Abstract:

This paper presents a potential mechanism for the conscious brain to anticipate impending opportunities and threats to survival through massively parallel weak quantum measurement (MPWQM) induced by the combined effects of edge of chaos sensitivity and phase coherence sampling of brain states. It concludes that the underpinnings of this process emerged in single-celled eucaryotes in association with (a) excitability-induced sensitivity to electro-chemical perturbations in the milieu as an anticipatory sense organ and (b) cell-to-cell signaling necessary for critical phases in the life cycle. This gives rise to watershed implications for the capacity of conscious experience to anticipate impending events in direct ways which complement computation based on past experiences and implies that conscious intentionality or 'free-will' may have physical influences beyond the raw application of the brain to an organism’s immediate behavior.

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1: Introduction: Consciousness Entangled

Subjective consciousness poses the ultimate dilemma for the scientific description of reality. We still have no idea of how the brain generates it, or even how, or why, such an objectively elusive phenomenon can come about from the physiology of brain dynamics. The problem is fundamental because, from birth to death, the sum total of all our observations of the physical world, and all our notions about it, come exclusively through our subjective conscious experience. Although neuroscience has produced new techniques for visualizing brain function, from EEG and MEG to PET and fMRI scans, which show a parallel relationship between mental states and brain processing, these go no way in themselves to solving the so-called 'hard problem of consciousness research' (Chalmers 1996) – how these objective physiological processes give rise to the subjective effects of conscious experience.

One key to the possible role of subjective consciousness is that it appears to be a product of coordinated brain activity involving diverse regions operating together in a coherent manner so as to anticipate environmental challenges (see section 3).

This leads to another critical question: “Why did nervous systems evolve subjective consciousness?” If nervous systems are able to fully provide adaptive solutions simply as heuristic computers, there is no role for extraneous brain functions that simply add a subjective shadow reality, with no adaptive function, and presumably a physiological cost. A digital computer is a purely functional entity, so has no role for a subjective aspect, no matter how complex it becomes.
Diverse higher animal nervous systems appear to work on a common basis of edge-of-chaos excitation (see section 5) that arose in excitable single cells before multi-celled organisms evolved (see section 2), which, in humans is accompanied by subjective consciousness (King 2008). This suggests that subjectivity is a critical survival attribute, which has been reinforced by natural selection, its key role being anticipating opportunities and threats to survival (see section 4).

Strategic decision-making in the open environment is notorious for being computationally intractable because of super-exponential runaway as the number of contingencies increases (see section 4). By contrast, vertebrate brains have a common mechanism of massively parallel processing using wave phase coherence to distinguish ground noise from attended signal, accompanied by transitions at the edge of chaos (see section 5), which successfully resolves intractability in real time.

A non-computational form of space-time anticipation may aid this process (see section 6). Chaotic sensitivity and self-organized criticality combined with stochastic resonance may enable the ongoing brain state to become sensitive to quantum uncertainties through nested instabilities running from the molecular level, through cell organelles and neurons to global activations, when the global context is critically poised (see section 5). Quantum entangled phase coherence sampling accompanying the wave excitations of brain states could then provide a means for anticipation of future threats to survival through massively parallel weak quantum measurement (see section 6). We shall explore how this capacity might provide an explanation for subjective consciousness and the notion of free-will.

Fig 1: A: Evolutionary diversification of 5HT1 and 5HT2 receptor families occurred before the diversification of molluscs, arthropods and vertebrates (Blenau & Thamm). B: Serotonin signalling in hydra involves ectodermal neurons (Umbrico et al. 1990). C: Heptahelicical 5HT2a receptor protein. D: Evolutionary diversification of Na+ channels from Ca++ channels, essential for the action potential, occurred before the existence of nervous systems in founding single-celled eucaryotes leading to the metazoa before the choanoflagellates such as monosiga (Liebeskind et al. 2011). E: G-protein linked receptors and Histidine signaling are among several signalling systems found in Naegleria gruberi (Fritz-Laylin et al 2010), a free living single celled bikont amoeboid, belonging to the excavata, which include some of the most primitive eucaryotes such as Giardia and Trichomonads, implying these mechanisms were present in the last common eucaryote ancestor.

2: Underpinnings of Consciousness Emerged in Single Celled Eucaryotes

The neurodynamic processes underpinning subjective consciousness are evolutionarily ancient, are based on fundamental bifurcations evident in biogenesis, and originate in single-celled protista before the emergence of multi-celled animals and nervous systems (King 2002, 2011).

Excitable membranes are universal to eucaryote cells, as is the need to sense electrochemical and nutrient changes in their milieu. The sodium channel key to the axon potential, for example, arose in
founding single-celled eucaryotes. Chay and Rinzell’s (1985) model of bursting and beating derived from the alga Nitella demonstrates the widespread nature of chaotic excitability arising before animals and plants diverged. Similar excitability has been observed through cAMP dynamics in the social amoeba Dictyostelium (Mestler 2011) and action potentials in Paramecium (Hinrichsen & Schultz 1988).

The elementary neurotransmitter types, many of which are fundamental amino acids (glutamate, glycine, GABA) or amines derived from amino acids (serotonin, dopamine, histamine, choline) have primordial relationships with the membrane, as soluble molecules with complementary charge relationships to the hydrophilic ends of the phospholipids, which later became encoded in protein receptors.

Tryptophan, the amino acid from which serotonin (5-hydroxytryptamine) is generated, plays a key role in the transfer of electric charge in the earliest forms of photosynthesis. To make serotonin from tryptophan, oxygen is needed. Thus, serotonin is made specifically in unicellular systems capable of photosynthesis and the cellular production of oxygen. Consequently serotonin is up to 100 times more plentiful in plants, and animals have ceased to synthesize tryptophan depending on plants for their supply. This relationship with light continues to this day in human use of melatonin to define the circadian cycle and serotonin in wakefulness and sleep, with light deprivation causing depression through serotonin (Azmitia 2010).

The 5-HT1a receptor is estimated to have evolved 750 million to 1 billion years ago, (Peroutka & Howell 2004, Peroutka 2005) long before the Cambrian radiation. This places the emergence of receptor proteins and their neurotransmitters as occurring before the multicellular nervous systems, as cell-to-cell signalling molecules essential for survival, reproduction and positive and negative responses to nutrition and danger. It also explains that neurotransmitters originated from direct signalling pathways between the cell membrane and gene expression in the nucleus of single cells. Key enzymes in neurotransmitter pathways may have become ubiquitous through horizontal gene transfer from bacteria placing their emergence even earlier (Iyer et al. 2004).

Receptor proteins, including G-protein linked receptors, second signalling pathways and key neurotransmitters occur widely in single-celled protists including the free living excavate Naegleria gruberi (Fritz-leylin et al. 2010) implying these systems already existed in the last common ancestor of the eucaryotes. Both Crithidia and Tetrahymena contain norepinephrine, epinephrine, and serotonin (Blum 1969). Aggregation of slime molds such as Dictyostelium is mediated by cyclic-AMP and uses glutamate and GABA (Halloy et al. 1998, Goldbeter 2006, Taniura et al. 2006, Anjard & Loomis 2006, Brizzi & Blum 1970, Essman 1987, Takeda & Sugiya 1993, Nomura et al. 1998). Tetrahymena pyriformis also has circadian light-related melatonin expression (Kohidai et al. 2003). Trypanosoma cruzi can be induced to differentiate by increased cAMP levels that resulted from addition of epinephrine (Gonzalez-Perdomo et al. 1988). Species of Entamoeba secrete serotonin and the neuropeptides neurotensin and substance P (McGowan et al. 1985) and release and respond to catecholamine compounds during differentiation from the trophozoite stage into the dormant or transmissible cyst stage (Eichinger et al. 2002, 2005). Plasmodium falciparum malaria replication can be blocked by 5HT1a agonists (Locher et al. 2003).

This leads to a picture where the essential physiological components of conscious brain activity arose in single-celled eucaryotes, both in intra and intercellular communication, and in the chaotic excitability of single cells in sensing and responding to their environment. These include ion channel based excitability and action potentials, neurotransmitter modulated activity based on specific receptor proteins, membrane-nucleus signalling and precursors of synaptic communication.

Edge of chaos dynamics is a natural consequence of excitability providing arbitrary sensitivity to disturbances caused by predators and prey in the active environment. It is a function critical for survival in both single-celled and multicellular organisms, providing a selective advantage for the evolution of chaotically excitable brains from chaotically excitable cells. Once in place, this form of active anticipation, if linked to the anticipatory quantum process we are going to investigate, would then lead to a continuing use of edge of chaos wave coherence processing, subsequently expanded to primitive nervous systems as multicellular organisms evolved. One can see such strategically purposive
behaviour in both single celled protists such as paramecium and in active human cells such as neutrophils hunting and consuming bacteria (King 2008, fig 3).

Consequently the major neuroreceptor classes have a very ancient origin, with the 5HT1 and 5HT2 families diverging before the molluscs, arthropods and vertebrates diverged, close to the level of the founding metazoa. Sponges, with only two cell types, express serotonin (Wayrer et al. 1999) and have been shown to have the critical gene networks to generate synapses, in a pre-coordinated form (Conaco et al. 2012). Coelenterates already have all the key components of serotonin pathways, involved in signalling by sensory cells and neurons, despite having only a primitive nerve network (McCauley et al. 1997, Umbrico et al. 1990). Given its ancient origin serotonin is also found to play a key role in development and embryogenesis in Molluscs (Buznikov et al. 2001, 2003, sea urchins (Brown and Shaver) and mammals, where the expression of serotonin receptors occurs at the earliest stages, activated by circulating plasma serotonin from the mother.

The metabotropic (protein-activating) glutamate and GABA receptors likewise go back to the social amoeba *Dictyostelium discoideum*, where there is a family of 17 GABA receptors and a glutamate receptor involved in differentiation (Taniura et al 2006). The glutamate-binding “fly trap” section of both ionotropic and metabotropic glutamate receptors show homologies with the bacterial periplasmic amino-acid binding protein (Felder et al 1999, Oh et al 1994, Lampinen et al 1998). The membrane-spanning section of the iGluRs also show homology with the bacterial voltage-gated K+ channel (Chen et al 1999). These changes are already in place in the cyanobacterial ionotropic glutamate receptor. The fact that an iGluR has also been found in *Arabidopsis* (Turan et al 2001) shows this class entered the eucaryotes before the plants, animals and fungi diverged. Elements of the protein signalling pathways, such as protein kinase C, essential to neuronal synaptic contact originated close to the eucaryote origin (Emes et al. 2008, Ryan & Grant 2009). Likewise the *Dlg* family of postsynaptic scaffold proteins, which bind neurotransmitter receptors and enzymes into signaling complexes originated before the divergence of the vertebrates and arthropods (Nithianantharajah et al. 2012).

Thus we can see how the survival modalities of complex organisms have continued to be mediated by classes of neurotransmitters modulating key motivational, aversive and social dynamics, from single cells to multi-celled organisms, with ascending central nervous system complexity. There are thus strong parallels in how the key classes of neurotransmitters modulate affect in organisms as diverse as arthropods and vertebrates.

In higher animals, 5-HT continues in its role as a homeostatic regulator in adjusting the dynamic interactions of these many functions within the organism, and how the organism interacts with the outside world, elaborated in humans into a variety of functions including the sleep-wakefulness cycle, triggering the psychedelic state, depression and social delinquency (King 2012). Similarly, dopamine and nor-epinephrine pathways modulate reward and vigilance, forming a spectrum of fundamental strategic responses in humans, including motor coordination roles whose overstimulation or disruption can lead to Parkinson’s, dependency and psychosis. Reports of increased social dominance in primates (Edwards and Kravitz, 1997) and improved mood and confidence in social interactions in humans after using drugs which increase serotonin levels are well documented (Kramer, 1993; Young and Leyton, 2002).

Functional studies in the honey bee and fruit fly have shown that serotonergic signaling participates in aggression, sleep, circadian rhythms, responses to visual stimuli, and associative learning (Blenau & Thamm 2011). Serotonin in lobsters regulates socially relevant behaviours such as dominance-type posture, offensive tail flicks, and escape responses (Kravitz, 2000, Sosa et al. 2004). In insects, dopamine acts instead as a punishment signal and is necessary to form aversive memories (Barron et al. 2007, Schweerzel et al. 2003, Selcho et al. 2009). In flies dopamine modulates locomotor activity, sexual function and the response to cocaine, nicotine, and alcohol (Hearn et al. 2002). Octopamine, the arthropod analogue of norepinephrine, regulates desensitization of sensory inputs, arousal, initiation, and maintenance of various rhythmic behaviors and complex behaviors such as learning and memory, and endocrine gland activity (Farooqui 2007). Web building in spiders is likewise affected by stimulants and psychedelics (Dunn).
These neurotransmitters are thus playing a similar role in humans in modulating the excitable brain to attune it to survival objectives that these same signalling molecules had in single celled eucaryote social and reproductive behaviours.

Moreover, although most neurophysiological investigations of arthropod and mollusc neural ganglia tend to be recordings of single neuronal action potentials (e.g. Paulk & Gronenberg 2005), “silent” cells with graded electrical responses are also integral to the function of small neuronal circuits (Kandel 1979), and as we have already noted, chaotic excitability occurs in bursting and beating action potentials in amoebae, Paramecium and simple algae. Furthermore studies in both molluscs (Schütt & Basar 1992) and arthropods (Kirschfeld 1992, fig 4F) have demonstrated coherent gamma-type oscillations. These results lead us to the hypothesis that there is a common basis of attentive processing in the gamma band across wide branches of the metazoa, based on edge-of-chaos processing and wave phase coherence, despite their highly varied neuroanatomies (Basar et al. 2001).

Fig 2: A: Existential reality presents as a complementary paradox. While we acknowledge our subjective consciousness is somehow a product of our biological brain, which is in turn a fragile product of physical forces on a cosmological scale, all our experiences of reality, including our perceptions of the physical world, as well as dreams memories and reflections, come exclusively and totally from our subjective consciousness. This suggests that existential cosmology is a complementarity between subjective consciousness and the physical universe, in which both are fundamental. B: In the veridical way existential reality is generated, subjective experience is primary. In the consensual overlap of our subjective experiences we gain a common experience of the physical world, which we then interpret as containing biological brains, which may also be able to have subjective experiences. However, attempted construction of reality from the physical universe and its brains remains incomplete because there is no explanation of how the brains can also have subjective conscious experiences – the hard problem of consciousness research. C: Regions in the saliency circuit. D: Regions causing disruptions of active consciousness when injured (Bor 2013). Thalamus. Common regions involved in the self, the default network and alert consciousness. E: Regions in the self network (Zimmer 2005). F: The default network (Fox 2008). (a, a2) Medial/Lateral prefrontal, (b,b2) Precuneus / Posterior cingulated, (c) Anterior insula, (d,d2) Lateral/Posterior parietal running to the temporo-parietal junction (e), anterior cingulate (f) and fronto-insular (g).

3: Consciousness - Coordinated Activity Anticipating Future Challenges

In the face of the apparent causality of the Laplacian universe, many 20th century philosophers assigned to consciousness the orphan status of an epiphenomenon, a mere reflection of physical reality which could have no influence upon it. Some, such as Gilbert Ryle (1949), who coined the term “the ghost in the machine”, went further, attempting to deconstruct the dualistic notion of mind altogether, as a form of false reasoning, claiming “that the idea of Mind as an independent entity, inhabiting and governing the body, should be rejected as a redundant piece of literalism carried over from the era before the biological sciences became established. The proper function of Mind-body language, he suggests, is to describe how higher organisms such as humans demonstrate resourcefulness, strategy, the ability to abstract and hypothesize and so on from the evidences of their behaviour”.

Derived from the dualistic cosmology of Rene Descartes, the subjective arena of conscious awareness
is frequently referred to as the "Cartesian theatre", sometimes constructively, as in Barrs (2001), who describes the theatre of the conscious in terms of working memory and its associated backdrops, but other times in somewhat disparaging terms as in Dennett's Consciousness Explained (1991), who, rather than explaining consciousness, as he claims, replaces it with a "multiple drafts model", more representative of the publishing industry, than either the conscious mind, or the sentient brain, a work critics have said should have been entitled "Consciousness Ignored".

Running counter to the reduction of consciousness to a combination of deterministic laws and utterly random perturbations, are approaches in which consciousness is seen as somehow fundamental to the existential condition, complementary to physical phenomena and processes.

The nature of this complementarity in contrast to attempts on the part of functionalists to finesse consciousness to be merely an aspect of the attention process, or certain classes of excitation, such as those in the gamma range of the electroencephalogram, or EEG (30-60 Hz), have been highlighted in David Chalmers' enunciation of the so-called "Hard Problem" in consciousness research, - "explaining why we have qualitative phenomenal experiences". It is contrasted with the "easy problems" of explaining the ability to discriminate, integrate information, report mental states, focus attention, etc. Easy problems are easy because all that is required for their solution is to specify a mechanism that can perform the function. For example Crick and Koch (1992) identify conscious states accompanying attentive processes with higher frequency EEG signals in the gamma range. Defining consciousness as a functional process associated with attention and/or working memory is addressing an easy problem in consciousness research. The dilemma of the hard problem implies that no purely objective mechanism can suffice to explain subjective consciousness as a phenomenon in its own right. This leads ultimately to a cosmology in which consciousness and the physical universe are complementary.

The organization of the cerebral cortex and its underlying structures, consist of a series of microcolumns vertically spanning the three to six layers of the cortex, acting as parallel processing units for an envelope of characteristics, a hologram-like featural mathematical transform space. Typical features represented in particular cortical regions include sensory attributes such as the line orientation and binocular dominance of visual processing, tonotopic processing of sounds, somato-sensory bodily maps, and higher level features such as facial expressions and the faces of individuals, leading to the strategic executive modules of the prefrontal cortex and our life aims and thought processes.

The many-to-many nature of synaptic connections forms the basis of this abstract representation, which is also adaptive through neural plasticity. Space and time also become features in the transform mapping, so that certain e.g. parietal areas have major roles in spatial navigation while other areas, for example in the temporal lobes elicit experiences of a memory-episodic nature. The hippocampus pivotal in consolidating sequential memory also appears to function as a spatial GPS, emphasizing the mutual relation between space and time in transform space (see fig4E). A key role of wave-based brain processing is to harness this transform representation to predict, using experiential memory and contextual clues, the ongoing nature of opportunities and threats to survival.

Subjective consciousness involves coordinated whole-brain activity (Baars 1997, 2001), as opposed to local activations, which reach only the subconscious level, as evidenced in both experiments on conscious processing and the effects of dissociative anaesthetics (Alkire et al. 2008). Attempts to find the functional locus of subjective consciousness in brain regions have arrived at the conclusion that active conscious experiences are not generated in a specific cortical region but are a product of integrated coherent activity of global cortical dynamics (Ananthaswamy 2009, 2010). This distributed view of conscious brain activity is consistent with experimental studies in which the cortical modules we see activated in fMRI and PET scans correspond to salient features of subjective conscious experience.

This implies that the so-called Cartesian theatre of consciousness is a product of the entire active cortex and that the particular form of phase coherent, edge-of-chaos processing adopted by the mammalian brain is responsible for the manifestation of subjective experience. This allows for a theory of consciousness in which preconscious processing e.g. of sensory information can occur in specific brain areas, which then reaches the conscious level only when these enter into coherent global neuronal activity integrating the processing, as Baars’ global workspace theory (1997, 2001) proposes,
rather than being a product of a specific region such as the supplementary motor cortex (Eccles 1982, Fried et al. 1991, Haggard 2005).

Several lines of research have highlighted the idea of the present moment encapsulated in brain function in terms of processes which extend over short periods of time enabling a sustained observation of anticipated events binding together functional and experiential moments of 2-3 seconds duration, which are subsequently bound into memory, a concept first enunciated by Augustine (Wittman 2011, Fairhall et al. 2014, Spinney 2015) and that this is linked directly to the phase timing of coherent neural oscillations under experimental conditions where cross-sensory delays are artificially induced in the processing of stimuli (Kosem et al. 2014).

The approach is also consistent with there being broadly only one dominant stream of conscious thought and experience at a given time, as diverse forms of local processing give way to an integrated global response. A series of experiments involving ‘nattentional blindness’ (Thakral 2011) - perceptual masking of brief stimuli to inhibit their entry into conscious perception (Sergent et al. 2005, Sigman and Dehaene 2005, 2006, Dehaene and Changeux 2005, Del Cul et al. 2007, 2009, Gaillard et al. 2009), studies of pathological conditions such as multiple sclerosis (Reuter et al. 2009, Schnakers 2009), and brief episodes in which direct cortical electrodes are being used during operations for intractable epilepsy (Quiroga et al. 2008) have tended to confirm the overall features of Baars’ model (Ananthaswamy 2009, 2010). EEG studies also show that under diverse anesthetics, as consciousness fades, there is a loss of synchrony between different areas of the cortex (Alkire et al. 2008). The theory also tallies with Tononi’s idea of phi, a function of integrated complexity used as a measure of consciousness (Barras 2013, Pagel 2012).

Two opposing global attention systems have been identified, one the dorsal attention network deals with focal attention in the global workspace and is bilateral connecting areas such as the frontal eye fields to parietal and other areas. Complementing this is the ventral attention network whose role is to bring in salient stimuli, important to the subject, from the periphery. Intriguingly this has lateralized activity in the right cortex, complementing the left hemisphere regions traditionally associated with language, lending support to the above model of lateralization. A third system sometimes called the salience network (Seeley et al. 2007), closely overlapping with the ventral network (Farrant & Uddin 2015), connects the frontal anterior insula and the anterior cingulate, involving fast-transmitting von Economo neurons, and may mediate integrated bodily interoception, emotional and cognitive awareness and timed framing of the immediate present, forming a central process of self-consciousness (Allman et al, Cauda et al, Craig, Williams C). It may also be associated with intentional will (Parvizi et al. 2013).

Brain regions involved in our sense of self - the actor-agent behind conscious states - are also specifically activated in idle periods, when the salience and attention networks become inactive, the so-called default network, whose function appears to be adaptively envisaging future challenges. The default network (Fox 2008, Zimmer 2005, Buckner et al, Mason et al, Raichle. Raichle. & Snyder) encompasses posterior-cingulate/precuneus, anterior cingulate/mesiofrontal cortex and temporoparietal junctions, several of which have key integrating functions. The ventral medial prefrontal (Macrae et al. 2004) is implicated in processing risk and fear. It also plays a role in the inhibition of emotional responses, and decision-making. It has been shown to be active when experimental subjects are shown imagery they think apply to themselves. The precuneus (Cavanna & Trimble 2006) is involved with episodic memory, visuo-spatial processing, reflections upon self, and aspects of consciousness. The insulae are also believed to be involved in consciousness and play a role in diverse functions usually linked to emotion and the regulation of the body's homeostasis, including perception, motor control, self-awareness, cognitive functioning, and interpersonal experience. The anterior insula is activated in subjects who are shown pictures of their own faces, or who are identifying their own memories. The temporo-parietal junction is known to play a crucial role in self-other distinction and theory of mind. Studies indicate that the temporo-parietal junction has altered function during simulated out of body experiences (Ananthaswamy 2013).

Although subjective consciousness involves the entire cortex in coherent activation, brain scans highlight certain areas of pivotal importance, whose disruption can impede active consciousness. Three regions associated with global workspace have been identified as key participants in these higher integrative functions, the thalamus which is a critical set of relay centres underlying all cortical
areas and possibly driving the EEG, lateral prefrontal executive function and posterior parietal spatial integration (Bor 2013). Another set of two regions, anterior cingulate and fronto-insular are highlighted in the saliency circuit (Williams 2012) in which von Economo (VEN) bipolar neurons provide fast connectivity between regions to maintain a sense of the conscious present providing a sense of immediate anticipation of the ongoing external and internal condition (saliency and interoception). These appear prominently in large brained animals, including humans, elephants and cetaceans where there is greater need to rapidly stitch together related processing areas critical to the ongoing conscious state. The claustrum has wide-ranging neural connections and has also been implicated in reversible disruption of consciousness when stimulated (Koubeissi et al. 2014).

Several researchers have highlighted specific aspects of consciousness in an attempt to understand how it evolved. Higher integrative processing associated with global workspace has been extended to other animals such as apes and dolphins (Wilson 2013). Another approach suggests that making integrative decisions socially would have aided better environmental decision-making concerning hard to discern situations involving the combined senses in which social discussion aids survival, such as two hunters trying to assess whether dust on the prairie suggests running from lions or hunting buffalo, or women discussing where to find hard to get herbs from the visual appearance, taste and smell of a sample (Bahrami et al. 2010).

4: Conscious Survival in the Wild

To discover what advantage subjective consciousness has over purely computational processing, we need to examine the survival situations that are pivotal to organisms in the open environment and the sorts of computational dilemmas involved in decision-making processes on which survival depends.

Many open environment problems of survival are computationally intractable and would leave a digital antelope stranded at the crossroads until pounced upon by a predator, because they involve a number \( n \) of factors, which increase super-exponentially with \( n \). For example, in the traveling salesman problem - finding the shortest path around \( n \) cities - the calculation time grows super-exponentially with the factorial \( (n-1)!/2 \) - the number of possible routes which could be taken, each of which needs to be measured to find the shortest path (King 1991). There are probabilistic methods which can give a sub-optimal answer and artificial neural nets solve the problem in parallel by simulating a synaptic potential energy landscape, using thermodynamic annealing to find a local minimum not too far from the global one. Vertebrate brains appear to use edge of chaos dynamics to similar effect.

Fig 3: A: Foreboding prescience is key when a young shark lunges at a gull, which faces it head on squawking and then manages to escape in the nick of time when it lunges again at speed. B: Decision-making in the open environment involves computationally intractable problems, which cannot necessarily be solved by probabilities alone. Which path should we take to the water hole today? There could be a tiger on the shady path or a lion on the stony path. Both of these animals are also trying to out-maneuver us by changing their decision-making. C: A neutrophil relentlessly chases a flagellated bacterium through erythrocytes before eventually engulfing it showing similar interactions to the shark and gull occur in cellular predator-prey interactions through single cell excitability (https://www.youtube.com/watch?v=JnlULQ|uhSQ).
Open environment problems are intractable both because they fall into this broad class and also because they are prone to irresolvable structural instabilities, which defy a stable probabilistic outcome. Suppose a gazelle is trying to get to the waterhole along various paths. On a probability basis it is bound to choose the path, which, from its past experience, it perceives to be the least likely to have a predator, i.e. the ‘safest’. But the predator is likewise going to make a probabilistic calculation to choose the path that the prey is most likely to be on given these factors i.e. the same one. Ultimately this is an unstable problem that has no consistent computational solution.

Research on monkeys playing versions of the prisoners’ dilemma (Haroush & Williams 2015) has shown that there are neurons in the dorsal anterior cingulate that selectively predict an opponent’s yet unknown decision to invest in their common good or defect and distinct neurons that encode the monkey’s own current decision based on prior outcomes. This context shows active anticipation in social contexts in a single species another situation in which individual survival in a social community is at stake is driven by specific neural circuits devoted to social ‘future prediction’.

There is a deeper issue in these types of situation. Probabilistic calculations, both in the real world and in quantum mechanics, require the context to be repeated to build up a statistical distribution. In an interference experiment (fig 5) we get the bands of light and dark color representing the wave amplitudes as probability distributions of photons on the photographic plate only when a significant number have passed through the apparatus in the same configuration. The same is true for estimating a probabilistically most viable route to the waterhole. But real life problems are plagued by the fact that both living organisms and evolution itself are processes in which the context is endlessly being changed by the decision-making processes. Repetition occurs only in the most abstract sense, which is one reason why massively parallel brains we have are so good at such problems.

Finally, in many real life situations, there is not one optimal outcome but a whole series of possible choices, any or all of which could lead either to death, or survival and reproduction. This is the super-abundance problem we shall investigate shortly.

Despite having complex brains, even humans are very inferior computers with a digit span of only six or seven and a calculation capacity little better than a pocket calculator. We all know what we do and what conscious animals do in this situation. They look at the paths forward. If they have had a bad experience on one they will probably avoid it, but otherwise they will try to assess how risky each looks and make a decision on intuitive hunch to follow one or the other. In a sense, all their previous life experience is being summed up in their conscious awareness and their contextual memory. The critical point is that consciousness is providing something completely different from a computational algorithm, it is a form of real time anticipation of threats and survival that is sensitively dependent on environmental perturbation and attuned to be anticipatory in real time just sufficiently to jump out of the way and bolt for it and survive. Thus the key role of consciousness is to keep watch on the unfolding living environment, to be paranoid to hair-trigger sensitivity for any impending hint of a movement, or the signs, or sound of a pouncing predator – an integrated ‘holographic’ form of space-time anticipation.

This is precisely the basis of an innovative evolutionary theory of consciousness. The Attention Schema Theory (AST), suggests that consciousness arises as a solution to the environmental informational overload problem: Too much information constantly flows in to be fully processed, so nervous systems evolved increasingly sophisticated mechanisms for deeply processing a few selected signals at the expense of others Consciousness is the ultimate result of this evolutionary sequence (Graziano 2016).

All vertebrates fish, even lowly lampreys without a jaw, have a tectum meaning ‘roof’ in Latin, which generally covers the top of the brain. The tectum’s internal model simulates the current state of the eyes, head, and other major body parts, making predictions about how these body parts will move next and about the consequences of their movement. The tectum compares the predicted visual signals to the actual visual input, to make sure that your movements are going as planned. In fish and amphibians, the tectum is the pinnacle of sophistication and the largest part of the brain - in effect a self-simulation, but with the evolution of reptiles, a new brain structure the wulst emerged. Birds inherited a wulst and mammals did too, in the form of the cerebral cortex. The tectum is the master of
overt attention—pointing the sensory apparatus toward anything important. The cortex abstracts this a more flexible form of covert attention. Even if you’ve turn your back on an object, your cortex can still focus its processing resources on it sometimes referred to as a spotlight.

According to the AST, the cortex gains its abstraction by constructing an attention schema - a constantly updated set of information that describes what covert attention is doing moment-by-moment and what its consequences are. This first evolved as a model of one's own covert attention, but once in place, it adapted to model the attentional states of others, to allow for social prediction. Not only could the brain attribute consciousness to itself, it began to attribute consciousness to others. We understand other people by projecting ourselves onto them. But we also understand ourselves by considering the way other people might see us. Thus the cortical networks in the human brain that allow us to attribute consciousness to others overlap extensively with the networks that construct our own sense of consciousness.

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Fig 4: A: Evidence for both dynamical chaos and phase wave-front 'holographic' processing. (a) Freeman's model of olfactory recognition (Skarda and Freeman 1987) involves a transition from high-energy chaos on inhalation to enter a new or existing strange attractor basin as the energy is lowered on exhalation, represented (b) in distinct global patterns of olfactory bulb activation. Extended spatial distribution of cortical activation accompanying recognition of an odour. (c) Putative strange attractors in the electroencephalogram (Freeman 1991). (d) Fourier transforms of an electroencephalogram, showing broad-spectrum excitation and correlation dimensions both consistent with global chaotic dynamics. (e) Correlation dimensions of various brains states. (f) Increased phase coherence when a musical note becomes anticipated (Basar et al. 1989) (g) Wavelet (morlet) transform, showing time evolution of amplitudes with a peak in the gamma band accompanying recognition of an anomalous note is consistent with phase-front processing. Spectral product (right) illustrates coherence across several eeg channels.

B: Evidence for complex system coupling between the molecular and global levels in stochastic resonance (Liljenström and Uno 2005). Activation of single ion channels in hippocampal cells (a) leads to activation of the cells (c). Activation of such individual cells can in turn lead to formation of global excitations as a result of stochastic resonance (d). Individual cells are also capable of issuing action potentials in synchronization with peaks in the eeg (e). C: Chandelier cells (Molnar et al. 2008). Left: Single pre-synaptic pyramidal action potential leads to multiple post-synaptic excitations. Right: Structure of chandelier or axon-axonal cells with dendrites (blue) and axons (red). D: VEN neurons contrasted with neighbouring pyramidal neurons. E: The hippocampus, which is believed to have a pivotal role in the consolidation of sequential memory, the capacity to access past events in temporal order, also generates a spatial map of an organism’s behavioral environment, in which particular hippocampal ‘place’ cells fire in response to a given location, much like a GPS (erdiklab.technion.ac.il). Hippocampal cells have also been shown to activate in response to desired locations in an animals anticipated future (Olafsdottir et al. 2105, Wilson 2015). F: Coherent HF oscillations in the optic ganglion of the blowfly, shows similar activity to vertebrate gamma frequency oscillations (Kirschfeld 1992).
Partly because of the emergence of language and culture, humans have a ‘hair-trigger’ tendency to attribute consciousness to everything around us, from characters in a story, puppets and dolls, storms, rivers, empty spaces, and ghosts to gods - referred to as the Hyperactive Agency Detection Device, or HADD. This is the key attribute of consciousness discussed in figure 3 and in the discussion above. It brings us full circle to the acuteness of consciousness in survival in the wild, and it applies to the survival of all sentient animals:

“It's better to be safe than sorry. If the wind rustles the grass and you misinterpret it as a lion, no harm done. But if you fail to detect an actual lion, you are taken out of the gene pool.” (Graziano 2016).

However HADD in humans goes way beyond detecting predators. We have become supremely attuned to each other’s mind states. It gives each of us our adaptive edge.

5: Edge of Chaos Sensitivity and Phase Coherence Processing

From the work of Walter Freeman (1991, Skarda & Freeman 1987) and others (Basar et al. 1989) it has been established that the electroencephalogram shows characteristics of chaos, including broad-spectrum frequency activity, strange attractors with low fractal dimension and transitions from high-energy chaos, to learned, or new attractors, during sensory and perceptual processing. A fundamental property of chaos is sensitivity to arbitrarily small perturbations - the ‘butterfly effect’. Notably certain forms of chaotic process consistent with analog neural nets have been claimed to work beyond the Turing limit (Siegelmann 1995).

Between the global, the cellular and the molecular level are a fractal cascade of central nervous processes, which, in combination, make it theoretically possible for a quantum fluctuation to become amplified into a change of global brain state. The neuron is itself a fractal with multiply branching dendrites and axonal terminals, which are essential to provide the many-to-many synaptic connections between neurons, which make adaptation and the transform representation of reality possible. Furthermore, like all tissues, biological organization is achieved through non-linear interactions which begin at the molecular level and have secondary perturbations upward in a series of fractal scale transformations through complex molecules such as enzymes, supra-molecular complexes such as ion channels and the membrane, organelles such as synaptic junctions, to neurons and then to neuronal complexes such as cortical mini-columns and finally to global brain processes.

Because neurons tend to tune to their threshold with a sigmoidal activation function, which has maximum limiting slope at threshold, they are capable of becoming critically poised at their activation threshold. It is thus possible in principle for a single ion channel, potentially triggered by only one or two neurotransmitter molecules, if suitably situated on the receptor neuron, e.g. at the cell body, where an action potential begins, to act as the trigger for activation (King 2008).

The lessons of the butterfly effect and evidence for transitions from chaos in perceptual recognition suggest that if a brain state is critically poised, the system may become sensitive to instability at the neuronal, synaptic, ion-channel, or quantum level. A variety of lines of evidence have demonstrated that fluctuations in single cells can lead to a change of brain state. In addition to sensitive dependence in chaotic systems, stochastic resonance (Liljenström and Uno 2005), in which the presence of noise, somewhat paradoxically, leads to the capacity of ion channels to sensitively excite hippocampal cells and in turn to cause a change in global brain state (fig 4). In this sense ‘noise’ is equivalent to the properties of dynamical chaos, which distribute through the dynamic pseudo-randomly preventing the dynamic getting locked in a stable attractor. Such a dynamic is thus able to explore its dynamical space, just as thermodynamic ‘annealing’ is used in artificial neural nets to avoid them becoming locked in sub-optimal local minima.

Chandelier cells, which are more common in humans than other mammals, such as the mouse, and were originally thought to be purely inhibitory, are axon-axon cells, which can result in specific polysynaptic activation of pyramidal cells. It has been discovered (Molnar 2008, Woodruff and Yuste 2008) that chandelier cells are capable of changing the patterns of excitation between pyramidal neurons that drive active output to other cortical regions and to the peripheral nervous system, in such a way that single action potentials are sufficient to recruit neuronal assemblies that are proposed to participate in cognitive processes.
Confirmation of edge of chaos processing has come with several recent experimental studies.

Schurger et al. (2010, 2015) have developed notions of what distinguishes a consciously perceived stimulus from a non-conscious one. Stability is defined in terms of directional consistency of a vector representation whose coordinates are the values of sensors in a series of time samples within a trial, while reproducibility is defined between trials, as noted in fig 6(c, d). Thus consciously perceived stimuli appear as islands of relative stability in a sea of stochastic or chaotic unconscious processing. London et al. (2010), have confirmed the butterfly effect in individual rodent somatosensory neurons. They suggest a spike rate encoding at the individual neuron level, as specific time-sensitive events, which might deal with the sensitive dependence, were found to be very rare. This would nevertheless be consistent with phase coherence processing among populations of neurons at the level of cortical waves.

Solovey et al. (2015) using high density EEG demonstrate that the brain, as a dynamical system, is self-regulated at the boundary between stable and unstable regimes, allowing it in particular to maintain high susceptibility to stimuli. During loss of consciousness due to anesthetics, the number of eigenmodes at the edge of instability decreases smoothly, independently of the type of anesthetic and specific features of brain activity. The eigenmodes drift back toward the unstable line during recovery of consciousness. Stability is an emergent phenomenon dependent on the correlations among activity in different cortical regions rather than signals taken in isolation. These findings imply that dynamics at the edge of instability are essential for maintaining consciousness.

Moore et al. (2017) investigating dendritic potential recorded in freely behaving rats founds that digital action potential firing rates were several fold larger than somatic rates emanating from the neuronal body and disseminated out the axons, but these rates were modulated by dendritic membrane potential fluctuations which were far larger than action potential amplitude, indicting hybrid, analog-digital coding in the dendrites. Parietal dendritic potentials exhibited spatial maps comparable to pyramidal neurons, supporting the idea that dendritic potentials were performing complex neural computations, unfolding a whole hidden level of computational complexity in brain processes. Mayank Mehta, a lead author noted: "We found that dendrites are hybrids that do both analog and digital computations, which are therefore fundamentally different from purely digital computers, but somewhat similar to quantum computers that are analog".

Taking this process into the evolutionary context, Pryluk et al. (2019) have found that comparisons of human and macaque neurons in the amygdala and cingulate cortex reveal species- and region-specific differences in information efficiency and robustness, pointing to evolutionary changes that could help explain human cognitive advantages and susceptibility to psychopathologies. Many evolutionary years separate humans and macaques, and although the amygdala and cingulate cortex evolved to enable emotion and cognition in both, an evident functional gap exists. They find that human neurons better utilize information capacity (efficient coding) than macaque neurons in both regions, and that cingulate neurons are more efficient than amygdala neurons in both species. In contrast, they find more overlap in the neural vocabulary and more synchronized activity (robustness coding) in monkeys in both regions and in the amygdala of both species. Their findings demonstrate a tradeoff between robustness and efficiency across species and regions implying that increasing efficiency is a trade-off against robustness again putting the human brain in a paradigm of evolving toward increasing dynamic instability in the pursuit of cognitive efficiency.
Fig 4a: The transition probabilities show an ordinal relationship with the level of consciousness. Black arrows indicate a higher probability to transit between the coordination patterns in healthy controls (HC) as opposed to patients in MCS and patients in UWS (HC > MCS > UWS). Gray arrows indicate the opposite trend (HC < MCS < UWS). Right: Patients in MCS were more likely to stay in the complex pattern 1 and to transition from this pattern to patterns 2 and 3. On the other hand, unresponsive patients were more likely to stay in the pattern most similar to anatomical constraints (pattern 4). Red arrows indicate higher transitional probabilities for patients in MCS, and blue arrows indicate higher transitional probabilities for unresponsive patients.

Investigating the energetic processes underlying active consciousness, also highlighting the increased instability idea of active consciousness, Sitt and his colleagues (Demertzi et al. 2019) scrutinized functional MRI data that captured the brain activity of 125 people as they rested inside scanners. Forty-seven of these people were healthy. The rest had unresponsive wakefulness syndrome, in which their eyes were open but they showed no signs of awareness, or were in a minimally conscious state, in which they could follow simple instructions such as moving their eyes on command. Two distinct patterns of brain activity emerged. The first was a complex pattern characterized in part by opposites. When one neural spot was active, others were not. This complex pattern also didn't follow the anatomy of the brain; signals ping-ponged far away from their anatomical connections. The second pattern was simpler, and more closely constrained by the anatomy of the brain. The brains of people who were fully conscious spent more time exhibiting the complex pattern, Sitt and his colleagues found. People who were diagnosed with unresponsive wakefulness syndrome spent more of their time in the simple pattern, while those in the minimally conscious state split the difference, spending time in both states to varying degrees.

6: Quantum Reality, Sentience and Intentional Will

Many scientists assume that all human activity must be a product of brain function and that any notion of conscious will acting on the physical is delusory. This flies in contradiction to our subjective assessment that we are autonomous beings with voluntary control over our fates.

To claim free will is a delusion leads to a catatonic impotence of consciousness and contradicts the assumptions of legal accountability, where we assume a person of sound mind is physically responsible for the consequences of their consciously intentional actions.

Many physicists, from Arthur Eddington's citation of the uncertainty of position of a synaptic vesicle in relation to the thickness of the membrane to Robert Kane (1996), have drawn attention to the fact that the quantum universe is not deterministic in the manner of classical causality and that quantum uncertainty provides a causal loophole, which might make it possible for free will to coexist in the
quantum universe.

Moreover John Horton Conway and Simon Kochen (2006, 2009) have shown that using basic axioms derived from quantum theory and relativity, not even including probabilities, that free-will on the part of the experimental physicist implies free-will for fundamental particles in the sense that their ‘responses’ are not defined by the past history of the universe. They also claim this rules out relativistic versions of theories of wave function collapse based on stochastic flashes in space-time (Ghirardi et. al 1986, Tumulka 2007a,b). The free will theorem has a close relationship with Bell’s (1966) theorem governing quantum entanglement (Landsman & Cator 2014, Hermens 2014).

Biology is full of phenomena at the quantum level, which are essential to biological function. Enzymes invoke quantum tunneling to enable transitions through their substrates’ activation energy. Protein folding is a manifestation of quantum computation intractable by classical computing. When a photosynthetic active centre absorbs a photon, the wave function of the excitation is able to perform a quantum computation, which enables the excitation to travel down the most efficient route to reach the chemical reaction site (McAlpine 2010, Hildne et al. 2013). Recent research confirms the conscious brain can detect single photons and is able to amplify sensitivity given previous threshold input (Castelvecchi 2015, Tinsley et al. 2016).

Quantum entanglement is believed to be behind the way some birds navigate in the magnetic field (Amit 2012, Courtland 2011, Giachello et al. 2016, Paul et al. 2017). Light excites two electrons on one molecule and shunts one of them onto a second molecule. Their spins are linked through quantum entanglement. Before they relax into a decoherent state, the Earth’s magnetic field can alter the relative alignment of the electrons’ spins, which in turn alters the chemical properties of the molecules involved. Quantum coherence is an established technique in tissue imaging, demonstrating quantum entanglement in biological tissues at the molecular level (Samuel 2001, Warren 1998). An interesting possible type of entanglement in the brain could occur as a result of spin in Calcium phosphate Posner’s clusters, which have an estimated coherence time of 105 seconds (Fisher 2015).

Although the brain needs to able to be resilient to noise in its stable functioning, in the event of a critically poised dynamic in which there is no stable determining outcome, several key processes, may make the brain state capable of being sensitive to fluctuations at the quantum level. These include chaotic sensitivity, self-organized criticality, the amplifying effects of chandelier cells and stochastic resonance (King 2008, 2012).

Karl Pribram (1991, 1999, Pribram & Meade 1999, 2004), in the notion of holonomic processing in the brain, has drawn attention to the similarity between phase coherence processing of brain waves e.g. in the gamma frequency range believed to be responsible for cognitive processes and the wave amplitude basis of quantum uncertainty in reduction of the wave packet and quantum measurements based on the uncertainty relation \( \Delta E \Delta t = \hbar \), where the relation is determined by the number of phase fronts to be counted (fig 5B). He attributes this to the continuously varying potentials in the dendritic web, rather than the discrete pulse-coded action potential of pyramidal neurons, as supported by Moore et al. (2017), as noted above. He sees this as encoding a holographic representation, in which memories are stored in a distributed manner that allows for connections between different regions.
integrating the aspects of a stored memory and the non-locality of memory storage (a specific memory is not stored in a specific location. Poznanski et al. (2017) suggest this forms a quantum electrodynamical field in interfacial water spanning brain tissue. It has also been proposed that low intensity photon emission from the mitochondria of neurons, possibly transmitted through the microtubules, may constitute a photonic field that binds the coherence of the EEG across brain regions (Rahnama et al. 2010).

This raises an interesting implication, that the evolution of nervous systems may have arrived at a neurodynamic homologous with quantum processes at the foundation of physics, suggesting that quantum entanglement in brain states could in turn be a basis for active biological anticipation of immediate threats to survival through the forms of subjective consciousness the brain generates.

In quantum mechanics, not only are all probability paths traced in the wave function, but past and future are interconnected in a time-symmetric hand-shaking relationship, so that the final states of a wave-particle or entangled ensemble, on absorption, are boundary conditions for the interaction, just as the initial states that created them are. The transactional interpretation of quantum mechanics expresses this relationship neatly in terms of offer waves from the past emitter/s and confirmation waves from the future absorbers, whose wave interference becomes the single or entangled particles passing between (fig 5E). When an entangled pair are created, each particle knows instantaneously the state of the other and if one is found to be in a given state, e.g. of polarization or spin, the other is immediately in the complementary state, no matter how far away it is in space-time. This is the 'spooky action at a distance', which Einstein feared because quantum reality adheres to Bell’s (1966) theorem, which is inconsistent with local Einsteinian causality – particles not communicating faster than the speed of light.
Fig 5: A: Schrodinger cat experiment has a cat in a box with a radioactive scintillation counter, with quantum tunneling out of the nucleus triggering a hammer to smash a cyanide flask pronouncing a cat alive and dead with differing probabilities according to the tunneling wave function of the nucleus potential well. However we find the cat is either alive or dead with certainty. B: The uncertainty relation $\Delta E \Delta t \approx \hbar$ is derived directly from the counting of wave coherence beats, since energy is related to frequency by $E = h\nu$ and $\Delta t \approx 1 / \Delta \nu$. C: Quantum interference experiment shows wave-particle complementarity and reduction of the wave packet occurs statistically (centre) according to the squared amplitude of the wave function (right) although the wave-particle reduction of individual quanta (left) is unpredictable. D: Wheeler delayed choice shows time reversed boundary condition. A cosmic scale version of the interference experiment using galactic gravitational lensing can be adjusted at the detector after the photons have traversed space to either sample a particle going one way round, or a wave interference going both ways. E: The transactional interpretation visualizes an exchanged particle wave function as the interference of a retarded usual time direction offer wave and a time-reversed advanced confirmation wave. F: Time symmetric interactions also occur in quantum field theories where special relativity allows both advanced and retarded solutions because of the energy relation $E = \pm \sqrt{p^2 + m^2}$. (a,b) Virtual photons and electron-positron pairs deflecting an electron in quantum electrodynamics. Since the photon is its own anti-particle, a negative energy photon traveling backwards in time is precisely a positive energy one traveling forwards. (c) weak force exchange (d) An electron scattering backwards in time is the same as positron creation-annihilation. G: Weak quantum measurement in a double slit apparatus generating single photons using a laser stimulated quantum dot and split fiber optics. The overlapping wave function is elliptically polarized in the $xy$-plane transverse to the $z$-direction of travel. A calcite crystal is used to make a small shift in the phase of one component, while the other retains the information leading to absorption of the photon on a charged coupled device. By combining the information from the two transverse components at varying lens settings, it becomes possible to make a statistical portrait of the evolving particle trajectories within the wave function. Pivotal the weak quantum measurement is made in a way, which is confirmed only in the future of the ensemble when the absorption takes place (Kocsis et al. 2011). H: Top to bottom classical and quantum kicked top phase spaces and linear entropies, with left to right ordered and chaotic dynamics. The lack of a dip in linear entropies in the chaotic regime indicates entanglement with nuclear spin, rather than quantum suppression of chaos, as occurs in closed quantum systems (Chaudhury et al. 2009, Steck 2009). I: Time may itself be an emergent property of quantum entanglement (Moreva et al. 2013). An external observer (a) sees a fixed correlated state, while an internal observer using one particle of a correlated pair as a clock (b) sees the quantum state evolving through two time measurements using polarization-rotating quartz plates and two beam splitters PBS1 and PBS2. A further theoretical link between space-time and quantum entanglement on the holographic boundary has also been discovered, suggesting gravitation and relativity are a product of quantum entanglement (Lin et al. 2015).
The brain explores ongoing situations which have no deductive solution, by evoking an edge-of-chaos state which, when it transitions out of chaos, results in the ‘aha’ of insight learning. The same process remains sensitively tuned for anticipating any signs of danger in the wild. This is pretty much how we do experience waking consciousness.

If this process involves sensitivity to quantum indeterminacy the coherent excitations would be quantum entangled, invoking new forms of quantum ‘computation’. However quantum entanglement cannot be used to make classical causal predictions, which would formally anticipate a future event, so the past-future hand-shaking lasts only as long as a particle or entangled ensemble persist in their wave function.

Weak quantum measurement (WQM) is one way a form of quantum anticipation could arise. Weak quantum measurement (Aharonov et al. 1988) is a process where a quantum wave function is not irreversibly collapsed by absorbing the particle but a small deformation is made in the wave function whose effects become apparent later when the particle is eventually absorbed e.g. on a photographic plate in a strong quantum measurement. Weak quantum measurement changes the wave function slightly mid-flight between emission and absorption, and hence before the particle meets the future absorber involved in eventual detection (fig 5G). A small change is induced in the wave function, e.g. by slightly altering its polarization along a given axis (Kocsis et al. 2011). This cannot be used to deduce the state of a given wave-particle at the time of measurement because the wave function is only slightly perturbed, and is not collapsed or absorbed, as in strong measurement, but one can build up a prediction statistically over many repeated quanta of the conditions at the point of weak measurement, once post-selection data is assembled after absorption.

The space-time profile of WQM displays detection trajectories comparable with David Bohm’s (1952) ‘pilot wave theory’ (fig 5G) in which the particle has a defined position and the wave acts simply as a guide. However the pilot wave cannot explain all aspects of wave-function collapse because of cases like the decay of a photon into an electron-positron pair, where there are more degrees of freedom in the more complicated massive two-particle outcome than the initial conditions.

This suggests (Merali 2010, Cho 2011) that, in some sense, the future is determining the present, but in a way we can discover conclusively only by many repeats. Focus on any single instance and you are left with an effect with no apparent cause, which one has to put it down to a random experimental error. This has led some physicists to suggest that free-will exists only in the freedom to choose not to make the post-selection(s) revealing the future’s pull on the present. Yakir Aharonov, the co-discoverer of weak quantum measurement (Aharonov et al. 1988) sees this occurring through an advanced wave travelling backwards in time from the future absorbing states to the time of weak measurement. What God gains by ‘playing dice with the universe’, in Einstein’s words, in the quantum fuzziness of uncertainty, is just what is needed, so that the future can exert an effect on the present, without ever being caught in the act of doing it in any particular instance: “The future can only affect the present if there is room to write its influence off as a mistake”, neatly explaining why no subjective account of prescience can do so either.

Weak quantum measurements have been used to elucidate the trajectories of the wave function during its passage through a two-slit interference apparatus (fig 5G, Kocsis et al. 2011), to determine all aspects of the complex waveform of the wave function (Hosten 2011, Lunden et al. 2011), to make ultra sensitive measurements of small deflections (Hosten & Kwiat 2008, Dixon et al. 2008) and to demonstrate counterfactual results involving both negative and positive post-selection probabilities, which still add up to certainty, when two interference pathways overlap in a way which could result in annihilation (Lundeen & Steinberg 2009). In a more recent development, a team led by Aharanov (et al. 2014) has found that post-selection can also induce forms of entanglement in particles even if they have no previous quantum connection coupling their wave functions. This ties in closely with the notion of quantum discord (Ollivier & Zurek 2002), where partial correlations induced through interaction with mixed state particles can still be used to induce quantum correlated effects (Gu et al. 2012). Quantum discord does not require isolation from decoherence, and is thus a viable model for processes ongoing at biological temperatures which could disrupt full entanglement.

WQM provides a potential way that the brain might use its brain waves and phase coherence to evoke
entangled (coherent) states that carry quantum encrypted information about immediate future states of experience as well as immediately past states, in an expanded envelope - the quantum present. It is this coordinated state that corresponds to subjective experience of the present moment, encoded through the parallel feature envelope of the cerebral cortex, including the areas associated with consciousness illustrated C-F in fig 2.

Effectively the brain is a massively parallel ensemble of wave excitations reverberating with one another, through couplings of varying strength in which excitations are emitted, modulated and absorbed. Interpreted in terms of quantum excitations, the ongoing conscious brain state could be a reverberating system of massively parallel weak quantum measurements (MPWQMs) of its ongoing state. This could in principle give the conscious brain a capacity to anticipate immediate future threats through the intuitive avenues of prescience, paranoia and foreboding. This suggests that the reverberating ensemble of the ‘quantum present’ could provide an intuitive form of anticipation complementing computational predictions.

This would require significant differences from the post-selection paradigm of weak quantum measurement experiments, which are designed to produce a classically confirmed result from an eventual statistical distribution in the future. In the brain, consciousness being identified with the coherent excitations and hence the entangled condition could reverse the implication of backwards causality of advanced waves, with the future effectively informing the present of itself in quantum encrypted form through the space-time expansion of the ‘quantum present.’ Discovering a molecular-biological basis for such an effect would pose an ultimate challenge to experimental neuroscience.

An indication of how quantum chaos might lead to complex forms of quantum entanglement can be gleaned from an ingenious experiment forming a quantum analogue of a kicked top using an ultra-cold cesium atom kicked by a laser pulse in a magnetic field. In figure 5H is shown (top pair) the classical dynamical space of the kicked top, showing domains of order where there is periodic motion and complementary regions of chaos where there is sensitive dependence on initial conditions. In the quantum system (middle pair), in the ordered dynamic (left), the linear entropy of the system (bottom pair) is reduced and there is no quantum entanglement between the orbital and nuclear spin of the atom. However in the chaotic dynamic (right) there is no such dip, as the orbital and nuclear spins have become entangled as a result of the chaotic perturbations of the quantum top’s motion (Chaudhury et al. 2009, Steck 2009). This shows that, rather than the suppression of classical chaos seen in closed quantum systems (King 2013), reverberating chaotic quantum systems can introduce new entanglements.

The prevailing theory for loss of phase coherence and entanglement with the transition to classicality is decoherence caused by the interaction of a wave-particle with other wave particles in the environmental milieu (Zurek 1991), and possibly also with time-dilation effects of general relativity (Pikovski et al. 2015), although one has to take this off against the idea that gravitation emerges from holographic entanglement (Lin et al. 2015). In the former, the coherence of the original entanglement becomes perturbed by other successive forms of entanglement, which successively reduce the coherence exponentially over time in the manner of an open system chaotic billiards. More generally decoherence involves a loss of off-diagonal amplitudes, resulting in a classical portrait (Zurek 1991).

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However in a ‘closed universe’, such as the global excitations of a brain state, decoherence does not necessarily approach the classical limit, but may retain encoded entangled information, just as the above example of the quantum kicked top does in a simpler atomic system, which could be referenced by the brain in the same way multiple hippocampal representations over time can, as an organism explores a changing habitat. Intriguingly, continued weak quantum measurement, rather than provoking decoherence tends to preserve entanglement because the ordered nature of the weak quantum measurements reduces the disordered nature of the environment (Hosten 2011, Lundeen et al. 2011). Entanglement swapping can also lead to extended relationships over space and time, when an entangled pair say a, b has one of its members successively entangled with other pairs c, d, so that a and c become entangled and so on (Ananthaswamy 2012, Megidish et al. 2012). This could lead to a long chain of entangled states in the brain over much longer time intervals than the individual states themselves. Massively parallel weak quantum measurements in the brain might thus function to maintain the ongoing entanglement.
Finally, completing the enigma, it has also been proposed that elapsing time is itself an emergent property of quantum entanglement. The difficulty of uniting quantum mechanics with general relativity stems from the fact that in quantum theory, time is an independent variable, so that quantum measurements can be made at different points in time, while in relativity gravitation is measured by the curvature of space-time in which time has become part of the topological curvature, so that the picture is essentially eternally static. One way of resolving this paradox is that quantum entanglement creates the time as an emergent property through the relative relationships between entangled states while an external observer will see an unchanging fixed correlated state (Moreva et al. 2013).

7: Is Free-will Actually Free?

Sam Harris (2012) in a radio discussion puts the case against free-will in the following terms:

“You feel like you are a thinker of thoughts - the author of intentions - you fell like you are a subject and commensurate with that feeling is the sense that you are in a position to do what it is you do, to decide to lift my left or right hand and deliberate between the two and I can have reasons for one or the other and I’m in the driver’s seat - I really am - and that's where everyone is starting. The problem with that is that objectively we know that everything you are consciously aware of - all your thoughts and your intentions and your impulses and your intentions to resist those impulses - whatever's coming up for you - but we know that's all preceded by events in your nervous system of which you’re not aware and which you didn't create and the state of your brain in this moment in every sense is the product of variables that you are not responsible for - you didn't pick your parents, you didn't pick your genes, you didn't pick the environment in which your genome was going to be expressed, you didn’t pick the way your interaction with other people and the world sculpted the microstructure of your brain so as to give you the brain you have - you didn't pick the number of receptors you have of every type at each synapse, you didn't pick all the charges that are currently in place in your brain at this moment - you haven't created your neuronal physiology and yet your neuronal physiology is going to give rise to every next thought and intention that shows up for you”.

Mozes (2013) in a review critical of Harris's position points out that his premises fall into classical reductionist views of the Newtonian universe, claiming his actual scientific is absent:

Harris advocates determinism as part of a more general model of the universe, which involves two basic principles:

(1) The universe is built out of physical particles whose movements are determined by their previous movements and their physical impact on each other. (A principle commonly referred to as mechanism.)
(2) Human beings are complex systems of these physical particles, and causal laws governing those particles completely determine the actions of the system. (A principle commonly referred to as reductionism -.)

The model of the universe based on these two principles was originated by the Greek atomists, and is associated in modern times with the physicist Pierre-Simon Laplace. It is held by Harris, Daniel Dennett (and many other contemporary determinists.

Harris also presents two lines of alleged observational evidence for determinism:

(1) The claim that introspective experience, when seen with “serious self-scrutiny,” demonstrates that we do not control our actions.
(2) The claim that the Libet experiments, and similar subsequent experiments, demonstrate that we do not control our actions.

Mozes is correct and this position was articulated long before Harris and Dennett. Henry Thomas Buckle, a 19th century British historian wrote in History of Civilization in England (1864):

“When we perform an action, we perform it in consequence of some motive or motives that … are the results of some antecedents. If we were acquainted with the whole of the antecedents, and with all the laws of their movements, we could with unerring certainty predict the whole of the immediate results.

This again is a reflection of the idea of Laplacian causality in a classical Newtonian universe:

We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes (Pierre Simon Laplace, A Philosophical Essay on Probabilities).
We have discussed several reasons why this position is incorrect and will do so further in section 9:

**Firstly**, the fact that many conscious processes may arise from pre-conscious processing doesn’t mean that there is no capacity of consciousness to decide a course of action changing physical circumstances, as the very role of consciousness is to make an efficiency trade-off to make viable courses of action in real-time given the pre-processing and filtering of salient stimuli necessary for survival. The fact that we don’t consciously process all the myriad stimuli doesn’t in any way mean that our decisions do not take place.

**Secondly**, neither the quantum universe in which uncertainty and entanglement pertain, nor the unpredictable edge-of-chaos processing in the brain, on which conscious decision-making depends can be confirmed to be deterministic in the classical way Sam Harris naively describes. Reductionism - the idea that human beings are simply complex systems of physical particles, and that causal laws governing those particles completely determine the actions of the system cannot be demonstrated in unstable quantum systems such as the brain. The fact we know how receptors and synapses, long-term potentiation and genetic factors affect brain function and that neuroscience is revealing which brain processes are associated with conscious decision-making doesn’t answer either the question of how such processes are also experienced subjectively nor whether subjective decisions can affect physical outcomes.

**Thirdly**, we all know that environmental circumstances, our genes, upbringing and physiology all affect our decision-making in the real world, but these processes themselves and history itself are highly unstable, so that key decisions we do make are always relating to choices where we ascertain we are free to, and maybe need to use split-second timing to, take a circumstantial opportunity or avoid a catastrophic outcome. This no form of conditioning constitutes a blanket denial of free-will, but merely limits the degrees of freedom in which a decision operates.

**Fourthly**, we will show that the Libet experiments reviewed in the section 9 have since been confounded by research that takes into account instabilities in brain function.

In a further review of Dennett's Freedom Evolves (2003), Mozes (2003) shows that Dennett is not talking about the evolution of free will but merely of morality in a deterministic organism:

"Dennett defends a particular form of determinism known as compatibilism. This is the view that the concept of free will should be redefined so that it no longer involves a free choice among alternatives and can thus be made compatible with the mechanist/reductionist model of the universe. Dennett suggests that calling an action "freely chosen" should not mean that the person had some other possible alternative action (which Dennett claims is never true), but rather should mean that we are justified in holding the person morally responsible for that action: "In other words, the fact that free will is worth wanting can be used to anchor our conception of free will in a way metaphysical myths fail to do".

In explaining the evolution of human culture, Dennett employs the concept of "meme," coined by Richard Dawkins. A meme is an idea viewed as an agent seeking to reproduce itself in people's minds and competing with other memes through a cultural version of Darwinian natural selection. Dennett takes pains to state that he and other writers who use the concept of memes are not denying that people think. Rather, thinking is the process underlying natural selection among memes, in the same way that biological reproduction is the process underlying natural selection among genes.

Neither are physicists immune from making false assumptions about the relationship between the quantum universe and free-will. A central error is: (1) that the quantum universe is divided between deterministic laws, including both Newtonian mechanics and the Hamiltonian wave functions of quantum mechanics, the only exception being the probability laws of quantum mechanics giving rise to particle ensembles and statistical mechanics of thermodynamics and kinetic processes. These are, in turn, assigned to be as unyielding to free-will as deterministic mechanisms, because we are merely replacing a stipulated action by law with a random unspecified action. Since the universe is governed by unyielding determinism and unrelenting randomness, the notion of free-will is meaningless even in the quantum universe. This then enables the argument to descend (2) to a reductionist stochastic mechanism in which particulate molecules interact kinetically reducing the brain (3) to a complex probabilistic automaton.
For example Carlo Rovelli (2013), who is a gravitational theorist, who specifically states his support for Dennet's position, sets out in his Edge article to claim that: "Free will has nothing to do with quantum mechanics. We are deeply unpredictable beings, like most macroscopic systems. There is no incompatibility between free will and microscopic determinism. ... The issue has no bearing on questions of a moral or legal nature. Our idea of being free is correct, but it is just a way to say that we are ignorant on why we make choices."

In making this argument, he states exactly the above three errors:

The first is that the indeterminism of quantum mechanics is governed by a rigorous probabilistic dynamics. The equations of quantum mechanics do not determine what will happen, but determine strictly the probability of what will happen. In other words, they certify that the violation of determinism is strictly random. This goes in exactly the opposite direction from human freedom to choose.

If an element of randomness is sufficient to account for free will, there is no need to search it into quantum uncertainty, because in a complex open system such as a human being there are already many sources of uncertainty, entirely independent of quantum mechanics. The microscopic atomic dynamic inside of a man is influenced by countless random events: just consider the fact that it occurs at room temperature, where the thermal motion of the molecules is completely random.

The same balance between rigidity and chance plays an important role in our brain, which functions, in spite of the illuminating similarities with good software, because of the ubiquity of statistics in his working. ... Our brain is a machine, but it is a machine that works in a manner where statistical elements play a continuous and persistent role, next to deterministic functions.

Essentially the problem is that we can exert the strictness of the probability interpretation only when the process is repeated in a systematically consistent way, as in an interference experiment. If we allow only one event to occur in a complex open system such as a being there are already many sources of uncertainty, entirely independent of quantum mechanics. The microscopic atomic dynamic inside of a man is influenced by countless random events: just consider the fact that it occurs at room temperature, where the thermal motion of the molecules is completely random.

If the brain sets up criteria for future firing, and if spike timing is made random by the amplification of quantum-level events in the synapse, it is down to chance how these criteria are met. The inputs that meet criteria cannot be predicted - the outcome depends on which spikes coincidentally arrive first.

He also notes the importance of the link to long-term potentiation changing the circumstances of each decision:

The missing piece is that neurons can rewire each other. Spikes don’t just trigger subsequent spikes in other neurons. Within milliseconds, they can temporarily change the degree to which synapses -- the nerve structures that pass signals to other neurons -- trigger future spikes ... rapid bursts of spikes trigger the opening of specialised synaptic receptors, altering the responsiveness of neurons to subsequent spikes.

Finally he brings it to the conscious subject:

With synaptic reweighting, mental events don’t change their present physical basis. They change the neuronal basis of possible future events. But this alone is not enough for free will. The brain of a zombie who lacked consciousness could use this mechanism too, but we would not say it had free will. To have free will requires that
our self - that which we feel directs our attention around our conscious experience - has some say in the matter of what we do or think. If consciousness plays no part in the synaptic reweighting process, there is hardly a free will worth having. Fortunately, the neural activity associated with consciousness does play a necessary role.

He then illustrates this with the brain deliberating an outcome in a new situation which has features that have not occurred previously, leading to a creative or diplomatic outcome as a result of the unstable brain dynamics which then becomes a process in the real world acting out the creative outcome. We can then make verifiable tests that consciously willed actions do indeed result in historically verifiable outcomes, closing the circle.

So what are the potential consequences of the thrust of such classical physical arguments or even religious ones such as divine fatalism, where the supreme will of God is dominant over fallible humans, also claimed to be cursed with original sin?

Regardless of cultural and religious history, belief in free-will appears to be a normal biological condition. In 1998, the International Social Survey Programme asked around 40,000 people from 34 countries: "Do we make our own fate?" More than 70 per cent answered in the affirmative. In experiments where volunteers read statements reinforcing or undermining belief in free will, the first group behaved no differently from volunteers who had not been primed to think of free will at all indicating we naturally act as though we possess it. Moreover those with a greater belief in their own free will were generally rated as performing better than those with weaker beliefs (Stillman et al. 2010). And people don't just believe they have free will, they also believe they have more of it than others. (Pronin & Kugler 2010).

"You,' your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules. Who you are is nothing but a pack of neurons … although we appear to have free will, in fact, our choices have already been predetermined for us and we cannot change that (Francis Crick The Astonishing Hypothesis Scribner).

Given the scientific assault on free-will from neurological determinism it is intriguing to discover what the eroding the belief in free-will does to human behavior (Jones 2011). For example, it has been found that those whose belief in free will had been eroded by passages, such as the one above, were more likely to cheat (Vohs & Schooler 2008). People whose belief in free will was challenged by statements such as "Like everything else in the universe, all human actions follow from prior events and ultimately can be understood in terms of the movement of molecules" were, on average, less altruistic than groups that received neutral "Oceans cover 71 percent of the earth's surface." Or positive messages about free-will "I demonstrate my free will every day when I make decisions", and they behaved more aggressively towards strangers, such as adding hot sauce when they were told they didn't like it (Baumeister et al. 2009).

This has led Baumeister et al. to be skeptical of the general public accepting determinism can support ethical behaviour:

Some philosophical analyses may conclude that a fatalistic determinism is compatible with highly ethical behavior, but the present results suggest that many laypersons do not yet appreciate that possibility

It also brought Vohs & Schooler to effectively suggest lying about the true causes of social behaviour:

If exposure to deterministic messages increases the likelihood of unethical actions, then identifying approaches for insulating the public against this danger becomes imperative.

In studies using various described scenarios, even in a supposedly deterministic universe in which a super-computer could predict people's criminal actions 83% of subjects saying "Yes" the culprit still had free will and were thus morally responsible for their behaviour (Nahmias et al. 2006). However another study appeared to contradict this with 86% of respondents saying "No". However in cases of crimes in which a person was emotionally culpable such as rape the respondents 66% of people still held them accountable. The key to whether people are morally responsible thus appeared to be emotion (Nichols & Knobe 2007, Sarkissian et al. 2010).
Although this might seem to be good news for social accountability in a deterministic universe, other studies have found evidence to the contrary. Two-thirds of participants were of the opinion that people cannot be held responsible for their actions without free will, with 25% holding those who still believed they had free-will accountable in both emotionally charged and neutral situations and 8% only in the emotional cases (Feltz et al. 2009). One characteristic that stood out in people's responses was extroversion which can also be associated with social warmth and sensitivity (Feltz & Cokely 2009). As such, they may feel the pain of moral transgressions more acutely than others, and be more likely to hold people to account for what they have done. Descriptions involving psychological or environmental determinism rather than sheer neuronal determinism in the brain were treated with more attribution of personal responsibility, presumably because these situations involve acceptance of a sense of self.

Turning this whole picture around, In a paper surveying several studies (Clark et al. 2014) a key factor promoting belief in free will was a fundamental desire to hold others morally responsible for their wrongful behaviors, suggesting that free-will is a device we use to hold other people accountable for their actions and punish them to maintain a semblance of order in society protective to our fears of chaotic strife and exploitation – altruistic punishment based on self-deception.

Nahmias argues that instead of rendering conscious thoughts and decision-making irrelevant fictions, neuroscience could actually illuminate the biological basis of free will - belief in free will doesn't depend on having a soul, but on feeling in control of "your" actions - an aim which is central to the thrust of this article.

8: Unraveling the Readiness Potential and other Oddities

In a classic paper, Wegner and Wheatley (1999) made the revolutionary proposal: The experience of intentionally willing an action, they suggested, is often nothing more than a post hoc causal inference that our thoughts caused some behavior. The feeling itself, however, plays no causal role in producing that behavior.

Supporting evidence for what is termed "choice blindness" has come from a study in which participants failed to notice conspicuous mismatches between their intended choice and the outcome they were presented with, while nevertheless offering introspectively derived reasons for why they chose the way they did (Johansson et al. 2005).

Perhaps, consistent with the illusion of seeing the apparent motion of a dot before seeing that dot reach its destination (www.michaelbach.de/ot/colorPhi/index.html), in the very moments that we experience a choice, our minds are rewriting history, fooling us into thinking that this choice—which was actually completed after its consequences were subconsciously perceived — was a choice that we had made all along.

Some aspects of our conscious experience of the world do make it possible for the brain to sometimes construct a present that has never actually occurred. In the "flash-lag" illusion, a screen displays a rotating disc with an arrow on it, pointing outwards. Next to the disc is a spot of light that is programmed to flash at the exact moment the spinning arrow passes it. Instead, to our experience, the flash lags behind, apparently occurring after the arrow has passed (Westerhoff 2013). One explanation is that our brain extrapolates into the future, making up for visual processing time by predicting where the arrow will be, however, rather than extrapolating into the future, our brain is actually interpolating events in the past, assembling a story of what happened retrospectively, as was shown by a subtle variant of the illusion (Eagleman and Sejnowski 2000). If the brain were predicting the spinning arrow's trajectory, people would see the lag even if the arrow stopped at the exact moment it was pointing at the spot. But in this case the lag does not occur. If the arrow begins stationary and moves in either direction immediately after the flash, the movement is perceived before the flash. How can the brain predict the direction of movement if it doesn't start until after the flash? The perception of what is happening at the moment of the flash is determined by what happens to the disc after it. This seems paradoxical, but other tests have confirmed that what is perceived to have occurred at a certain time can be influenced by what happens later. This again does not show that the brain is unable to anticipate reality because it applies only to very short time interval spatial reconstructions by the brain, which would naturally be more accurate by retrospective interpolation.
In a more recent study (Bear & Bloom 2016), participants were repeatedly presented with five white circles in random locations and were asked to quickly choose one of before one lit up red. If a circle turned red too fast, they could indicate they ran out of time, otherwise, they indicated whether they had chosen the red circle (beforehand) or had chosen a different one. Unbeknown to the participants, the one that lit up red on each trial was selected randomly. Hence, if participants were truly completing their choices when they claimed to be completing them—before one of the circles turned red—they should have chosen the red circle in 20% trials. Yet they reported performance exceeding 30% when a circle turned red especially quickly. This suggests that participants’ minds had sometimes swapped the order of events in conscious awareness, creating an illusion that a choice had preceded the color change. Performance dropped to near 20% when the delay was long enough that the subconscious mind could no longer play this trick in consciousness and get wind of the color change before a conscious choice was completed. These findings suggest that we may be systematically misled about how we make choices, even when we have strong intuitions to the contrary.

The illusion can simply be explained by appeal to limits in the brain’s perceptual processing, which only messes up at the very short time scales measured in our (or similar) experiments and which are unlikely to affect us in the real world. A more speculative possibility is that our minds are designed to distort our perception of choice and that this distortion is an important feature (not simply a bug) of our cognitive machinery. More broadly, this illusion may be central to developing a belief in free will and, in turn, motivating punishment as we saw in the previous section.

The "Passive Frame Theory" (Morsella et al. 2016, Hubbard et al. 2011, 2013) suggests that the conscious mind is like an interpreter helping speakers of different languages communicate. Consciousness, in Morsella’s theory, is more reflexive and less purposeful than conventional wisdom would dictate. Because the human mind experiences its own consciousness as sifting through urges, thoughts, feelings and physical actions, people understand their consciousness to be in control of these myriad impulses. But in reality, Morsella argues, consciousness does the same simple task over and over, giving the impression that it is doing more than it actually is. 

The interpreter presents the information but is not the one making any arguments or acting upon the knowledge that is shared, similarly, the information we perceive in our consciousness is not created by conscious processes, nor is it reacted to by conscious processes. Consciousness is the middle-man, and it doesn’t do as much work as you think.

According to Morsella’s framework, the “free will” that people typically attribute to their conscious mind - the idea that our consciousness, as a “decider” guides us to a course of action - does not exist. Instead, consciousness only relays information to control "voluntary" action, or goal-oriented movement involving the skeletal muscle system.

For the vast majority of human history, we were hunting and gathering and had more pressing concerns that required rapidly executed voluntary actions. Consciousness seems to have evolved for these types of actions rather than to understand itself.

In a study by the group 32 SF State students were taught or reminded how to rearrange words in pig latin (removing the first letter of a word and adding it in front of "ay" at the end of the word). They were then told to not perform this transformation in their heads when prompted with another set of words, but to press the spacebar during the computerized test if they did perform the transformation unintentionally. The students involuntarily created pig latin words in 43 percent of the word trials they received, “and these people were trying actively to not have the effect occur, so this high-level process is going against the intentions of the subjects in the study," Morsella said.

But all of the above theories are dealing with a brain that we know needs to perform subconscious processing to enable a stream of predictive information for conscious attention to selectively spotlight in real time to enable split-second judgments necessary for survival. There thus has to be a trade off between conscious attention doing all the work, slowing the process down and a degree of constructive integration that arranges the scenario into the anticipated sequence. We also know some conscious decisions are strongly shaped by ongoing, or emerging, circumstances, so sub-conscious processing is essential for ‘instantaneously' defining the context. The real test of the role consciousness is the space-time causality question of whether subconscious processing is selected by
Many aspects of brain function display dynamic features, which show the brain is focused on attempting to anticipate ongoing events. When a cat is dropped into unfamiliar territory, the pyramidal cells in its hippocampus become desynchronized and hunt chaotically, in what is called the orienting reaction, until the animal discovers where it is, or gains familiarity with its environment, when phase synchronization ensues (Coleman & Lindsay 1975). In a similar manner, the EEG will show a desynchronized pattern when a subject is listening for a sound which is irregularly spaced, but will fall into a synchronized pattern if the subject can confidently anticipate when the next sound is going to occur (fig 4Af). Greater capacity to shift synchronization rather than it remaining locked has been associated with higher IQ (Jung-Beeman 2008).

This kind of processing is consistent with a computational process involving transitions from chaos to order. The chaotic regime acts both to provide sensitive dependence on any changes in boundary conditions such as sensory or cognitive inputs, at the same time as preventing the dynamical system getting caught in a suboptimal attractor, by providing sufficient energy to cause the process to fully explore the space of dynamical solutions. Artificial neural net annealing and quantum annealing both follow similar paradigms using random fluctuations and uncertainty to achieve a similar global optimization. Such a dynamic also allows for ordered deductive computation, but enables the system to evolve chaotically when the ordered process fails to arrive at a computational solution. In combination with quantum entanglement and massively parallel weak quantum measurement, as we have seen, this process may enable the ongoing conscious state to be anticipative.

However, a historical experiment suggested that, far from anticipating reality in real time, conscious awareness of a decision might actually lag behind unconscious brain processing which is already leading to the decision, although being placed by subjective experience at the time the conscious decision was made. In 1983, neuroscientist Benjamin Libet and co-workers (1983, 1989) asked volunteers wearing scalp electrodes to flex a finger or wrist. When they did, the movements were preceded by a dip in the signals being recorded, called the "readiness potential". Libet interpreted this RP as the brain preparing for movement. Crucially, the RP came a few tenths of a second before the volunteers said they had decided to move. Libet concluded that unconscious neural processes determine our actions before we are ever aware of making a decision. Since then, others have quoted the experiment as evidence that free will is an illusion - a conclusion that was always controversial, particularly as there is no proof the RP represents a decision to move.

Fig 6: (a) Simulated stochastic accumulator readiness potential and empirical results verify the accuracy of the model (Schurger et al 2012). (b) The interruptus experiment also confirms fast responses to surprise interruptions were preceded by a slow negative-going buildup in the EEG signal, just as the accumulator model predicted (Schurger et al 2012). This buildup even preceded the randomly-delivered surprise cues, which does not make sense if the buildup is supposed to be preparatory, since the brain cannot prepare for a movement that it does not know it is going to make (Schurger & Uithol 2015). (c) Stimuli for consciously perceived stimulus and otherwise (Schurger et al 2010). (d) Evidence for both stability (consistency within a trial) and reproducibility (consistency between trials) in consciously perceived stimuli or otherwise (Schurger et al 2015).
How long before the awareness of intention to move precedes the perception of actual movement also varies extensively between individuals. Meditators in a study had a longer gap in time between when they felt like they decided to move their finger and when it physically moved - 149 compared with 68 milliseconds for other people and for an easily hypnotisable group it was 23 milliseconds (Lush, Naish & Dienes 2016).

With contemporary brain scanning technology, Soon et al. (2008) were able to predict with 60% accuracy whether subjects would press a button with their left or right hand up to 10 seconds before the subject became aware of having made that choice. This doesn't of itself negate conscious willing because these prefrontal and parietal patterns of activation merely indicate a process is in play, which may become consciously invoked at the time of the decision, and clearly many subjects (40% of trials) were in fact making a contrary decision. Neuroscientist John-Dylan Haynes, who led the study, notes: "I wouldn't interpret these early signals as an 'unconscious decision', I would think of it more like an unconscious bias of a later decision" (Williams 2012). Moreover how early a perceived intention appears in consciousness varies extensively between individuals with different sensitivities. Meditators experience this.

The assumption that Libet's RP is a subconscious decision has been undermined by subsequent studies. Instead of letting volunteers decide when to move, Trevena and Miller (2010) asked them to wait for an audio tone before deciding whether to tap a key. If Libet's interpretation were correct, the RP should be greater after the tone when a person chose to tap the key. While there was an RP before volunteers made their decision to move, the signal was the same whether or not they elected to tap. Miller concludes that the RP may merely be a sign that the brain is paying attention and does not indicate that a decision has been made. They also failed to find evidence of subconscious decision-making in a second experiment. This time they asked volunteers to press a key after the tone, but to decide on the spot whether to use their left or right hand. As movement in the right limb is related to the brain signals in the left hemisphere and vice versa, they reasoned that if an unconscious process is driving this decision, where it occurs in the brain should depend on which hand is chosen, but they found no such correlation.

Schurger and colleagues (2012) have elucidated an explanation. Previous studies have shown that, when we have to make a decision based on sensory input, assemblies of neurons start accumulating evidence in favor of the various possible outcomes. A decision is triggered when the evidence favoring one particular outcome becomes strong enough to tip its associated assembly of neurons across a threshold. The team hypothesized that a similar process happens in the brain during the Libet experiment. They reasoned that movement is triggered when this neural noise generated by random or chaotic activity accumulates and crosses a threshold. The team repeated Libet's experiment, but this time if, while waiting to act spontaneously, the volunteers heard a click they had to act immediately. The researchers predicted that the fastest response to the click would be seen in those in whom the accumulation of neural noise had neared the threshold - something that would show up in their EEG as a readiness potential. In those with slower responses to the click, the readiness potential was indeed absent in the EEG recordings. "We argue that what looks like a pre-conscious decision process may not in fact reflect a decision at all. It only looks that way because of the nature of spontaneous brain activity." Both these newer studies thus cast serious doubt on Libet's claim that a conscious decision is made after the brain has already put the decision in motion, leaving open the possibility that conscious decisions are actually made in real time.

Schurger and Uithol (2015) specifically note the evidence of a sensitively dependent butterfly effect (London et al. 2010) as a reason why nervous systems vary their responses on identical stimuli as an explanation for why it could be impossible in practice to set out a deterministic decision making path from contributory systems to a conscious decision, supporting their stochastic accumulator model.

9: Prescience - Three Personal Experiences

To fathom situations where real time anticipation may have occurred without any prevailing causal implication leading up to it, we need to turn to rare instances of prescience with no reasonable prior cause. These kinds of events tend to be rare, apocryphal and lack independent corroborolation, like stories of telepathic connection or the sense of foreboding that a relative has died, which later receives
confirmation. Paradoxically some of the most outstanding examples can come from alleged precognitive dreaming rather than the waking state, which tends to be more circumscribed by commonsense everyday affairs.

As a student, I picked up and read “An Experiment with Time” by J W Dunne (1929), which outlined double blind experiments in which the dream diaries led to as many accounts linking to future events in the people’s lives as they did to past experiences. A few weeks later I had a horrific double nightmare that I was being agonizingly stung. In the dream it was a spider which I couldn’t remove because it would leave poison fangs inside me (as a bee or wasp does) and in the second dream it had returned to sting me again when I was distracted, as one often is in dreams. At eight in the morning as my wife woke, I recounted the nightmares in detail to her, before falling asleep again. About an hour later I was stung wide-awake by a wasp that had flown in the window, which my wife had opened after getting up. Suddenly the dream I had reported to my wife had become a reality. A skeptic might try to interpret this as a coincidence - merely an application of Bayes theorem of conditional probabilities - but the complete absence of any such dream before, drove home to me that dreaming, and by implication waking experiences too, have properties violating classical causality. The fact that it closely followed on reading the book gave this prescience an added dimension, capped by the fact that the scientist providing an introduction to the work was none other than Arthur Eddington, who had suggested quantum uncertainty of the synaptic vesicle as a basis for free will.

My dreams have had other paradoxes to do with multiple concident streams of consciousness in time. The first time I successfully explored lucid dreaming, using the technique of trying to remind myself to look at the backs of my hands, I finally succeeded with a sense of dread. As I pulled my hands up to look, I was standing on a beach promenade and there was an enigmatic woman like a character out of Carlos Casteneda's allegories staring at me. All of a sudden there was a gust of wind from the sea and I could sense every single droplet hitting my flimsy Indian shirt. It was a riveting experience of itself to see and to experience every separate droplet. I looked up at the sky and the layers of the clouds and I realized there was no way back to the world of waking life. I ran to the woman grabbing her by the shoulders and staring deeply down into her dilated eyes expressed the ultimate question - "Where is the way back?". She just smiled and shook her head - you have always known there is no way back to
Ixtlan. But at the same time I was having a second experience coincident with the gust of wind. The energy released when I looked at my hands had launched me upwards with an ever increasing acceleration - the kind of relentless levitation that leads to effortless flying dreams. But there was a third stream of consciousness as well. An out-of-the-body experience that I was bobbing gently, floating just below the ceiling above my bed looking down at my body saying to myself "No it's alright you are just down there in the bed asleep!". At this point, like a lot of lucid dreaming which arises on the energetic cusp of basal brain activation, I suddenly came wide awake in a state of shock and awe at what had just happened.

These experiences raise a series of questions about coincidence and Carl Jung’s (1952) notion of synchronicity, the idea that seemingly unrelated events and experiences may be caught up in a deeper correspondence, as reminiscent of quantum entanglement as phase coherence in brain processing appears to be. Many people’s personal accounts attest to a currency of such prescience.

Fig 8: Dreaming is conventionally associated with periods of REM, or rapid eye movement sleep in which the EEG closely resembles waking brain waves, rather than the slow, high amplitude waves of deep sleep, but the above EEG portraits show that dreaming is more closely associated with high frequency activation of key hotspots involving visual and other areas in a manner that can occur in both REM and NREM sleep (Siclari et al. 2017).

A month before the twin towers fell in New York I wrote a song and posted the lyrics online. They contained several prescient lines, one invoking jihad: “When it comes to the final struggle, jihad of the biosphere, there’s only one true rogue nation - the great American shaitan”. The lyrics continue with a lament for the dark canyons of lower Manhattan among the fallen towers; “walking in the twilight, down in the valley of shadows”, and then the plane “We’ll fly so high well pass right to the other side and never fall in flames again”. Then I watched live in prescient horror as one of the two planes struck the tower and passed right through, coming out in a burst of flames on the other side. The lyrics continue with the genocide - “when will you comprehend the damage you have wrought in your indiscretion, can we undo the death trance you have set in motion?” The last line closed with “Can we bear it all again? It thus presciently echoed the Mayor of New York’s own words on TV “This … will be more than any of us can bear”. I was singing about a mass extinction of life, but why the Islamic jihad, meeting Icarus descending?
All shamanic practitioners have to answer a question of coincidence. When curing a sick person, it is not to explain why the person has contracted tuberculosis or leprosy i.e. that the respective bacteria were infectious, or their immune system was weakened, but why this person caught this sickness at this particular time.

In the process of writing this paper, I awoke from a dream in which I was gazing at a pregnant woman, touching her on the shoulders, absorbed in the glowing beauty and fecundity of her pregnant state. Then when I sat down to look at the news next morning, I found myself watching this time-lapse video clip taken of a woman’s 40 week pregnancy by photographer, Nicole Gourley: http://www.nzherald.co.nz/lifestyle/news/video.cfm?c_id=6&gallery_id=140135&gal_objectid=11183174

Scientific studies of precognition have had mixed results. Darryl Bem and coworkers (2011) reported precognitive effects in linked subjects, creating a stir in the academic community, but four later studies, three of which were reported together (French Ritchie, Wiseman, French 2012) failed to replicate these results, emphasizing the ephemeral nature of scientific research in this area.

Telepathy, like prescience, is a phenomenon that has an elusive presence in human anecdotal accounts, which are difficult to replicate reliably at above chance levels, leading some to conclude it is another example of Bayes theorem on conditional probabilities where there is mental bias towards affirmation of a sporadic phenomenon, due to counting only the wins.

Many cultures report accounts where individuals are intuitively aware of a relative for example having passed away. The space and time-spanning nature of the Aboriginal dreamtime and the shamanic world-view generally, represent perspectives in which such mental connections can be perceived as intrinsic.

On my first sabbatical, while in London, I had a transient relationship with an ex-student of mine. After a few weeks we parted ways, heading in different directions around the planet - she heading East through Europe, while I flew West to the US. Several months later, back in the antipodes, I was at an evening performance and suddenly had the most uncanny sensation that she was somehow present right there in the room. This caused me to turn around 180 degrees and there she was directly behind me. Key here is the complete separation of two parties who have become intuitively acquainted and make no further contact until the event occurs leaving the mind clear of confounding stimuli, but it could also be regarded as a case of precognition, rather than telepathy.

Alexandra David-Neel, reported the technique of mutual meditation with implied telepathic contact, which she first witnessed in the communication between a disciple and his Lama guru (Foster & Foster 1998): “The Gomchen and Alexandra would sit together in silence in a darkened room, focused on the same object, the aspects of a deity for example. After a time the Gomchen would ask what she had seen and if it were the same as his projection. The goal was an entirely unified mental state. Later, camping in the wilds, Alexandra would record instances of the use of telepathy at great distances, of receiving messages the Tibetans termed “written on the wind.”
The concept of telepathy has been repeatedly explored in various forms of experiment. Classic Psi experiments by J B Rhine, Pearce-Pratt were performed using symbolic flash cards (Radin 2009), and those of Upton Sinclair and Stanley Krippner et al. (1993) the latter using an entire Greatful Dead concert’s attendees, involved the transmitter making drawings or the crowd watching an image which the receivers attempted to replicate.

Duane (1965) reported an experiment in which spatially-separated identical twins had coupled changes in their EEGs in which one twin closing their eyes elicited an alpha rhythm in the other, consistent with some form of direct mental or physical connection. A similar follow-up experiment (Gioldini et al. 2015) showed slight changes in the filtered alpha rhythm of the ‘receiving’ twin which was deemed statistically significant on careful Monte Carlo analysis.

Grau C et al. (2014) have reported success at transferring information from a subject in France to another in India, but here the EEG signal of the ‘transmitter’ was transcribed into a digital code sent over the internet and transformed into non-invasive stimulation the receiver succeeded in using to distinguish one of two signals ‘ciao’ or ‘hola’, so this experiment says nothing about purely spontaneous interactions.

10: Anticipating the Multiverse

The central enigma of quantum reality is the causality-violating reduction of the wave packet. We see this in Schrödinger’s cat paradox (fig 5A), a cat set to be killed by a radioactive scintillation breaking a cyanide flask. In quantum reality the cat is both alive and dead with differing probabilities, but in our subjective experience, when we open the box the cat is either alive, or dead, with certainty. Reduction also occurs when a wave is absorbed as a particle in an interference experiment (fig 5C) Quantum mechanics appears to preserve all the conceivable outcomes in parallel superposition. Not only is Schrödinger’s cat both alive and dead, but Napoleon has both won and lost the battle of Waterloo. Many of these strategic outcomes, indeed all accidents of history, depend on uncertainties that go, in principle, right down to the quantum level.

There is continuing debate among physicists about how and where in the causal chain, reduction of the wave packet actually occurs. While decoherence theories suggest this may occur simply through interaction of single or entangled states with other particles, the wave function of the entire universe is in effect one single multi-particle entangled state and so the whole notion of a single line of history unfolding seems to be something only our conscious awareness is able to determine.

Several of the founding quantum physicists adhered to this view. John von Neumann suggested that quantum observation is the action of a conscious mind and that everything in the universe that is subject to the laws of quantum physics creates one vast quantum superposition. But the conscious mind is different, being able to select out one of the quantum possibilities on offer, making it real - to that mind. Max Planck, the founder of quantum theory, said in 1931, "I regard consciousness as fundamental. I regard matter as derivative from consciousness." Werner Heisenberg also maintained that wave function collapse - the destruction of quantum superposition - occurs when the result of a measurement is registered in the mind of an observer. In Henry Stapp’s words we are "participating observers" whose minds cause the collapse of superpositions. “Before human consciousness appeared, there existed a multiverse of potential universes. The emergence of a conscious mind in one of these potential universes, ours, gives it a special status: reality” (Brooks 2012). This is a complement to the anthropic principle of physical cosmology in which conscious observers are selective boundary conditions on the laws of nature in the universe (Barrow & Tipler 1988).

Two experimental studies supporting the observer having a critical role in collapse are the delayed-choice quantum eraser (Kim et al. 2000) in which a careful arrangement of detectors using a pair which are simultaneously entangled with another pair whose paths are only detected later pass through a detector which cannot distinguish their paths leading to a superposition/ However the later detection of their entangled siblings in a manner which can also be subsequently erased shows that it is the observers later knowledge of the pair, not whether there was a detector at one of the slits that determines collapse. A second experiment (Ma et al. 2012) involves delayed-choice entanglement swapping. Here, entanglement can be “produced a posteriori, after the entangled particles have been
measured and may no longer exist. A third observer by making a choice of detector determines which arrangement two other observers experience of an entangled pair shows decisively that a change induced by a third-party observer can alter the observation of an entangled pair.

Thus another idea of the role of subjective consciousness is that it is a way the universe can solve the super-abundance of multiverses to bring about a natural universe in which some things do happen and other things don’t. One of the most central experiences of our transient mortal lives is historicity – that there is a line of actual history, in which each of us, however small and insignificant our lives, are participating in bringing the world into actual being, albeit sometimes rather diabolically in times of exploitation, but with some reflection on our own transience, perhaps reaching towards a more enlightened existence, in which the passage of the generations is able to reach towards a state where the universe comes to consciously understand itself even more deeply and completely.

The idea that consciousness collapses the wave functions of the universe leads to some counter-intuitive conclusions, because it implies that the consciousness itself is inducing the historical collapse that is in turn causing my brain to have a memory of this process.

On the other hand, the notion of the brain using entanglement provides a paradigm for resolving many of the contradictory situations that arise when classical causality is applied to anticipatory processes. A premonition being either a cause of a future event or caused by it leads to contradiction, which is resolved in the space-time hand-shaking of the entanglement.

The process goes like this: Memory systems are used to form a model of the quantum collapsed history already experienced, which is sequentially stored in the hippocampus and then semantically re-encoded into the cortical feature envelope so that it can be interrogated from any contingent perspective. The conscious cerebral cortex contains a dynamical system of entangled states, which together envelop a space-time region extending a limited distance into both the past and future - the quantum-delocalized present. The cortical envelope thus maintains a state of context-modulated sensitively-dependent dynamic excitation which generates our conscious sense of the present moment by encoding the immediate past and future together in a wave function representation entangled in the global coherent dynamic.

The ‘quantum present’ would extend over the entangled life-time of the coherent excitations, incorporating quantum-encrypted information about the immediate past and future of the organism into the current state of subjective experience. The quantum present provides the loophole in classical causality that permits intentional will, or free-will to alter brain states and hence physical states in the world through behavior, as an effect of the entanglement. The experiencing subject perceives they are making an autonomous decision. An external observer will simply see a brain process sensitively dependent on quantum uncertainty bifurcating into a defined outcome.

It may also be possible for the brain to encode entangled states in a more permanent form. Highly active brain states have been shown in fMRI studies to elicit changes in cerebral activation lasting over 24 hours (Heaven 2013, Harmelech et al. 2013). Long-term potentiation and memory processes are in principle permanent and may involve epigenetic changes (Levenson & Sweatt 2005).

11: Entanglement and Intentional Will in the Unfolding Universe

Many scientists see modern neuroscience as supporting the notion that the brain operates almost entirely mechanically, and that consciousness, reasoning and free will have almost no effect. While the prevailing assumptions of scientific thought are based on a physical materialism that asserts that the conscious mind cannot affect physical brain function, this view has not been shared by several of the founders of modern neuroscience. The notion of the conscious mind acting on the body to induce actions and complex behavior has been described by funding brain researchers, from David Eccles to Roger Sperry, as an 'act of psychokinesis.'

Eccles followed Karl Popper's triune notion of a three-aspect cosmos in which mental experiences and decisions, physical systems composed of quantum and molecular structures, and abstract knowledge, form three interacting components. Initially Sperry agreed with Popper and Eccles, like them, rejecting materialism and reductionism about the mind and brain. In 1966 he began referring to himself as a
"mentalist." Sperry's idea of emergent downward causal control gave the subjective experience of consciousness (regarded as an emergent property of brain activity) a causal role in the control of brain function. While this was still a causal deterministic model and did not involve quantum uncertainty, it did centrally involve mind as experienced by the observer acting on matter in the form of physical brain dynamics. Investigating split brains, Sperry found what he considered science-based examples of ideas, not just chemical events, running the show. From this he developed the idea that the conscious mind and the physical brain were really part of "a single unified system extending from sub-nuclear forces at the bottom up through ideas at the top. Mind and consciousness are put in the driver's seat, as it were: They give the orders, and they push and haul around the physiology and the physical and chemical processes as much as or more than the latter processes direct them." What this meant to Sperry was that free will, and responsibility, were no illusion. "It is possible to see today," he believed, "an objective, explanatory model of brain function that neither contradicts nor degrades but rather affirms age-old humanist values, ideals, and meaning in human endeavor" - the notion that we are autonomous conscious beings capable of exerting a mental control over our own and other people's fates.

We can see that quantum uncertainty and chaotic sensitive dependence do provide a loophole for mental decisions to induce physical outcomes in the form of a bifurcation of an unstable brain state, which from the subjective point of view, is perceived to be the conscious experiencer coming to a decision under salient circumstances and choosing a course of action, which is then played out in brain function, and ultimately physical behavior.

A theory which is in effect a description of how the entanglement within the cosmic wave function might contribute to a fundamental form of free-will (Siegfried 2014) has been proposed by Scott Aaronson (2013), who advocates the unpredictability description of free-will and uses it to develop a description of the universe explaining how the early universe may have given rise to unpredictable degrees of freedom which could open another quantum basis for free-will:

*I advocate replacing the question of whether humans have free will, by the question of how accurately their choices can be predicted, in principle, by external agents compatible with the laws of physics.*

He cites a form of unpredictability which is more fundamental than mere statistical uncertainty which he calls "Knightian freedom" after the economist Frank Knight, who wrote about uncertainty that can't be quantified with probabilities.

A form of Knightian freedom might be possible thanks to the no-cloning theorem, which asserts that cloning a quantum is equivalent to making a (destructive) measurement. He speculates that the initial conditions of the universe included elements of unpredictability that prevent equations from ever forecasting every single aspect of the future. - a certain strong kind of physical unpredictability: a lack of determination, even probabilistic determination, by knowable external factors. He suggests that floating throughout the universe are qubits that have never been measured by any process, retaining their original freedom and might have Knightian uncertainty. The presence of such "freebits" with quantum-mechanical degrees of freedom preventing their cloning makes predicting certain future events — possibly including some human decisions — physically impossible, even probabilistically and even with arbitrarily advanced future technology. Our ignorance about the freebits would ultimately need to be traceable back to ignorance about the microstate of the early universe. Thus it’s possible that humans will never become as predictable as digital computers, because of chaotic amplification of unknowable microscopic events. He likens this imaginatively to:

*A 'quantum pixie-dust' left over from the Big Bang ... gets into our brains and gives us the capacity for free will. I don't see that any of it is ruled out by current scientific understanding - though conceivably it could be ruled out in the future.*

Another cosmological description by Martin Green (2003, 2014) involves a hidden "Bare World" which he sees as the ultimate reality. The Bare World precedes all ordinary notions of the "Real World" that people perceive and study in physics. The Real World emerges from Bare World as a description dressed up in Newtonian, Einsteinian or quantum clothing. Observers, matter, time, all come into existence within Real World. None of these exist within Bare World, which is pre-physical. It is the "foundation for all that might ever be perceived in the universe". Since it contains much more
information than Real World can ever accumulate, the laws of Real World do not constrain Bare World from introducing surprises.

Human free will is therefore not constrained by the laws of physics - which simulate, and thus represent, aspects of emergent reality and apply only to Real World, not Bare World. Free will is a manifestation of the ability of conscious observers to influence the order in which previously unknown information about Bare World is consistently incorporated into their reality.

We actively participate in our perceived reality. We control our bodies and the world we inhabit sufficiently to collectively investigate, formulate, record, and debate fundamental ideas regarding the world. We refine our models by acting on the world and sensing its response. And so the future is not strictly determined by the past. Humans can shape it. Within bounds - consistent with our limited present knowledge, a prohibition on revising history, and severely limited scope and capacity — we are able to consciously influence our future. Contrasting with the perception that we can act independently on the world is the obvious requirement for mutual consistency of the perceptions of all observers. Such consistency can be understood only if consciousness is actually a single, global phenomenon.

Fig 10: Cosmological features of Life: The symmetry-breaking of the forces of nature (a) leads to the hierarchical structure of molecular matter (b). High-energy multiple bonded molecules such as HCN (c) result in polymerizations to heterocyclic products leading to RNA (d) and proteins (e) resulting in fractal structures. With the advent of nucleic acid replication these become encoded on the structure of tissues (f, g) leading to evolution of higher organisms (i) with the formation of the eucaryote cell (h) through endosymbiosis between an archote and a proteobacterium to form the nucleated eucaryote cell with mitochondria. Evolution of life is thus an interactive Σ point - paradise on the cosmological equator (j) - as significant as the α origin and alternative Ω culminations. Universality in evolution is expressed in homeotic genes (k). The broadening of narrow genetic selection arises from the evolution of emotions (l) showing micro-expressions for sadness, happiness, fear, anger, contempt, disgust, and surprise (Tim Roth).

But just how far does the notion of mental causation go? If we can exert psychokinetic control over our arm movements to give the thumbs up to personal autonomy, or just to wave out to a friend, are there potentially other manifestations of this mental-physical interaction?
The lessons of entanglement as a possible central process in anticipating threats to survival extends readily to other such effects, but at the same time places potential limitations on their action. The key lesson of pair-splitting experiments is that, while entangled states are correlated, we can't use them to send locally-Einsteinian causal information between the entangled components. Thus we might well find ourselves having an ad-hoc evolutionary survival advantage through our conscious experience, while never being able to prove this in a set of causally verifiable experiments.

By the same token any other effects of mental causation on material phenomena would not be causally controllable because, although changes to the entanglement arising from a mental decision might ramify throughout the cosmic wave function, a change in one component, i.e. one's mental state, cannot necessarily be used to causally induce some other physical manifestation, because of the barrier to causal determinacy in the entanglement.

This could mean that our mental decisions might potentially have other effects, both on other people's mental experiences, and on diverse physical states in the universe across space-time, but not necessarily in a way we can determine or demonstrate conclusively. Thus notions of mental action, from telepathy and prescience to poltergeists and other 'super-natural' phenomena, would remain unverifiable anecdotal occurrences, which could not be replicated scientifically to produce an experimental verification, as exemplified by the failure to replicate Darryl Bem's studies into claimed precognition (French 2012), and other parapsychology experiments.

This is a field ripe with hopeful psychic monsters. Rupert Sheldrake (1981, 1988) for example has developed the notion of 'morphic resonance' - that "memory is inherent in nature" and that "natural systems, such as termite colonies, pigeons, orchid plants, or insulin molecules, inherit a collective memory from all previous things of their kind". He proposes that it is also responsible for "telepathy-type interconnections between organisms". However, this idea, which does have 'resonances' with the notion of entanglement, may itself be an oversimplified quasi-causal misrepresentation of how nature actually works.

This however does not mean that we should conclude that all such phenomena are non-existent and that such non-ordinary phenomena are just wishful fantasies. The evolutionary emergence of conscious sentence in organismic brains itself suggests that seemingly materialistic interactions among genetic and other molecules in simple living systems have somehow given rise to an emergent phenomenon having existential status even more immediate than the material phenomena from which it emerged, since we access the material world only through our conscious sensory experience. Biogenesis likewise remains an enigma whose processes, from simple high-energy molecules such as HCN, through RNA and proteins, to the first organisms (King 2002) depends on emergent properties hidden in the non-linear interactions among the four forces of nature that occur at the quantum level.

Likewise the evolution of emotional experience and expression in mammals has given rise to a new paradigm in sociobiology leading to human culture, which broadens the narrow genetic bases of genetic selfishness, moderated by kin and reciprocal altruism into a complex social interplay of nuanced extremes from love to hate, happiness to despair, intimate trust to jealousy and paranoia, contempt, anger, disgust, fear, excitement, intimacy, compassion, forgiveness and all the social interactions they provide, giving not just humans but all mammals a more oceanic form of social participation. Despite the seven deadly sins and our reluctance to be ruled by our worldly desires, it is precisely these emotional nuances that have made the world a place in which love and caring form a basis of resolution of our belonging in an often perilous world of tooth and claw, and it is the higher virtues of these emotions which people define as the guiding light of spiritual illumination.

Evolution, while we conceive it as a molecular process of conservation and mutation of genes, is also threaded through the life and reproductive investments of participant organisms and in the context of higher animals in all the (conscious) decisions they make to the extent that what appears to be simply an adventitious molecular dance improbable in the extreme, a little like a monkey playing Beethoven's Moonlight Sonata, is an emergent manifestation of a universe coming to know itself ever more deeply in a redemption of the mechanistic fallacy that we are merely a meaningless collocation of atoms.

Thus it may be that the very conscious decisions we make as individuals, not only through our survival and reproduction, the examples they set for others and the knowledge they provide in the cultural
epoch, but also through the unseen effects of the entanglement, extending far and wide across the universe, may be a key part of the way the universe as a whole comes to unfold its flowering of knowing. This may both aid the flowering of life in the universe over time and a deeper meaning in space-time that stands even when the Earth, the human race and our future forebears, become extinguished in the nemesis of the solar system as the sun transforms into a red giant, or on a cosmological scale, as the universe itself enters the eventual big crunch, or heat death. In this sense, what is achieved may ultimately be achieved eternally in space-time by having occurred at some phase in the life of the universe, rather than life gaining meaning only because it will lead to further exponentiating outcomes in future.

References

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