https://www.scirp.org/journal/ns Natural Science, 2022, Vol. 14, (No. 11), pp: 463-471

Neurons Can Generate Electromagnetic Waves

Zuodong Sun

Ya'ou Brain Science Institute of Heilongjiang Province, Harbin, China

Correspondence to: Zuodong Sun, sunzuodong@pai314.com

Keywords: Neuron, Electromagnetic Wave, Accelerated Motion Charge, Antenna, The Nature of Consciousness

Received: October 9, 2022 **Accepted:** November 5, 2022 **Published:** November 8, 2022

ABSTRACT

Based on the potassium channel "origami windmill" model, and the conservation law of cell membrane area and ion inequality equation of based on the potassium channel "origami windmill" model, and Maxwell's electromagnetic theory, it is theoretically proved that neurons can generate electromagnetic waves. The electromagnetic wave is an energy wave, never disappear. Neurons are equivalent to engineering antennas, and information between neurons can be transmitted through electromagnetic waves. The material basis for neurons to generate electromagnetic waves is the result of the exchange of cations on the inner surface of the cell membrane, especially Na^+ and K^+; The essence of consciousness should be electromagnetic wave. The conclusion that "neurons can generate electromagnetic waves" provides theoretical support for human beings to finally solve the mystery of the brain. At the same time, the author gives seven falsification schemes. The brain is a huge gold mine, and it is too important to crack the mystery of the brain. It should be a joint operation of "multiple arms". It should not only be the work of brain scientists, but also the participation of physicists, chemists and mathematicians.

1. INTRODUCTION

Neurons, composed of cell body, dendrites and axons, are the basic functional units of the brain. Since the late 17th century, the era of Luigi Galvani, people have known that the brain transmits information through electrical pulses. However, it was not until a century later that Santiago Ramón y Cajal described in his theory of dynamic polarization how information is conducted inside a single neuron-electrical signals are transmitted from the dendrites of neurons to the cell body, and finally to the axons. Later research proved that Cajal was right [1]. So, how do neurons communicate information with each other? It is generally believed that the nerve electrical pulse will be transmitted along the axon to the end, and the axon end will release the chemical neurotransmitter into the synaptic space, and then the neurotransmitter will act on the post synaptic dendrites or cell bodies, that is, "electricity → chemistry → electricity" conduction [2, 3] (**Figure 1**).

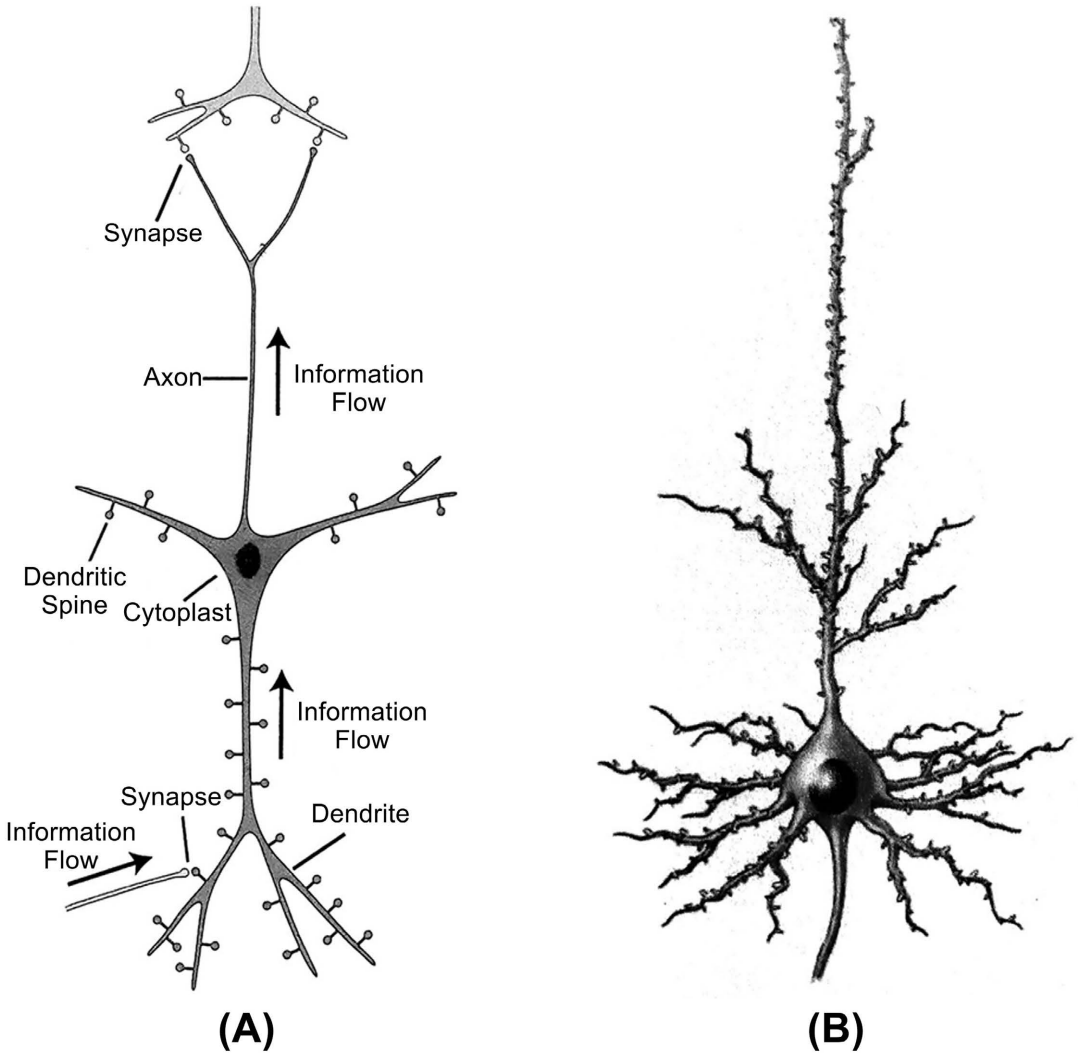

Figure 1. Neuron, information flow and engineering antenna. (A) Information flow of neurons. The dendrites of neurons receive input information from other neurons, and then transmit it to the cell body, and then to the axons, which in turn transmit information away from the cell body; (B) Neurons and Engineering Antennas. The shape of neurons is similar to whip antenna or Yagi antenna (fishbone shaped).

We believe that the conduction mode of "electricity → chemistry → electricity" may not be the whole truth. For example, in a simple reflection, when a person steps on a pushpin, the person's reaction from stepping on the pushpin to lifting his foot may be less than 1 second. At this moment, hundreds of millions of neurons in several regions of the brain need to be mobilized, and neuronal signals are sent from the brain to the spinal cord to "lift the foot" by controlling the muscles. If it is conducted by "electricity → chemistry → electricity", it is impossible to complete the task in one second. Our reasons are as follows: 1) Nerve axons are bathed in extracellular fluid, if only through the conduction mode of "electricity → chemistry → electricity", the electrical signal carried cannot not be attenuated; 2) The so-called neurotransmitters cannot carry such complete "thought" information; 3) The single or a few neurons that first receive external information have fixed positions. If they are completely "electricity → chemistry → electricity", it is impossible to spread information to different regions of the brain in an instant and "synchronously" activate hundreds of millions of neurons.

Therefore, after our research, we believe that the mode of information transmission between neurons may also include electromagnetic waves. If there are electromagnetic waves, then we need to find the open source that can generate electromagnetic waves. Previously, we have established the potassium channel "origami windmill" model [4] (2019). The potassium channel "origami windmill" model is based on the biophysical principle of cells and the observation test of MacKinnon's laboratory on the crystal structure of K^+ channel. It discusses how the K^+ of K^+ channel is transferred from extracellular transmembrane into cells, as well as the conversion process and mechanism of "opening" and "closing" of K^+ channel. Based on the potassium channel "origami windmill" model, the whole process of action potential generation in nerve fiber cells and cardiomyocytes was reasonably explained [5] (2020). Based on the potassium channel "origami windmill" model, a new theory that can reasonably explain the mechanism of bioelectricity, the law of conservation of cell membrane area, and a new mathematical model based on the new theory, ion inequality equation, are also proposed [6] (2020), and Maxwell's electromagnetic theory (1873). All these have strengthened our confidence in writing this article and are the biophysical basis for us to explore whether neurons can generate electromagnetic waves. In addition, in order to explain the problem accurately, this paper is only based on the original data of the Hodgkin and Huxley experiments in 1939—the measured action potential results of the giant axon of the squid with a microelectrode [7] (**Figure 2**).

2. NEURONS AND ELECTROMAGNETIC WAVES

We know that the electrical signal transmitted inside a single neuron is transmitted from the dendrite of the neuron to the cell body, and finally to the axon. Its circuit is approximately equivalent to **Figure 3**, but not completely equivalent. It should be noted that the understanding of "neurons and electromagnetic waves" cannot be completely limited by the capacitance in engineering technology, and the information flow, electrical signal and current cannot be completely equivalent, especially in the flow "direction".

"When the switch and power supply are turned on", it is equivalent to the resting potential period (−60 mV to −40 mV) in the neuron, and the capacitor is charged by 20%. It is the process of Na^+ entering the cell from the outside through dendrites in a uniform linear motion. It is a self-field and will not form electromagnetic waves moving in space [6, 8] (**Figure 3(A)**). Because only the accelerating charge can excite the electromagnetic wave that can separate from the opening source and move independently in space. The static charge can only excite the electrostatic field and will not form the electromagnetic wave that moves in space. The field excited by the uniformly moving charge is carried by the moving charge and

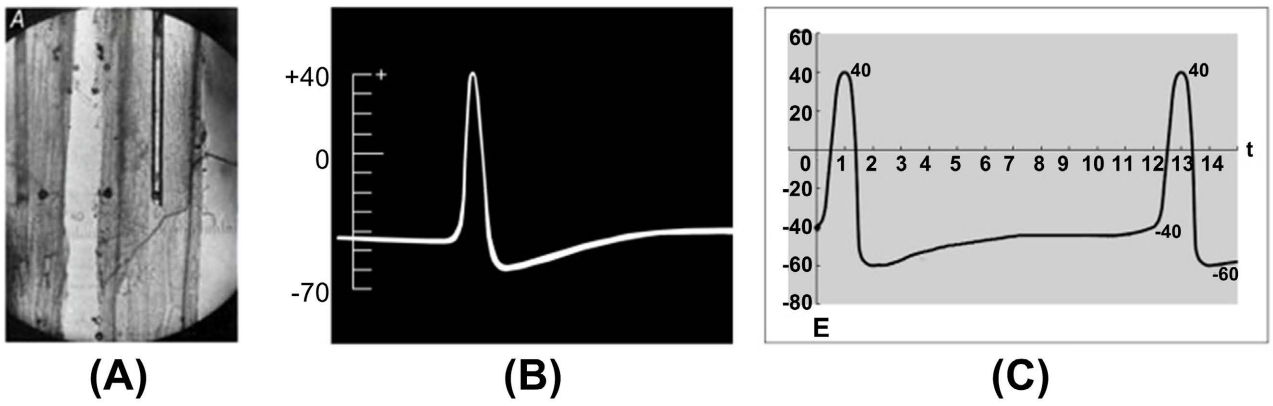

Figure 2. Intracellular recording of giant axon action potential of cuttlefish. (A) Micrograph of the electrode inside the giant axon of Squid (diameter approx. 500 μm). Two views of the same axon can be seen from the microscope designed by Huxley; (B) The first intracellular action potential recording; (C) The basic expectation of resting potential and action potential by using the ion inequalitye quation, resting potential: $N = -60 + 2t$, in which t is about 0 - 10 ms; Action potential: $N = -40 + 170t - 90t^2$, in which t is about 0 - 2 ms.

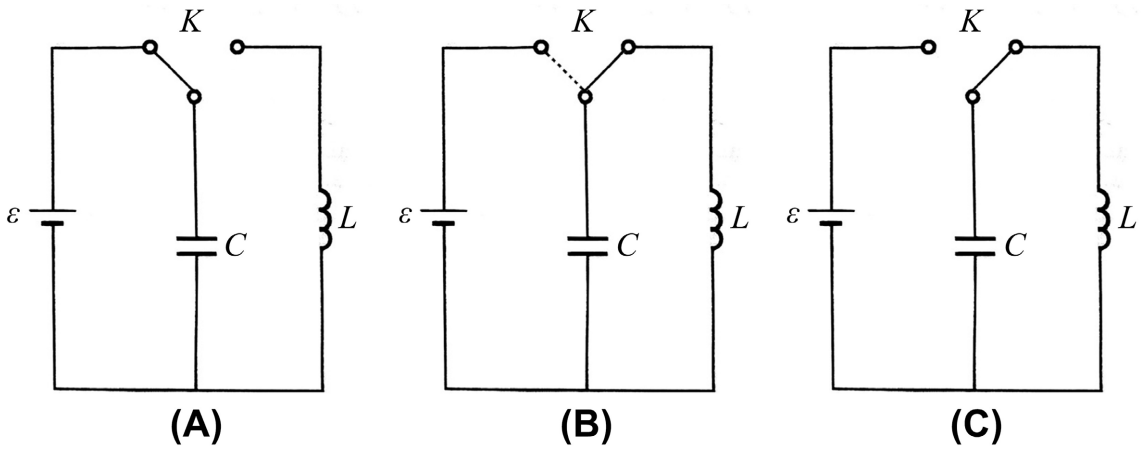

Figure 3. Action potential equivalent circuit. Essentially, all antennas can be regarded as LC oscillators consisting of an inductor and a capacitor with lumped parameters. (A) Equivalent circuit during resting potential period (−60 mV to −40 mV); (B) Equivalent circuit of action potential rising phase (−40 mV to +40 mV); (C) Equivalent circuit of action potential falling phase (+40 mV to −60 mV).

moves with the charge, which is called the self-fields. In the moving reference system, the self-fields is still a static field [9].

"Move the switch and connect with inductor L at the same time", which is equivalent to the action potential in the neuron. In the rising phase of the action potential (−40 mV to +40 mV), its equivalent circuit should be **Figure 3(B)**, it is equivalent to continuing to charge 80% of the capacitor. It is a process in which extracellular Na^+ enter the cell through the dendrites in a uniform accelerated linear motion; The equivalent circuit of the action potential falling phase (+40 mV to −60 mV) is shown in **Figure 3(C)**, which is equivalent to the discharge process. The discharge is completed by 100%. It is a process in which extracellular K^+ enter the cell through dendrites in a uniform accelerated linear motion [6].

Compared with extracellular, it is the process of Na^+ (in the rising phase) and K^+ (in the falling phase) entering the cell from the outside, the process of information flow entering the cell body, and this process still occurs in dendrites. But relative to the cell, it is the process of K^+ (in the rising phase) and Na^+ (in the falling phase) accelerating from the cell to the outside, and the process of information flow out of the cell, which occurs in the axon. See the attached **Table 1**: corresponding relationship with the whole process of neuronal action potential. Na^+ and K^+ complete the acceleration of electric charge together by relay, and the whole process of neuron action potential meets the necessary conditions for generating electromagnetic waves.

The neuron is equivalent to the "antenna" in engineering technology, and the shape of the neuron is more like a whip antenna or a Yagi antenna (fishbone shaped), as shown in **Figure 1(B)**, **Figure 4**. Therefore, neurons can not only transmit electrical signals, but also receive electrical signals. When an electromagnetic wave propagates in space, if it encounters a conductor, it will cause the conductor to produce an induced current whose frequency is the same as that of the electromagnetic wave that excites it. Therefore, the electromagnetic wave can be received by using the conductor existing in the electromagnetic wave propagation space. When the natural frequency of the receiving circuit is the same as the frequency of the received electromagnetic wave, the oscillating current generated in the receiving circuit is the strongest. The principle of the transmission of electrical signals between neurons in the "brain" should be the same. It should be noted that the axon itself is "cell membrane".

−60 mV to +40 mV, or+40 mV to −60 mV, the difference is 100 mV, which can also be understood as: 100G (G is constant, $G = 1.25 \times 10^3$ ions/mV) positive charge enters the cell through dendrites in a uniform and uniformly accelerated linear motion, and then leaves the cell through axons in a uniformly accelerated linear motion. Relative to the position of +40 mV, the cation on the surface of the cell inner

Table 1. Corresponding relationship with the whole process of neuronal action potential.

potential / Counterpart	Resting potential	action potential	
		rising phase	falling phase
Voltage variation	−60 mV - −40 mV	−40 mV - +40 mV	+40 mV - −60 mV
Sports mode	Na^+ enters the cell through dendrites with uniform linear motion	Na^+ uniformly accelerates into, K^+ leaves with uniform acceleration, the replacement ratio is 3:2:1	K^+ enters with uniform acceleration, Na^+ leaves with uniform acceleration, and the replacement ratio is 2:3:1
Charging and discharging	20% of charging process completed	80% of charging process completed	100% of discharge process completed
Neuron site	Occurs in dendrites	Na^+ accelerates from dendrite to cell body K^+ accelerates to leave the cell body from the axon	K^+ accelerates from dendrite to cell body Na^+ accelerates to leave the cell body from the axon
Charge change	Charge: 0 - 100G +40 mV cell inner membrane ion saturation, 300G Na^+		Charge: 100G - 0 −60 mV cell inner membrane ion saturation, 200G K^+
Origami windmill	Uniform rotation	Uniformly accelerated rotation	Uniform deceleration rotation
Electromagnetic wave	The static field does not generate electromagnetic waves	An accelerating charge can produce electromagnetic waves	

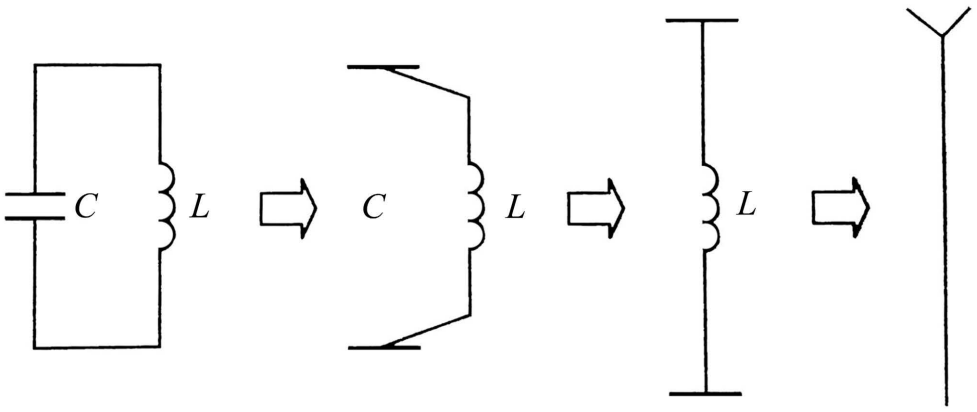

Figure 4. LC oscillator transformed into antenna. In engineering, the device that actually emits electromagnetic waves is the antenna. All antennas can be regarded as LC oscillators composed of an inductor and a capacitor in essence. The LC oscillator is transformed into an antenna by gradually pulling the two plates of the capacitor apart and finally being replaced by "sky" and "earth".

membrane is saturated, all of which are Na^+, with a quantity of 300G, which is 100G more positive charge than the position of −60 mV; Relative to the position of −60 mV, the cation on the surface of the cell inner

membrane is saturated, all of which are K^+, with the amount of 200G, which is 100G less positive charge than the position of+40 mV. It conforms to the law of equal charge [6, 8].

Although the direction of information flow in the dendrites and axons of neurons has not changed, the number of charges on the surface of the cell inner membrane has been reversed instantaneously during the transformation of the rising and falling phases of action potential. The change from 0 to 100G to 100G to 0 is equivalent to an instant reversal of the charge number on the two plates of the capacitor, or an electromagnetic shock. Like a river, the flow direction of the river has not changed, but the water level has changed. The instantaneous fluctuation difference is 100G, not plus or minus 100G.The accelerating motion electric charge is like "sailing against the current". Therefore, in theory, neurons can generate electromagnetic waves. It should be noted that the K^+ and Na^+ or charge uniform motion and uniform acceleration motion mentioned in this article mean that the number of K^+ and Na^+ or the number of charges changes at a uniform speed or uniform acceleration, not the real motion mode of K^+ and Na^+ or charge entering and leaving neurons.

Falsificationist method: 1) It can overturn the potassium channel "origami windmill" model; 2) It can overturn the conservation law of cell membrane area; 3) It can overturn the ion inequality equation; 4) It can overturn Cajal's Theory of Dynamic Polarization; 5) It can be proved that: in the falling phase of cell action potential, K^+ flow out rather than inflow; 6) It can be proved that the neurons cannot be equivalent to the "antenna" in engineering; 7) It can be proved that the information between neurons in the "brain" is indeed transmitted through the way of "electricity → chemistry → electricity". As long as any of the above seven experimental schemes is true, the conclusion that "neurons can generate electromagnetic waves" is not true.

3. NEURON INFORMATION TRANSMISSION

In fact, the two neurons are not directly connected. There is an obvious gap between the two neurons, which is about one fortieth of a micron wide. This gap is called the synaptic gap. When an electrical pulse reaches the front of a synapse, it releases a small packet of chemicals (called vesicles) into the synaptic fissure. The previous general view was that these small chemical molecules were rapidly diffusing in the fissure, some of which were combined with molecular gates on the postsynaptic cell membrane to open these special gates, and allow charged particles to flow into or out of the postsynaptic membrane, so as to change the transmembrane local potential. The whole process was considered as an "electricity → chemistry → electricity" process [2]. This may not be the whole truth.

The peak potential in the axon is not like the current in the wire. In the metal wire, the current is carried by a mass of electrons. In neurons, the electrical effect depends on the charged ions entering and leaving the axon, such as K^+ and Na^+. The final charge is determined by the difference between the number of ions entering and leaving. The propagation speed of electrical signals from dendrites to axons is determined by the speed of ion exchange on the cell inner membrane, so it is impossible to approach the speed of light as the current in the metal wire. In the middle of the 19th century, Helmholtz finally measured the speed of signal transmission from dendrites to axons, and found that it rarely exceeded 30 feet per second, which was about one-third of the speed of sound transmission in the air. For the axon without myelin sheath, its speed is generally 5 feet per second, which seems quite low. It is equivalent to walking 1.5 mm per millisecond, which is equivalent to 1.5 meters per second [2].

Because the nerve axon is immersed in the extracellular fluid, its insulation is so poor. If the conduction mode of "electricity → chemistry → electricity" is completely followed, the electrical signal carried by it impossible not be attenuated. However, it is an iron fact that the occurrence of neuronal action potential does not decline with distance [10]. The transmission of neurotransmitters in extracellular fluid takes time, even if it is conducted in the way of dominoes, time is not allowed. Therefore, we believe that the information transmission mode between neurons in the "brain" should include electromagnetic waves, which is equivalent to the mass sending of information on our mobile phones. The neuron receiving the signal is activated by the electric field induced by the magnetic field, reaching the action potential threshold of −40 mV, and the activated neuron can be regarded as a new electric field "opening source", which

almost "synchronously" generates a new magnetic field. According to the superposition principle of electromagnetic waves, hundreds of millions of activated neurons synchronously "generate electricity" or "generate force" to complete the task of "lifting feet" at the moment of "stepping on the pushpin", which is not the work of a single neuron. Only through the "electricity → chemistry → electricity" conduction mode, it is impossible to "synchronously" activate hundreds of millions of neurons, and the electrical signal impossible not be attenuated. When a neuron receives a signal, it will "modulate" the signal and send it to all neurons in the brain, but not all neurons can make a positive response.

The background wave of the neuron (**Figure 2(C)**) is equivalent to the natural frequency in the LC oscillation circuit. This background wave also exists when it is not stimulated by the outside world, and its frequency is generally 1 - 5 Hz. One of its functions may be to maintain the normal operation of our autonomic nervous system, such as heart rate, respiration, digestion, blood pressure, metabolism, etc; Another main function of this background wave may be "carrier", which can carry "thought" information after modulation. When a neuron receives an external stimulus signal, its transmitting frequency will increase to a large value, which is equivalent to the "modulation" of electromagnetic waves in engineering, and the modulation methods include amplitude modulation, frequency modulation, or the transmission of digital information by electromagnetic waves, typically 50 - 100 Hz or higher. In a short time interval, the firing frequency can be as high as 500 Hz [2], and the upper limit of the maximum firing frequency is about 1000 Hz [10]. Another possible role of neurotransmitters is to be recycled by neurons. Similar to the role of Na^+, neurotransmitters are used to "reconstruct" background waves.

What is the wavelength of the electromagnetic wave generated by the neuron? The propagation speed of electromagnetic wave in various media is different, because electromagnetic wave is shear wave, and its propagation speed in solid is about 4 - 8 km/s, which should be equivalent to the propagation speed of electromagnetic wave in our "mind". The relationship between wavelength, wave velocity and frequency: $c = \lambda f$. Where **c** is the speed of light, λ is the wavelength and f is the frequency. Because "when the electromagnetic wave propagates in space, if it encounters a conductor, it will cause the conductor to produce an induced current, and the frequency of the induced current is the same as the frequency of the electromagnetic wave that excites it", the frequency of the background wave in the "brain" is generally 1 - 5 Hz, and the frequency of the information carried is 50 - 1000 Hz. Calculated according to the frequency of 500 Hz, and the average propagation speed in the "brain" is 6 km/s, its wavelength is λ = 12 m, belonging to the long band of electromagnetic wave.

If the electromagnetic wave generated in the "brain" leaves the "brain source", the speed of propagation in space can be understood as the speed of light. Medium and long waves can bypass obstacles and spread on the earth's surface. Although the ionosphere reflects long, medium and short waves, and the longer the wavelength is, the easier it is to reflect, the absorption of the ionosphere to electromagnetic waves also increases with the increase of the wavelength [9]. Therefore, if the electromagnetic wave generated in the brain leaves the "brain source", its final destination should be the same as the electromagnetic wave in engineering technology. Some are reflected by the ionosphere, some are absorbed by the ionosphere, and some "escape" to space through the ionosphere. Electromagnetic waves are energy waves and never disappear.

4. CONCLUSIONS AND DISCUSSION

Theoretically, neurons can generate electromagnetic waves. Electromagnetic waves are energy waves and never disappear. Neurons are equivalent to engineering antennas. In addition to "electricity → chemistry → electricity", the information transmission mode between neurons may also include electromagnetic waves. The material basis for neurons to generate electromagnetic waves is the result of the mutual replacement of cations on the inner surface of the cell membrane, especially Na^+ and K^+. The essence of consciousness should be electromagnetic wave. The conclusion that "neurons can produce electromagnetic waves" provides theoretical support for human beings to finally solve the mysteries of the brain and reveal the essence of consciousness.

In the dynamic polarization theory, Cajal described how information is transmitted within a single neuron, but he did not doubt that the "electricity → chemistry → electricity" conduction mode between neurons was not unique. Francis Crick believed that all aspects of brain behavior came from the activity of neurons, but Crick's work did not find that the neurons were "antennas". In fact, is there a so-called ionosphere in our "mind"? Could it be cerebrospinal fluid? Because our brain is suspended in the cerebrospinal fluid.

In addition, is it possible for the electromagnetic wave in our brain to pass through the "cerebrospinal fluid" and float in the air? How to explain human telepathy [11]? Also, the phospholipid bilayer of the cell membrane is a light oil liquidthat can flow [10]. Can it be regarded as the "ionosphere" of the cell? A single neuron is equivalent to a person with independent thinking. Is the information exchange between neurons with reservations that between human beings? Are animals and people alike able to generate electromagnetic waves in theory?

The brain waves we usually speak of are not electromagnetic waves, but the wave patterns measured are just the maps of voltage fluctuations with time. Brain waves, electroencephalogram, artificial intelligence (AI), etc. have not really touched the mystery of the brain. From the perspective of human historical development, the main goal of brain research is not only to understand and treat various brain diseases, although this is very important, but also to master the true essence of the human soul [2]. The brain is a huge gold mine, and it is too important to crack the mystery of the brain. It should be a joint operation of "multiple arms". It should not only be the work of brain scientists, but also the participation of physicists, chemists and mathematicians.

CONFLICTS OF INTEREST

The author declares no conflicts of interest regarding the publication of this paper.

REFERENCES

1. Newman, E.A., Swanson, L.W., Araque, A., *et al.* (2017) The Beautiful Brain: The Drawings of Santiago Ramóny Cajal. Harry N. Abrams, Inc., New York.
2. Crick, F. (1995) The Astonishing Hypothesis: The Scientific Search for the Soul. Simon & Schuster, New York. https://doi.org/10.1097/00005053-199606000-00013
3. Han, J.S. (2009) Neuro Science. 3rd Edition. Peking University Medical Press, Beijing.
4. Sun, Z.D. (2019) Potassium Channel Origami Windmill Model. *Journal of US-China Medical Science*, **16**, 1-4. https://doi.org/10.17265/1548-6648/2019.04.002
5. Sun, Z.D. (2020) Interpretation of Action Potential Generation Mechanism in Cardiomyocytes by Potassium Channel "Origami Windmill" Model. *Journal of US-China Medical Science*, **17**, 132-139. https://doi.org/10.17265/1548-6648/2020.04.002
6. Sun, Z.D. (2020) Conservation Law of Cell Bioelectricity Membrane Area and Ion Inequality Equation Based on Potassium Channel "Origami Windmill" Model. *Journal of US-China Medical Science*, **17**, 177-192. https://doi.org/10.17265/1548-6648/2020.05.001
7. Hodgkin, A.L. and Huxley, A.F. (1939) Action Potentials Recorded from Inside a Nerve Fibre. *Nature*, **144**, 710-711. https://doi.org/10.1038/144710a0
8. Li, C.Z. and Yang, L.J. (2009) University Physics. Volume II. China Science Publishing & Media Ltd., Beijing.
9. Cheng, S.Z. and Jiang, Z.Y. (2006) General Physics. 6th Edition. Volume II. Higher Education Press, Beijing.
10. Bear, M.F. (2004) Neuroscience: Explore the Brain. 2nd Edition. Higher Education Press, Beijing.
11. Njikeh, K.D. (2014) Electromagnetic Wave and Gaseous Communication between Individuals. *Neuroscience & Medicine*, **5**, 20-22. https://doi.org/10.4236/nm.2014.51004

CORRIGENDUM

The author made corrigendum to the References 6 article *Conservation Law of Cell Bioelectricity Membrane Area and Ion Inequality Equation Based on Potassium Channel "Origami Windmill" Model* of cited in this paper due to two clerical errors:

Original content: The third paragraph of "1.2 Physical phenomena of cell membrane ion exchange", "Action potential, relative to K^+, rises from −40 mV to +40 mV, which is the process of intracellular K^+ from the L channel uniform deceleration flowing to the extracellular;" "the decrease from +40 mV to −60 mV, is a process of uniform deceleration of intracellular Na^+ from the L channel to the extracellular."

The "uniform deceleration" mentioned twice is changed to "uniform acceleration".

Content after change: "Action potential, relative to K^+, rises from −40 mV to +40 mV, which is the process of intracellular the amount of K^+ from the L channel uniform acceleration flowing to the extracellular;" "the decrease from +40 mV to −60 mV, is a process of uniform acceleration of intracellular the amount of Na^+ from the L channel to the extracellular. "Among them, the K^+ and Na^+ uniform motion and uniform acceleration motion mentioned in the article mean that the number of K^+ and Na^+ or the number of charges changes at a uniform speed or uniform acceleration, not the real motion mode of K^+ and Na^+ or charge entering and leaving neurons.

By taking the opportunity of the official publication of this paper to corrigendum and declare that it will not affect the conclusions of the relevant papers.