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The Neural Conduction

The Personal View vs. the International View

I do believe the mechanism of the neural conduction is simpler than its worldwide conception. Moreover, I do believe the main stone of the neural conduction is a pressure wave generated at the distal limit of the Axon Hillock. Like any other longitudinal waves, the action pressure wave has two distinctive elements, the tail and the front. The front of the pressure wave is of a positive pressure, while its tail is of a negative pressure. The negative pressure of the tail opens the gates of the sodium channels and invites the positive sodium ions Na^+ from the outside space into the axon hillock' lumen. The incoming sodium ions Na^+ charge positively the tail of the pressure wave, and creates the anode of the future neural conduction current. While, due to the intra cellular proteins, the negative charge of the axon cytoplasm forms its cathode.

Hereafter, I will develop my personal conception of the mechanism of the neural conduction in the neural fibers. One could read the international conception of the neural conduction, and then could recognize the differences between the two theories.

1- The Action Pressure Wave

The action pressure wave is the generator and the porter of the neural conduction current in both the motor and sensory neurons. In the sensory neurons, the components (wave units) of the action pressure wave are built up in the sensory receptors. However, in the motor neurons, the action pressure wave is built up in one single block at the border area between the axon hillock and the axon. The both, the action pressure wave and the neural conduction current, run on throughout the neural fiber's lumen at the center.

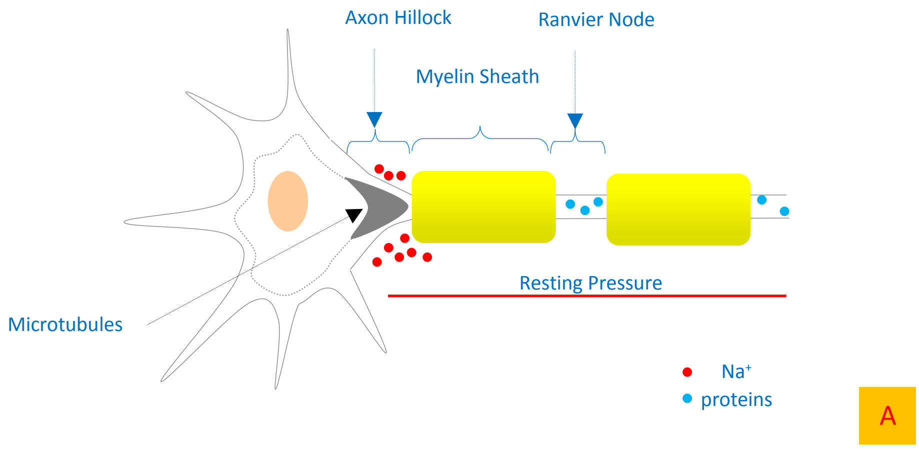
1-1 The Action Pressure Wave in the Motor Neuron

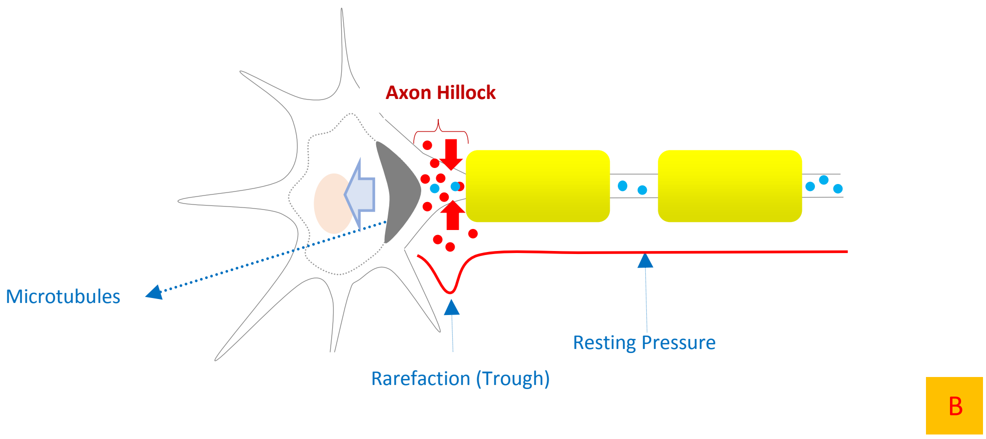
At rest, a resting pressure dominates inside the soma (the cell body of the neuron) and inside the axon as well. This resting pressure is considered the base line pressure; ***figure (1-A).***

In the axon hillock, after reaching the threshold, the massively present microtubules contract and withdraw toward the soma. Thus, they create the central pressure wave (***figure 2***). Moreover, an area of negative pressure is created inside the axon hillock. The induced negative pressure opens the gates of the sodium channels and invites the sodium ions to enter into the lumen of the axon hillock. These incoming positive sodium ions positively charge the cytoplasm in this specific area (axon hillock), while the rest of the axon's cytoplasm is negatively charged due mainly to the negative charge of intra cellular proteins***; figure (1-B).***

After contracting, the microtubules of the axon hillock relax and return to its essential position influenced by the rebound of the central pressure (***figure 2***). Their return to the starting position compresses the incoming sodium ions and creates a pressure impulse, which is the action pressure wave; ***figure (1-C).***

Consequently, the incoming positive sodium ions create the anode of the action neural conduction current, whereas the negative charge of the distal axon makes its cathode.


Axon Hillock
Ranvier Node
Myelin Sheath
Resting Pressure
Microtubules
Na+
proteins
A


Axon Hillock
Microtubules
Resting Pressure
Rarefaction (Trough)
B

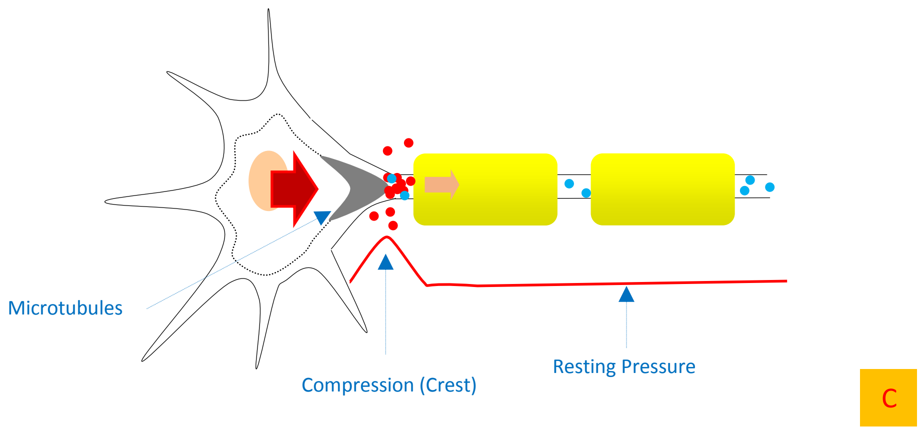

Microtubules
Compression (Crest)
Resting Pressure
C

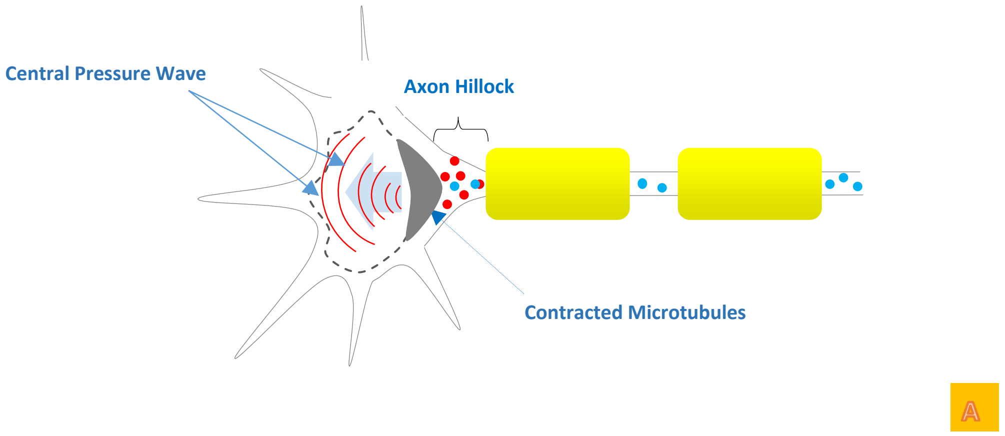
Figure (1)
The Action Pressure Wave & The Neural conduction Current
(Personal Approach)
The Axon Hillock is the area located between the body of the neuron (Soma) and its axon. I do believe the neural conduction starts from its distal portion, at the border between it and the axon. The axon hillock contains a huge quantity of microtubules in the form of a pyramid with its apex regarding the axon. Moreover, a large number of pressure gated sodium channels is omnipresent in this area.

Figure (A) At rest, a resting pressure dominates inside the soma (the cell body of the neuron) and inside the axon as well. This resting pressure is considered the base line pressure.

Figure (B) Reaching the threshold, the massively present microtubules contract and withdraw toward the soma. Thus, they create an area of negative pressure inside the axon hillock. The induced negative pressure opens the gates of the sodium channels and invites the sodium ions to enter into the lumen of the axon hillock. These incoming positive sodium ions positively charge the cytoplasm in this specific area (axon hillock), while the rest of the axon cytoplasm is negatively charged due to the negative charge of proteins.

Figure (c) After contracting, the microtubules of the axon hillock relax and return to its essential position. Their return to the starting position compresses the incoming sodium ions and creates a pressure impulse, which is the action pressure wave.

Consequently, the incoming positive sodium ions create the anode of the action neural conduction current, whereas the negative charge of the distal axon makes its cathode.



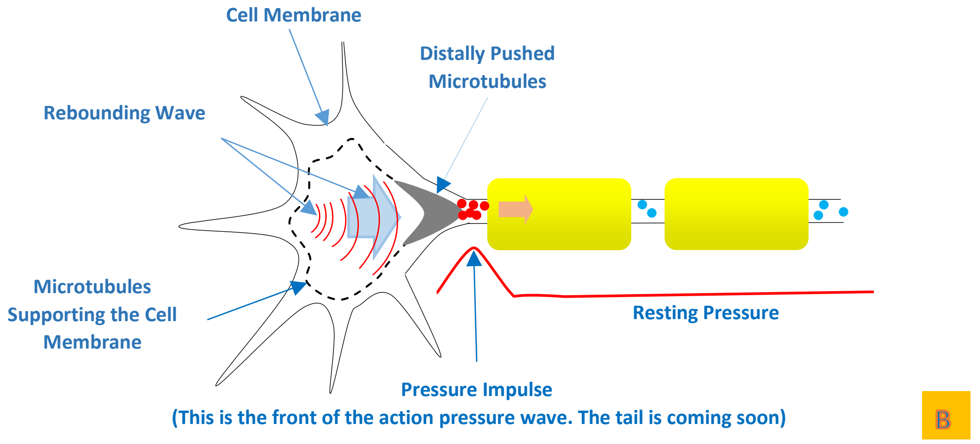


Figure (2)
The Central Pressure Wave
is the Starter of the Action Pressure Wave
Figure (A) reaching the threshold, the microtubules in the axon hillock contract creating a central pressure wave (large light blue arrow), that invades the cytoplasm of the soma (cell body).

Figure (B) the central pressure wave rebounds from the membrane of the soma, and returns to its origin. The rebounding wave hits the contracted microtubules and pushes them back to their starting position. By consequent, a pressure impulse (red arrow) is built up in the distal portion of the axon hillock.

1-2 The Action Pressure Wave in the Sensory Neurons*

In response to a stimulant, a mini pressure wave (Wave Unit) is built up in every sensory receptor. At its passage through the first node of Ranvier, every wave unit builds up its mini neural conduction current (Current Unit)***; (figure 4***). At the root of the dendrites, all the units of the same neuron merge together to form one single action pressure wave, and one neural conduction current as well, ***figure (3).***

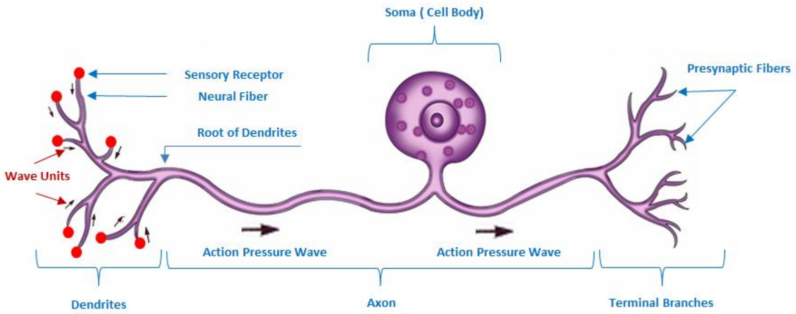


Figure (3)
The Sensory Neuron, The Action Pressure Wave
In every sensory receptor, a wave unit is built up in response to the stimulation. During its passage through the first node of Ranvier, the negative pressure of the wave unit's tail invites the positively charged sodium ions into the lumen of the neural fiber. Consequently, the current unit is built up (see **figure 4**). At the root of the dendrites, all the wave units and the current units emerge together in one single action pressure wave and one single action current respectively. Then, the two, the action wave and the action current, run on throughout the axon at the center sector of the lumen.
Note: I used the term ***UNIT***$_{(s)}$, such as the ***Wave Units*** and the ***Current Unit***s, to identify the ingredients of the final entity, such as the ***Action Pressure Wave*** and the ***Neural Conduction Current***.

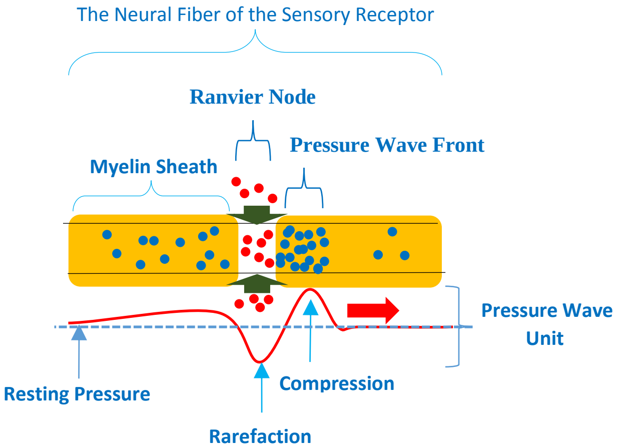


Figure (4)
The Neural Fiber of The Sensory Receptor & the First Node of Ranvier
How to Build up the Current Unit
At its passage through the first node of Ranvier, the negative pressure (Rarefaction) of the tail of the wave unit opens the gates of the sodium ion channels, and invites the sodium ions Na^+ (red balls) to come into the lumen of the neural fiber. The incoming sodium ions form the anode of the current unit, while the distal part of the fiber itself natively forms its cathode.
Note1: the pressure gated sodium ion channels are invisible in the figure. However, they remarkably exist in the cell membrane of the node of Ranvier ten to twenty times more than their existence in the axon hillock.

Note2: the blue balls represent the cytoplasmic elements and the intra cellular proteins in particular. These proteins are negatively charged.

2- The Pressure-Gated Sodium Ions Channels**

The pressure-gated sodium ions channels are omnipresent throughout the cell membrane of the unmyelinated neural fibers. In contrast, they only exist in the cell membrane of both the axon hillock and the nodes of Ranvier of the myelinated neural fiber. They play the essential role in the generation of the neural conduction current and in the maintenance of the action pressure wave.

The pressure-gated sodium ion channel consists of a channel through which the sodium ions pass, and a gate that controls the one-way outside-to-inside passage through the channel. The gate is connected to the proximal wall of the channel in the lumen of the neural fiber; ***figure (5).***

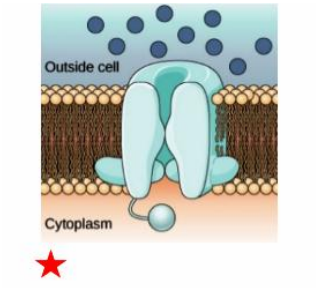


Figure (5)
The Pressure Gated Sodium Ion Channel
It is a communicative channel between the outside cell and the cytoplasm. The gate is connected to the proximal wall of the channel. The red star refers to the proximal side, i.e. the side of the cell body. The blue balls refer to the extra cellular sodium ions Na^+.

The gate's architecture of the sodium ion channel imply the role of the pressure wave in its function. It is logical to refer the gate's closure to the high pressure of the wave's front, and to refer its opening to the negative pressure of the wave's tail.

During the passage of the action pressure wave at the level of the channel, the high pressure of the front will push up the gate and will close the channel for a while. However, it is the role of the negative pressure of the wave's tail to open the gate of the sodium channel, and to invite the sodium ions into the lumen of the neural fiber; ***figure (6).***

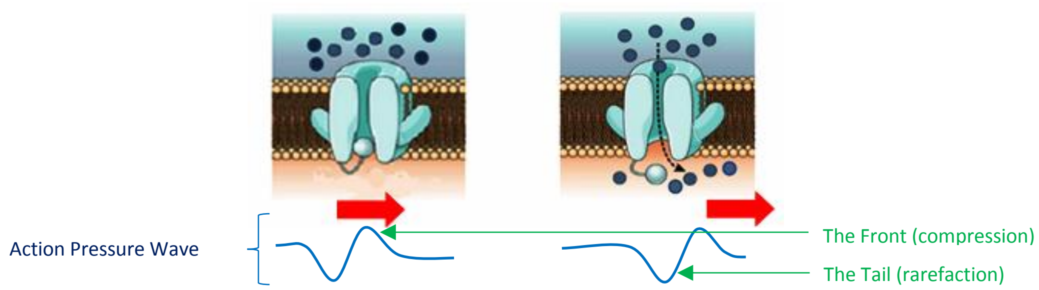


Figure (6)
Pressure-Gated Sodium Ion Channel in Action
The high pressure of the front of the action pressure wave pushes up the gate and subsequently closes the channel. After a while, the negative pressure of the tail of the wave will open the gate and will invite the sodium ions to enter into the lumen of the neural fiber.

Note1: the red large arrow locates the position and the direction of the front of the action pressure wave in a specific moment.

Note2: The two green arrows refer to the sector of wave in action in the same specific moment. note3: The blue balls represent the sodium ions Na^+.

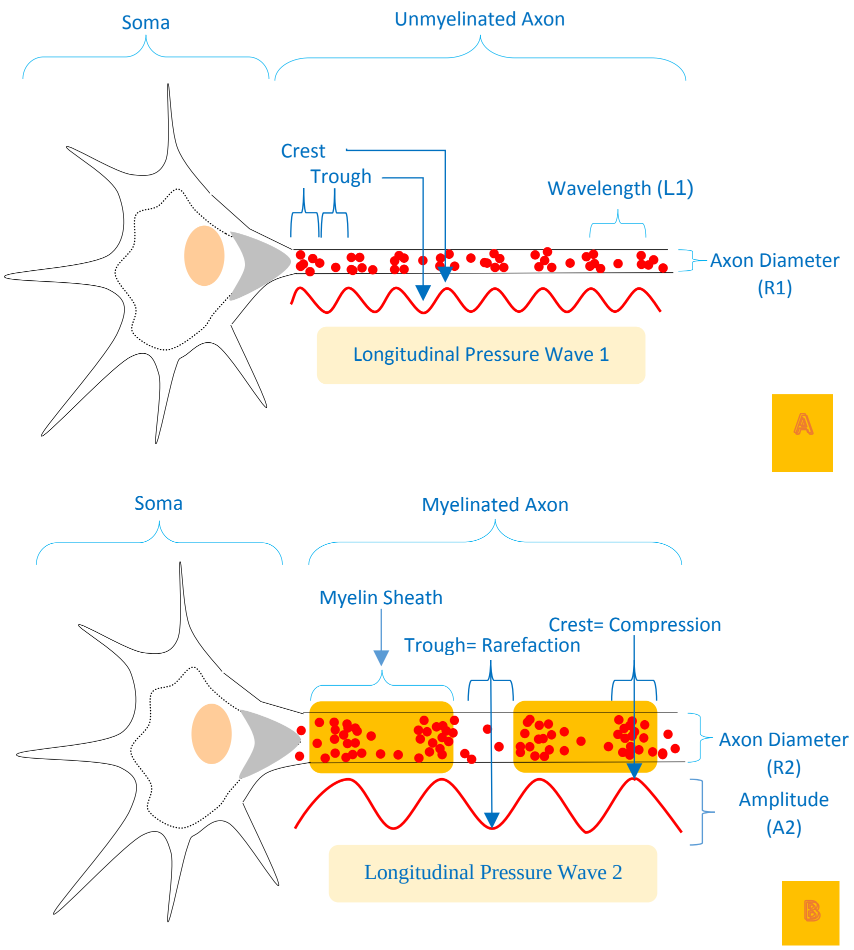
3- The Myelin Sheath

Like any other longitudinal wave, the pressure wave has its parameters, i.e. the wavelength and amplitude, the wave velocity, and the wave energy. The velocity of the pressure wave is proportionally related to its wavelength. The wavelength increases, its velocity increases and all the other parameters increase as well. Among the enforced wave parameters is the wave energy.

Moreover, to generate an action pressure wave of high velocity, it is obligatory to build up an elevated resting pressure inside the neural fiber.

The cell membrane of the neural fiber per se cannot tolerate the elevated values of the both, the resting pressure and the action pressure wave. For that, the neuron enforces its neural fibers of high velocity par the myelin sheath.

The myelin sheath enables the neuron to build up wider and stronger neural fibers. The two last parameters of neural fibers are indispensable for a higher velocity in conducting the information and the orders. For this reason, the neural conduction in the myelinated neural fibers is faster than the neural conduction in the unmyelinated ones; ***figure (7)***.



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The Myelin Sheath is Indispensable for a Fast Neural Conduction

Like any other longitudinal wave, the energy and the velocity of the action pressure wave are proportionally correlated to its wavelength. The wavelength and the wave amplitude are attached to each other. Consequently, a faster pressure wave is equivalent to a longer wavelength, and to a higher amplitude. Therefore, in order to obtain a faster neural conduction, it is obligatory for the neurons to build up a wider, and a stronger, neural fiber that can tolerate the action pressure waves of high energy and of high velocity. Their tool to do that is the myelin sheath.

(V) Wave Velocity ↑ ⟷ (L) Wavelength ↑ ⟷ (E) Wave Energy ↑

Wavelength (L) ↑ ⟷ Wave Amplitude (A) ↑

Figure (A) Unmyelinated Neural Fiber: It cannot be but of a small diameter (R1). The small diameter of the unmyelinated fiber cannot allow passage but an action pressure wave of a short wavelength and of a slow velocity (V1).

Figure (B) Myelinated Neural Fiber: The myelin sheath permits to build up a wider (R2) and a stronger neural fiber.

Thus, a longer and a faster pressure wave can freely run on without any difficulties.

$V1 < V2 \leftarrow R1 < R2$

Note: the red balls represent the intracellular elements, i.e. the intra cellular proteins, the intracellular ions, the micro vesicles.

Discussion

This is my way to understand the mechanism of the neural conduction through the neural fiber. I insist on the essential role of the pressure wave in generating and maintaining the neural conduction current.

In the motor neuron, the action pressure wave is born at the distal portion of the axon hillock. In response to a stimulant, the microtubules of the axon hillock contract generating the central pressure wave. The central pressure wave rebounds back from the enforced membrane of the cell body. The rebounding wave hits the contracted microtubules and pushes them distally. Thus, the action pressure wave is built up.

Upon their contraction, the microtubules generate a zone of negative pressure (vacuum) inside the axon hillock. The vacuum will open the gates of the massively present sodium ion channels, and will absorb the positive sodium ions Na^+ in. The incoming sodium ions Na^+ build up the anode of the neural conduction current. The cathode of the neural conduction current is already present mainly due to the negatively charged intra cellular proteins. So that, the conduction current is fired on within the lumen of the neural fiber.

In contrast, in the sensory neuron, the wave units arise distally in the sensory receptors par different method. It is the role of the sensory receptor to invert a specific spectrum of the stimulant energy to a wave pressure (wave unit). However, at the pathway towards the root of the dendrites, the current units are generated upon the passage of every wave unit through the first node of Ranvier. Then, the wave units, and the current units, emerge together to form one single action pressure wave and one single conduction current respectively.

The pressure-gated sodium ions channel allows the positive sodium ions to enter into the lumen of the neural fiber. The pressure wave controls the movement of the channels' gates. The wave's front closes the gates, while its tail opens them. In fact, it is the negative pressure of the wave's tail, which invites the positive sodium ions into the lumen of the neural fiber. The incoming sodium ions build up the anode of the neural current. Since the cathode of the current is already present, due the negatively charged intra cellular proteins, the current circle is complete and the current runs on.

The two, the action pressure wave and the action neural conduction current, run together inside the neural fiber. They occupy the center sector of the neural fiber. It is the role of the nodes of Ranvier to fix their trajectory at the center of the fiber (one can read more information about the Ranvier node in the coming article).

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In the same context, one could read:

- * The Sensory Receptors, The Genius of Creation and the Beauty of Creature (Innovated Conception)
- The Neural Conduction in the Synapses (Innovated Conception)
- **The Node of Ranvier, the Equalizer (Innovated Conception)
- The Philosophy of Pain, Pain Comes First (Innovated Conception)
- The Philosophy of Form, (Innovated Conception)
- The Spinal Injury, the Pathology of the Spinal Shock, the Pathology of the Hyperreflexia (Innovated Conception)
- The Nerve Conduction Study, The Wrong Hypothesis is the Origin of the Misinterpretations (Innovated Conception)
- The Wallerian Degeneration, Attacks the Motor Axons of Peripheral Nerve, while Conserves its Sensory Axons(Innovated Conception)

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