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Abstract

There are many interpretations of what consciousness is. In the past decade materialist and reductionist theories have gained in popularity as many neurological correlates of consciousness have been identified experimentally. This article presents a neurogenetic account of the underpinnings of neuron-based consciousness. In this paradigm, human consciousness is supported by genes that are involved in three distinct neurogenetic phases: 1) the emergence of neuron-based consciousness, 2) the continuum of neuron-based consciousness, and 3) the neurodegeneration of human consciousness. The methodology implemented to establish these three neurogenetic phases was a systematic search and evaluation of genes that have been proven to support an active role in one or more of these three phases. This article demonstrates that there is a substructure of gene-based correlates that functions in the three neurogenetic phases. These phases work in tandem with the conscious experience. Consequently, it is established that explanations of human consciousness that rely solely on regions of the brain and neurons are deficient without taking into consideration the neurogenetic element of human consciousness. This presentation of the neurogenetic dimensions of human consciousness is the first of its kind.

Introduction

There are many neural theories of consciousness that focus on neural correlates of consciousness (NCC). A framework of consciousness based on the NCC was first proposed by Francis Crick and Christof Koch (Crick & Koch 2003). In this proposal regions of the brain are active in tandem with the conscious experience. Much research has been done at this level of the neurobiological explanation of human consciousness and consequently several NCC have been recognized. Some of the NCC have been summarized in several articles. For example, in the conference report on the Towards a Science of Consciousness Conference 2012, some of the NCC were summarized (Grandy 2012a):

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• Areas of the brain that are affected by anesthesia, e.g., the frontal cortex integration to the posterior parietal cortex.
• Decreases in cerebral integration and connectivity to other areas of the brain. This has been demonstrated in studies using PET scans and fMRI in patients with unresponsive wakefulness syndrome (also known as vegetative state) and in minimally conscious states.
• Frontoparietal connections in the brain that provide a global workspace. Two examples of these types of connections are: 1) lateral prefrontal and parietal cortices that function to provide external sensory awareness and 2) precuneal and mesiofrontal midline activity, which functions to provide an internal awareness.
• Thalamo-cortical regions that have been shown to provide critically emergent properties of collective widespread connectivity of consciousness.

These are just four examples, but there are many more NCC that are currently being researched. However, there is another very important neurobiological model that deserves to be mentioned here that is called the *dynamic core hypothesis*. This model was originally proposed by Nobel laureate Gerald Edelman and later collaborated on with many others, and eventually conjoined with the *global workspace hypothesis*. In the dynamic core hypothesis, consciousness is viewed as a dynamic, integrated, and multimodal process. This process is primarily supported by a dynamic infrastructure of cortical-cortical, cortical-thalamic, and thalamo-cortical neuron connections (Edelman 2011). Furthermore, the dynamic core supports that reentrant neural activity in the thalamocortical system can give rise to the conscious experience. The global workspace hypothesis merges the limited capacity of transient conscious content with the vast repertoire of long-term memory that is contained in the dynamics of the hippocampus. Collectively, these two hypotheses propose a purely mechanistic and neurobiological account of how the brain can generate conscious mental content. This serves as a clear example of what most would consider a materialist/reductionist neurobiological model to explain human consciousness, in addition to the four examples of NCC summarized earlier.

While observing the topography of human consciousness from the perspective of NCC and the dynamic core/global workspace hypotheses we may find ourselves asking if there is anything inscrutably beneath the labyrinth of the neurons. The answer inevitably is DNA. That is to say, underneath the functioning of every neuron, every compartmentalized brain region, and every multimodal integrated brain system there is the cascade of DNA, several RNA subspecies, proteins, and multiple epigenetic factors.
Hence a neurogenetic account of human consciousness will reveal a clandestine layer and a substructure beneath the brain and neurons. Within this substructure there is a dynamic fluidity of gene-based correlates that spans three neurogenetic phases that have a profound effect on the neurons and the brain, and consequently human consciousness. However, before a neurogenetic account of human consciousness can be explained. Another concept must first be discussed: the theory of DNA consciousness. For it is in the theory of DNA consciousness that the neurogenetic account of human consciousness finds its roots.

The Theory of DNA Consciousness

The original proposal of the theory of DNA consciousness was first published in 2006 (Grandy 2006). The theory has two parts. The first part proposes that the DNA molecule possess a degree of consciousness of its own, which is uniquely different from the degree of human consciousness. The second part of the theory of DNA consciousness maintains that DNA is responsible for giving rise to other higher degrees of consciousness, e.g., cellular consciousness and human consciousness. Therefore, DNA consciousness can be viewed as both a degree of consciousness and a type of proto-consciousness that gives rise to higher degrees of consciousness. This proceeds in an intentional and orchestrated manner. In addition to the original proposal of DNA consciousness, other subsequent proposals have been made. Next, a few of these proposals will be discussed in order to illuminate this theory.

Swedish physical biologist Carl Johan Calleman proposed in his book *The Purposeful Universe* that anything that originates or is generated from the Cosmic Tree of Life is not only life, but consciousness as well; this includes sequences of DNA (Calleman 2009). He further proposes that it was “DNA consciousness” that precipitated the primitive metabolisms of the first cells. This would imply that the appearance of the first functional cells was not a random event but rather a product of a proto-consciousness seen in the degree of DNA consciousness.

Chun Yang, a physician, has proposed similar ideas that support the theory of DNA consciousness. In his work he proposed that DNA defines consciousness in a Recording-Relating Principle (Yang 2010). According to this R-R Principle, the recording portion is that any life form can sense or detect the internal or external interactions, whereas the relating portion is that those life forms can integrate the sensed interactions within its molecular network, which consists of protein, RNA, and DNA, in order to generate consequential courses of action. At the DNA level, Yang surmises that stable and adjustable sequence regions in the genome provide limited consciousness to each species.
There is another idea that supports the theory of DNA consciousness. Developmental biologist Scott Gilbert points out in his *Questions: Introducing Developmental Biology* that as an embryo “You had to respire before you had lungs, digest before you had a gut, build bones when you were pulpy, and form orderly arrays of neurons before you knew how to think. One of the critical differences between you and a machine is that a machine is never required to function until after it is built. Every animal has to function even as it builds itself” (Gilbert 2014). Gilbert does not specifically use the phrase “DNA consciousness,” but is it possible that DNA consciousness affords the embryo the capability to function before being fully developed. This capability materializes in the form of master genes high in the developmental hierarchy, as it is these genes that perform all of the numerous vital functions during the development of the embryo.

Now that this review of proposals and ideas that support the theory of DNA consciousness has been completed, two main points must be made to conclude this section.

Firstly, DNA as a conscious entity can be objectified scientifically on three dynamic levels that rely on interactions. These three dynamic levels of DNA consciousness are: gene-gene interactions (also known as epistasis), interactions between other nucleic entities (e.g., several RNA species, viruses, mitochondria, and other cells), and interactions between DNA and the external environment (Grandy 2013a). All three of these levels have been validated with the support of several lines of evidence found within the scientific literature. In addition, many genes have demonstrated the ability to provide DNA, and on a larger scale the cell, with the characteristics of autopoiesis (Grandy 2011).

Secondly, when DNA gives rise to human consciousness, this takes place in three neurogenetic phases: the emergence of human consciousness, the continuum of human consciousness, and neurodegeneration (Grandy 2014). In the following sections it will be made clear that each of these three neurogenic phases are composed of gene-based neurogenic correlates of consciousness (NgCC). Just as NCC have been proposed to be involved in human consciousness, NgCC are also involved as they provide a substructure that is equally important. Next I will discuss and elucidate each of the three neurogenetic phases of human consciousness.

**Neurogenetic Correlates of Human Consciousness**

NgCC are defined as gene or gene products (e.g., transcription factors or splice-variants) that have an objective and causal effect on the process of consciousness (Grandy 2013b). While observing the neurogenic substructure involved in human consciousness, there is an
implicit acknowledgement that neuron-based consciousness runs in tandem with human consciousness in the form of NCC and the NgCC running in tandem underneath. It can be argued that human consciousness is more than just neurons, and for that matter more than just neurogenetics. However, it is not the goal of this article to defend the point of view of a materialist/reductionist interpretation of consciousness; rather it is to present an account of the neurogenetic substructures of human consciousness. Since this article is not intended for an audience of molecular biologists or neurogenetic experts, the explanation of each of the three neurogenetic phases will maintain a minimum of technical jargon and scientific detail. More specific detail can be obtained in the more lengthy publication, *The Three Neurogenetic Phases of Human Consciousness* (Grandy2013c). It is also important to acknowledge that although each of these three phases is discussed separately, they are to be visualized as a collective whole when considering a true account of the neurogenetic underpinnings of human consciousness.

**The First Neurogenetic Phase: The Emergence of Human Consciousness**

In the first neurogenetic phase, the emergence of the machinery that will allow human consciousness to be manifested (namely, the neurons and the brain) will take place. The genomic DNA yields a genetic blueprint, which among its many responsibilities determines the production of different types of neurons and ultimately brain morphogenesis. During the development of the human brain there are master genes that are activated high in the developmental hierarchy. These master genes induce other genes downstream that produce additional genetic cascades, which include the interactions between various transcription factors, species of RNAs, and proteins.

Two examples of master genes that are involved in the emergence of neuron-based consciousness will now be discussed. The Pax3 gene controls many other genes during development. For example, Pax3 inactivates TP53 during the closure of the neural tube (Wang 2011), regulates Hes1 and Neurog2 (Shunsuke 2011), and in collaboration with Pax7 it modulates Meis2 (Agoston 2012). Each gene controlled by Pax3 contributes to the production of neuron specification or the development of a brain region.

The Pax6 gene is also a master gene and is responsible for eye development, which is highly conserved throughout the animal kingdom (Callaerts 1997). One example of how Pax6 controls eye development is its influence over other genes that produce parts of the eye e.g. L-maf, Sox1, Prox1, and the crystalline genes (alpha, beta, and gamma) (Quiring 1994). Pax6 controls other genes as well, e.g., Neurog1, Neurog2, and Spag5 (Asami 2011; Wang 2011). Additionally, Pax6 also is critical to the neurogenic fates of neural
progenitor cells in the forebrain (Jang & Goldman 2011). Similarly to Pax3, the Pax6 master gene controls other genes that are critical to the development of brain regions and the specification of neurons.

There are many other genes that may not act as master genes but play pivotal roles in the morphogenesis of brain regions that are crucial to the first neurogenetic phase of human consciousness. For example, Hoxb4 and Hoxd4; in collaboration with retinoic acid receptor beta-gene, enforce the borders of rhombomeres 6 and 7 (Serpente 2005). A few more examples of genes that have a profound effect on the brain are Otx1 and Otx2. The Otx1 affects the overall development and size of the cerebral cortex (Ando 2008), and the Otx2 gene is essential for the identity and fate of the neuronal progenitor domains in the ventral midbrain (Puelles 2004). Consequently, it is evident that NgCC such as Hoxb4, Hoxd4, Otx1, and Otx2 are just as important as master genes Pax3 and Pax6.

The first neurogenetic phase has been summarized using just a few examples of genes that are involved. Keep in mind that hundreds, perhaps thousands, more are involved in this phase. Note that not just one gene is responsible for one brain region. Rather it is an orchestrated effort that involves the interactions of many genes and gene products. Most importantly, the results of this neurogenetic phase are not a random act of biology or the surreptitious product of evolution. This is a degree of consciousness at work—DNA consciousness.

The Second Neurogenetic Phase: The Continuum of Neuron-Based Human Consciousness

Moment to moment throughout the lifespan there is a continuum of human consciousness. However, during this continuum there is a prerequisite of the proper functioning of the genetic expression that runs in tandem with the neurons, the brain, and the conscious experience. Currently, there is a large amount of literature supporting both various NCC and Gerald Edelman’s dynamic core hypothesis. However, the evidence supporting NgCC and a neurogenetic account of human consciousness is relatively new.

In the second genetic phase of neuron-based human consciousness there is a complete substructure of gene-based NgCC that are active during the continuum of neuron-based consciousness. Two very important genetic phenomena can be studied objectively to support this notion. The first is the abnormal genetic expressions seen in certain psychiatric disorders, and the second is gene-dependent neuron plasticity. Next we will look at genes involved in both of these genetic phenomena.
Psychiatric disorders, from a certain point of view, can represent a disruption in the normal functioning in the continuum of human consciousness. In certain psychiatric conditions, e.g., autism and schizophrenia, there is an abnormal regulation in how the brain reacts with and interprets the external environment. This affords the opportunity to observe a disruption in the continuum of human consciousness and search for NgCC that are associated with such anomalies.

Autism is a disorder that clearly demonstrates a breakdown in the reciprocal interactions with the environment and is also associated with other symptoms, e.g., motor hyperactivity/inattention, repetitive behaviors, and irritability. Locus disruptions in the PTCHD1 gene have been associated with several forms of autism (Filges 2011; Noor 2010). Currently, several other genes are being researched, as the pathogenesis of autism likely involves the derailment of some of the processes of synaptic plasticity, maturation of neuron signaling, myelination, and neurite outgrowth during development.

Schizophrenia exemplifies a breakdown and distortion in the perception of reality that is marked by hallucinations and aberrations in volition. There are several schizophrenia-related genes that have been identified, e.g., PDE4B, DISC1, and the expression of transcription factor ZNF804a (Girgenti 2012; Guan 2012; Millar 2007). Schizophrenia has a very complicated underlying neurobiology that involves changes in the structural and functional dysregulation of the neural circuitry. Consequently, many other genes are being investigated (Sun 2010).

At this point two psychiatric disorders have been used as examples of aberrations in the second neurogenetic phase of human consciousness. Some genes have been correlated with these disorders. It is important to keep in mind that many more genes are likely involved, as well as other nongenetic factors in certain cases. In addition, other psychiatric disorders with genetic correlations may provide more insight into the complexity of the second neurogenetic phase of human consciousness. Next, some genes involved in neuron plasticity will be briefly discussed.

Neuron plasticity is typically defined as the ability of the neurons, and consequently the brain, to change in response to new information and sensory input. This attribute of neuron plasticity is critical to the neurons and their ability to perform the multifarious functions of neuron-based consciousness. Hence, it is quite conceivable that without this ability the individual would be perpetually stuck in the same conscious scene or would be unable to adapt cognitively to new information.
It is also worth mentioning that neuron plasticity is dependent upon two fundamentally different developmental programs: molecular guidance cues and patterned neural activities. Early in development there are molecular guidance cues that escort axons to their target regions and then commence the development of the synaptic connections in the brain. After these synaptic connections are established, further development relies on the coordination of neural activity between both the presynaptic and postsynaptic portions of the neurons. This system allows activity-dependent reorganizations during the acquisition of coordinated skills and behavior in general. This reorganization of neural activity is also required for the underlying neural functions that are critical for cognitive functions and human consciousness to stream on a continuum.

Certain genes are involved in neuron plasticity. The first two examples are BDNF and FGF-2 (Cowansage 2010; Zechel 2010), which are also well known for their involvement in memory and learning. The third example is the delta-FosB transcription factor, which is a spliced gene variant produced from the FosB gene. It is involved in neuron plasticity by its influence of the expression of four other genes: GluR, Cdk5, NF-kappaB, and dynorphin, and all four of these genes have neuroplastic effects on specific brain regions (Grandy 2013d). Therefore there are three examples of NgCC mentioned that are involved in neuron plasticity—BDNF, FGF-2, and FosB. Of course it must be kept in mind that many more genes are involved in this neurobiological phenomenon.

The second neurogenetic phase of human consciousness can be observed objectively by at least to different phenomena: genetic abnormalities involved in certain psychiatric disorders and genes involved in neuron plasticity. However, after this neurogenetic system emerges and then runs a continuum during a lifespan, what happens when that system breaks down over time? This question is addressed in the next section of this paper.

**The Third Neurogenetic Phase: Neurodegeneration**

Neurodegeneration is the breakdown of the neurons and the brain. This takes place in a time-dependent fashion and can be manifested clinically as mild cognitive impairment, which is the normal age-related deterioration of cognitive functions. This ultimately results in a decrease in the degree of that individual’s neuron-based consciousness. There are certain genetic mutations that are associated with forms of dementia, e.g., Alzheimer disease. Alzheimer disease is a form of dementia that is associated with an earlier age of onset, an accelerated course, and a poorer prognosis. It provides an excellent model to observe the third neurogenetic phase of human consciousness because several genes have been identified that have a direct correlation.
Alzheimer disease has been correlated with mutations in several genes: APP (Goate 1991; Mullan 1992), PSEN1 (Cruts 1996), PSEN2 (Cruts 1996), APOE-epsilon4 gene variant (Leoni 2011; Strittmatter 1995), and TREM2 (Guerreiro 2013; Jonsson 2013). In other publications Alzheimer disease has been correlated with the distinction of decreases in human consciousness manifested by these gene mutations and the consequent aberrant functions of their protein products (Grandy 2012b). Keep in mind that other genes are under investigation and many other genes have been correlated with different types of dementia that are not Alzheimer-related.

Alzheimer disease is pathology that slowly erodes modalities of human consciousness, e.g., memory, cognitive functions, and inhibition of inappropriate behavior. In essence, individuals afflicted with Alzheimer disease cease to be the persons they once were and in a very profound way their degree of consciousness is decreased on several levels. The involvement of certain gene mutations demonstrates tangible NgCC of the third neurogenetic phase of human consciousness.

**Conclusion**

This article has proposed and supported a novel neurogenetic substructure of human consciousness. Three distinct neurogenetic phases have been established, but they are all connected by genetic cascades to create a collective whole in terms of the individual’s lifespan. This is significant for several reasons. First, it forces consciousness researchers to look beneath the level of brain and neuron to account for human consciousness. Secondly, it brings into question several philosophical questions in terms of what individual consciousness is relative to the dynamics of the inherited genome. For example, is consciousness in the brain, the genes, or both? Is our free will, to some degree, controlled by NgCC? Do neurogenetic substrates represent an intermediate or interface between the realm of quantum consciousness and degrees of consciousness on the macroscopic scale? Thirdly, it establishes an initial enumeration of genes for each of the three phases, which should stimulate further research that may add to this list and to our understanding of a neurogenetic substructure of human consciousness.

In the past some individuals in different areas of research may have made statements such as “gene may have something to do with consciousness” or “of course DNA is involved in consciousness.” This article goes further by presenting a neurogenetic paradigm in which specific genes and gene products are identified and organized into three never before recognized phases of human consciousness. In addition, all three neurogenetic phases have been supported and validated by numerous scientific findings.
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