sense that each specific type of elementary particle should be seen as one modality of vibration of strings. As mentioned earlier, strings might represent the most fundamental supposed building blocks of the universe according to the string and M-theories (Fig. 14).

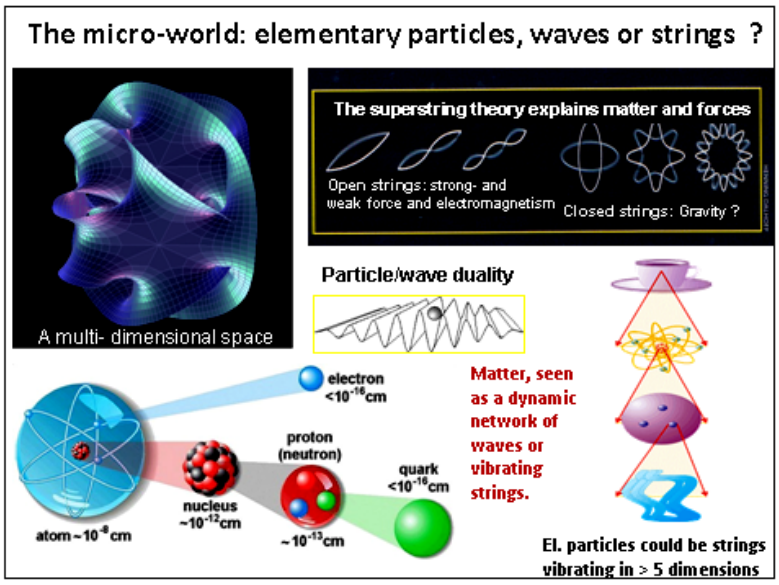


Fig. 14: Elementary particles (below left), may also behave as waves (middle) or, even smaller, string elements that can take different forms (upper part right) and are supposed to vibrate in a >5-dimensional space, (depicted in the cartoon up left), according to the current M-theory.

Yet, as treated above, it should be realized that we cannot really detect what an electron or even an atom is really like: we will only see their shadows as representations on the background (as exemplified in the metaphor of Plato's cave). All of the above mentioned micro-events cannot be observed directly by humans since, as treated before, the measuring instruments and the act of observation intrinsically disturbs the bound information. Such events can only be indirectly inferred by postulating theories, designing models and verification of these models by experimentation. On the human level, this feeling of the future aspect may be a brain process that occurs in the unconscious domain that is proposed to represent 90% of the brain's workspace and has also be related to aspects of clairvoyance and telepathy (see Radin, 1997, 2006, Grof, 1987 and Griffin, 1997).

What is the underlying basis for all of these processes in nature? There are now attempts to develop a "theory of everything, abbreviated TOE" on the basis of string theories (see Greene, 2004). Such a theory should be valid both on the micro (quantum) level and macro (cosmological) level including an adequate concept of gravity. (Fig. 14, see also section 10). Another candidate to describe the deep structure of reality, therefore, is the so called loop quantum gravity theory (see Smolin, 2004),

in which matter exists at the nodes of an extremely fine spin network. Interestingly attempts have been made by describing consciousness as being produced by the network of spin movements of elementary particles that make up our brain (see Penrose, 2004; Hu and Wu, 2010), and also Meijer and Korf, 2013.

Several authors have proposed that the entire universe can be calculated (Lloyd, 2006) and may have a mathematically defined structure (see Tegmark, 2008, Fig. 15), as also earlier implied by Wigner, 1960. Of note, it should be stressed that such theories can never fully describe reality without taking into account the phenomenon of consciousness and self-awareness, as essential parts of an information-generating and as well as information-processing system in our world. Anyway, a consistent "theory of everything, TEO" should also contain an explanation for itself (Vedral, 2010, 2012).

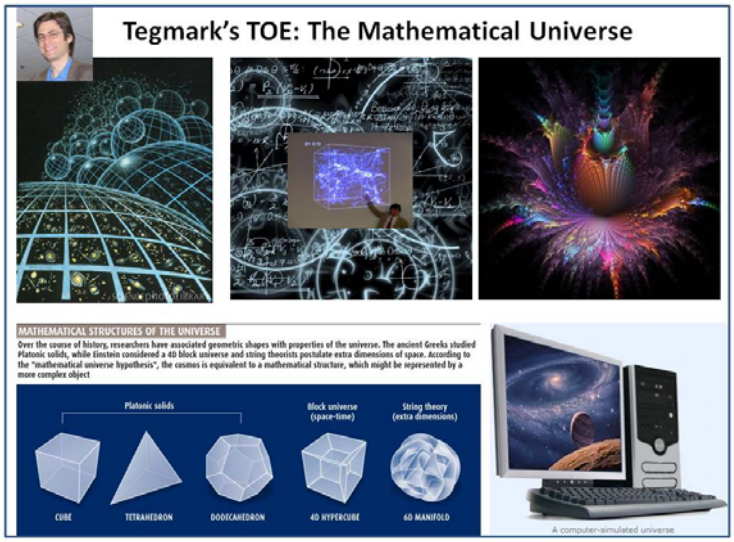


Fig. 15:The information Universe may have a mathematical foundation (see references Wigner, Bostrom Lloyd and Tegmark), that geometrically maybe composed out of mathematical structures(left below), that finally may enable a perfect computer simulation of the entire cosmos(see cartoon right below)

Charles Seife (2012), recently, postulated a natural teleology for the efficient causation in biological evolution, meaning that "the universe is rationally governed in more than one way, not only through the universal quantitative laws of physics that underlie this efficient causation, but also through principles which imply that things happen because they are on a path that leads to certain outcomes, notably the existence of living, and ultimately of conscious organisms". He further argued that "not only emergence of life from a lifeless universe of reproducing organisms but also consciousness should be included in a TEO, including the development of consciousness into an instrument of transcendence that can grasp objective reality and objective value. The universe has become not only conscious and aware of itself, but capable of some respects of choosing a path for the future".

9. Information as self-organized complexity in the evolution of life

Information and life processes

According to Gershenson, 2010: ”The last decades there is a great interest in the relationship between energy, matter, and information. One of the main reasons for this arises because this relationship plays a central role in the definition of life: Hopfield, 1989 suggests that the difference between biological and physical systems is given by the meaningful information content of the former ones. This does not imply that information is not present in physical systems, but, as Roederer, 2005 puts it, information is passive in physics and active in biology. However, this requires a complicated concept in which information is expressed in terms of the physical laws of matter and energy. In the particular paper, the inverse approach was proposed: let us describe matter and energy in terms of information ! If atoms, molecules and cells are described as modalities of information, there is no need of a *qualitative* shift (from non-living to living matter) while describing the origin and evolution of life. In this sense rather a *quantitative* shift (from less complex to more complex information) is at stake.

In *Living Systems* Miller, 1978 provided a detailed look at a number of systems in order of increasing size, and identifies his subsystems in each. By definition, living systems are open, self-organizing systems that have the special characteristics of life and interact with their environment. *This takes place by means of information and material-energy exchanges.* Essential subsystems process information for the coordination, guidance and control of the system. The twenty subsystems and processes of all living systems are arranged by information input-throughput-output processes which take place in a so called input transducer that brings information into the system, and an ingestor that brings material-energy into the system. Processes which take place in the systems throughput stage, are information processes and are summarized as follows:

An *internal transducer* receives and converts information brought into system channel and a so called “net” distributes information throughout the system, *a decoder* prepares information for use by the system timer that maintains the appropriate spatial/temporal relationships. An *associator* maintains the appropriate relationships between information sources memory that stores information for system use. A *decider*: makes decisions about various system operations, an *encoder* converts information to needed and usable form. A *reproducer* handles this information and carries on reproductive function boundary that with information, and protects the system from outside influences. Finally, processes which take place in the systems output stage output, make use of a *transducer* that handles information output of the system.

According to Davies, “the drawback with the physics-based approach to the studies of life and cognition is that it requires a new category, that in the best situations can be referred to as “emergent”. Emergence can, in some cases, be a useful concept, but it is clearly not explanatory: obviously it is always an explanation in retrospect and as such does not contain predictive power. No physical model have been developed that can predict an emergent phenomenon. Moreover, the concept of emergency stealthily introduces a dualist view of the world: if we cannot properly relate matter and energy with processes such as life and cognition, we are forced to see these as separate categories. Once this step is made, there is no clear way of studying or understanding how systems with life and cognition evolved from those without it. *However, if we see matter and energy as particular, simple cases of information, the dualist trap is avoided by following a continuum of information processing in the evolution of the universe.* Physical laws are suitable for describing

phenomena at the physical scale. The tentative laws of information, presented here, aim at being suitable for describing phenomena at *any scale*. Certainly, there are other approaches to describe phenomena at multiple scales, such as general systems theory and dynamical systems theory. These approaches are not exclusive, since one can use several of them, including information, to describe different aspects of the same phenomena".

A unified concept of information was earlier proposed also as a form of self-organized complexity, a model that may be equally applicable to the physical, biological and human/social domains by Bawden, (2007). We cite the following section from this excellent article: "The seemingly empty space around us is seething with information. Much of it we cannot be aware of because our senses do not respond to it. Much of it we ignore because we have more interesting things to attend to. But we cannot ignore it if we are seeking a general theory of information. As mentioned above, Stonier, (1990, 1992, 1997) made one of the first detailed attempts to unify the concept of information in the physical, biological and human domains. Starting from the concept of information as a fundamental constituent of the physical world, Stonier proposed relations between information and the basic physical quantities of energy and entropy, and suggested that a general theory of information may be possible, based on the idea that the universe is organized into a hierarchy of information levels. Stonier identified self-organizing information processing systems as the "physical roots of intelligence", based on his conception of information as a basic property of the universe".

Madden, (2004) focused on the biological domain in his evolutionary treatment of information, examining information processing as a fundamental characteristic of most forms of life. He argued that Lamarckian evolution, the idea that characteristics acquired by a biological organism during its lifetime can be passed on to their descendants, while discredited in general biology, may be appropriate for understand the evolution of human societies, including their information behavior. Madden proposed that insights from the information sciences may be valuable to the supposedly more 'basic' sciences, in this case the biological sciences, because of the commonality of the "information" concept. Bates, (2005), like Stonier seeking to reconcile the physical, biological and human forms of information, took the general definition that "information is the pattern of organization of everything". All information is "natural information", existing in the physical universe of matter and energy. "Represented information" is either "encoded" (having symbolic, linguistic or signal-based patterns of organization) or "embodied" (encoded information expressed in physical form), and can only be found in association with living creatures. Beyond this, Bates defined three further forms of information: Information type1: the pattern of organization of matter and energy; Information type 2: some pattern of organization of matter and energy given meaning by a living being (or its constituent parts) as well as Information type 3: knowledge, that is information given meaning and integrated with other contents of understanding. This corresponds with the subdivision of information by the present author see section 3, page 10, although it is preferred to combine the type 2 and type 3 since a sharp differentiation of the two types seems cumbersome.

Self-organizing systems are not only a topic of relatively recent interest, but are of importance in a variety of areas in the physical sciences (Davies, 1987, 1998). The interest in them comes from two perspectives. The ubiquitousness of self-organization has led some scientists to propose that there may be 'laws of complexity', such that the universe has an 'in-built' propensity to organize itself in this way; this view is far from generally accepted, but is gaining support. On the small-scale, it may be observed that simple physical and chemical systems show a propensity to 'self-organize': to spontaneously move towards a mode which is both organized and also highly complex (Kauffman, 1993, 2008). Both evolution of species and individual ontology have a common principle: relatively

simple entities evolve to more complicated organisms. However, the Darwinian type of evolution does not solely lead to biological structures with higher complexity, but also to entirely new structures that cannot be predicted or deduced from the properties of precursor components. The properties of the constituting elements, somehow, enable an integrated and interacting network that is largely unpredictable from the properties of these precursor elements. In other words, a cell is more than a collection of molecules such as proteins, lipids and nucleic acids. Rather, it is a well-organized entity that, for instance, entertains a correct replication process and gains survival based on an adequate adaptive response to environmental challenges (Kauffman, 2012) On the large scale, science must account for the emergence of highly complex organized structures - stars, galaxies, clusters of galaxies, and so on - in a universe which theorists assure us was entirely uniform and homogenous immediately after its creation. It is still not clear what the origins of this complexity are; it is generally assumed to come from gravitational effects, acting on very small inhomogeneities (Davies, 2003). Gravity in the early universe can therefore be seen as "the fountainhead of all cosmic organization, triggering a cascade of self-organizing processes" (Davies, 2007, Fig.16).

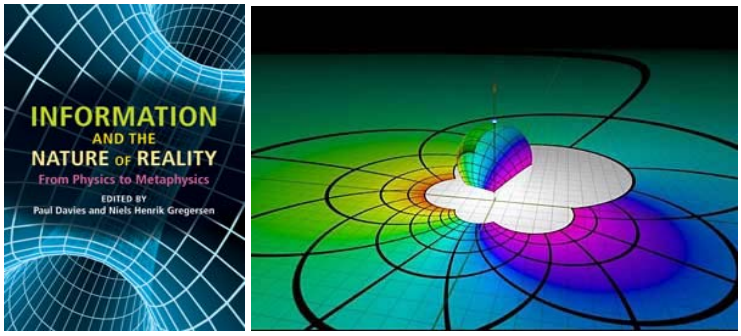


Fig. 16: The nature of reality on the basis of information, as treated in the book of Davies and Gregersen

With the increasing emphasis on the understanding of genetic information is the tendency to describe life itself as an informational phenomenon. Rather than defining living things, and their differences from non-living, in terms of arrangements of matter and energy, and of life processes, metabolism, reproduction, etc., it is increasingly usual to refer to information concepts. Life, thought of in these terms, is the example of self-organized complexity par excellence. But with life comes a change from the organized complexity in the physical universe: with life we find the fusion of meaning and context. The genetic code, for example, allows a particular triplet of DNA bases to have the meaning a particular amino acid is to be added to a protein under construction; but only in the context of the cell nucleus.

Thus, it became clear that the origin of life itself, may best be viewed as an “information event”: the crucial aspect is not the arrangement of materials to form the anatomy of a living creature, nor the beginning of metabolic processes; rather it is the initiation of information storage and communication between generations which marks the origin of life (Davies 2003, Floridi, 2005). An exponent of a new interest in the 'philosophy of information' within the discipline of philosophy itself, recasts the idea of knowledge as “justified, true belief” into the idea that information is “well-formed, meaningful and truthful data”. This seems more suitable for the needs of information science, but does not reflect the rather muddled reality of the human record. Perhaps the most interesting philosophical approach is that of Kvanvig (2003), who argues that we should replace “knowledge' with 'understanding” as a focus for interest. Understanding, for Kvanvig, requires "the

grasping of explanatory and other coherence-making relationships in a large and comprehensive body of information".

The linking thread, and the unifying concept of information here, is self-organized but guided complexity. The crucial events which allow the emergence of new properties are: the origin of the universe, which spawned organized complexity itself; the origin of life, which allowed meaning-in-context to emerge; and the origin of consciousness, which allows self-reflection, and the emergence of understanding, at least partly occasioned when the self reflects on the recorded knowledge created by other selves. If, therefore, we understood these three origins fully, we would, presumably, understand information itself equally fully, and the ways in which its various forms emerged. Sadly, the beginnings of the universe, of life, and of consciousness, are among the most deep and difficult problems for science (Gleiser, 2004).

As mentioned before, there has been a trend in science, following the so-called "strong anthropic principle', to conjecture that the emergence of life and consciousness may, in some ill-understood way, have an effect of backward causation, so as to affect the nature of the universe which have rise to it. The analogy for our purposes would be to allow the possibility that the emergence of human information, knowledge and understanding is in itself a force in the physical universe, which can influence the generation of complexity in all domains (see Fig.17). This is an intriguing speculation, but it is not necessary to accept it in order to believe that this studies may have some value for the understanding of self-organization and complexity in other domains".

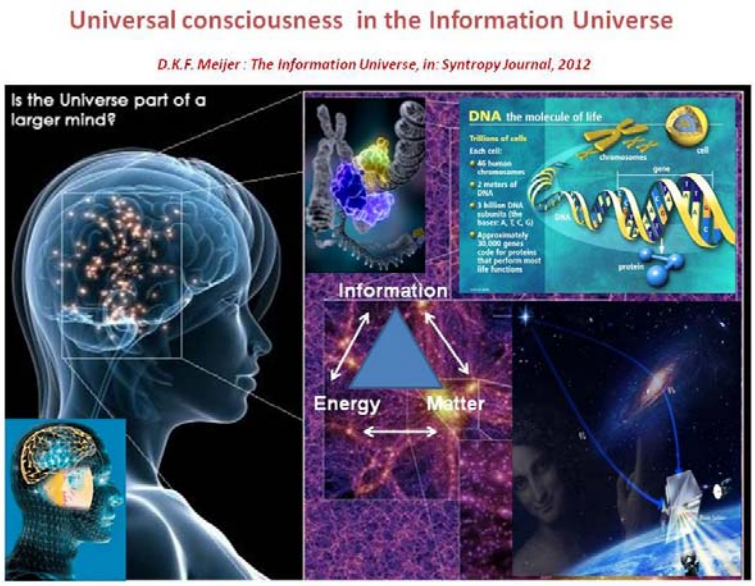


Fig. 17: Compressed universal information, expressed in our self-reflective consciousness (left), also providing the recipe for basic biological life processes(upper right inset) and in combination with energy and matter enables cosmic evolution (right below).

Davies, 2003 explains: The missing concepts that prevented the earliest investigators of life and consciousness from succeeding in their quest were: 1) a generalized theory of information; 2) a deeper understanding of quantum science itself, with its associated phenomena of non-locality/entanglement, and quantum holography; 3) an adequate theory on chaotic processes, that is necessary to understand the nonlinear evolutionary processes that caused consciousness to evolve toward the self-consciousness experienced by humans. As mentioned before, on the basis of these

concepts, consciousness now seems an essential and integral modality in the manifestation of the material world.

One blind spot in evolutionary theory is the possible influence of non-local quantum information transfer in the bio-construction of the first primitive cells (Fig. 18 and 20), in which information processing and replicating abilities are at stake rather than complexity per se. According to Davies (2003) and the same author in Abbott (2008), quantum mechanics provides a way to drastically shorten the trajectory of matter to life, by exploiting the parallel processing properties of superpositions and wave interference. It is quite likely that bio-systems selected potential life components from a great number of non-living states through wave superposition.

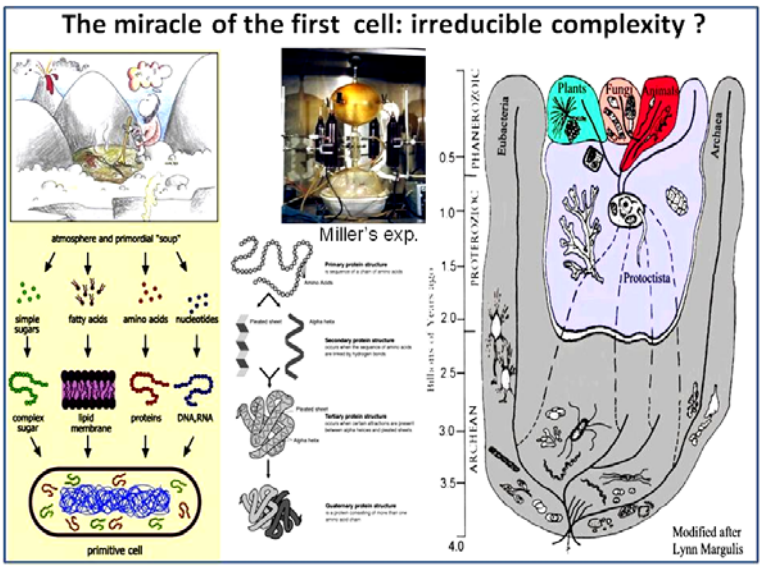


Fig. 18: Biological evolution guest: how was the first reproducing cell formed from its molecular components and functional organellesout of a supposed organic soup (upper left), containing amino acids (possibly produced from electricity and ureum, as being suggested in Miller's experiment (upper part, middle), to a final state of irriducible compexity (left below). The assembly of the cell is partly based on the quided selection and integration of microbial components in evolution that, among others, provided organelles for energy production in the cells (see Margulis, inset on the right)

The transition from non-life to life can, in this manner, be considered as a quantum-mediated process in which the environment served as a sort of measuring device, that enabled the material expression of the particular wave patterns. These dynamic conditions also enable top-down causation (Fig. 19), by information control, that is likely to play a central role in evolution and comprises aspects that are basic for any information acquisition process, namely mutual information and information selection (see also Patel, 2001, and Mc Fadden, 2001).

But what is information control in this framework really? This is *not* related to Shannon's (1959) theory of communication (in the context of controlled transmission), that is a general theory of information. A mentioned earlier, this theory is centered on signal/noise discrimination, the message is already selected and well defined from the start: the selection among several alternative states already occurred at the level of input or sender. The crucial item here is only to reliably transmit the sequence of bits that has been selected, in the presence of potential disturbances. In contrast, a real information theory, for instance that of Wiener's (1948), starts with an input as a source of variety and has the selection only at the end of the information-processing. Thus, a

message here is rather the message selected by the receiver. It goes without saying that any information reception will be subject to the initial variety, in addition to the influences of disturbance, dispersion, and use of any of this information, at the most elementary level, already constitutes information selection.

This is of major relevance for biological systems, since they are confronted with an environment that includes sources of uncertainty, and for this reason such systems do not have control from the start of the information that has been sent. Even inside a single cell (Fig. 20), there is such a problem, due to the modularization of the different subsystems. Consequently, in this case, the control must somehow be exerted while having only a limited pool of resources. An important question remains: if a sort of "recipe for life" was present non-locally in the context of a bidirectional time concept and/or potential backward causation, how did this information influence evolutionary processes such as self-assembly and auto-catalysis? (see Paul Davies in: Abbott et al., 2008). According to the traditional information theory, the main item is reliability, understood as the matching between input and output. However, in biological phenomena one has a condition in which the receiver does not have full control over the input and therefore is forced to "guess" the nature of the input by taking the received partial information rather as a sign of it. As mentioned above, at any biological level, the receiver is in general flooded with incoming data, and has to separate background data (important but constant) and noise (irrelevant data) from relevant information, data that are needed for some purpose and may be expressed in algorithmic terms (see Fig. 19). Therefore, information control consists in information selection, often involving a sort of guess from a certain point of view, and this represents the goal of the system. For instance, a bacterium searching for an energy source may use a specific temperature gradient (the received information) as a sign of this source. In this framework it is necessary to state how goals and feedback control are linked (see, Murphy, 2011 Fig 19).

According to Auletta et al, 2008, Murphy, 2011 and Paul Davies in: Abbott et al., 2008, information control via feedback is not the only way to have control via information, yet it plays a fundamental role in living systems, being involved in any homeostatic process. In conclusion, in any information exchange we have selection at the end, not at the start. That is, if the output selection is saying something about the input, the receiver starts a new information process aiming at the source, thereby inverting somehow the ordinary flow of information from the source to the receiver, and in other words enters the process of backward causation.

An attractive hypothesis is that quantum mechanical mechanisms, acting upon primordial information, were instrumental in the origin of first life and the construction of the first homeostatic and replicating cells. In this framework one should realize the extremely complex structure of the cellular machinery (see Fig. 20), not only its versatile plasma (outer) membrane, that is equipped with transport, channel and signal-transducing proteins, (Meijer et al, 1999) but also within the cell the various organelles, for instance involved in the production of energy and storage of genes. The genome is read out to produce at least 100.000 functional proteins in the cytoplasm, involved in a network of metabolic and repair processes as well as in intracellular movements (see for quantum mechanical mechanisms in genetics Patel, 2001, Mc Fadden, 2001, Schempp, 2003).

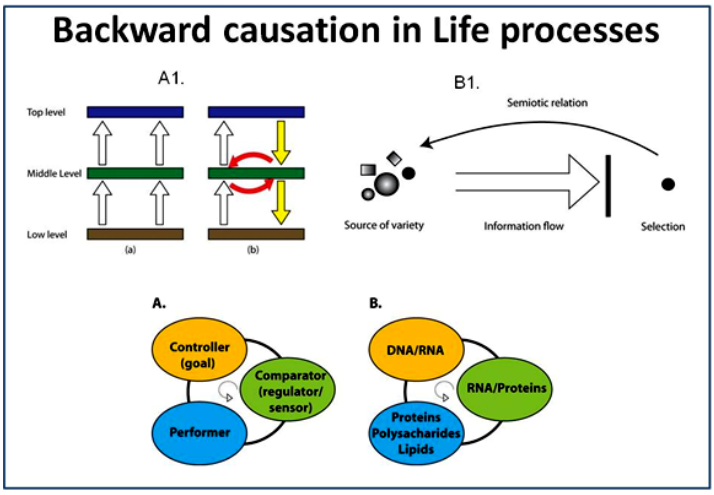


Fig. 19: Backward (downward) causation in (neuro)-biological processes on the basis of (see A 1) a space of possibilities, at an intermediate level, on the basis of a circular mode (upper left inset). Feed–back control, is shown as a comparator that determines the difference between a system state and goal and provides an error signal, activating the controller to correct the particular error, a mechanism that operates for example in the DNA/RNA protein synthesis machinery (lower part, A and B). B1: Input information as a source of variety, initiates an information process that is finalized when information selection is accomplished, that is then taken again as informative for the further input relation, by which a new information round is started (above right, modified from Auletta et al.).

Seife (2012) asked a rightful question: "*is it likely that only the process of natural selection generated creatures with the capacity to discover by reason the truth about reality that extends vastly beyond the initial appearances as we continue to do and is it credible that selection of fitness in the prehistoric past should have fixed capacities that are effective in theoretical pursuits that were unimaginable at that time?*"

If one further realizes that survival implies a fine-tuned homeostatic effort, we may conclude that it is highly unlikely that all of this was coming together by pure chance, even if it took billions of years to let these chains of events be developed into a coordinated cellular network. Only by a primordial recipe or through backward causation that enabled a "feeling of a future" this amazing becoming can be imagined. Of note: a collective memory of the whole nature was therefore a prerequisite for the origin of life. On the basis of a combination of these elements, in a concerted action, it was possible that, as treated above, parallel innovations in biophysical complexity occurred. Only expressed in wave functions such quantum states could be brought in superposition, yet only after an intelligent search and selection process in nature. One prominent example was the construction of whole series of individual proteins, each having an exact spatial structure, in order to render them functional as enzymes or to be instrumental in the cooperation of large series of functionally related proteins in regulatory or cell-protective processes in the whole organism.

Davies (2004) further explains: "*Quantum mechanics provides an explanation for the shapes of molecules, crucial to the templating functions of nucleic acids and the specificity of proteins. The Pauli exclusion principle ensures that atoms and molecules possess definite sizes, which in turn determines not just templating, but differential diffusion rates, membrane properties and many other important biological functions. Quantum mechanics also accounts for the strengths of molecular bonds that hold the machinery of life together and permit metabolism. But these*

examples are not quite what Schrödinger and Bohr were hinting at. They merely serve to determine the structure, stereochemistry and chemical properties of molecules, which may thereafter be treated as essentially classical. This leads to the ball-and-rod view of life, which is the one routinely adopted by biochemists and molecular biologists, according to which all essential biological functions may be understood in terms of the arrangements and rearrangements of classical molecular units of various shapes, sizes and stickiness."

But there are fundamental aspects of quantum mechanics that go beyond this description, such as:

- Superpositions and various aspects of quantum phases, such as resonances.
- Entanglement.
- Tunneling.
- Aspects of environmental interactions, such as the watchdog and inverse watchdog effects.
- Abstract quantum properties such as supersymmetry

Davies distinguished three possibilities of potential interest:

- Quantum mechanics played a significant role in the emergence of life from nonliving chemical systems in the first place, but ceased to be a significant factor when life got going.
- Quantum information processing may have played a key role in the emergence of life, and a sporadic or subsidiary role in its subsequent development. There may be relics of ancient quantum information processing systems in extant organisms, just as there are biochemical remnants that give clues about ancient biological, or even pre-biological, processes.
- Life started out as a classical complex system, but later evolved some form of quantum behavior as a refinement. For example, if biological systems can process information quantum mechanically, they would gain a distinct advantage in speed and power, so it might be expected that natural selection would discover and amplify such capabilities, if they are possible. This is an extension of the dictum that whatever technology humans invent, nature normally gets there first.

Both experimental and theoretical work offers circumstantial evidence that non-trivial quantum mechanical processes might be at work in biological systems. Some examples are:

1. *Mutations*. Ever since Crick and Watson elucidated the structure of DNA, the possibility has been seriously entertained that mutations might occur as a result of quantum fluctuations, which would serve as a source of random biological information. Proton tunneling can indeed spontaneously alter the structure of nucleotide bases, leading to incorrect pair bonding. McFadden and Al-Khalili, 1999, have suggested that, in some circumstances, the genetic code should be regarded as a quantum code, so that superpositions of coding states might occur, leading to spontaneous errors in base pairing.
2. *Enzyme action*. Enzymes are proteins that catalyze biochemical reactions but their hugely accelerated reactions rates, with factors as large as 10, are difficult to account for by conventional catalytic mechanisms. Evidence that quantum tunneling plays an essential role has been obtained for many enzyme-driven reactions, and it is likely that tunneling is an important factor contributing to the extraordinary efficiency of enzyme catalysis.
3. *Genetic code*. The origin of the genetic code is a major area of study. Patel has argued that the code contains evidence for optimization of a quantum search algorithm.

Living systems form a very special subset among the set of all complex systems. Biological complexity is distinguished by being information-based complexity, and a fundamental challenge to science is to provide an account of how this unique information content and processing machinery of life came into existence. Most commentators agree that the subset of living systems represents an extremely small fraction of the total space of complex systems. For example, the fraction of peptide chains that have biological efficacy is exponentially small among the set of all possible sequences. Viewed this way, the origin of life is a type of search problem. Given a soup of classical molecular building blocks, how did this mixture "discover" the appropriate extremely improbable combination by chance in a reasonable period of time? Simple calculation shows that it would take much longer than the age of the universe.

Since quantum systems can exist in superpositions of states, searches of sequence space or configuration space may proceed much faster. In effect, a quantum system may "feel out" a vast array of alternatives simultaneously. In some cases, this speed-up factor is exponential. systems exploit quantum information processing in some way, either to kick-start life, or to assist in its more efficient running? "

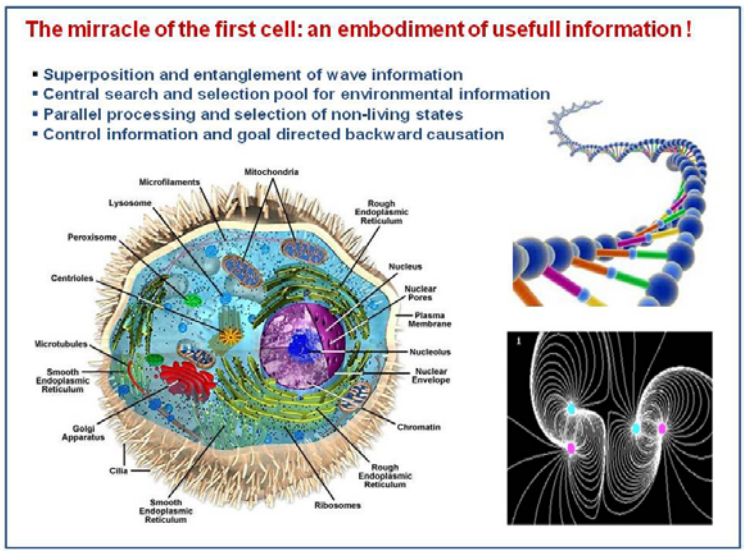


Fig. 20: Diagram of the cell with its membranes and organelles and nucleus and gene-stored information encoded in DNA (see Meijer, 1999.)Right: Mutations in DNA (upper right) may involve quantum wav superposition (cartoon below right), as well as other quantum based processes, as indicated at the upper left.

According to Conrad, 1989: "Biological systems have a vertical architecture that allows them to exploit micro-physical dynamics for information processing and related macroscopic functions. Macroscopic sensory information in this vertical picture is transduced to increasingly microscopic forms within biological cells and then back to macroscopic form. Processing of information can occur at any level of organization, but much of the most powerful processing occurs at the molecular and submolecular level. The open process of Darwinian evolution plays an important role, since this provides the mechanism for harnessing physical dynamics for coherent function. The vertical architecture is analogous to a quantum measurement system, with transduction of input signals corresponding to state preparation and amplification of the microstate corresponding to measurement. The key point is that the microphysical dynamics is not classically picturable, whereas the macroscopic actions are definite and picturable. If this analogy is taken seriously, it becomes necessary to suppose that irreversible projection processes occur in organisms, despite the

fact that the standard equations of motion are reversible. We construct a model that embeds such irreversible measurement interactions into interactions that mediate the conventional forces. The idea is that the forces between observable particles depend on the density of negative energy particles in a surrounding Dirac type vacuum. In systems that are not overly macroscopic or overly far from equilibrium this dependence is hidden, and as a consequence the force appears conservative. The model suggests that the irreversible aspect of the dynamics played an important role in the early universe, but became masked in ordinary laboratory situations as the structure of the vacuum and the distribution of mass and charge equilibrated. Organisms are particularly effective at unmasking the underlying irreversibility due to their sensitive amplification mechanisms. Unifying measurement and force type interactions makes it possible for physical models to fit more naturally to models of cognition".

10. Information transfer in the human cultural evolution

It should be stressed that using the term "transmission of information", several aspects should be distinguished: the level at which information transfer takes place (in the atom, in the cell, in the brain), the actual content of the information, the type of information (vibration pattern, sequence of nucleotides, spatial forms of a protein, etc.), the density of information (the data content per unit of space), as well as the impact of the particular information, for instance in evolutionary processes or in a cultural setting. As treated above, with regard to the latter aspect, it has been proposed earlier (see Shannon, 1949), that the impact of information is inversely proportional to the probability that the information arises. Nature preferentially detects anomalies and deviations from normal patterns of common reality and this may also hold for human culture! (see also Vedral, 2010, 2012).

Generally speaking, the concept of information in our world seems closely related to notions of news, constraint, communication, control of data, form, instruction, knowledge, meaning, mental stimulus, repeating patterns, perception of experience, as well as representation of observations and pattern recognition.

Since "Information", is often used as a "container term", it seems important to differentiate information in its daily use and in its very nature into, at least, four interrelated layers:

A. *Intrinsic information*, such as the micro-physical properties of the constituent elementary particles
B. *Shaping information*, which is the neg-intropic or syntropic information that gives form to matter/energy and, for instance, is expressed the basic genetic information of living organisms.
C. *Information containing meaning*: the type of information that is produced in our brain and represents explicit information that was obtained through interaction with the environment and subsequently translated, stored as scientific and/or cultural representations, percepts, concepts and/or models that have meaning for us.
D. *Sub-numinous information* (mostly non-conscious), that extends to feeling the future, qualia, intuition serendipity, synchronicity, channeling, telepathy, clairvoyance and other subjective human experiences.

In the biological and cultural evolution, with their ever-increasing complexity, information is a key aspect and in particular the mechanisms of information transfer deserve further attention. *Information may be transmitted in very different ways and at very different levels* (see Fig. 21). In the living cell this may constitute chemical and electrical signals, but also specific spatial

perturbations, for instance, in the 3-dimemsional structure of proteins as well as in specific sequences of nucleotide building blocks of DNA in the genes (belonging to the earlier mentioned category A, or intrinsic information).

At the level of human communication, vibration patterns can be expressed in electromagnetic waves in the form of light, sound, music, as well as in images and stories (transmitted by radio, telephone, internet and TV, for example). Such information is transferred into the brain through specifically tailored sensory organs that accommodate complex patterns of wave activity, that subsequently are converted to neural activities in the nervous system.(Meijer, 2007). Information type B gets significance only after reception, perception and representation (see Fig. 21).

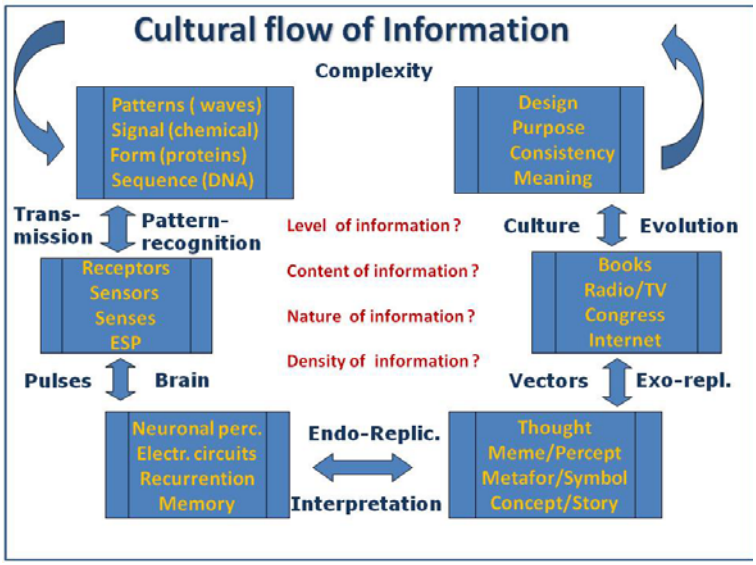


Fig. 21: The different forms of information and information processing in living organisms and human culture, represented as a circular process of pattern recognition and signal processing through detection by senses, leading to activation of neurons. Neuronal storage (short and long term memory) takes the form of neuronal firing patterns, leading to representations of thoughts, ideas, percepts and concepts. Metaphors and memes (Meijer, 2007), are forms of information (units of information, compiled from various information components). They are willingly or unwillingly combined with culture-specific features by the individual, so that the whole is suitable for transmission to other individuals, for example through the media. In this circular process of information processing, these information units obtain cultural significance. Information transfer is therefore based on sequential steps of information detection, perception (interpretation), representation and cultural transmission. Information is extracted from the environment by observation, and can also be derived through extra-sensory perception from knowledge fields, that store quantum information (ESP).

An important question here is how the diverse information that reaches our brains through our senses (sensory or potential extrasensory signals) is selected, stored, retrieved and then exported from the individual to, for example, the public domain. These processes are obviously crucial for the generation and processing of knowledge and also the transfer of cultural knowledge in society (see Heylighen, 2010; Meijer, 2007). In a recent study on quantum modeling of the mental state (Meijer and Korf, 2013) it was put forward that taking into account the constituting elements of the human brain, such as neuronal networks, individual neurons, trans-membrane ion-fluxes and energy producing cellular metabolism as well as other molecules that promote neural activity, there is clear

consensus that the present knowledge of the brain, collectively, is insufficient to explain higher mental processes such as (self)consciousness, qualia, intuition, meditative states, transpersonal experiences as well as functional binding between distant parts of the brain.

Meijer and Korf, 2013, argue that super-causal mechanisms are required to optimally integrate the above mentioned building blocks of brain function, also enabling the brain to amplify minimal perturbations for proper anticipation and action. They proposed that such a super-causal structure may function as an interface between molecular transitions and the particular higher mental functions. As attractive bridging principles, the iso-energetic brain model and the physical-mathematical hypotheses denoted as quantum brain theories were treated. It was acknowledged that elementary quantum processes are likely to be essential for higher brain functions, as well as behavior and cognitive processing, since our central nervous system forms an integral part of a dynamic universe as a non-local information processing modality. In addition the authors conclude that quantum concepts may, at least, serve as a useful probability model and/or metaphor for human cognition.

Yet, versatile brain function may require *complementary* information processing mechanisms at the classical and quantum (macro- and micro-) levels, both enabling bottom up and top down information processing. Concerted action of isoenergetic and quantum physics-based cognitive mechanisms in the human brain, requires a nested organization of fine-tuned neural micro-sites that enable decoherence-protected information transfer. For a rapid and causally effective flux of information, as well as a continuous updating of meaningful information, a super-causal field model is required. This neural structure wass conceived as a “bi-cyclic” mental workspace, housing interacting and entangled wave/particle modalities that are integral parts of an a-temporal and universal knowledge domain (Meijer and Korf, 2013).

Quantum information may be detected by our brain and interchanged with the so-called quantum vacuum field, scientifically identified as the non-local "zero-point energy field". This is a field with fluctuating energy, in which symmetric pairs of particle/anti-particles are continuously created and disappearing. Some consider it, by its nature, to represent a permanent storage medium for wave information and as such it can be seen as the physical basis for an assumed universal consciousness (see Lázsló, 2007). The latter domain may also incorporate information from the category D, as mentioned above.

Although many definitions for information have been proposed, the present author favors that of David Deutsch (1997).


David Deutch

He stated that: “Information is that which is encoded in the structure of discernible patterns, where the discerner of the patterns is an experiential process. Hence information is a subjective measure that depends on the observer's capacity to receive and the fidelity of his/her interpretation. A field of discernible difference is an information medium that comprises an information space. Data exist encoded within an information space, i.e. data are not things in themselves, they are just discernible features of the information space. *To the extent that it is capable, each system is resolving and refining an internal mirror of itself and its world, thereby gaining in knowledge.* As self-knowledge leads to general knowledge of the nature of reality, this reality-model is a novel instance of the computational process within the universe, which is a new level of creation and manifestation. *This self-realization creates a resonance, where the veil of virtual appearances is*

subtly penetrated and the system apprehends the computational nature of reality and comes to know itself as reality in action."

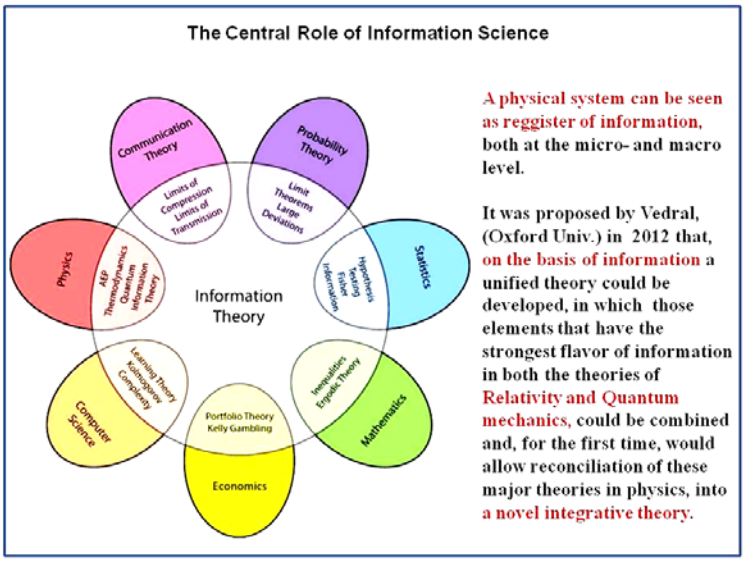


Fig. 26: The central position of information science, as a bridging principle between a spectrum of disciplines

In conclusion: In modern physics, quantum mechanics is an essential instrument. It is basically a theory about the representation and manipulation as well as the communication of information and as such should be regarded as a new physical primitive that may explain a deep nature of physical reality (Fig. 26). Zeilinger, 2000, agreeing with earlier statements of Wheeler, 1990, even proposed that information should be seen as more fundamental than matter/energy, since it fully determines what we can say about reality. Information was therefore also pictured as "the missing link in current concepts on the architecture of reality" (Meijer, 2012).

It is no wonder that, recently, a new information paradigm (see Fig. 26) was proposed, that represents a *new integral science of information, on a physical and metaphysical basis* (see DeWitt Doucette, 2012).

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