

THINKING OUTSIDE THE BOX: THE ESSENCE AND IMPLICATIONS OF QUANTUM ENTANGLEMENT

Huping Hu¹ and Maoxin Wu

ABSTRACT

Many experiments have shown that quantum entanglement is physically real. In this paper, we will discuss its ontological origin, implications and applications by thinking outside the standard interpretations of quantum mechanics. We argue that quantum entanglement originates from the primordial spin processes in non-spatial and non-temporal pre-spacetime, implies genuine interconnectedness and inseparableness of once interacting quantum entities, plays vital roles in biology and consciousness and, once better understood and harnessed, has far-reaching consequences and applications in many fields such as medicine and neuroscience. We further argue that quantum computation power also originates from the primordial spin processes in pre-spacetime. Finally, we discuss the roles of quantum entanglement in spin-mediated consciousness theory.

Key Words: Spin, Entanglement, Interconnectedness, Inseparableness

When in the course of scientific endeavor, it becomes apparent that deeper truths exist, a decent respect to Nature requires that such truths be explored. We hold these truths to be scientifically approachable, that all forms of existence are interconnected, that they possess certain fundamental and unalienable properties. That to describe this interconnectedness and these properties, successive theories shall be constructed by mankind, deriving their explanatory and predictive powers from the approximations of laws of Nature. That whenever any theory becomes inadequate of these ends, it is the duties of mankind to modify it or to abolish it, and to establish new ones, laying the foundation on such principles and organizing the structures in such forms, as to mankind shall seem most likely to reflect their understanding and knowledge of Nature.

In memory of Thomas Jefferson

¹Corresponding author: Huping Hu, Ph.D., J.D., Biophysics Consulting Group, 25 Lubber Street, Stony Brook, NY 11790, USA. E-mail: hupinghu@quantumbrain.org

1. Introduction

Quantum entanglement is ubiquitous, appears everywhere in the microscopic world (See, e.g., Durt, 2004; Brooks, 2005) and under some circumstances manifests itself macroscopically (Arnesen, *et al*, 2001; Ghost *et al*, 2003 & Julsgaard *et al*, 2001). Indeed, it is currently the most intensely studied subject in physics. Further, speculations abound as to its nature and implications (See, e.g., Clarke, 2004, Josephson, 1991 & Radin, 2004). There are many general and technical papers written on the subject. So cutting to the chase, we shall immediately outline our propositions on the subject and then discuss each in some detail with references to existing literature whenever possible. Readers are advised that our propositions are outside the mainstream physics and other authors may hold similar views on some of the points we shall make in this paper. We will also discuss the roles of quantum entanglement in spin-mediated consciousness theory (Hu & Wu, 2002, 2003, 2004a-d).

The following are our propositions about the ontological origin, implications and applications of quantum entanglement besides quantum computation:

- 1) It originates from the primordial spin processes in non-spatial and non-temporal pre-spacetime. It is the quantum “glue” holding once interacting quantum entities together in pre-spacetime, implies genuine interconnectedness and inseparableness of the said quantum entities and can be directly sensed and utilized by the entangled quantum entities.
- 2) Thus, it can influence chemical/biochemical reactions, other physical processes and micro- and macroscopic properties of all forms of matters, thus, playing vital roles in many biological processes and consciousness. It is the genuine cause of many anomalous effects (if they do exist) in parapsychology, alternative medicine and other fields as some authors have already suspected in some cases.
- 3) Further, it can be harnessed, tamed and developed into revolutionary technologies to serve the mankind in many areas such as health, medicine and even recreation besides the already emerging fields of quantum computation.

2. The Origin and Nature of Quantum Entanglement

Popular opinion has it that Erwin Shrödinger coined the word “entanglement” and first used it in 1935 in his article published in the Proceedings of Cambridge Philosophical Society (Shrödinger, 1935). Mathematically, Shrödinger showed that entanglement arises from the interactions of two particles through the evolution of Shrödinger equation and called this phenomenon the characteristic trait of quantum theory (*id.*). Einstein called quantum entanglement “spooky action at a distance” in the famous EPR debate (See, e.g., Einstein *et al*, 1935).

Ontologically, we argue that quantum entanglement arises from the primordial self-referential spin processes which we had argued previously are the driving force behind quantum effects, spacetime dynamics and consciousness (Hu & Wu, 2003; 2004a). Pictorially, two interacting quantum entities such as two electrons get entangled with each other through the said spin processes by exchanging one or more entangling photons with entangling occurring in pre-spacetime. Such ontological interpretation is supported by existing literature as discussed below.

First, Hestenes showed that in the geometric picture for the Dirac electron the zitterbewegung associated with the spin is responsible for all known quantum effects of said electron and the imagery number i in the Dirac equation is said to be due to electronic spin (See, e.g., Hestenes, 1983).

Second, in Bohmian mechanics the “quantum potential” is responsible for quantum effects (Bohm and Hiley, 1993). Salesi and Recami (1998) have recently shown that said potential is a pure consequence of “internal motion” associated with spin evidencing that the quantum behavior is a direct consequence of the fundamental existence of spin. Esposito (1999) has expanded this result by showing that “internal motion” is due to the spin of the particle, whatever its value. Bogan (2002) has further expanded these results by deriving a spin-dependent gauge transformation between the Hamilton-Jacobi equation of classical mechanics and the time-dependent Schrödinger equation of quantum mechanics which is a function of the quantum potential of Bohmian mechanics.

Third, spin is a unique quantum concept often being said to have no classical counterpart (See Tomonaga, 1997) and associated with the “internal motion” of a point particle. Unlike mass and charge that enter a dynamic equation as arbitrary parameters, spin reveals itself through the structure of the relativistic quantum equation for fermions that combines quantum mechanics with special relativity (Dirac, 1928). Indeed, many models of elementary particles and even space-time itself are built with spinors (Budinich, 2001; Penrose, 1960 & 1967). Pauli (1927) and Dirac (1928) were the first to use spinors to describe the electron. Also, Kiehn (1999) showed that the absolute square of the wave function could be interpreted as vorticity distribution of a viscous compressible fluid that also indicates that spin is the process driving quantum mechanics.

Therefore, in view of the foregoing it could be said that the driving force behind the evolution of Schrödinger equation is quantum spin and, since quantum entanglement arises from the evolution of Schrödinger equation the said spin is the genuine cause of quantum entanglement.

What do we mean by pre-spacetime? Pre-spacetime in this article means a non-spatial and non-temporal domain but it is not associated with an extra-dimension in the usual sense since there is no distance or time in such domain (See, e.g., Hu & Wu, 2002). We have argued before that in a dualistic approach mind resides in this domain and unpaired nuclear and/or electronic spins are its pixels in the reductionist perspective (*id.*). So pre-spacetime

is a holistic domain located outside spacetime but connected through quantum thread/channel to everywhere in spacetime enabling quantum entanglement or Einstein's "spooky action at a distance." It has similarity to Bohm's concept of implicate order (Bohm & Hiley, 1993). Aerts (2004), Clarke (2004) and others have also expressed the non-space view of quantum nonlocality.

Such a non-spatial and non-temporal pre-spacetime is a "world" beyond Einstein's relativistic world but does not contradict with the latter since the latter deals with classical physical events occurring within spacetime. In contrast, quantum entanglement occurs within non-spatial and non-temporal domain. Therefore, instantaneous signaling through quantum entanglement in pre-spacetime is possible if the entangled quantum entities can directly sense and/or utilize the entanglement.

So what is then the essence of quantum entanglement? We propose that quantum entanglement is not merely the correlations of certain observable physical parameters in the process of measurement but genuine interconnectedness and inseparableness of once interacting quantum entities. It is the quantum "glue" holding once interacting quantum entities together in pre-spacetime and can be directly sensed and utilized by the entangled quantum entities as further discussed below. It can be diluted through entanglement with the environment, *i.e.*, decoherence.

3. Implications of Quantum Entanglement

It is often said that instantaneous signaling through quantum entanglement is impossible because of Eberhard's theorem that basically says that since local measurements always produce random results no information can be sent through quantum entanglement alone (Eberhard, 1978). However, there are at least two ways to circumvent this impossibility. The first is to assume that the statistical distribution can be modified and utilized to transmit information. Quite a few authors have expressed this view (Josephson, 1991; Stapp, 1982 & Walker, 1974) especially when discussing the roles of consciousness in parapsychology such as telepathy. The second is to assume that each quantum entity can directly sense and utilize quantum entanglement as already mentioned before. This latter view is the view we subscribe to and it is permissible in the Bohmian picture (Bohm & Hiley, 1993).

The implication of the second view is far-reaching. It means that quantum entanglement can influence chemical and biochemical reactions and other physical processes. Thus, it plays vital roles in many biological processes and consciousness and is the genuine cause of many anomalous effects, if they do exist, in parapsychology, alternative medicine and other fields as some authors have already suspected in some case. It can affect the micro- and macroscopic properties of all forms of matters such solid and liquid.

For example, the results reported by Rey (2003) that heavy water and highly diluted solutions of sodium chloride and lithium chloride behaved differently in the thermoluminescence tests can be explained as the consequence of water molecules forming different hydrogen bonds due to the entanglement of water molecule with sodium chloride or lithium chloride ions being diluted out of existence and its subsequent effect on hydrogen bond formation during freezing. Indeed, in light of the recent results on observable macroscopic entanglement effects (Arnesen, *et al*, 2001; Ghost *et al*, 2003), the explanation offered herein is most likely true.

For a second example, the so called “memory of water” effect (Davenas, *et al*, 1988), which is largely discredited by the mainstream scientists because of non-reproducibility, can be explained as the result of entanglement of the substances being diluted with water and then the subsequent entanglement of water with the quantum entities in the biochemical processes responsible for producing certain visible or detectable result. Of course, quantum entanglement cannot directly serve as a reagent in a chemical reaction nor can it be recorded or transferred through any classical means such as a digital device within a computer or the telephone wire. So any claim of recordable or telephone -wire-transferable “chemical signal” cannot be attributed to quantum entanglement.

Similarly, the therapeutic effect of a homeopathic remedy, if it truly exists beyond and above the placebo effect, can be explained as the entanglement of the substances being diluted out of existence through vigorous shaking/stirring with the diluting solvent and then the subsequent entanglement of the solvent with the quantum entities involved in the diseased biological and/or physiological processes and the effect of such entanglement on the latter processes. Indeed, there are reports in the existing literature exploring the use of generalized entanglement to explain the therapeutic ingredient in a homeopathic remedy (See, e.g., Milgrom, 2002; Wallach, 2000 & Weingärtner, 2003).

Further, many other unconventional healing effects reported in alternative medicine such as Qi Gong and other types of bioenergy healing, if they are genuine, can be explained as the results of quantum entanglement between the quantum entities involved in the diseased processes and the quantum entities in the healing sources, such as a healthy biological entity, and the effect of the former on the latter processes.

For yet another example, all the results from Princeton Engineering Anomalies Research program over the last 26 years (Jahn & Dunne, 2005) can also be straightforwardly explained as the entanglement of the quantum entities controlled by human mind with the quantum entities responsible for the physical processes capable of producing modified random results. By the same token, many if not all anomalous effects reported in parapsychology such as telepathy and those results reported by Grinberg-Zylberbaum (1987) and the repeaters (For a summary, see, Wackermann, 2005) can be simply explained as the results of quantum entanglement between the quantum entities capable of invoking action potentials in one person and those in a second person and the effect of one on the other through quantum entanglement. Grinberg-Zylberbaum himself speculated that his results had something to do with quantum entanglement (1994).

4. The Ontological Origin of Quantum Computation Power

It is said that the computational speed-up of a quantum computer is due to quantum entanglement (See, *e.g.*, Steane, 2000). However, the ontological origin of its power over classical computation is very much in dispute due to different interpretations of quantum mechanics (*id.*).

For example, some argue that, in terms of the amount of information manipulated in a given time, quantum superposition/entanglement permits quantum computers to “perform many computations simultaneously” which invoke the concept of vast numbers of parallel universes (See, *e.g.*, Deutsch & Hayden, 2000; Deutsch, 2002). Others argue that quantum entanglement makes available types of computation process, which, while not exponentially larger than classical ones, are unavailable to classical systems (See, *e.g.*, Steane, 2000). Thus, according to Steane (2000), the essence of quantum computation is that it uses entanglement to generate and manipulate a physical representation of the correlations between logical entities, without the need to completely represent the logical entities themselves (*id.*).

Do we have anything to add in light of our view expressed in this paper? The answer is “Yes.” We argue that the types of computation process made available by quantum entanglement are the ones driven by the primordial spin processes in the non-spatial and non-temporal pre-spacetime. Or, if you like, the power of quantum computation over classical computation originates from Bohm’s implicate order driven by the primordial spin processes.

5. Applications of Quantum Entanglement

Recently, quantum computations have been achieved in the laboratory but they are implemented in controlled environment to prevent decoherence through entanglement of the system of interests with its surrounding environment. Indeed, it is also often said that the reason why we don’t experience quantum entanglement in the macroscopic world is because of rapid decoherence within the macroscopic system. However, this view may rapidly change (See, *e.g.*, Brooks, 2005). We are convinced that quantum entanglement can be harnessed, tamed and developed into revolutionary technologies to serve the mankind in many areas such as health, medicine and even recreation besides the emerging fields of quantum computation and communications.

For example, once harnessed, quantum entanglement technologies can be used to deliver the therapeutic effects of many drugs to a target biological system such as a human body without ever physically administering the said drugs to the said system. Such technology would dramatically reduce waste and increase productivity because the same

drugs can be repeatedly used to deliver their therapeutic effects to the mass. By the same token, many substances of nutritional and even recreational values can be repeatedly administered to the human body through the said technologies. For a second example, the harnessed quantum entanglement technologies can also be used to entangle two or more human minds for legitimate purposes. Further, the said technologies can be used for instantaneous communications with humans sent to the outer space.

Are we delusional? We think not. We predict that the wonders of quantum entanglement technologies will be soon widely utilized to serve the mankind and a new paradigm of science will be born in the near future.

6. Quantum Entanglement in Spin-Mediated Consciousness Theory

Our spin-mediated consciousness theory says that quantum spin is the seat of consciousness and the linchpin between mind and the brain, that is, spin is the mind-pixel (Hu & Wu, 2002, 2004a-d). The starting point is the fact that spin is basic quantum bit ("qubit") for encoding information and, on the other hand, neural membranes and proteins are saturated with nuclear spin carrying nuclei and form the matrices of brain electrical activities. Indeed, as discussed above, spin is embedded in the microscopic structure of spacetime as reflected by Dirac equation and is likely more fundamental than spacetime itself as implicated by Roger Penrose's work. In the Hestenes picture the zitterbewegung associated with spin was shown to be responsible for the quantum effects of the fermion. Further, in the Bohm picture the internal motion associated with spin has been shown to be responsible for the quantum potential which, in turn, is responsible for quantum effects. Thus, if one adopts the minority quantum mind view, nuclear spins and possibly unpaired electron spins become natural candidates for mind-pixels (Hu & Wu, 2002; 2003; 2004a-d).

Applying these ideas to the particular structures and dynamics of the brain, we have theorized that human brain works as follows: Through action potential modulated nuclear spin interactions and paramagnetic O₂/NO driven activations, the nuclear spins inside neural membranes and proteins form various entangled quantum states and, in turn, the collective dynamics of the said entangled quantum states produces consciousness through contextual, irreversible and non-computable means and influences the classical neural activities through spin chemistry (Hu & Wu, 2002; 2003; 2004a-d).

Existing literature supports the possibility of a spin-mediated consciousness. For example, it was shown that proton nuclear spins in nematic liquid crystal could achieve long-lived intra-molecular quantum coherence with entanglement in room temperature for information storage (Khitrin *et al.*, 2002). Long-ranged (>10 microns) intermolecular multiple-quantum coherence in NMR spectroscopy was discovered about a decade ago (Warren, *et al.* 1993). Long-lived (>.05 milliseconds) entanglement of two macroscopic spin ensembles in room temperature has been achieved recently (Julsgaard, *et al.* 2001). Further, NMR quantum computation in room temperature is reality (Gershenfeld & Chuang, 1997).

Therefore, according to our theory, consciousness is intrinsically connected to the spin process and emerges from the collective dynamics of various entangled spin states and the unity of mind is achieved by entanglement of these mind-pixels (Hu & Wu, 2002; 2003; 2004a-d). Our theory is tentative as are all current theories about consciousness. As with other quantum mind theories, decoherence is a major concern as pointed out by Tegmark (2000) but may not be insurmountable (See, e.g., Hagan, *et.al.*, 2002). We believe that the solution will be found through the study of the nature of quantum entanglement.

Indeed, our dualistic approach adopted earlier (Hu & Wu, 2002) and described in more detail in this paper allows mind to utilize quantum entanglement to achieve the unity of mind in pre-spacetime. The essential question is then how does mind process and harness the information from the mind-pixels which form various entangled spin states so that it can have conscious experience. We have argued that contextual, irreversible and non-computable means within pre-spacetime are utilized by mind to do this. Furthermore, we recognize that there may not be any large-scale quantum coherence in the warm and wet brain to support those quantum theories of mind that require macroscopic quantum effects. However, our theory does not depend on such a coherence to work in the dualistic approach.

7. Conclusion

In this article, we have discussed the ontological origin, implications and applications of quantum entanglement by thinking outside the standard interpretations of quantum mechanics. We have argued that quantum entanglement originates from the primordial self-referential spin processes in non-spatial and non-temporal pre-spacetime, implies genuine interconnectedness and inseparableness of once interacting quantum entities, play vital roles in biology and consciousness and, once better understood and harnessed, has far-reaching consequences and applications in many fields such as medicine and neuroscience. It follows then that quantum computation power also originates from the primordial spin processes in pre-spacetime. We have also discussed the roles of quantum entanglement in our spin-mediated consciousness theory.

Finally, the principle of science dictates that a scientific theory/hypothesis should only achieve legitimacy if it is experimentally verified. Thus, since the summer of 2004 to the present, we have mainly focused our efforts on the quantification of our theory and the designs and implementations of computer simulations and experiments for the verifications of the same. Important results shall be reported as soon as feasible.

REFERENCES

- Aerts, D. & Aerts, S. Towards a general operational and realistic framework for quantum mechanics and relativity theory. In *Quo Vadis Quantum Mechanics?* ed. A. C. Elitzur *et al.* (Berlin: Springer, 2004).
- Arnesen, M. C., Bose, S. & Vedral, V. Natural thermal and magnetic entanglement in the 1D Heisenberg model. *Phys. Rev. Lett.* **87**, 017901/1-4 (2001).
- Bohm, D. & Hiley, B. J. *The Undivided Universe* (London: Routledge, 1993).
- Bogan, J. R. Spin: the classical to quantum connection. *arXiv* quant-ph/0212110 (2002).
- Brooks, M. Entanglement: weirdest link. *New Scientist* **818**: 32 (2005).
- Budinich, P. From the geometry of pure spinors with their division algebra to fermions's physics. *arXiv* hep-th/0102049 (2001).
- Clarke, C. Quantum mechanics, consciousness and the self. in *Science, Consciousness and Ultimate Reality*, ed. D. Lorimer (Exeter: Imprint Academic, 2004).
- Deutsch, D. and Hayden, P. Information flow in entangled quantum systems. *Proc. Royal. Soc.* **A456**: 1759-1774 (2000).
- Deutsch, D. The structure of the multiverse. *Proc. Royal. Soc.* **A458**: 2911-2923 (2002).
- Davenas, E. *et al.* Human basophil degranulation triggered by very dilute antiserum against IgE. *Nature* **333**:816-818 (1988).
- Dirac, P. A. M. The quantum theory of the electron. *Proc. R. Soc. A* **117**: 610-624 (1928).
- Durt, T. Quantum entanglement, interaction, and the classical limit. *quant-ph/0401121* (2004).
- Eberhard, P. Bell's theorem and the different concepts of locality. *Nuovo Cimento* **46B**: 392-419 (1978).
- Einstein, A., Podolsky, B. & Rosen, N. Can quantum-mechanical description of physical reality be considered complete? *Phys. Rev.* **47**: 777-780 (1935).
- Esposito, S. On the role of spin in quantum mechanics. *Found. Phys. Lett.* **12**: 165 (1999).
- Gershenfeld, N. & Chuang, I. L. Bulk spin resonance quantum computation. *Science* **275**: 350-356 (1997).
- Ghosh, S., Rosenbaum, T. F., Aeppli, G. & Coppersmith, S. N. Entangled quantum state of magnetic dipoles. *Nature* **425**:48-51 (2003).
- Grinberg-Zylberbaum, J. & Ramos, J. Patterns of interhemispheric correlation during human communication. *Int'l J. Neurosci.* **36**: 41-53 (1987).

Grinberg-Zylberbaum, J. *et al* The Einstein-Podolsky-Rosen paradox in the brain: The transferred potential. *Phys. Essays* **7**: 422–427 (1994).

Hameroff, S. & Penrose, R. Conscious events as orchestrated spacetime selections. *J. Conscious Stud.*, **3**: 36-53 (1996).

Hagan, S, Hameroff, S. R. & Tuszynski, J. A. Quantum computation in brain microtubules: Decoherence and biological feasibility. *Phys. Rev.* **E65**, 061901 (2002).

Hestenes, D. Quantum mechanics from self-interaction. *Found. Physics* **15**: 63-87 (1983).

Hu, H. & Wu, M. Mechanism of anesthetic action: oxygen pathway perturbation hypothesis. *Med. Hypotheses* **57**: 619-627 (2001).

Hu, H. & Wu, M. Spin-mediated consciousness theory: possible roles of oxygen unpaired electronic spins and neural membrane nuclear spin ensemble in memory and consciousness. *arXiv quant-ph/0208068* (2002).

Hu, H. & Wu, M. Spin as primordial self-referential process driving quantum mechanics, spacetime dynamics and consciousness *Cogprints* ID3544 (2003); *NeuroQuantology* **2**:41-49 (2004a).

Hu, H. & Wu, M. Spin-mediated consciousness theory: possible roles of neural membrane nuclear spin ensembles and paramagnetic oxygen. *Med. Hypotheses* **63**: 633-646 (2004b).

Hu, H. & Wu, M. Action potential modulation of neural spin networks suggests possible role of spin in memory and consciousness *NeuroQuantology* **2**:309-317 (2004c).

Hu, H. & Wu, M. Possible roles of neural electron spin networks in memory and consciousness. *Cogprints* ID3544 (2004d).

Jahn, R. G. & Dunne, B. J. The PEAR proposition. *J. Sci. Exploration* **19**: 195–245 (2005).

Josephson, B. D. & Pallikari-Viras, F. Biological utilisation of quantum nonlocality. *Found. Phys.* **21**: 197-207 (1991).

Julsgaard, B., Kozhekin, A. & Polzik, E. S. Experimentally long-lived entanglement of two macroscopic objects. *Nature* **413**, 400–403 (2001).

Kiehn, R. M. An extension to Bohm's quantum theory to include non-gradient potentials and the production of nanometer vortices. <http://www22.pair.com/csdc/pdf/bohmlplus.pdf> (1999).

Khitrin, A. K., Ermakov, V. L. & Fung, B. M. NMR molecular photography. *J. Chem. Phys.* **117**: 6903-6906 (2002).

Milgrom, L. R. Patient-practitioner-remedy (PPR) entanglement. *Homeopathy* **91**: 239-248 (2002).

Pauli, W. Zur quantenmechanik des magnetischen electrons. *Z. Phys.*, **43**: 601-623 (1927).

Penrose, R. A spinor approach to general relativity. *Ann. Phys.* **10**: 171 (1960).

Penrose, R. Twistor algebra. *J. Math. Phys.*, **8**: 345 (1967).

Radin, D. Entangled minds *Shift*, **5**: 10–14 (2004).

Rey, L. Thermoluminescence of ultra-high dilutions of lithium chloride and sodium chloride. *Physica A* 323: 67-74 (2003).

Salesi, G. & Recami, E. Hydrodynamics of spinning particles. *Phys. Rev. A* **57**: 98 (1998).

Schrödinger, E. Discussion of probability relations between separated systems, *Proc. Cambridge Philos. Soc.* **31**: 555 (1935).

Stapp, H. E. Mind, Matter and Quantum Mechanics. *Found. Phys.* **12**: 363-99 (1982).

Tegmark, M. The importance of quantum decoherence in brain processes. *Phys. Rev.*, **61E**: 4194 (2000).

Tomonaga, S. *The Story of Spin* (Chicago: The Univ. Press of Chicago 1997).

Wackermann, J. Dyadic correlations between brain functional states: present facts and future perspectives. *Mind and Matter* **2**: 105-122 (2005).

Walach, H. Magic of signs: a non-local interpretation of homeopathy. *Homeopathy* **89**: 127-140 (2000).

Walker, E. H. Consciousness and Quantum Theory. *Psychic Exploration*, ed. J. White, 544-68 (Putnam's, New York, 1974).

Warren, W. S. *et al.* Generation of impossible correlation peaks between bulk water and biomolecules in solution NMR. *Science* **262**: 2005 (1993).

Weingärtner, O. What is the therapeutically active ingredient of homeopathic potencies? *Homeopathy* **92**: 145-151 (2003).