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Sensory Receptors:
A Novel Mechanism for Sustained Tactile Perception

How Pulse Pressure Overcomes Receptor Adaptation to Maintain Continuous Perception

The initial detection of contact with the skin is well-understood: mechanoreceptors (e.g., Pacinian corpuscles) transduce mechanical energy into neural signals. However, the persistent awareness of sustained contact—such as the continuous feel of an object held in the hand—has remained a physiological enigma.

Superficial Sensory Receptors (SSRs)

SSRs are distributed across all contact surfaces between an organism and its environment, serving as communication bridges linking the internal and external environments.

Sensory receptors (SRs) associated with a single sensory neuron (SN) share identical structural and functional properties. Furthermore, SSRs performing the same role exhibit consistent architecture regardless of their location.

*Each dendritic neural fiber innervates a single SR, forming the receptor's core (**central neurite**). Every SSR is sensitive to a specific energy spectrum of stimuli. Regardless of the stimulus type, the SSR transduces this energy into a **pressure Wave Unit**. These Wave Units aggregate at the dendritic root to form an **Action Pressure Wave** (Figure 1), which carries the afferent signal to the central nervous system.*

*In subsequent sections, I will elaborate on the operational mechanism of SSRs, using **Pacinian corpuscles** as a model. This choice is twofold:*

1. *Pacinian corpuscles exemplify the general functional principles shared by all SSRs.*
2. *Their mechanotransductive properties vividly illustrate the proposed mode of action.*

The Wave Units

*In sensory neurons (SNs), **Action Pressure Waves** are generated peripherally at the dendritic root. These waves propagate centrally toward the axon terminal branches and consist of aggregated components termed **Wave Units**. Each Wave Unit originates in the **central neurite** of a sensory receptor (SR). At the dendritic root, Wave Units from multiple SRs within a single SN converge to form an Action Pressure Wave (Figure 1).*

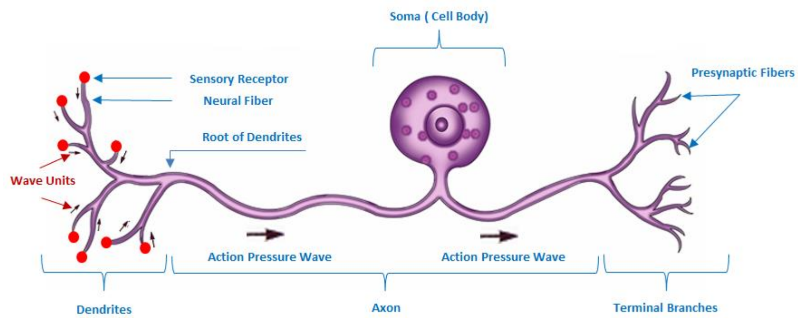


Figure 1: Generation and Propagation of Wave Units

***Wave Units** are generated within the nerve fiber. At the dendritic root, multiple Wave Units from activated sensory receptors converge to form a single **Action Pressure Wave**. This wave propagates along the axon toward its terminal branches, facilitating signal transmission to downstream neural circuits.*

A mechanical stimulus (e.g., contact) activates an SR only once, irrespective of the stimulus duration. In response, the SR emits a single Wave Unit. This mechanism explains why a pinprick elicits immediate pain (a "flash" signal), while sustained contact (e.g., a stationary pin) does not produce ongoing pain—a critical protective feature of nociceptors (pain receptors).

*However, continuous detection of prolonged contact is physiologically essential. Without it, organisms might fail to perceive retained objects (e.g., a held item slipping from the hand). To resolve this, the nervous system employs **pulse pressure** (Figure 4), which cyclically reactivates receptors, enabling persistent monitoring of static stimuli.*

The All-or-None Law

Unlike motor neurons, ***sensory neurons (SNs)*** *do not strictly adhere to the* ***all-or-none principle*** *(Figure 2). This deviation is critical to their function: somatosensory receptors (SSRs) must detect even minimal contact with external stimuli. If SNs followed the all-or-none law, subthreshold stimuli (e.g., light touch) would fail to elicit action potentials, rendering many subtle contact events imperceptible.*

As demonstrated in ***Figure 2****, sensory neurons encode stimulus intensity through* ***graded receptor activation*** *rather than binary firing. For example, weak stimuli activate only a subset of receptors (Figure 2-A), generating proportional signals (e.g., 5/8 of a full Action Pressure Wave). This mechanism allows the nervous system to distinguish between faint and strong stimuli, ensuring sensitivity to even the slightest environmental changes.*

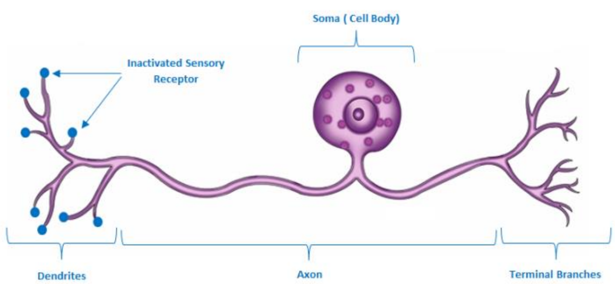
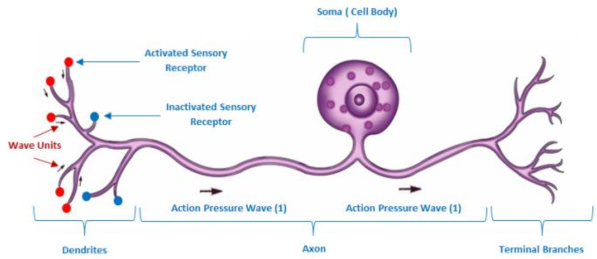


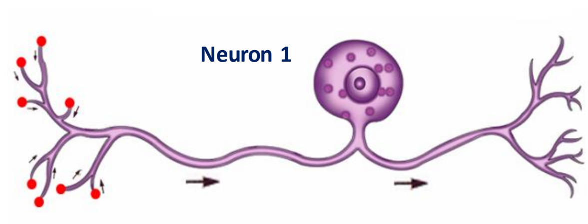
Figure 2: Sensory Receptor Activation States
(A) Inactive Sensory Receptors

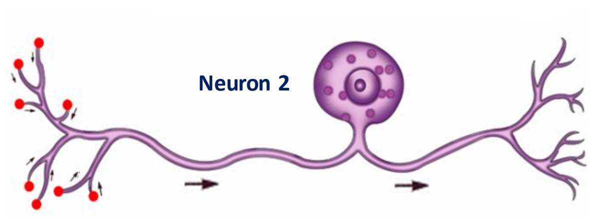
- *Each sensory receptor (blue circles) surrounds a dendritic neural fiber.*
- *At rest, no receptors are activated by external stimuli.*

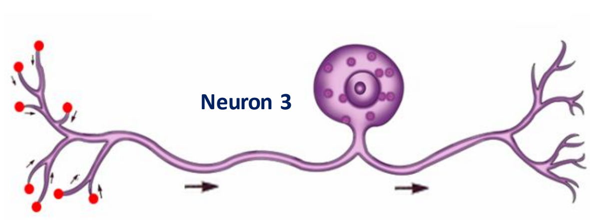


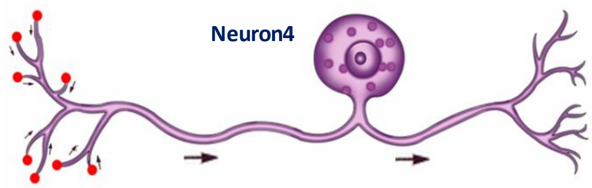
(B) Partial Activation (Subthreshold Stimulus)

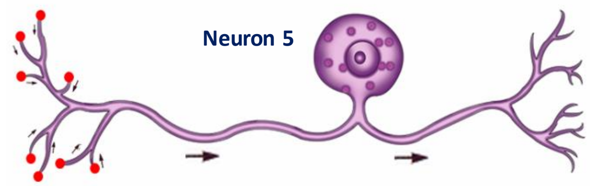
- *A weak stimulus activates 5 out of 8 receptors (red circles) on a single sensory neuron.*
- *Activated receptors generate* ***pressure wave units****, which converge to form a single* ***Action Pressure Wave*** *at the dendritic root.*
- *The remaining 3 receptors (blue circles) remain inactive.*
- *The sensory processing center interprets the stimulus intensity as proportional to the activated receptor ratio (5/8 of a full Action Pressure Wave's magnitude).*











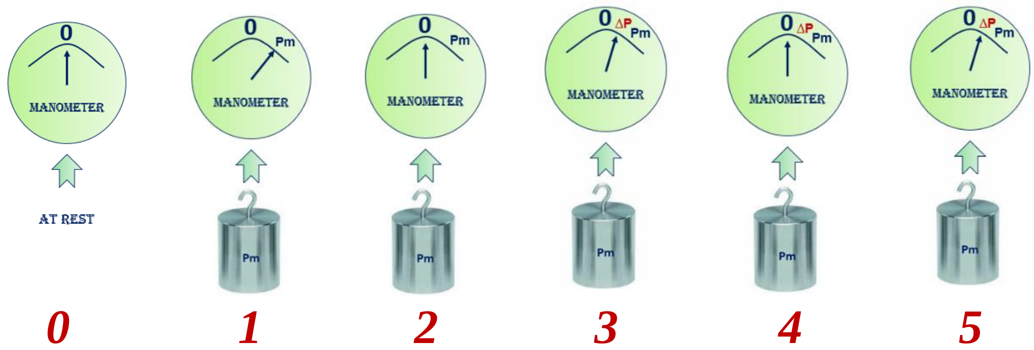
(C) Full Activation (Suprathreshold Stimulus)

- *A strong stimulus activates all receptors across a group of 5 sensory neurons (40 receptors total; 8 per neuron).*
- *Each neuron generates a full **Action Pressure Wave** from its 8 activated receptors.*
- *The sensory processing center integrates these signals, interpreting the stimulus intensity as the sum of all 5 Action Pressure Waves.*

Pressure Receptors (Pacinian Corpuscles)

*Like other **somatosensory receptors (SSRs)**, Pacinian corpuscles detect mechanical stimuli (e.g., pressure) upon initial contact. They encode the precise magnitude of the applied pressure (**Pm mmHg**) instantaneously. However, these receptors rapidly adapt, ceasing to respond to sustained stimuli within moments (Figure 4).*

*This adaptation occurs because Pacinian corpuscles are activated by changes in pressure (i.e., the **pressure differential** created by the stimulus). When the stimulus remains static, this differential dissipates (reaching zero), causing the receptor to stop signaling. To maintain detection during prolonged contact, **pulse pressure** provides a cyclical, intrinsic pressure differential. This pulsatile mechanism reactivates the receptors repeatedly, enabling ongoing monitoring of the stimulus.*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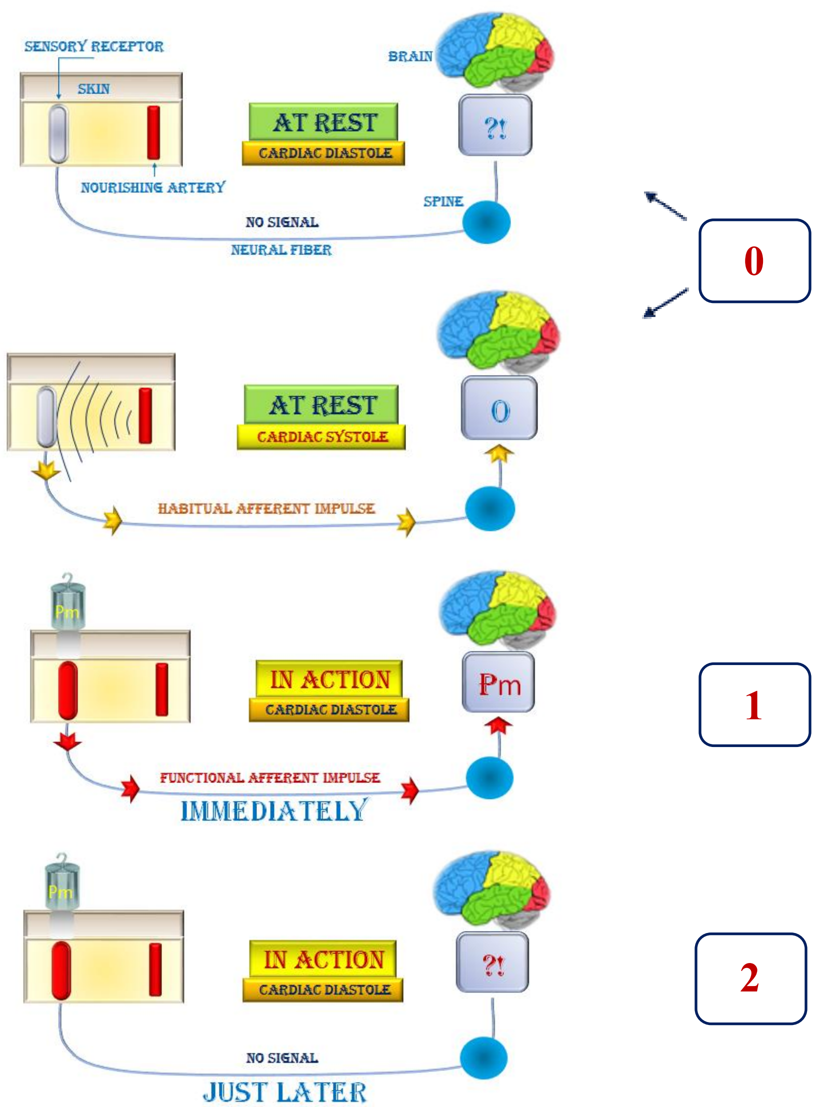
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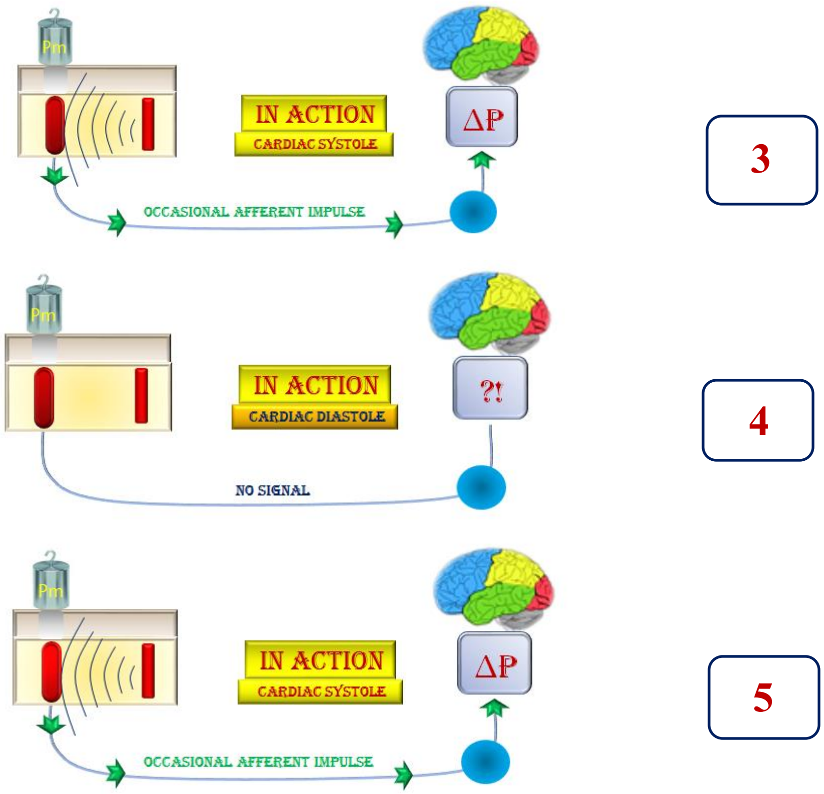

Figure 4:

Mechanism of Sensory Receptor Signaling During Rest and Object Contact

(0) At Rest (No Contact): *During diastole, peripheral signals cease ("silent phase"). The brain perceives this absence of input as anomalous and activates pulse pressure to scan the tissue. In systole, sensory receptors detect the pulse pressure wave and transmit* ***Habitual Afferent Impulses*** *to the brain. With no external stimulus, the brain registers a null outcome (0), resolving its "anxiety."*

(1) Initial Contact (Object Detected): *Upon contact, the sensory receptor immediately detects the object's pressure (**Pm mmHg**) and transmits a **Stimulus-Specific Afferent Impulse**. The brain interprets this accurately, estimating the object's pressure as ≈ **Pm mmHg**.*

(2) Sustained Contact (Signal Loss): *Shortly after, the receptor loses the pressure differential (due to adaptation) and stops signaling. The brain rejects this peripheral silence as implausible.*

(3) Sustained Contact (Pulse Pressure Compensation): *Subsequently, the receptor utilizes pulse pressure as a surrogate differential value, transmitting* ***Stimulus-***

Evoked Afferent Impulses (Occasional Afferent Impulses). *The brain now estimates the object's pressure based on pulse pressure magnitude (≈* ***ΔP).***

(4) Sustained Contact (Diastolic Silence): *During diastole, pulse pressure subsides, and the receptor re-enters a silent phase. No afferent signals are sent.*

(5) Sustained Contact (Cyclic Reactivation): *In the next systolic phase, pulse pressure restores the differential value, reactivating the receptor-brain signaling loop.*

Thus, only the initial pressure reading reflects the true magnitude of the external stimulus. Subsequent signals are mediated by pulse pressure, resulting in estimations based on its amplitude (≈ ΔP) rather than the object's actual pressure (Figure 4).

For more clarity, watch the linked video:

Discussion

Pulse pressure serves as the primary driver for sensory receptors to detect even subtle changes in their environment. It generates a sustained pressure differential, essential for the continuous functioning of all sensory receptors.

This pressure differential arises from the pulsations of local arteries and arterioles. While distinct from the pressure changes induced by external stimuli themselves, this mechanism operates with remarkable efficiency. Consequently, even as a stimulus interacts with the organism, Pacinian corpuscles persist in detecting its presence, albeit through a distinct modality.

Both at rest and during stimulation, sensory receptors (e.g., Pacinian corpuscles) consistently respond to pulse pressure. They transmit afferent impulses to the brain, which then interprets these signals appropriately.

At rest (in the absence of external contact), afferent impulses generated by pulse pressure exhibit a baseline pattern. These are termed ***Habitual Afferent Impulses****. The brain recognizes this baseline activity and interprets it as the absence of contact (Figure 4-0).*

*During stimulation, however, once an object makes contact, the afferent impulses shift to an altered pattern. These are termed **Stimulus-Evoked Afferent Impulses**. Through this mechanism, the brain continuously detects the object's presence on the surface (Figure 4).*

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