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The Neural Conduction in Neural Fiber

(Personal View)

N.B. the Arabic version of this article is the reference,
read it via one of the following links:

النَّقلُ العَصبيُّ، مُقاربةٌ شخصيَّةٌ لآليَّةِ النَّقل العصبيّ عبرَ المحاور العصبيَّة

Neural Conduction in Neural Fibers, Personal View vs. International View

I believe neural conduction in nerve fibers is simpler than the prevailing understanding suggests. Furthermore, I propose that the cornerstone of this process lies in a pressure impulse generated at the distal end of the axon hillock in motor neurons and at the sensory receptor sites in sensory neurons.

In the following sections, I will elaborate on my perspective regarding the mechanism of neural conduction within nerve fibers.

1. The Resting Pressure

At rest, a positive pressure dominates ***within the soma*** *(the neuronal cell body)* ***and throughout nerve fibers****. This* ***Resting Pressure*** *serves as the* ***baseline state****, essential for maintaining proper neural function. Critically, it establishes the foundational parameters for the* ***Action Pressure Wave****, thereby directly influencing the velocity of neural conduction.*

For further details on this concept, refer to the following video:

2. The Central Action Pressure Wave

In the axon hillock of a motor neuron, once the threshold is reached, the densely packed microtubules contract and retract into the soma. This retraction generates a ***Central Action Pressure Wave****.*

The wave propagates through the intracellular space of the soma until it encounters the structurally reinforced cell membrane. The membrane reflects the wave, compelling it to return to the axon hillock.

*The rebound wave collides forcefully with the retracting microtubule network, propelling it further along the axon hillock. This collision initiates the **Action Pressure Wave**—the primary carrier of the neural signal.*

For further details on this concept, refer to the following video:

3. The Action Pressure Wave

*The **Action Pressure Wave** serves as the primary carrier of neural signals in the nerve fibers of both motor and sensory neurons. A single neural signal transmission corresponds to one discrete Action Pressure Wave. However, the parameters of this pressure impulse undergo dynamic modulation.*

*Initially, due to the forceful mechanism of its generation, the Action Pressure Wave begins with **excessively high parameters**. As it propagates through the first node of Ranvier, these parameters stabilize to a standardized profile. To distinguish these phases, I introduce two terms: the **Preliminary Action Pressure Wave** (initial high-energy state) and the **Standard Action Pressure Wave** (stabilized state post-node).*

For further details on this concept, refer to the following video:

3.1. The Preliminary Action Pressure Wave

*The **Action Pressure Wave** originates with elevated parameters due to its forceful generation within the axon hillock. This initial phase is termed the **Preliminary Action Pressure Wave**. It propagates through the pre-nodal segment of the axon until reaching the first node of Ranvier.*

*At this node, the wave's parameters stabilize to standardized values, and it transitions to the **Standard Action Pressure Wave**. Beyond this point, the signal is exclusively referred to by this latter term.*

For further details on this concept, refer to the following video:

3.2. The Standard Action Pressure Wave

*Beyond the first node of Ranvier, the parameters of the **Action Pressure Wave** are adjusted to standardized values. At this stage, the wave adopts a predetermined wavelength, amplitude, and velocity, thereby transitioning into the **Standard Action Pressure Wave**.*

This standardized wave propagates uniformly along the nerve fiber, with subsequent nodes of Ranvier actively maintaining its parameters throughout the conduction pathway.

For further details on this concept, refer to the following video:

4. The Action Potentials

Within this framework, a single neural signal transmission involves ***multiple distinct phases of action potentials****:*

- *A* ***Preliminary Action Potential*** *initiates the signal at the axon hillock,*
- *Followed by a series of* ***Standard Action Potentials*** *propagating through the nerve fiber,*
- *Culminating in a* ***Terminal Action Potential*** *at the synaptic terminus.*

Each phase corresponds to specific pressure wave dynamics, as outlined in preceding sections.

For further details on this concept, refer to the following video:

4.1. The Preliminary Action Potential

As previously described, when the threshold is reached in the axon hillock of a motor neuron, the densely packed microtubules contract and retract toward the soma. This retraction generates a localized negative pressure within the axon hillock.

The resulting pressure gradient triggers the opening of pressure-sensitive sodium channels, initiating an influx of sodium ions into the axon hillock's lumen. These positively charged ions invert the intracellular polarity of the axon hillock from its resting negative state to a transient ***positive polarity region****. In contrast, the adjacent pre-nodal axon segment retains its baseline* ***negative polarity region****, primarily due to the electrostatic influence of negatively charged intracellular proteins.*

This polarity disparity establishes an electrochemical dipole:

- *The* ***positive polarity region*** *(site of depolarization),*
- *The* ***negative polarity region*** *(adjacent polarized zone).*

Together, these components define the Preliminary Action Potential—the initiating electrical manifestation of the pressure-driven signal.

For further details on this concept, refer to the following video:

4.2. The Standard Action Potentials

*When the **Action Pressure Wave** reaches the first node of Ranvier, the negative pressure (rarefaction) in its trough opens **pressure-gated Na^+ channels** in the cell membrane. This initiates an influx of sodium ions into the intracellular space, generating a **positive polarity region** at the node. Concurrently, the **negative polarity region** arises inherently from the baseline negative charge of the intracellular cytoplasm, thereby completing the electrochemical gradient.*

*This process repeats at each subsequent node of Ranvier, producing a homogeneous series of **Standard Action Potentials**. Each potential is discrete and autonomous:*

- ***Independent generation**: No temporal or spatial overlap exists between consecutive potentials.*
- ***Pressure-driven initiation**: The trough of the Action Pressure Wave is the sole trigger, eliminating dependency on upstream events.*
- ***Nodal specificity**: Nodes of Ranvier act as self-contained generators, ensuring localized signal fidelity.*

Each Standard Action Potential shapes the trajectory of the Action Pressure Wave within its respective inter-nodal segment. These segmental trajectories collectively determine the wave's propagation path along the nerve fiber.

For further details on this concept, refer to the following video:

4.3. The Terminal Action Potential

*The **Terminal Action Potential** represents the final phase of neural conduction. Its **positive polarity region** forms within the presynaptic knob due to the negative pressure (rarefaction) in the trough of the arriving **Action Pressure Wave**.*

*Upon reaching the presynaptic terminus, this pressure gradient opens **pressure-gated Ca^{2+} channels** in the membrane, triggering an* *influx of calcium ions. The accumulated Ca^{2+} establishes a strong positive polarity within the presynaptic knob. Concurrently, the* ***negative polarity region*** *arises from the baseline negative polarity of the postsynaptic dendrites, maintained by negatively charged intracellular proteins.*

This configuration generates a ***trans-synaptic action potential****, characterized by an elevated depolarization magnitude due to two factors:*

1. ***High charge density****: Divalent Ca^{2+} ions contribute greater charge per ion compared to monovalent cations.*
2. ***Spatial summation****: The presynaptic knob's larger volume accommodates a greater ion influx, amplifying polarity inversion.*

For further details on this concept, refer to the following video:

5. The Action Electrical Currents

Each ***Action Potential*** *generates a corresponding electrical current, inheriting its name and amplitude. These currents propagate the neural signal in tandem with the mechanical pressure wave dynamics described earlier.*

5.1. The Preliminary Electrical Current

The ***Preliminary Action Potential*** *immediately generates the* ***Preliminary Electrical Current (PEC)****. This current originates in the axon hillock and propagates to the first node of Ranvier, priming the axon for subsequent signal transmission.*

For further details on this concept, refer to the following video:

5.2. The Standard Electrical Currents

A series of ***Standard Electrical Currents (SECs)*** *arise sequentially from their respective* ***Standard Action Potentials****. Key features include:*

- ***Localized propagation****: Each SEC spans from one node of Ranvier to the next.*
- ***Functional parity****: Every SEC retains the amplitude and functional role of its generating Action Potential.*

- **Independence**: No causal relationship exists between consecutive SECs; each is autonomously triggered by nodal pressure dynamics.

Collectively, these currents ensure uninterrupted signal conduction along the nerve fiber.

For further details on this concept, refer to the following video:

5.3. The Terminal Electrical Current

The **Terminal Action Potential** generates the **Terminal Electrical Current (TEC)**, a trans-synaptic current bridging the presynaptic knob and postsynaptic effector organ. As the definitive carrier of the neural signal, the TEC delivers the depolarizing stimulus necessary to activate the target tissue.

For further details on this concept, refer to the following video:

6. The Function of the Standard Action Potentials & the Standard Electrical Currents

The **Standard Action Potentials (SAPs)** and their corresponding **Standard Electrical Currents (SECs)** collectively optimize the trajectory of the **Action Pressure Wave (APW)**, ensuring its rapid propagation through the nerve fiber. This is achieved via two coordinated mechanisms:

1. **Intracellular Crowding**:
    - SAPs and SECs mobilize intracellular components (e.g., organelles, cytoskeletal elements), concentrating them along the APW's projected path.
    - This creates a **structurally consolidated**, high-density intracellular corridor, minimizing resistance to wave propagation.
2. **Segmental Guidance**:
    - Each SAP-SEC pair operates within a single **inter-nodal segment**, refining the APW's trajectory locally.
    - The collective integration of these segmental trajectories determines the APW's global path along the nerve fiber.

By aligning intracellular architecture with wave dynamics, SAPs and SECs enable the APW to propagate efficiently at velocities exceeding those predicted by classical ion-driven models.

For further details on this concept, refer to the following video:

7. The Action Pressure Wave in the Sensory Neurons

In sensory neurons, external stimuli trigger the generation of localized ***mini pressure waves*** *(termed* ***Wave Units****) within sensory receptor sites. These Wave Units propagate toward the dendritic root, where they converge and coalesce into a single* ***Action Pressure Wave*** *(Figure 1).*

Once integrated, the unified Action Pressure Wave travels along the axon, propagating through the central lumen of the nerve fiber.

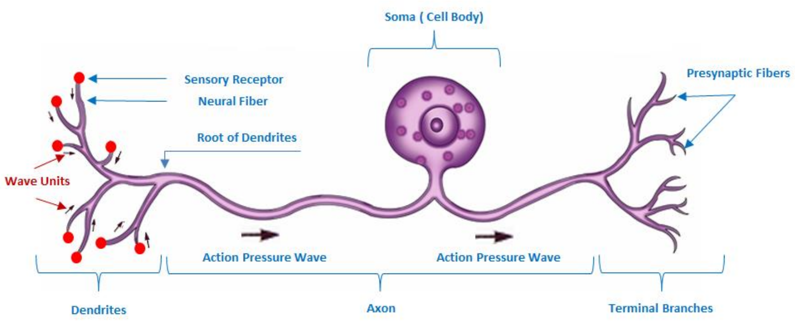

Figure 1: Action Pressure Wave Generation in Sensory Neurons

1. ***Stimulus Detection****: Individual sensory receptors generate localized* ***Wave Units*** *in response to stimulation.*
2. ***Integration****: Wave Units converge at the dendritic root, merging into a unified* ***Action Pressure Wave****.*
3. ***Propagation****: The integrated wave travels centrally along the axon's lumen to relay the sensory signal.*

8. The Three Phases of the Neural Conduction

Neural conduction operates through three sequential phases:

1. ***Initial Electrical Phase****: The signal is received via* ***trans-synaptic electrical transmission*** *at the dendrites or soma.*

2. ***Pressure-Mediated Phase****: Within the nerve fiber, the signal transitions to a* ***mechanical pressure impulse*** *(the* ***Action Pressure Wave****), optimized for rapid propagation through the axon's enclosed lumen.*

3. ***Terminal Electrical Phase****: At the synaptic terminus, the signal reverts to* ***trans-synaptic electrical transmission*** *to activate the postsynaptic effector organ.*

This triphasic mechanism addresses a critical functional constraint: while pressure waves excel in closed intracellular environments (e.g., axons), they are ineffective in open extracellular spaces like synaptic clefts. Electrical transmission thus bridges these gaps, ensuring seamless signal continuity.

For further details on this concept, refer to the following video:

9. The Pressure-Gated Sodium Ions Channels

Pressure-gated sodium (Na^+) ion channels are integral to neural signal generation. Their distribution and structure reflect specialized roles:

- *Unmyelinated nerve fibers: Ubiquitous across the cell membrane.*
- *Myelinated nerve fibers: Restricted to the axon hillock and nodes of Ranvier.*

These channels mediate the mechanoelectrical coupling critical for generating Action Potentials and their associated Electrical Currents.

Structure of the Pressure-Gated Sodium Ion Channel

Each channel comprises:

1. *Transmembrane pore: Permits selective Na^+ ion flow.*
2. *Mechanical gate: Anchored to the channel's inner wall, responsive to pressure gradients from the Action Pressure Wave (Figure 2).*

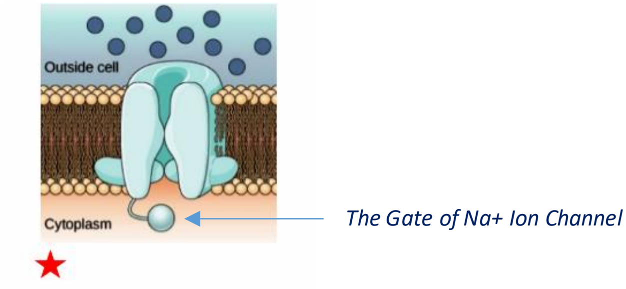

Figure 2: Pressure-Gated Sodium Ion Channel Architecture

- *Channel: Transmembrane conduit linking extracellular space and cytoplasm.*
- *Gate: Mechanosensitive structure positioned to interact with the Action Pressure Wave.*
- *Key Features:*
  - *Red star: Site of Action Pressure Wave initiation (axon hillock in motor neurons; sensory receptors in sensory neurons).*
  - *Blue spheres: Extracellular Na^+ ions.*

Mechanism of Operation

The gate's function is governed by dynamic pressure shifts during wave passage (Figure 3):

1. *Wavefront (High Pressure):*
   - *Compresses the gate upward, closing the channel and halting Na^+ influx.*
2. *Wavetail (Negative Pressure/Rarefaction):*
   - *Creates suction, opening the gate and facilitating Na^+ influx into the axon lumen.*

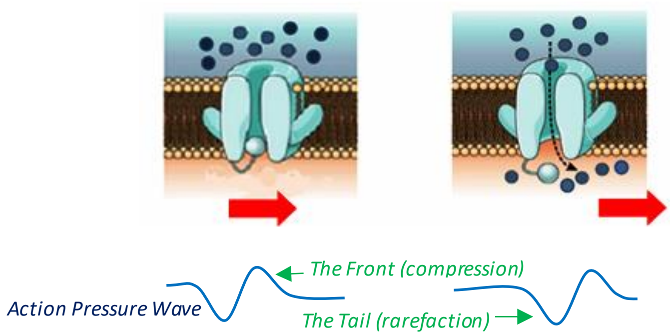

Figure 3: Pressure-Gated Sodium Ion Channel Dynamics

- *Red arrows: Direction and location of the Action Pressure Wave's advancing front.*
- *Green arrows: Segment of the wave actively interacting with the channel.*
- *Blue spheres: Influxing Na^+ ions during gate opening.*

10. The Myelin Sheath

*Like all longitudinal waves, the **Action Pressure Wave** is characterized by its **wavelength**, **amplitude**, **velocity**, and **energy**. Crucially, wave velocity is proportional to wavelength in this system: as wavelength increases, velocity and other parameters (amplitude, energy) escalate accordingly.*

*To generate a high-velocity Action Pressure Wave, neurons must maintain an elevated **Resting Pressure** within the nerve fiber. However, the cell membrane alone cannot structurally withstand the extreme pressures required for rapid signal transmission. Myelination resolves this limitation through two key adaptations:*

1. ***Structural Reinforcement**: The myelin sheath enables larger axon diameters and reinforced walls, accommodating higher Resting and Action Pressure Wave magnitudes.*
2. ***Parameter Optimization**: By supporting wider axons, myelination permits longer wavelengths and faster wave propagation.*

*Thus, myelinated nerve fibers achieve significantly faster conduction velocities than unmyelinated fibers, as illustrated in **Figure 4**.*

Figure 4: Myelination and Conduction Velocity

- ***Myelinated Fiber**:*
  - *Larger diameter and reinforced structure sustain elevated pressures.*
  - *Longer wavelength Action Pressure Wave achieves higher velocity.*
- ***Unmyelinated Fiber**:*
  - *Narrower diameter limits pressure tolerance.*

- *Shorter wavelength results in slower conduction.*

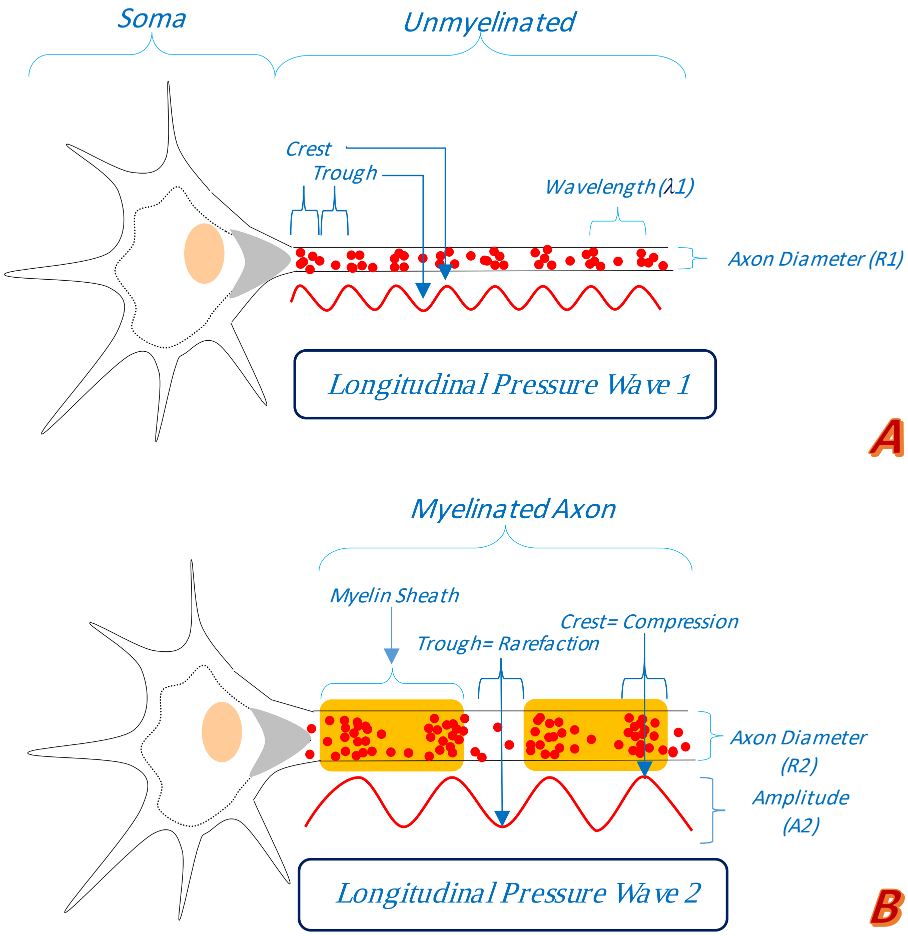

Figure 4: Myelin Sheath – An Indispensable Tool for Fast Neural Conduction

*The **Action Pressure Wave** obeys principles common to all longitudinal waves:*

- ***Energy**, **velocity**, and **wavelength** are proportionally interrelated.*
- ***Wavelength** and **amplitude** are intrinsically linked; longer wavelengths correlate with higher amplitudes and faster velocities.*

*To achieve rapid neural conduction, neurons must sustain high-energy Action Pressure Waves. This requires **wider and structurally reinforced nerve fibers**, which the **myelin sheath** enables (see Figures A and B).*

Figure A: Unmyelinated Nerve Fiber

- ***Diameter**: Small (R_1).*
- ***Wave Parameters**:*

- *Short wavelength (λ_1).*
- *Low velocity (V_1).*

- ***Limitation**: Unable to sustain high-energy pressure waves due to structural fragility.*

Figure B: Myelinated Nerve Fiber

- ***Myelin's Role**:*
  - *Enables larger diameter ($R_2 > R_1$) and reinforced axon walls.*
  - *Supports Action Pressure Waves with:*
    - *Longer wavelength ($\lambda_2 > \lambda_1$).*
    - *Higher velocity ($V_2 > V_1$).*
- ***Advantage**: Efficient propagation of high-energy waves without structural compromise.*

$R2 > R1 \Rightarrow V2 > V1$

***Key Annotations**:*

- ***Red spheres**: Intracellular components (proteins, ions, microvesicles) mobilized to optimize wave trajectory.*

***Mechanistic Summary**:*

1. ***Structural Demand**: High-velocity waves necessitate robust, wide axons to tolerate elevated pressures.*
2. ***Myelin's Contribution**: By reinforcing axon structure, myelination allows neurons to meet these demands, enabling faster signal transmission.*

Summary of the Neural Conduction Model

*This theory reimagines neural conduction through a **pressure-driven mechanism**, emphasizing mechanical waves and structural dynamics over classical electrochemical gradients. Key components include:*

1. Motor Neurons: Pressure Wave Initiation

- ***Origin**: The Action Pressure Wave (APW) begins at the **distal axon hillock**.*
  - *Microtubule contraction generates a **Central Pressure Wave**, which rebounds off the soma's reinforced membrane.*

- *The rebounding wave propels microtubules distally, creating the APW.*

- ***Ion Dynamics**:*
  - *Microtubule contraction creates a **negative pressure (vacuum)**, opening pressure-gated Na^+ channels.*
  - *Influx of Na^+ forms the **positive polarity region** of the Preliminary Action Potential, while intrinsic intracellular negativity serves as the **negative polarity region**.*
  - *This initiates the **Preliminary Electrical Current** in the pre-nodal axon segment.*

2. Sensory Neurons: Wave Integration

- ***Stimulus Conversion**: Sensory receptors transduce stimuli into localized **Wave Units** (mini pressure waves).*
- ***Integration**: Wave Units merge at dendritic roots into a single **APW**, which propagates centrally within the axon lumen.*

3. Pressure-Gated Sodium Channels

- ***Mechanism**:*
  - ***Wavefront (high pressure)**: Closes channel gates.*
  - ***Wavetail (negative pressure)**: Opens gates, allowing Na^+ influx to form positive polarity.*
- ***Negative polarity Source**: Pre-existing negativity from intracellular proteins completes the circuit, firing **Standard Electrical Currents**.*

4. Role of Myelin and Nodes of Ranvier

- ***Myelin Sheath**:*
  - *Enables **wider, stronger axons** to sustain high-energy APWs with longer wavelengths and faster velocities.*
  - *Contrasts with classical insulation theory; here, myelin provides **structural reinforcement**.*

- ***Nodes of Ranvier**:*
  - *Act as **autonomous generators** of Standard Action Potentials.*
  - *Guide the APW's trajectory centrally via segmental optimization.*
  - ***Adjusting Action Pressure Wave Parameters:** The nodes dynamically modulate the wave's parameters (amplitude, wavelength, velocity) during its passage to ensure compliance with standardized specifications. They correct deviations caused by fiber resistance or energy dissipation, thereby maintaining signal stability across extended neural pathways.*

5. Triphasic Conduction

1. ***Electrical Initiation**: Trans-synaptic electrical signals at dendrites/soma.*
2. ***Pressure-Mediated Propagation**: APW traverses the axon, optimized by myelination.*
3. ***Electrical Termination**: Trans-synaptic current activates effector organs.*

6. Contrast with Classical Models

- ***Pressure vs. Voltage**: Replaces voltage-gated ion channels with **pressure-gated mechanisms**.*
- ***Structural Role of Myelin**: Prioritizes mechanical support over ionic insulation.*
- ***Node Function**: Nodes actively generate potentials and guide waves, rather than passively boosting depolarization.*

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In other contexts, you can also read the following articles:

[The Spinal Reflex, New Hypothesis of Physiology]

- *The Hyperreflexia, Innovated Pathophysiology*
- *The Spinal Shock*
- *The Spinal Injury, the Pathophysiology of the Spinal Shock, the Pathophysiology of the Hyperreflexia*
- *Upper Motor Neuron Lesions, the Pathophysiology of the Symptomatology*
- *The Hyperreflexia (1), the Pathophysiology of Hyperactivity*
- *The Hyperreflexia (2), the Pathophysiology of Bilateral Responses*
- *The Hyperreflexia (3), the Pathophysiology of Extended Hyperreflex*
- *The Hyperreflexia (4), the Pathophysiology of Multi-Response Hyperreflex*
- *The Clonus, 1st Hypothesis of Pathophysiology*
- *The Clonus, 2nd Hypothesis of Pathophysiology*
- *The Clonus, Two Hypotheses of Pathophysiology*

- *The Nerve Transmission through Neural Fiber, Personal View vs. International View*
- *The Nerve Transmission through Neural Fiber (1), The Action Pressure Waves*
- *The Nerve Transmission through Neural Fiber (2), The Action Potentials*
- *The Nerve Transmission through Neural Fiber (3), The Action Electrical Currents*
- *The Function of Standard Action Potentials & Currents*
- *The Three Phases of Nerve transmission*

- *Neural Conduction in the Synapse (Innovated)*

- *Nodes of Ranvier, the Equalizers*

- *Nodes of Ranvier, the Functions*
- *Nodes of Ranvier, First Function*
- *Nodes of Ranvier, Second Function*
- *Nodes of Ranvier, Third Function*
- *Node of Ranvier, The Anatomy*

- *The Wallerian Degeneration*
- *The Neural Regeneration*
- *The Wallerian Degeneration Attacks Motor Axons, While Avoids Sensory Axons*

- *The Sensory Receptors*

- *Nerve Conduction Study, Wrong Hypothesis is the Origin of the Misinterpretation (Innovated)*

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- Biceps Femoris' Long Head Syndrome (BFLHS)

- Barr Body, The Whole Story (Innovated)
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- Adam's Rib, could be the Original Sin?
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- This Woman Can Only Give Birth to Male Children
- This Woman Can Give Birth to Female Children More Than to Male Children
- This Woman Can Give Birth to Male Children More Than to Female Children
- This Woman Can Equally Give Birth to Male Children & to Female Children

- Eve Saved Human Identity; Adam Ensured Human Adaptation

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