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How Schrödinger's mice weave consciousness

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ABSTRACT

This paper continues the series of papers on DNA resonance signaling. The authors previously proposed that DNA is involved in the work of the mind directly and immediately via the network of optical fibers. The authors proposed the mechanism of signal transduction in DNA via a sequence-specific resonance between the clouds of delocalized charges in the base stack. It was computationally demonstrated that certain repetitive patterns of delocalized charge clouds were evolutionarily enriched in various genomes. Here, the authors propose that natural quantum computation in DNA in living cells is based on the tautomerization of basepairs and involves coordinated oscillations of hydrogen-bond protons and aromatic electrons. The authors expand the ORCH-OR theory to include the collapse of the wave function of aromatic electrons in purines and propose that such collapses and expansions produce the experience of consciousness and the perception of time. The above mechanisms are supported by an observation that the majority of the psychoactive drugs are aromatic and the suggestion that they modify the aromaticity of DNA by binding to it. Quantum mechanical considerations for the collapse of aromaticity by double proton transfer in basepairs are discussed in terms of the collapse of the wave function, loss of delocalization, and the dynamic balance between coherence and decoherence in DNA.

In the Introduction, we will review the previously published research that connects DNA resonances with the work of the mind. This area is not well known so it will be useful to revisit some of the published theories and evidence supporting them. Yet, the novelty of this paper is in the proposed molecular mechanism for the work of the mind, which will be presented in the Hypothesis section followed by the Discussion where we will link the proposed hypothesis with some of the theories of consciousness, quantum mechanics, and self-organization.

1. INTRODUCTION

DNA resonance and the mind

The role of DNA in the work of the mind is currently thought to be limited to protein-coding genes, which are dynamically regulated and which, in turn, regulate the levels of proteins that, in turn, regulate the work of the brain. This mechanism is indirect, slow, and seems insufficient to explain the complexity and speed of our thinking. Previously, we suggested that there is a much faster and more direct mechanism by which DNA is involved in the thinking process (Savelyev et al. 2019). It involves charge oscillations in DNA and the exchange of electromagnetic signals between cell nuclei via a network of microtubules and other fibers. In this way, the old picture of slow and indirect involvement of DNA in the work of the mind is supplemented by a model of direct and fast signaling between the DNA of all nuclei of the body via electromagnetic waves. This conceptual transformation could be likened to the supplementation of snail mail with the instantaneous connection of

billions of people into one constantly active internet network via electromagnetic waves.

Subcellular thinking structures

The exclusivity of the neuronal signaling mechanism for thinking is challenged by simple organisms that do not have neurons or have only a few neurons. The nematode Caenorhabditis elegans has only 302 neurons but displays several complex behaviors including predator escape and mating. Some single-cell organisms that have no neurons also demonstrate complex behaviors and the ability to learn. Moreover, free-living single-cell ciliates such as Stentor roeselii are capable of learning (Dexter, Prabakaran, and Gunawardena 2019) as is Plasmodium, which is a single large cell with many nuclei (Dussutour et al. 2010). Paramecium, a single-cell organism, can swim, learn, display complex behaviors, and sexually reproduce (Maegawa 2017). This demonstrates that there are subcellular structures capable of thinking and making decisions (Maegawa 2017).

DNA resonance signaling

The early theories for resonance signaling in biology were developed long before the discovery of the role of DNA in coding genetic information. The role of electric fields in morphogenesis was developed by Mathews (Mathews 1903), Morgan and Dimon (Morgan and Dimon 1904), Lund (Lund 1917), and others over 100 years ago. The existence of the morphogenetic field was proposed nearly 100 years ago (A. Gurwitsch 1922). It was proposed that the morphogenetic field is produced by the union of the cells of the organism, and this field guides the development of the shape of the body and regulates the function of each part and organ. Consider a modern analogy: GPS navigators tell drivers their location and centralized systems such as Uber wirelessly guide the drivers. Similarly, it was proposed that the body generates a morphogenetic field, which tells every cell its location and guides its actions. The existence of the morphogenetic field was experimentally demonstrated by independent groups (A. A. Gurwitsch 1988; Volodyaev and Beloussov 2015). In these experiments, perturbing one of the chemically separated biological samples leads to measurable effects in another (Cifra, Fields, and Farhadi 2011; Scholkmann, Fels, and Cifra 2013; Trushin 2004; Xu et al. 2017). The electromagnetic oscillations in the cells were proposed to be driven by the constant chemical energy flux and were estimated to be in the millimeter-wave region (Frohlich 1988).

Miller and Web proposed that genomic DNA is the main source and receiver of the morphogenetic field, allowing the genomic program to direct the morphogenesis directly via a holographic electromagnetic field (Miller et al., 1975; Miller and Webb, 1973). Moreover, it was proposed that through the same field, the genomic DNA of brain cells is directly involved in the work of the mind (Richard Alan Miller, Webb, and Dickson 1975). Hameroff proposed that microtubules in axons work as light guides and transmit information in neurons, thus explaining the high speed and bandwidth of the mind (Stuart Roy Hameroff 1974). We combined and expanded the ideas of Miller, Webb, and Hameroff by suggesting electromagnetic information transfer between the DNA in the nucleus, the microtubules in the cytoplasm, and the fibers of the extracellular matrix in the fascia (Savelyev et al. 2019).

An important factor to consider for the theory of the genomic biofield is the dissipation and scattering of electromagnetic signals in the tissues. Morphogenetic field and biofield is usually perceived as an unstructured field generated by the tissues and going in all directions. Let us call it the "Field Model". While we accept that some of the signaling is likely to occur via the Field Model, this model has a problem of dissipation and scattering of the signals. Therefore, we proposed a "Fiberoptic model" (Savelyev et al. 2019), in which genome copies of all cell nuclei of the organism exchange electromagnetic signals via a network of protein fibers serving as optical guides.

For an analogy of the field model, consider smartphones that send signals in all directions and contact cell towers in any direction: this information exchange is less specific and much of the signal is wasted. For the analogy of the fiberoptic model, consider broadband modems connected to internet hubs via fiberoptic cables: this exchange is specific, there is little interference and data loss, and the information transfer rate is much

higher than for the smartphones that send and receive signals in all directions. So far, experimental evidence is published only for the Field Model (Cifra, Fields, and Farhadi 2011; Scholkmann, Fels, and Cifra 2013; Trushin 2004; Xu et al. 2017). In these publications, the field and information transfer was demonstrated, yet the role of DNA in its generation and reception was not tested. We find it likely that both the field and the fiberoptic models coexist side by side, with some signals exchanged via microtubules and other signals exchanged via the field.

The fiberoptic model (Savelyev et al. 2019) has the advantage that it minimizes data loss and crosstalk: information can be exchanged between specific locations with high specificity. A substantial body of experimental evidence suggests the existence of a system that exchanges electromagnetic signals via fiberoptic-like tubular structures of fascia tissue (Maurer et al. 2019; Bai et al. 2011). These tissues wrap and penetrate the entire body and regulate its growth and health. This system closely corresponds to the placement of meridians in traditional Chinese medicine (Maurer et al. 2019; Bai et al. 2011). We proposed that genome copies of all cells of the body are vibrationally coupled with the signaling system of meridians in the fascia and thus are linked into a single fiberoptic network (Savelyev et al. 2019). The frequencies of the waves in this network may be in the infrared and millimeter-wave range (Savelyev et al. 2019).

For genome copies to communicate via electromagnetic waves, DNA fragments should be able to resonate in a sequence-dependent manner. Although mechanical oscillations in DNA have been proposed (Scott 1985; Volkov and Kosevich 1987), we reasoned that the mechanical oscillations would be damped by the viscosity of the nucleoplasm. Instead, we proposed that there must be oscillations of delocalized charges in the nucleobase stack, which would be protected by the DNA backbone from oscillation dumping. In this model, DNA harbors vibrationally coupled oscillations of delocalized proton and electron clouds in the base stack. We modeled their approximate shapes and, based on multiple genome sequences, produced statistical evidence for evolutionary selection and conservation of DNA sequences predicted to harbor repetitive electron and proton cloud patterns (Savelyev and Myakishev-Rempel 2019; Savelev and Myakishev-Rempel 2020). Thus, based on the genomic data from various species, we provided the initial evidence for the existence of resonance signaling in DNA.

Furthermore, in this model, the key oscillators serving as transmitting and receiving antennas are repetitive elements in DNA that comprise over 50% of our genome; the vibrational information is coded in positions of repetitive elements, variations within them, and in their flanking sequences; the repetitive elements work as radios by converting biomolecular information into electromagnetic wave messages and vice versa; repetitive elements create an interference pattern of waves that is united between all cells of the organism, guides its development, and is an integral part of the work of the mind; the wave signals that are received by the DNA resonance elements are guiding the expression of genes and chromatin dynamics. Much in this model remains to be proven. In our previous publications (Savelyev and Myakishev-Rempel 2019; Savelev and Myakishev-Rempel 2020) we only provided the initial computational-genomic evidence for the evolutionary selection for certain electron and proton cloud patterns, which suggests the existence of DNA resonance signaling. In this paper, we will further develop the aspects of this model that offer a more detailed mechanism for the link between DNA and consciousness.

2. HYPOTHESIS

Our main focus here will be on the hydrogen bonds and electrons in tautomeric forms of the DNA basepairs. The main question we asked was: which charged particles are delocalized in the basepairs and how do the shapes of delocalized charge clouds depend on the DNA sequence? The ultimate goal here was to understand the sequence dependence of the delocalized charge oscillations that potentially mediate our thinking process and other signaling in the body.

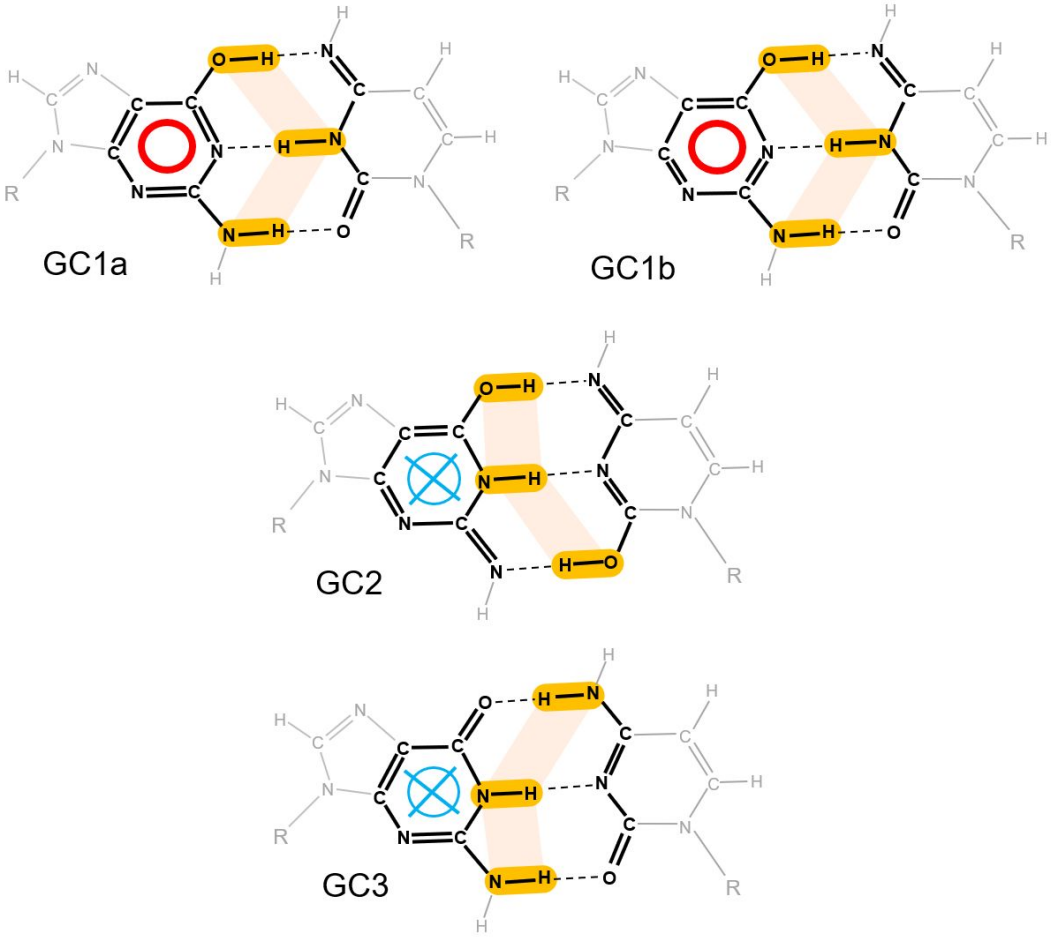


Fig. [GC] Tautomeric forms of GC basepair. *The hexagonal heterocycles of purines are called here "the central ring" and labeled with circles. The uncrossed circles signify the presence of aromaticity and the crossed circles signify the loss of aromaticity. The remaining heterocycles are not aromatic. The black lines signify the structures that undergo tautomerization and grey lines signify the structures that stay unchanged during tautomerization. Links to the backbone are shown as "R".*

The normal coexistence and interconversion of tautomeric forms of normal Watson-Crick basepairs are known from experiments in model systems (Abou-Zied, Jimenez, and Romesberg 2001), Fig. [GC].

From the classical chemistry perspective, basepairs oscillate between their tautomeric forms with the frequency in GHz - THz range (Pérez et al. 2010; Abou-Zied, Jimenez, and Romesberg 2001; Abo-Riziq et al. 2005). Yet, from the quantum chemistry perspective, the tautomeric forms coexist in the state of quantum superposition until they are forced to make a choice in which state they exist. The choice of a tautomeric form could be forced by the background infrared irradiation, which is high in living tissues, or by an interaction with small molecules, that are in Brownian motion, constantly bump the double helix, and sometimes reach the base stack.

Both the classical and the quantum chemistry perspectives are true at the same time and the description of the model depends from which perspective one looks at it. As one can see in Fig. [GC], it takes two proton relocations (a double proton transfer) to switch the basepair tautomeric form from GC1 to GC2, from GC2 to GC3, and from GC3 to GC1. The transition between forms GC1, GC2, and GC3 is also accompanied by electron relocations. As one positively charged proton jumps one step, two or more electrons in a chain jump one step each towards this proton to rebalance the electrical charge and to keep the charge of each of the larger atoms neutral.

Importantly, although the two hexagonal and one pentagonal rings in the basepair look similar and have alternating double bonds, only the central ring is aromatic (see Supplement 2 for details). Its aromaticity is classical and characterized by the unification of 6 pi electrons of the ring into one delocalized double-ring

shaped cloud, Fig. [Purines]. The other two rings do not have enough pi-electrons to create a delocalized ring and therefore are not aromatic.

The key observation here is that the central ring is only aromatic in GC1 and is not aromatic in GC2 and GC3. This happens because the relocation of protons causes the relocation of electrons and the ring loses an electron to a proton that attaches to the purine. In GC1, the electrons of the central ring exist in a superposition of two configurations GC1a and GC1b.

A similar dependence of the aromaticity of the central ring from the relocations of protons is observed in the classical Watson-Crick's basepair AT, Fig. [AT]

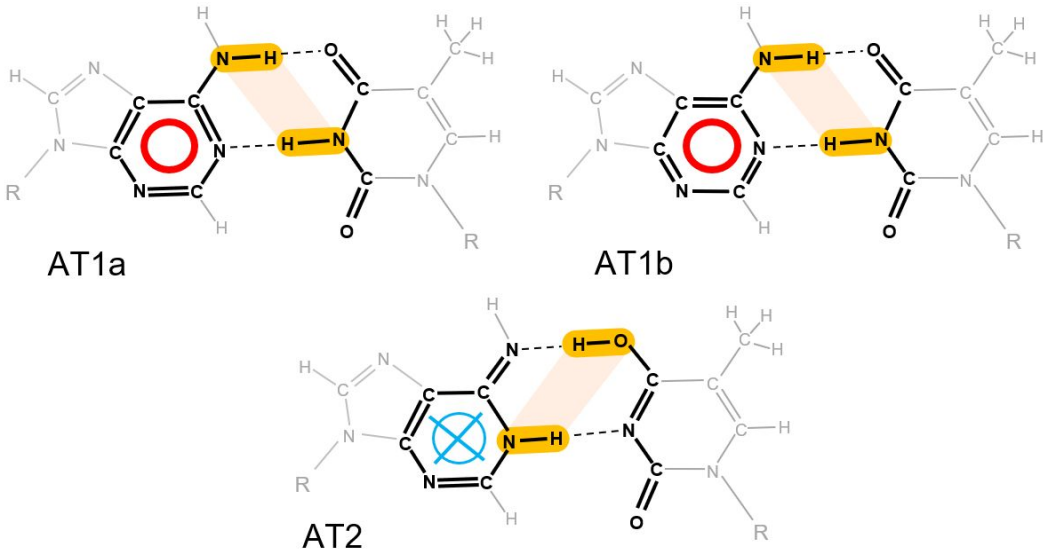


Fig. [AT] Tautomeric forms of basepair AT.

The main difference is that in AT there are only two tautomeric forms: AT1 and AT2. Tautomer AT1 is aromatic and AT2 is not.

Once we noticed the oscillation of aromaticity in basepairs, we realized that it may be involved in the work of the mind. Previously, we developed a model in which resonances in DNA are united over the entire organism by a network of optical fibers and thus participate in the work of the mind. Here, the process of enabling and collapsing aromaticity in basepairs reminded us of spinning and stopping a roulette wheel or throwing dice. It is well known that in the aromatic state the 6 pi electrons are delocalized, forming a stable ring that freely spins. The spinning of the ring creates a magnetic moment and, inversely, applying a magnetic field to the electron ring spins it (Katritzky et al. 1989; Gershoni-Poranne and Stanger 2015). Consider that DNA may perform logical operations and thinks by spinning its aromatic rings not unlike an electronic machine, as we previously proposed (Polesskaya et al. 2018). The stacked aromatic rings are attracted via a known effect of aromatic ring stacking and their magnetic moments unite, causing them to behave collectively. The external magnetic field can switch the polarity of the stretch of the rings and reverse their rotation. The attraction of rings spinning in the same direction and magnetized in the same direction would likely straighten and shorten the double helix, while repulsion of the rings spinning in the opposite directions and magnetized in the opposite directions would likely bend or expand the double helix. Therefore, supercoiling of DNA may be under the control of high-frequency waves. This is relevant to gene expression since it requires uncoiling of the regions harboring the genes to be expressed. Typically, in this process, the loops containing multiple genes to be transcribed are uncoiled by gyrases, the genes are transcribed, and then the loops are coiled back. Similarly, uncoiling of DNA happens during the process of replication. Thus, regulation of coiling is an essential process in gene and chromatin regulation. We suggest that possibly, in addition to gyrases, the cell uses voltage oscillations to control coiling of DNA and it is likely that this mechanism is used by DNA to control its own coiling.

Wave function collapse

We suggest that proton jumping coupled to the oscillation of aromaticity of purines is a natural mechanism for the ability of DNA to process information and think. As we illustrated above, jumping of protons causes the collapse and expansion of the wave function of the aromatic electrons of the central ring. Or in other words, the proton jumps force these aromatic electrons to localize and delocalize.

Such collapses of the wave function were proposed to be the mechanism underlying the work of the mind and consciousness (Shimony and Cushing 1994; Shimony 1997). On the molecular level, this idea was further developed by Hameroff (S. Hameroff 2003) for microtubules. Here, we propose that DNA, and more specifically the localization and delocalization of aromatic electrons in purines, is the mechanism for our thinking process.

Intuition versus logic

Furthermore, consider a connection between the proton jumps in basepairs with conscious choice-making and between the delocalization with electrons and intuition. Terrence McKenna and others suggested that it was the evolution of hominids from gathering to hunting that forced us to develop our logical mind (Thagard and Shelley 1997; Sheldrake, McKenna, and Abraham 1998). They reasoned that it is our predatory nature that requires us to logically create plans and execute them, otherwise, we would not survive. This leads our modern civilization to prefer logic over intuition and action over passivity. McKenna noted that traditional tribes had a different mindset which was much more passive and intuitive than modern-day humans. Consider also that such qualities as ego, logic, and choice-making (popularly called masculine and left-brain) may be mechanistically mediated by localization of aromatic electrons and temporary loss of aromaticity in DNA. Conversely, such qualities as selflessness, intuition, and passivity (popularly called feninine and right-brain) may be mechanistically mediated by delocalization of aromatic electrons and gain of aromaticity in DNA.

Collective behavior of purines

When multiple purines follow each other in the DNA sequence, Fig. [Purines], their aromatic rings are attracted by the stacking forces and their magnetic moments should face in one direction and add together thus stabilizing their collective orientation. This would likely create a delocalized cloud of aromatic electrons spanning this stretch of purines and thus create a structure prone to charge oscillations. Since stretches of purines are frequent in the genome, they would create antennas allowing for wireless communication between the parts of the genome and between the genome copies of all the cells in the body. Thus, the delocalized state of electrons in purine stretches would allow for organism-wide resonances and nonlocal communications that nicely produce the intuitive state of mind. Conversely, the collapse of the wave function and the loss of aromaticity in purine stretches would correspond to the logical way of thinking and choice making.

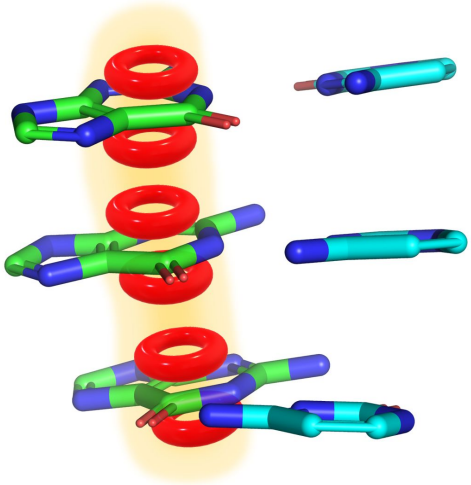


Fig. [Purines] Aromatic electron rings are merged in a purine stretch. *Three basepairs of the basestack are shown. The backbone is hidden. Aromatic pi electrons of the central rings are shown in red. A cloud of delocalized aromatic electrons is shown in yellow.*

Schrödinger's mice

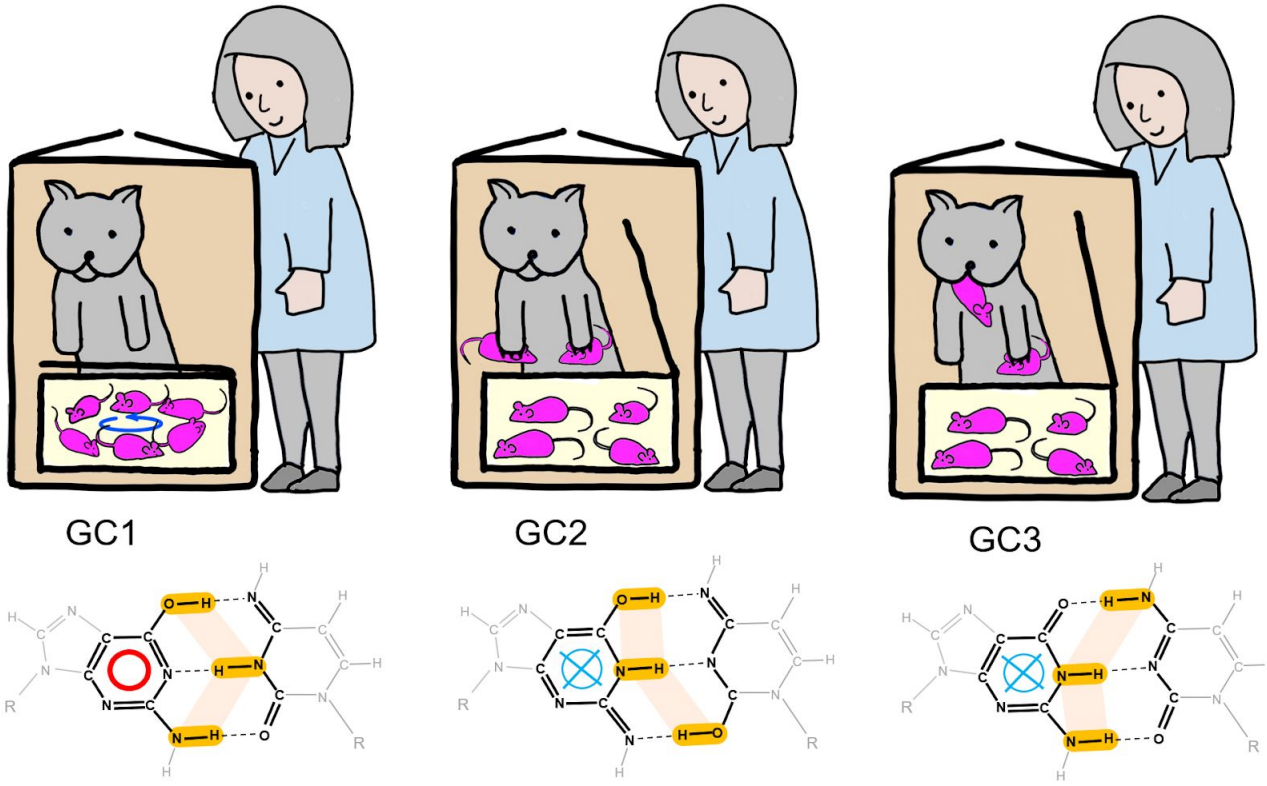
One peculiarity of the delocalization of charges in the basepair shown in Fig. [GC] is that it is not only electrons that are delocalized, but also protons. Quantum delocalization of protons in basepairs is known from molecular dynamic calculations (Pérez et al. 2010). Since protons are 800 times heavier than electrons, their delocalization, while less pronounced, is still real. Both protons and electrons exist in the state of delocalization, quantum superposition, and obey Heisenberg's uncertainty principle. In the basepair's natural state, an outside observer not only cannot know the position of electrons of the central ring but also cannot know the position of the protons of the hydrogen bonds. The electrons are fused together in a double electron ring above and below the central ring (Fig. [Purines]) and protons are delocalized into a probability cloud spreading along the hydrogen bond. When the basepair has a moment of quiet and is not bumped by infrared photons or water molecules, its electrons and protons delocalize and when it is disturbed by the bumps from outside, its delocalization collapses and protons and electrons take positions or in other words make a choice, as in Fig. [GC].

In this respect, the dependence of the basepair aromaticity on its tautomeric form is very interesting. Only tautomer GC1 enables the central ring to become aromatic, while GC2 and GC3 disable the aromaticity of the central ring. Yet, much of the time, all three tautomers coexist in a state of quantum superposition. Quantum superposition is incompatible with the deterministic logic of the macroworld, and it only can be embraced as a gimmick of the quantum world. DNA is auspiciously located at the mesoscopic scale, the shadowland between the macroscopic and microscopic scale.

Another level of complexity is added by the fact that electrons are much more prone to delocalization than protons. To illustrate the resulting intrigue, let's expand the analogy of Schrödinger's cat. Let's have the GC basepair symbolized by a Schrödinger's cat in a box, although without a threat to its life, Fig. [Mice]. The cat can exist in three positions GC1, GC2, and GC3 corresponding to three tautomers of the GC basepair. For the outside observer, the position of the cat is unknown, until the observer opens the box. The cat also is an observer. It observes a smaller closed box containing a self-spinning carousel with 6 mice representing 6 electrons of the central ring, this position of the cat represents the tautomer GC1. The mice have numbers on their t-shirts (not shown). The spinning of the wheel represents the delocalization of the electrons. Occasionally, the cat opens the smaller box and grabs two mice from the carousel and the remaining 4 mice hide in the corners. This represents the loss of aromaticity. If the cat grabs the 2 mice with two paws, this

represents his second position and the tautomer GC2. If the cat grabs the 2 mice with the right paw and the mouth, this represents his third position and the tautomer GC3. The cat reads the identifiers of the mice and lets them go, switching back to the first position GC1, and the 6 mice the 6 mice start spinning on the carousel again.

Therefore, we can see that the quantum effects (uncertainty, delocalization, and superposition) are nested. The human observer observes a cat, which observes the mice. What is fascinating in this model is that the mice are delocalized (superimposed and uncertain) only when the cat is in the position GC1. In the other two positions, the mice are fixed, localized, their positions are determined. Therefore the human observer observes a part-time delocalized cat that observes the delocalization of mice only part-time. This illustrates the idea that the aromatic electrons and hydrogen bond protons delocalize when the basepairs are undisturbed; when basepairs are disturbed by the bumps of infrared photons and water, the protons localize; if the protons localize into GC2 and GC3 tautomeric forms, the aromatic electrons localize too; if the protons localize into GC1 form, the aromatic electrons remain delocalized.



Schrödinger's mice as an analogy of tautomeric states of GC basepair. *The human observer is observing a closed box with a Schrödinger's cat. The cat is alive in all three superimposed states: GC1, GC2, and GC3. In GC1, the cat is observing a closed smaller box containing 6 mice which are numbered and spinning in a circle. In the state GC2, the cat has opened the box and grabbed 2 mice with two paws. Only at that point do the identifiers of the mice become visible to the cat. The state GC3 is the same as GC2 except the cat grabbed the mice with one paw and its mouth.*

Electron and proton relocations

To detail a little better the tautomeric transition, it is helpful to trace charge relocations accompanying it. Fig. [Transition] illustrates electron and proton relocations accompanying the transition from tautomer GC1a to GC2 and back. Transitions follow the rule that charges of all atoms remain neutral. Figs. [Transition] A to C show that there are relocations of electrons in both directions. Fig. [Transition] D summarizes the relocations to illustrate that as a result, in the GC1a to GC2 transition, the protons move one step counterclockwise and a chain of electrons moves one step clockwise, thus neutralizing the relocation of protons. All other classical Watson-Crick tautomeric transitions follow the same pattern. This also illustrates that the basic chemistry of tautomeric transitions is simple and can be formalized.

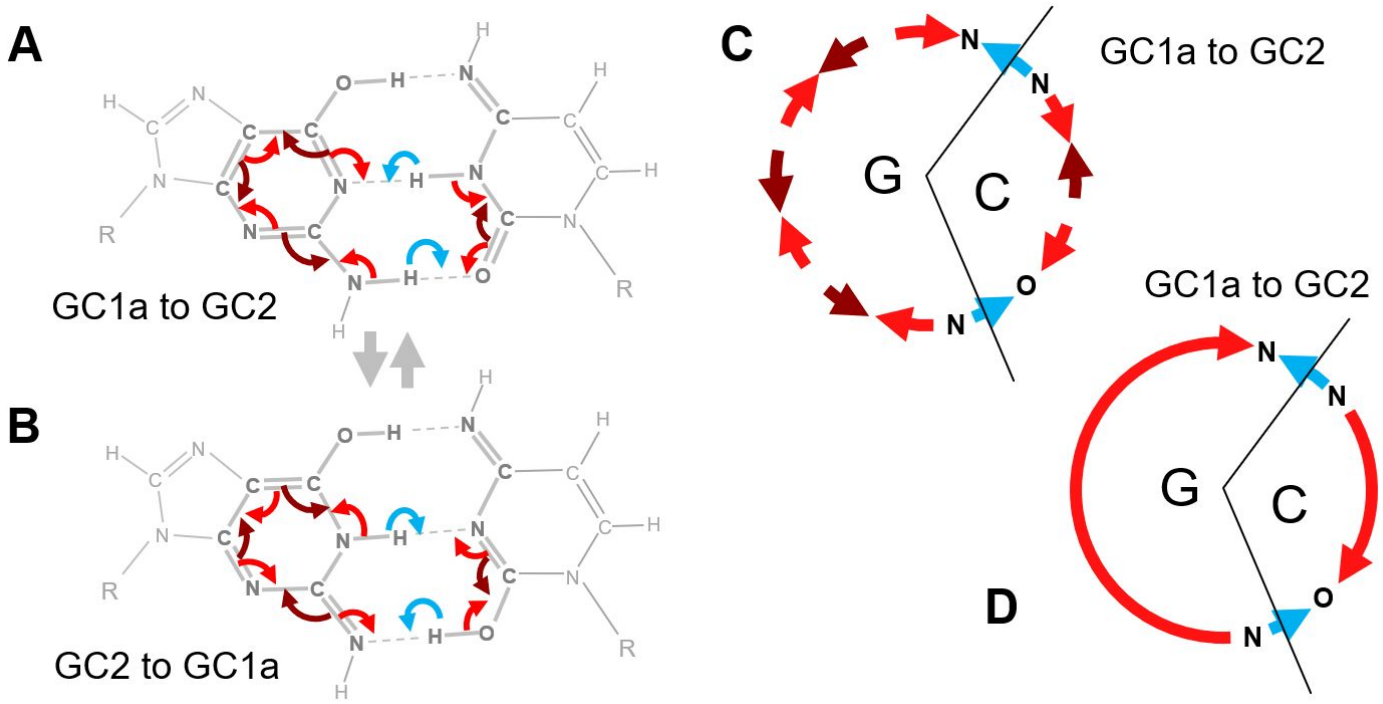


Fig. [Transition] Tautomeric transition GC1a to GC2. *Proton relocations are in blue. Relocations of individual electrons in the same direction as protons are in brown and relocations in the opposite direction are in red. (A) Transition GC1a to GC2. (B) Transition GC2 to GC1a. (C) Simplified summary of charge relocations GC1a to GC2. (D) Even more simplified summary of charge relocations GC1a to GC2.*

Proton clouds

In addition to electron clouds in purine stretches, we previously predicted the existence of delocalized proton clouds spanning multiple nucleotides in the DNA chain and produced preliminary evidence for their existence, Fig. [Protons A] (Savelev and Myakishev-Rempel 2020). Proton clouds are known from protein research where they are sometimes called proton wires (Shinobu and Agmon 2009).

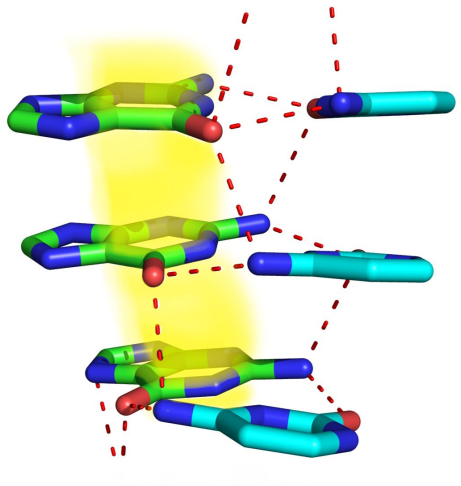


Fig. [Clouds] Electron clouds and proton wires in DNA. *A stretch of purines in the double helix is shown. It is a GGG sequence, GGG is shown in green and the complementary strand CCC in aqua color. The DNA backbone is not shown. The electron cloud is shown in yellow. Proton wires are shown in dotted lines.*

In our model of DNA resonance signaling, proton clouds also serve as antennas for wireless communication alongside with electron clouds. This way, there is an interplay of partially overlapping delocalized positive proton and negative electron clouds that are attracted to each other and oscillate in coordination with each other (Polesskaya et al. 2018; Savelyev and Myakishev-Rempel 2019; Savelev and Myakishev-Rempel 2020). Their oscillations would only partly overlap in frequency, since protons are 800 times heavier than electrons. Consider also that oscillations of delocalized charge clouds spanning multiple basepairs will be affected by the tautomeric transitions at each basepair. This simplified model gives us a glimpse into the sophisticated machinery that we believe underlies the intuitive and logical thinking processes in our DNA and in our minds.

Function

Until this point, we have been looking at resonance signaling mainly within DNA. Let us now consider the ways in which oscillations of aromaticity in basepairs can communicate with the biochemical processes outside of DNA. Consider collective delocalization of electrons in the stretch of purines. This would turn on their aromaticity, increase base stacking, increase the attraction of the bases to each other, and shorten the base stack. Since the phosphates are charged, they repel each other, keeping the length of the DNA backbone from shortening. This should increase DNA winding and bending. Conversely, tautomeric transitions leading delocalization and loss of aromaticity will cause DNA unwinding and straightening. These changes (winding and unwinding, bending and straightening) are known to affect chromatin structure and gene expression.

Another way aromaticity oscillations can affect biochemistry is via electromagnetic oscillations. Charge oscillations that we suggest occur in electron and proton clouds spanning multiple bases can add together and their lower harmonics in the MHz-GHz range can induce ultrasound waves in the nucleoplasm. The frequency of 214 MHz corresponds to the sound wavelength of 7 um, the size of the nucleus. 750 GHz corresponds to the sound wavelength of 2nm, the diameter of the double helix. Since DNA comprises a large part (about 1.5% of the nucleus mass) its harmonized oscillations could create moving sound interference patterns within the nucleus. This brings us to the ideas of cymatics, according to which moving sound patterns in tissues are responsible for structuring of the organism and driving organized motility of cellular components and proteins, reviewed in references (Meijer and Geesink 2016; Meijer et al. 2020). In this way the genome could move itself using cymatic propulsion and control the movements of proteins inside the nucleus. The reverse would be also possible - the interaction can be bidirectional - DNA could sense and influence the environment by interacting with the wave patterns.

Interface between chemical and vibrational signaling

According to our model, DNA serves as an interface between the chemical and vibrational signaling. Binding of proteins to a specific location in DNA will change its vibrational properties and thus biochemical information would be converted to wave information that DNA is sending and receiving. In other words, binding of proteins (and nucleosomes) to a genomic locus tunes it to different frequencies. Conversely, a resonance signal received by a locus can excite it and thus lead to a structural change, which in turn would attract or repel specific proteins, which in turn would affect its biochemical function. Moreover, charge oscillations could drive the opening and closing of chromatin, thus directly controlling gene transcription. Both conversion of the chemical to a resonance signal and back could be explicitly driven by chemical energy, such as the energy of ATP hydrolysis by proteins bound to DNA. Also, possibly, the energy of Brownian motion (Minchew and Didenko 2014) and infrared background radiation (Woller, Hannestad, and Albinsson 2013) could be harvested by DNA for the purposes of signal conversion.

Aromaticity

The idea that aromaticity of biopolymers is essential for consciousness is not new. The importance of aromaticity in microtubules for consciousness was developed by Hameroff during the past several decades (Stuart R. Hameroff, Craddock, and Tuszynski 2014). Classically, the psychoactive effects of drugs are explained via binding of drugs to proteins and blocking neurotransmitter reuptake, inhibiting neurotransmitter synthesis and inhibiting enzymes involved in molecular signaling pathways. Yet, the idea of DNA resonance signaling has been around at least since the early 1970s. Thus, 50 years ago, it was proposed that psychoactive substances, being predominantly aromatic, work by binding to DNA and changing its aromaticity and quantum delocalization of electrons (Smythies, Benington, and Morin 1970). Smythies pointed out that most of the psychoactive drugs contain aromatic groups similar to nucleobases, easily penetrate via cellular and nuclear membranes, and can bind to DNA either via intercalation or via hydrogen bonds (Smythies, Benington, and Morin 1970). Miller also emphasized the significance of aromaticity in DNA and electron delocalization for the phenomena of life (Richard Alan Miller, Webb, and Dickson 1975). Hameroff pointed out the correlation between the aromaticity correlates of anesthetic compounds and their potency (Stuart R. Hameroff, Craddock, and Tuszynski 2014).

To further highlight the importance of aromaticity for consciousness, we illustrated the aromaticity of the main psychoactive substances, their similarity to nucleobases and listed them according to the types of aromatic groups they contain, Fig. [Aromatics]. Also, to illustrate intercalating structures, included are two intercalating substances: ethidium and SYBR Green, for which psychoactive effects are unknown. Although the list of substances in Fig. [Aromatics] is far from exhaustive, this exercise strongly confirms the observation that the majority of psychoactive substances are aromatic and this further supports the model of the mind as a DNA resonance-based fiberoptic network.

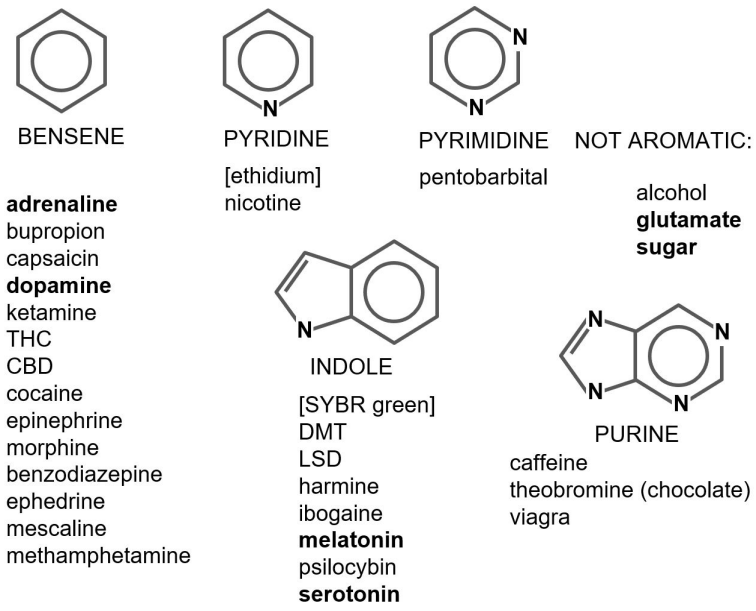


Fig. [Aromatics] Aromatic groups and exogenous and endogenous psychoactive substances classified by the aromatic groups they contain. In bold are endogenous psychoactive substances. *In square brackets are intercalating substances widely used in DNA research, for which psychoactive properties are unknown. Only the benzene, pyridine, pyrimidine, indole, and purine groups are shown. All the psychoactive substances listed underneath contain additional, sometimes also aromatic, radicals which are not shown.*

Binding of aromatic drugs to DNA

Small aromatic molecules such as the psychoactive substances listed in Fig. [Aromatics] easily penetrate the cell and nuclear membranes (Lafayette et al. 2017). Most of them bind to DNA (Rescifina et al. 2014). Indole derivatives such as melatonin, harmine (Vignoni et al. 2014) and ibogaine migrate into the nucleus and bind to DNA. Other indole derivatives also bind to DNA (Lafayette et al. 2017). Hallucinogen ibogaine enters the nucleus and regulates gene expression (Marton et al. 2019). Caffeine and chocolate's theobromine bind to DNA via hydrogen bonds (Johnson et al. 2012; Nafisi et al. 2008). Cannabinol (CBN) from cannabis binds in the major groove of DNA and does not intercalate into it (Tian et al. 2018). Prozac is a DNA groove binder (Kashanian et al. 2012).

Intercalation

When an aromatic small molecule intercalates into DNA, it inserts itself into the base stack as if it is an additional basepair in the DNA and its aromatic ring of pi-electrons is fuzed into the periodic set of pi-electron rings of the nucleobases (Rescifina et al. 2014). Morphine binds and intercalates into DNA (Li and Dong 2009; Talemi and Mashhadizadeh 2015). Adrenaline binds to DNA and may intercalate into DNA (Zheng and Lin 2003). Hallucinogen harmine penetrates into the nucleus and binds to DNA (Vignoni et al. 2014) via intercalation (Wink, Schmeller, and Latz-Brüning 1998). Serotonin and tryptamine intercalate into DNA (Hélène, Dimicoli, and Brun 1971). In summary, although the researchers of aromatic psychoactive drugs were primarily testing psychoactive drugs for the lack of mutagenic properties, they unwittingly produced supportive evidence for the hypothesis of Smythies from 50 years ago (Smythies, Benington, and Morin 1970) that psychoactive drugs are expanding consciousness by boosting the aromaticity of DNA.

Frequency of tautomerization

The classical Watson-Crick keto-amine tautomeric forms (GC3 and AT1, marked with a continuous border in Fig. [Stability]) are more stable than enol-imine forms (dotted border) (Pérez et al. 2010; Brovarets and Hovorun 2015; Brovarets', Oliynyk, and Hovorun 2019). The frequency of tautomerization was estimated to be in 100 MHz - 100 THz range using spectroscopy of model molecules (Pérez et al. 2010; Abou-Zied, Jimenez,

and Romesberg 2001; Abo-Riziq et al. 2005) and molecular dynamics calculations (Ol'ha and Hovorun 2018; Brovarets' and Hovorun 2014; Brovarets 2015). See also Supplement 1. Further understanding of tautomerization of basepairs in DNA can be done using two-dimensional Fourier-transform infrared spectroscopy. Note that tautomerization could be aperiodic or subject to complex oscillations, so the frequency estimate does not necessarily imply regularity in oscillations. Also, note that since the lifetime of more stable (keto-amine) tautomers is much longer than of less-stable (enol-imine) tautomers (Pérez et al. 2010; Brovarets and Hovorun 2015; Brovarets', Oliynyk, and Hovorun 2019), the oscillations have a character of short pulses. We have also noticed that aromaticity loss in GC and AT pairs goes in opposite directions, Fig. [Stability]. The more-stable GC form (GC3) is nonaromatic (or more precisely, has a lowered aromaticity) and it occasionally pulses into a less-stable GC1, which is fully aromatic - that is, the largely nonaromatic GC undergoes occasional short aromaticity bursts. Conversely, the more-stable AT form (AT1) is fully aromatic and it occasionally pulses into a less-stable nonaromatic GC1, in other words, the aromatic GC undergoes occasional short aromaticity lapses.

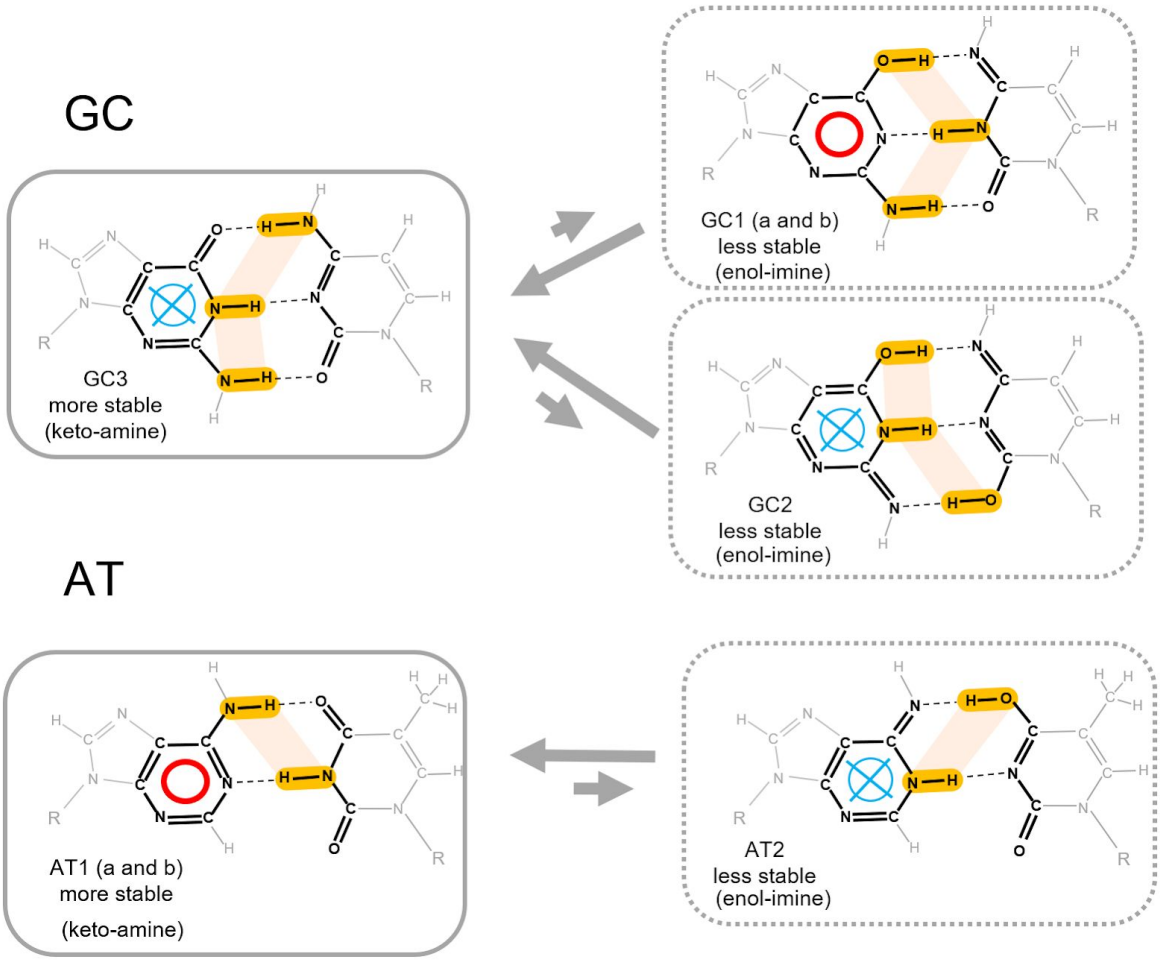


Fig. [Stability] Stability and aromaticity oscillations of purine tautomers in basepairs.

Purine stretches

Among functionally important and abundant genomic elements, genomic polyA tracts and CpG islands stand out. PolyA tracts are important for viruses and transposons and often a deletion of a polyA tract impairs gene function (Guerrini et al. 2007). CpG islands are typically located in genes and gene promoters and are involved in the activation of gene transcription (Deaton and Bird 2011). Based on the above observation of the opposite character of aromaticity oscillations between GC and AT basepairs, polyA tracts having a stretch of pi-electron

rings of adenines, should spend most of the duty cycle in an aromatic state and have occasional lapses of aromaticity loss. Since the pi electrons in the basestack are organized in a periodic structure, they very likely exist as a synchronized electron cloud and their aromaticity loss is coordinated within the entire polyA tract. Both high aromaticity of the uniformly periodic basestack and occasional coordinated loss of aromaticity might affect their oscillatory and biomolecular function due to possible effects on DNA structure, packing of chromatin, binding of nucleosomes, and protein factors. Similar aromaticity oscillation patterns would also be observed in $(AT)_n$ tandem repeats.

Just the opposite should happen to CpG islands made exclusively of GC basepairs. They should exist in a reduced aromaticity state for most of their duty cycle and collectively produce short aromatic bursts. This could also affect their DNA resonance signaling and biomolecular functions.

Coordination of aromaticity oscillations

There are several mechanisms that would synchronize aromaticity oscillations within stretches of basepairs in DNA. First, aromatic pi-electron rings of purines unite into a synchronized periodic pattern, especially when the sequence is periodic, such as in tandem genomic repeats. Such periodic stacking of pi-electron rings is thought to be responsible in part for the experimentally observed high electrical conductivity of DNA in physiological conditions (Kratochvílová et al. 2013). Second, as we previously published, basepairs are likely bound by delocalized proton wires composed of longitudinal hydrogen bonds (Savelev and Myakishev-Rempel 2020) which could also synchronize aromaticity oscillations. Third, the excitations caused by tautomerization could be transmitted via the sugar-phosphate backbone and lead to coordination between basepairs. Therefore, it is likely that aromaticity oscillations are synchronized and coordinated within stretches of basepairs. Since both stacking of aromatic electron rings and the formation of longitudinal hydrogen bonds depends on DNA sequence, the synchronization and coordination of aromaticity oscillations would also be highly sequence-dependent. Various sequences would provide different aromaticity oscillation patterns. The aromaticity oscillation pattern of a specific DNA fragment would be defined by the interplay between aromatic pi-electron stacks and proton wires, patterns of which would vary with DNA sequence. Yet, identical sequences will have identical aromaticity oscillation patterns and synchronize with each other, thus providing a mechanism for resonance signaling.

Epigenetic regulation

Methylation of cytosine bases, the most frequent epigenetic mark, does not change the DNA tautomerization formulas described above, but would certainly affect the tautomerization rates and stability. In particular, methylation is predicted to favor aromatic ring stacking interactions (Kabeláč and Hobza 2007) and thus should shift the balance towards the aromatic tautomers.

3. DISCUSSION

ORCH-OR theory

The delocalized state of aromatic electrons and protons in biological systems is described by Schrödinger's wave function. The loss of delocalization results in the collapse of Schrödinger's wave function and, according to Objective Reduction (OR) of the quantum state, this collapse is a choice and collectively these choices produce conscious awareness (Penrose 1994). This was expanded to the Orchestrated Objective Reduction (ORCH-OR) theory of Penrose and Hameroff (Hameroff 1997) which proposed the key role of microtubules. There, the aromatic rings of aromatic amino acids tyrosine, phenylalanine, and tryptophan of tubulin were suggested to periodically collapse and expand, producing choices and thus creating conscious awareness. Hameroff also posted online an unfinished paper suggesting the role of DNA in the process.

Here, we expand the ORCH-OR theory to include DNA in better detail. DNA and microtubules share aromatic and helical natures and their dimensions are comparable. DNA is plausible as a thinking molecular machine

since it carries the genetic code and has an efficient addressing system: it is often sufficient to know only 15 bases of the code to find a specific spot among the 3.2 billion bases of the genome. ORCH-OR theory proposes that the periodic collapse of the wave function of the aromatic aminoacids produces consciousness. Here, we propose the same for the aromaticity in DNA. In this process, basepairs oscillate between their aromatic and nonaromatic tautomeric forms, Fig. [GC], the aromatic electrons oscillate between delocalized and localized states and their wave functions collapse and expand. According to our model, this takes place in each of the 6.4 billion purines in the cell. This number can be multiplied by 80 billion neurons in the brain or up to 30 trillion cells of our body considering that not only brain neurons are involved in the thinking process. As we proposed previously (Savelyev et al. 2019), the genomes of the body located in the nuclei are informationally coupled into one fiberoptic network and thus all DNA and microtubules of the body are united into one thinking network.

Hameroff also proposed that occasional wave function collapses produce time as a byproduct of creating consciousness (S. Hameroff 2003). Here, we expand this by suggesting that it is the experience of time and self-awareness that are produced by the wave function collapses in the DNA of the body. Nonbiological objects and unidirectional processes also exist in the space-time of our universe, but we suggest that it is the wave function collapses and expansions of aromatic electrons in DNA that produce the experience of conscious awareness and sliding unidirectionally through time.

Decoherence

Understanding of decoherence is one of the key developments in the quantum mechanics of recent decades (Ball 2018). This concept allows modeling the biological processes in mesoscopic scale - the scale of DNA. When purines transition into their aromatic forms, their pi electrons are united into an aromatic ring and delocalize. This results in the quantum entanglement of these electrons and increases the coherence of their union. The loss of aromaticity could be caused when the base stack is bumped by the water molecules or infrared photons. The loss of aromaticity is accompanied by localization (or de-delocalization) of electrons of the aromatic ring, loss of coherence and collapse of Schrödinger's wave function. Thus, purines oscillate between two worlds - that is, between the quantum world of coherence and delocalization and the macroscopic world of decoherence and localization. The quantum delocalized coherent state occurs spontaneously whenever the electrons are left to themselves, which is possible because purines are protected from the outer nucleoplasm by the highly charged backbone of DNA. The macroscopic localized decoherent state is created when Brownian motion or infrared irradiation causes double proton transfer which pulls out an electron from the aromatic ring and causes the ring to fall apart. This way, oscillations of aromaticity in DNA provide an interface between the quantum world and the macroscopic world. DNA can be considered a natural quantum computer and possibly a receiver and transmitter of nonlocal quantum information.

Nonlocality

Nonlocality, or Einstein's "spooky action at a distance", is a quantum world phenomenon arising from the entanglement of elementary particles. Entanglement and nonlocality were demonstrated in experiments with electrons and photons. Although DNA, being of mesoscopic scale, is a few orders of magnitude larger than particles for which quantum effects were demonstrated, it still retains some of the properties of the microscopic world: delocalization of electrons in aromatic rings of purines is well known and delocalization of protons in hydrogen bonds has also been shown. Another quantum property in DNA is known from the experiments on its electrical conductivity. It was experimentally shown that, in short tandem DNA repeats, electrons tunnel (same as jump or hop) through more than one base (Lewis et al. 2002).

Nonlocality, or action at a distance, was also experimentally studied in biology. Thorough and well-controlled studies of Radin, Sheldrake and others demonstrate that consciousness has a nonlocal component (Radin 2009; Sheldrake 2009; Storm et al. 2017; Bem et al. 2015; Mossbridge and Radin 2018). Sheldrake proposed that a substantial part of the human consciousness is located outside of the body in a nonlocal "morphic field"

(Sheldrake 2009). To expand this, we suggest that oscillations of aromaticity in stretches of DNA could serve as an interface between the local macroscopic world and the nonlocal "morphic field" governed by the laws of quantum physics. This nonlocality would also correspond to Bohm's implicate order of the De Broglie–Bohm interpretation of quantum mechanics (Bohm 1980).

Sheldrake also convincingly argues that the work of the mind is not limited to the brain and the rest of the body is involved in the work of the mind (Sheldrake 2009). For example, there are documented cases in which organ transplants transferred memories and character traits of transplant donors to recipients (Sheldrake 2009; Pearsall, Schwartz, and Russek 2002; Joshi 2011; Liester 2020). On the same note, the fish having no visual cortex was able to perceive a visual illusion, the function traditionally ascribed to the visual cortex. The above observations are in agreement with our model that unites the DNA of all the cells of the brain and the rest of the body into a fiberoptic network.

Genome as a quantum computer

It has been previously proposed that the genome works as a quantum computer (Richard A. Miller and Webb 1973; Gariaev et al. 2001; Pitkänen 2010). Here, we expanded this by adding a specific mechanism for quantum computation. The aromaticity oscillations are coordinated in stretches of DNA and are coupled to the oscillations of delocalized protons. Sequence-specificity of the patterns of the electron and proton clouds allows the DNA code to directly define the oscillations and thus serve as a program for the quantum computer. According to our model, the key intuitive/logical unit in this computer is the basepair, which oscillates between intuitive uncertainty and logical certainty, thus making a choice every cycle that happens approximately with GHz-THz frequency. The number of intuitive-logical units in this computer can be obtained by multiplying 6.4 billion purines per cell and by 30 trillion cells per human body. Therefore, or body contains $2*10^{23}$ intuitive-logical units (basepairs) that make choices with GHz-THz frequency each.

An important role in the model of the genome as a quantum computer must be given to the balance between chaos and self-organization of chromatin. The theory of self-organization of chaos is gradually expanding from weather and financial forecasts to biology (Gleick 1997). Fractality of chromatin is experimentally demonstrated in living cells (Bancaud et al. 2009). High resolution spatial mapping of chromatin in cells demonstrates that chromatin oscillates between chaos and organization: it organizes itself into fractal structures which are then destroyed by the randomnicity of Brownian motion (Knoch 2020). Therefore the key features of the genome as a quantum computer are the interplay between order and randomnicity, coherence and decoherence, delocalization and localization, quantum and classical mechanics. The results of the genomic computation inside the nucleus are integrated by the nuclear membrane and then the information is integrated by the fiberoptic network, which unites all genome copies of the body. In this way, the intuitive and logical computation on the molecular level is integrated in the work of our mind.

Conclusions

In summary, we were searching for sequence-specific oscillations in DNA and this brought our attention to sequence-dependent stacking of aromatic rings and proton wires stretched along the base stack. We then noticed that tautomerization must be sequence-dependent and should affect oscillations in delocalized charge clouds. Then we noticed that purines would oscillate between aromatic and nonaromatic states. Further, we incorporated these observations with the idea of fiberoptic signal transmission and the work of the mind. Verification of this model will require further studies including spectroscopic studies and quantum mechanical molecular modeling.

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Author contributions

MMR developed the hypothesis and wrote the manuscript. IVS did the literature work and contributed to the discussion.

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