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The QBIT theory of consciousness

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Abstract

The QBIT theory is an attempt toward solving the problem of consciousness based on empirical evidence provided by various scientific disciplines including Quantum mechanics, Biology, Information theory, and Thermodynamics. This theory formulates the problem of consciousness in the following four questions: (1) What is the nature of qualia? (2) How are qualia generated? (3) Why are qualia subjective? (4) Why does a quale have a particular quality or meaning?

In sum, the QBIT theory proposes that (1) when certainty of an observer about an event exceeds a certain level, the observer becomes conscious of that event; (2) consciousness requires Maxwell demon-assisted quantum computation; (3) a quale is a dense pack of meaningful quantum information encoded in maximally entangled pure states; (4) a quale is generated when robustness of an internal representation exceeds a certain threshold; (5) the quality or meaning of a quale is determined by a process of information compression via the matching and unification of patterns; and (6) subjectivity of consciousness is due to the fact that maximally entangled pure states are private and unshareable.

Keywords: Coherence; Compression; Computation; Consciousness; Entanglement; Information; Qualia; Quantum; Representation

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Introduction

The problem of consciousness is one of the most difficult problems in biology, which has remained unresolved despite several decades of scientific research. The hard core of the problem of consciousness is in fact the problem of qualia.[1]

Qualia (plural for quale) refers to subjective conscious experiences or raw feels such as a red color, a particular smell, or a specific taste. As an example, when we see a red flower, the redness that we experience is a quale. Our consciousness at any moment consists of several different qualia. In fact, "To be conscious" means "to have qualia", and unconscious experience means "qualia-less experience".

To resolve the problem of consciousness, empirical evidence alone is not sufficient; we also need an appropriate theory to select and put together diverse (and sometimes seemingly unrelated) empirical evidence to reveal a hidden pattern. In this context, the QBIT theory is an attempt toward solving the puzzle of consciousness with pieces of evidence provided by various scientific disciplines including Quantum mechanics, Biology, Information theory, and Thermodynamics.

The QBIT theory formulates the problem of consciousness in the following four questions: What is the nature of qualia? How are qualia generated? Why are qualia subjective? Why does a quale have a particular quality or meaning? In sum, this theory proposes that (1) when certainty of an observer about an event exceeds a certain level, the observer becomes conscious of that event; (2) consciousness requires Maxwell demon-assisted quantum computation; (3) a quale is a dense pack of meaningful quantum information encoded in maximally entangled pure states; (4) a quale is generated when robustness of an internal representation exceeds a certain threshold; (5) the quality or meaning of a quale is determined by a process of information compression via the matching and unification of patterns; and (6) subjectivity of consciousness is due to the fact that maximally entangled pure states are private and unshareable.

Consciousness and computation

Although centuries of philosophical dualism have led us to consider consciousness as unreducible to physical interactions, scientific evidence is compatible with the proposition that consciousness arises from nothing more than a particular type of computation.[2] But what is computation, and what kind of computation is required for consciousness?

In cognitive science, computation could be regarded as transformation of one internal representation into another.[3,4] An internal representation is a pack of information that stands in for a particular feature of the external environment.[5,6] Here, external and internal are defined with reference to the computing system that is responsible for the generation of representations. For example, in animals, the nervous system is responsible for the generation of representations. Therefore, everything that occurs within the nervous system is internal, while everything that occurs outside the nervous system is external. A beam of light that is passing through the pupil towards the retina is an external stimulus (or event). A sound wave that hits the tympanic membrane is also an external stimulus. Even if an event is occurring within the body but outside the nervous system, it is considered an external event. In this context, a sudden release of adrenaline into the bloodstream is an external event, while a sudden burst of neuronal activity is an internal event.

In response to an external stimulus, the nervous system generates a hierarchy of internal representations with different levels of simplicity at different computational nodes. The lowest-level representation is the least simple one, generated by the most peripheral computational node. At the next computational node, a higher-level representation that is simpler than its predecessor is generated. This transformation of representations continues progressively in the subsequent computational nodes, until the highest-level representation (which is also the simplest one) is generated.

In line with this idea, empirical evidence implies that, in the mammalian brain, the early sensory processing can be considered as a process of feature extraction giving rise to the formation of low-level representations.[7] Furthermore, several other studies clearly demonstrate that, in the visual system, there is a hierarchy of representations, from low-level ones in the primary visual cortex to high-level representations in the lateral and ventral occipito-temporal cortex.[8] Higher-level

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representations are built upon lower-level ones and inherit their contents from them.[9]

Consciousness and representations

In the human nervous system, internal representations can be classified as low-level, intermediate-level, and high-level. Similar to this classification, Stanislas Dehaene and his colleagues[10] have proposed a taxonomy that distinguishes between three different levels of representations in the nervous system: subliminal, preconscious, and conscious representations. The QBIT theory adopts this taxonomy and considers qualia as conscious representations, internal models as preconscious representations, and all other lower-level representations as subliminal representations. In this context, an internal model is considered to be the ultimate limit of objective representation; a representation beyond that is subjective.

The importance of internal representations for a cognitive system is that they are mediators between the external world and internal cognitive processes.[11] Each internal representation transforms a huge amount of information into a format that is more convenient and usable for the system. This usable pack of information helps the system to better predict its environment and execute appropriate actions accordingly.

There is strong evidence that internal representations can be stored in a latent form within the sensory cortex, and reactivated at a later time.[12] This kind of memory is probably

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supported by rapid rearrangement of synaptic weights within sensory cortex following initial activation. Reactivation of this reconfigured network, through either top-down attention or a bottom-up boost from a following stimulus, would reveal this hidden structure and reactivate the latent representation.[12]

Internal representations stored in a cognitive system can help the system to make predictions or decisions in conjunction with sensory signals, and even in the absence of sensory signals. In the case of the human brain, as a cognitive system, internal representations could be metaphorically thought of as what the brain already knows about its environment with its eyes closed.[13]

Internal representations are necessary for intelligent behavior. Even in the absence of consciousness and sensory inputs, they can guide the behavior of a system.[14] Agents without internal representations are purely reactive agents because their decisions are solely based on sensory inputs. For this reason, their performance in a challenging environment may remain below an optimal level.[13]

Internal representations are not static entities sitting passively in the brain until they are activated by external stimuli. They are gradually formed and updated as the system repeatedly acts on the environment through its actuators and receives feedback through its sensors. For many tasks, the presence of a low-level or an intermediate-level representation (i.e., an internal model) is sufficient. When the tasks that should be performed to survive in the environment are complex

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enough, the cognitive system reacts to this challenge by developing higher levels of internal representations.[14] In other words, some challenging tasks and complex behaviors require high-level representations (i.e., qualia).

Internal representations are flexible. They could be shaped by learning, and become updated during the lifetime of an animal and over the course of the evolution.[14] As animals evolve to behave appropriately and survive in a dynamic environment, increasingly higher levels of representations (i.e., more robust representations) emerge within their nervous systems.

Consciousness and information compression

The QBIT theory hypothesizes that when robustness of an internal representation exceeds a certain threshold, a quale is generated. The degree of robustness of a representation is determined by two factors: the amount of information that the representation contains, and the amount of information compression that it provides.

Compressing a body of information could be considered as a process of reducing informational redundancy and consequently increasing its simplicity, while retaining as much as possible of its non-redundant predictive information. In fact, compression of information is a cognitive ability that allows predicting the future from the past and estimating probabilities.[15] By this cognitive ability, an animal, for example, can predict where food may be found or where there may be dangers. The better and more

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efficiently an organism can compress information, the more accurate its predictions will be.[16,17] All successful predictive systems, including the human brain, could be regarded as approximations of an ideal information compressor.[17]

The basis of all mechanisms of information compression is removing at least some of the redundancy from the body of information.[18] An effective and powerful strategy to compress a body of information is to find two or more patterns that match each other, and merge or unify them so that multiple configurations of the same pattern are reduced to one. James Gerard Wolff suggests that this kind of "information compression via the matching and unification of patterns" is an essential part of perception, cognition, and learning in the human brain.[19]

A benefit of information compression is a reduction in the computational requirements by a factor equal to the compression ratio. Such a reduction might be very important in systems in which the computing power is limited or too expensive.[20] In fact, all systems with limited resources that are located in a challenging environment and solve complex problems need to compress information.[21]

In the nervous system, a computational benefit of information compression is that the transfer and utilization of a huge amount of sensory information would become much easier and less costly. Furthermore, information compression causes a significant reduction in the amount of memory required to store a body of information.

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The information available to our sensory receptors is highly redundant. Information compression via the reduction of redundancy appears to be a major goal of computation in the earliest stages of sensory systems.[22] For example, lateral inhibition in the retina could be viewed as a process of removing local correlations in retinal input, thus providing a less redundant and hence more compressed representation of that input.[23] Therefore, a main goal of computation in the retina is to transform the visual input into a statistically independent form as a first step in creating a compressed representation in the cerebral cortex.[24] However, the amount of compression that could be performed in the retina is limited because of the need to suppress noise and correct errors in the visual input.[15] Here, it should be emphasized that redundancy is not something useless that should be stripped off and ignored. Redundancy is essential for the detection and correction of errors.[15]

Much of the input to the visual system is redundant. Computation within the retina removes some of this redundancy, and this process continues at successive stages along the visual pathway, from the lateral geniculate nucleus to the primary visual cortex and beyond.[25,26] Only a minimal amount of compression occurs in transferring information from the retina to the primary visual cortex.[27] For this reason, internal representations generated in the retina, the lateral geniculate nucleus, and the primary visual cortex are considered to be low-level representations. Intermediate-level

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and high-level representations are generated by higher visual cortical areas.

In general, low-level representations provide minimal amount of information compression. These minimally-compressed representations are considered to be subliminal. Intermediate-level representations provide moderate amount of compression. They are called internal models and are considered to be preconscious. An internal model has some residual redundancy that allows for further compression. High-level representations provide the maximum amount of compression that is possible. These maximally-compressed representations are conscious and are called qualia. Qualia, according to the QBIT theory, are incompressible or irreducible. Therefore, there is an intimate relationship between consciousness and information compression.

Based on evidence from cognitive science, it seems plausible to suggest that information compression is an important part of cognition.[19,28] The QBIT theory suggests that it is also an important and necessary part of consciousness.

The idea that consciousness requires information compression was first proposed by Phil Maguire and his colleagues.[17] They attempted to explain consciousness in terms of data compression. Later, Giulio Ruffini[29] proposed that consciousness is possible only in computing systems that are capable of creating compressed representations of the external world. The QBIT theory suggests that information compression is necessary but not sufficient for consciousness.

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The quality or meaning of a quale

According to the QBIT theory, a quale is a dense pack of information. However, information on its own has no intrinsic meaning. It is "interpretation" that adds a particular meaning (or semantic content) to information. The same bit of information can have different meanings, depending on how it is interpreted.[30] The QBIT theory proposes that what interprets information and gives meaning to it is a computational process which James Gerard Wolff calls "information compression via the matching and unification of patterns".[19] In this context, compressing a body of information is similar to interpreting (and hence giving a meaning to) that body of information.

Throughout the evolution, animals have evolved increasingly sophisticated nervous systems that are extraordinary compressors of information. Compressing sensory information provides animals with an understanding or comprehension of their environment, allowing them to make better predictions and to optimize their decision making.[17]

The more a system compresses a body of information, the more the system understands that body of information. In fact, compression could give rise to comprehension.[31] Comprehension or understanding a body of information could be regarded as attributing a meaning to that body of information.

A mechanism by which an organism can understand a stimulus is to create an internal representation of the stimulus with as little redundancy as possible.[32] Redundancy in a representation could be considered as the presence of two or more patterns that match each other, either completely or partially. Understanding or comprehension of a representation requires the ability to recognize patterns in that representation. In humans as well as machines, pattern recognition is linked to the elimination of redundancy and compression of information.[28]

Consciousness and quantum mechanics

As mentioned earlier, the QBIT theory proposes that a quale is a maximally compressed representation that contains a great amount of information. Achieving such a high levels of compression and obtaining such a great amount of information is not possible within the limits of classical mechanics. For consciousness, quantum phenomena are required. The reason behind this proposition is discussed below.

Information, correlation, and entropy (or uncertainty) are three distinct, but intimately related, concepts in classical (or Shannon) information theory. When an agent observes a system, a correlation is established between the agent and the system. As a result of this correlation, the agent obtains information about the system. As the strength of correlation is increased, the amount of information also increases, and entropy (or uncertainty of the agent about the system) decreases.[33,34]

To obtain great amounts of information and hence achieve very high levels of certainty, a very strong kind of correlation (or a supercorrelation) is required. Quantum mechanics has such a supercorrelation in its pocket.[35] It is called "entanglement". In fact, quantum entanglement is a kind of correlation whose amount exceeds anything that can be achieved in classical physics.[36]

The QBIT theory proposes that when certainty of an observer about an event exceeds a certain level, the observer becomes conscious of that event. To achieve this high level of certainty, quantum correlation and hence quantum information is required. As Patrick Hayden[37] nicely mentions, "with quantum information, it is possible not just to be certain, but to be more than certain." This wonderful effect of quantum information inspires the idea that in order to become conscious, we need to go beyond the limits of classical physics. Consciousness requires quantum phenomena, including entanglement.

Quantum entanglement is important for consciousness not only because it allows obtaining a great amount of information, but also because it allows a greater amount of compression. Evidence shows that entangled quantum states can be compressed much more than what is possible via classical lossless compression.[38] Furthermore, in quantum mechanics, entanglement is the most important resource for superdense coding.[39]

In addition to entanglement, another extraordinary quantum phenomenon that plays an important role in consciousness is "coherence". Quantum coherence is a direct manifestation of the superposition principle. According to the superposition principle, a quantum system (for example, a qubit) can exist in several different states at the same time. This is not allowed in classical mechanics.

Quantum entanglement and coherence are real physical resources which are indispensable for certain computational tasks that cannot be performed using classical resources such as energy.[36,40] However, these resources are very fragile at physiologic temperatures as compared to cryogenic temperatures, since the environmental noise increases with increasing temperature, resulting in rapid decoherence and loss of useful entanglement.[41] In fact, decoherence is a common obstacle for all phenomena that depends on the capacity of preserving and using quantum coherence and entanglement.[42] Typically, decoherence rapidly destroys coherence in a quantum system and the entanglement between its subsystems.[43]

Although coherence and entanglement are so fragile at physiologic temperatures, there is strong evidence that these two quantum phenomena play important roles in certain biological processes, including photosynthesis and bird navigation.[44-46] The QBIT theory suggests that these two quantum phenomena also play an essential role in consciousness. This idea is also the basis of the Orchestrated Objective Reduction (Orch OR) theory of consciousness, developed by Stuart Hameroff and Roger Penrose.[47]

The Orch OR theory suggests that, for consciousness to occur in a system, it is necessary that a sufficient amount of material (e.g. microtubule) be kept in a coherent (or pure)

state for a long enough time. In quantum mechanics, every system has a set of states. A state is called pure if it contains maximal information about the system.[48] The Orch OR theory suggests that different states of a tubulin represent information in the brain. The theory considers tubulin bits (and quantum bits, or qubits) as entangled coherent states. These coherent states of microtubules in one neuron can extend by entanglement to microtubules in adjacent neurons, potentially extending to brain-wide syncytia.[47] In line with this theory, evidence shows that long-lived quantum coherence is possible in microtubules as well as in some other molecules within the brain at physiologic temperatures.[49,50]
To achieve long-lived quantum coherence in the brain, anti-decoherence mechanisms are required. Stuart Hameroff suggests that there are at least two anti-decoherence mechanisms in the brain: (1) encasing bundles of microtubules in actin gel, which provides a shielded and isolated environment for quantum computation; (2) microtubule quantum error correction topology.[51] The QBIT theory suggests dynamical decoupling as another anti-decoherence mechanism in the brain and other biological systems. Dynamical decoupling could extend the lifetime of an entangled state.[52] Evidence shows that dynamical decoupling can be achieved using recurrent neural networks.[53,54]

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Maximally entangled pure states

The QBIT theory proposes that a quale is a dense pack of meaningful quantum information encoded in maximally entangled pure states.

Maximally entangled pure states are ideal resources for quantum computation, while mixed states are not very useful for this purpose.[55] Some unique and wonderful effects of quantum computation arise only when maximally entangled pure states are available for use.

From a thermodynamic point of view, production of maximally entangled pure states is costly, meaning that it requires consumption of energy and production of entropy. However, for some computational tasks such as estimating a given parameter with a high precision, it is more cost effective for a system to use maximally entangled pure states rather than using already available mixed states.[56] Therefore, above a certain level of precision, the cost of computation will be reduced if maximally entangled pure states are used.

Since consciousness requires quantum computation with maximally entangled pure states, a conscious agent should be endowed with a mechanism that constantly produces and preserves such states. The QBIT theory proposes that, in the brain and other conscious systems, the task of producing and preserving maximally entangled pure states is partly performed by something like a Maxwell demon.

In thermodynamics, a Maxwell demon is an observer-like entity that observes a system, and uses the obtained information to improve thermodynamic efficiency of that system.[57] In fact, a Maxwell demon extracts work and removes heat from a target system in a cyclic process. Work extraction and heat removal (which is a thermodynamic process) is equivalent to converting mixed states to pure states (which is an information theoretic process).[58]

In quantum mechanics, there is a special kind of Maxwell demon which is able to transition a qubit into a purer state.[59] In other words, it can inject pure states to an ongoing quantum computation. This kind of Maxwell demon is in sharp contrast to locally operating classical Maxwell demons. It can purify a target qubit over macroscopic distances on the order of meters and tolerates elevated temperatures of the order of a few Kelvin. Such a spatial separation between the system and the demon has practical benefits because it prevents undesired heating of the system during the demon's memory erasure. In fact, this particular demon not only purify a qubit but also makes the environment surrounding the qubit slightly colder. Furthermore, in contrast to the classical demon, this quantum demon utilizes its purity or coherence as a thermodynamic resource. The quantum demon does not measure the state of the target system; therefore, its operation is rooted in purity rather than information.[59]

Although the concept of Maxwell demon was first introduced in thermodynamics, it gradually found applications in other scientific disciplines including information theory and biology. In biology, for example, it has been demonstrated that the action of a Maxwell demon is necessary for chemotaxis in Escherichia coli.[60,61] In this case, the Maxwell demon attempts to reduce the effects of the environmental noise on the target system. The QBIT theory proposes that consciousness is another biological process in which a Maxwell demon could play important roles. One of these roles is production and preservation of maximally entangled pure states for quantum computation. The other possible role is compression of information to make a dense pack of information.

Consciousness and qubits

The QBIT theory proposes that consciousness requires quantum computation. Quantum computation requires quantum bits, or qubits. If the brain is a quantum computer, what plays the role of qubits in the brain? Tubulin bits described by Stuart Hameroff and Roger Penrose[47], as well as the neural qubits described by the physicist Matthew Fisher[62] are two candidates.

Matthew Fisher suggests that, in the brain, nuclear spin of a single phosphorus atom residing on a Posner molecule can serve as a qubit, called a "neural qubit".[62] A Posner molecule is a kind of calcium phosphate molecule with a unique chemical structure that can protect phosphorus nuclear spins from decoherence for very long times. Phosphorus nuclear spins in different Posner molecules can become entangled and remain so for relatively long periods of time.[50] Empirical evidence clearly demonstrates that phosphorus nuclear spins in silicon can serve as qubits with extraordinarily long coherence lifetimes of over 180 seconds.[63,64] Silicon is an excellent platform for spin-based quantum computation because it can provide very long spin coherence times. In the brain, the Posner molecule seems to be a promising platform for quantum computations based on phosphorus nuclear spin.

The nucleus of a phosphorus atom is an extremely weak magnet. It can be thought of as a compass needle that can point toward either north or south. These north or south positions are equivalent to zeros and ones of binary codes which form the basis of classical computation. In classical computers, information is encoded in zeros and ones, which themselves are represented by different voltages on semiconductors.[65] In general, information cannot exist without a physical substrate that encodes it.[66] Therefore, information that we retain in our brains should also have a physical substrate. Nuclear spins are a good candidate for this purpose.

In addition to nuclear spin-based qubits, researchers have also created electron spin-based qubits.[67] However, nuclear spin-based qubits might be more appropriate for quantum computation in the brain because the nucleus is about 2000 times less magnetic than the electron. This makes nuclear spin-based qubits nearly immune to electromagnetic noise of the surrounding environment. This endows nuclear spin-based qubits with an excellent coherence time during which delicate quantum computations can be performed with minimal errors. Successful quantum computation by the brain requires the ability to perform high-fidelity readout and control of individual qubits. In a realistically noisy environment (such as that of the brain), computational errors can be mitigated by using various quantum error correction protocols, provided that the probability of the errors occurring remains below a certain stringent threshold.[68]

To keep the probability of computational errors by the brain below a critical threshold, a kind of effective and robust-to-noise qubit is required. A promising candidate for this purpose is the phosphorus nuclear spin embedded in a Posner molecule. Clusters of highly entangled Posner molecules provide an ideal setting for quantum computation in the brain.[62]

In addition to spin-based qubits, there are at least two other types of qubits that could be used for quantum computations: superconducting qubits and trapped-ion qubits. However, spin-based qubits are probably more appropriate for quantum computation by the brain because they are relatively immune to electric field fluctuation which is the main source of decoherence for superconducting and trapped-ion qubits. Spin-based qubits can show record-length coherence times when they are embedded in a molecule that is free from other spins.[69] A Posner molecule (Ca9(PO4)6) is comprised of calcium, phosphorus, and oxygen. Most naturally occurring isotopes of calcium and oxygen have no nuclear spin.[50] For this reason, entangled phosphorus nuclear spins embedded in a Posner molecule are kept in a protected

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(or isolated) environment, and could remain in coherent (or pure) states for long times.

It should be emphasized that extremely isolated qubits are not very useful for quantum computation because computation, in essence, requires interaction between qubits. Therefore, a qualia-generating system (such as the brain) should be endowed with strategies that allow a combination of long-lived quantum coherence and strong qubit interactions.[69]

Why are qualia subjective?

A prime feature of qualia is that they are subjective. This means that they are private and unshareable, accessible only to the system that is generating them. Observation or measurement of qualia generated within a system is not possible for any other system.

"Entanglement is the quantum equivalent of what is meant by privacy." This nice statement, and the argument behind it, in a paper by the Horodecki family[55] provided insight for the QBIT theory to propose that quantum entanglement might be able to explain the subjectivity of consciousness. Quantum entanglement has limited shareability. In the case of pure states, it can even be absolutely unshareable.[70]

A quale could be regarded as a private key. In terms of information theory, a private key is a string of bits which has two important features. First, it is perfectly correlated. Second, it is inaccessible to any other person.[55] The first feature is due to maximal entanglement. The second feature is due to maximal coherence (or purity), because an eavesdropper who attempts to obtain knowledge about the private key will unavoidably disturb it, introducing a phase error into the system, which destroys purity.[55]

All these arguments can be expressed in terms of the monogamy of entanglement. According to the monogamy of entanglement, maximally entangled pure states are not shareable.[71,72] Since qualia are encoded in maximally entangled pure states, they should be private and unshareable. This explains why the QBIT theory proposes that subjectivity of consciousness is a consequence of entanglement monogamy.

Conclusion

The QBIT theory proposes that qualia are quantum information in nature, and emergence of qualia requires quantum computation. Most physical phenomena in nature can be formulated and better described in terms of information processing and computation.[73] Gravity is a prominent example. Reconciling quantum mechanics with gravity is a hard and yet unresolved problem in physics. Recently, quantum information theory and concepts like entanglement and quantum error correction have come to play a fundamental role in solving this problem. For example, it has been suggested that gravity comes from quantum information.[74] Furthermore, recent evidence from theoretical physics imply that entangled qubits are not only the origin of gravity, but also the origin of matter and space.[75] It seems

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that, at some level, everything reduces to information.[76] This inspires the QBIT theory to propose that, at a fundamental level, qualia are quantum information or entangled qubits. As our knowledge about the nature of quantum information increases, we would gain more insights about the nature of qualia. At present, we know that quantum information is nonlocal. It does not make sense to ask where quantum information is at any given time; it is nonlocally distributed in the entangled state.[72] Since quantum information is nonlocal, qualia should also be nonlocal. Furthermore, there is some evidence that quantum information is physical.[77] If this turns out to be true, then qualia must also be physical.

The fact that we have qualia strongly suggests that qualia must have some reason to exist.[78] One probable reason is that each quale packs a lot of information in a concise and usable format. In other words, a quale is a convenient summary of a huge amount of information.[78] A cognitive system can perform sophisticated tasks without generating qualia, but qualia might be necessary to perform some tasks that require greater speed and precision.

According to the QBIT theory, a specialized type of Maxwell demon is necessary for consciousness. Throughout evolution, nature has created a variety of different Maxwell demons, each for a specific purpose. These Maxwell demons are probably responsible for the emergence of life, evolution of biological organisms, and emergence of consciousness.

In the evolution of the universe, emergence of life could be thought of as a link in the long chain of matter upgrading events.[79] Emergence of life means emergence of living matter. The amazing complexity of living matter might be the outcome, over long evolutionary timescales, of a great work extraction process (or Maxwell demon) used to create new high-free-energy structures suitable to store huge amounts of information that would otherwise be erased by environmental noise and decoherence.[80] It could be proposed that, during the course of evolution, stronger and more sophisticated Maxwell demons (or work extraction mechanisms) have been created and, as a result, more complex matter has been emerged. This continued to the point that living matter was created. Further progress in evolution resulted in the creation of far more advanced Maxwell demons and thus the emergence of conscious matter. Emergence of conscious matter means emergence of consciousness. The QBIT theory suggests that emergence of consciousness is another link in the long chain of matter upgrading events.[81] If all these conjectures are correct, what is the next stage of the matter upgrading process? A possible next stage is superconscious matter. A superconscious agent might possess not only consciousness and self-consciousness (as humans possess), but also super-consciousness. A creature endowed with super-consciousness could potentially become aware of the contents of the minds of other conscious agents. For consciousness, a kind of super-correlation (i.e., entanglement) is necessary. For super-consciousness, a kind of super-entanglement or meta-entanglement might be required.

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