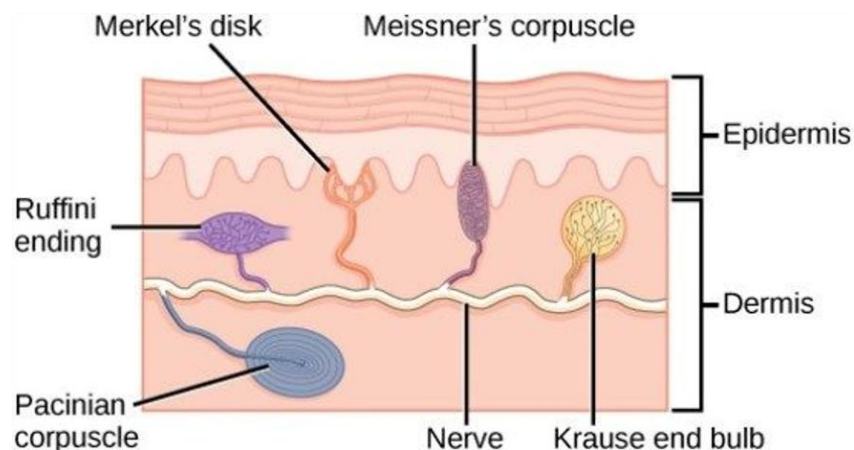


THE BIOLOGICAL SENSORS OF VIBRATION



Mechanotransduction is the process by which a mechanical stimulus is converted into a bioelectrical signal that can be interpreted by the nervous system. Vibroacoustics represents the key step through which sound-based and mechanical vibrations supplied to the human body are perceived and transformed into neurophysiological information.

Your skin and deeper tissues host a complex network of specialized sensory reception receptors--mechanoreceptors—capable of detecting changes in pressure, vibration, stretch, and movement. These structures function as true biological sensors, enabling the organism to interact with the environment and modulate a wide range of physiological responses.

The kind of receptors involved in vibro-mechanical perception include Pacinian corpuscles, Merkel cell-neurite complexes (Merkel discs), Meisner corpuscles, Ruffini endings, and hair follicle receptors. Each has distinct structural and functional properties, resulting in different response profiles to vibrational stimuli.

PACINIAN CORPUSCLES: RECEPTORS FOR DEEP, HIGH-FREQUENCY VIBRATION

Pacinian corpuscles are among the largest and most complex mechanoreceptors in the human body. They are located primarily in subcutaneous tissue, ligaments, joint capsules, and the periosteum. Anatomically, they exhibit a characteristic lamellar structure composed of multiple concentric layers of Pacinian corpuscles particularly sensitive to rapid vibrations.

They respond predominantly to higher-frequency vibration, Typically in the range of approximately 40 - 800 Hz, with peak sensitivity around 200 - 300 Hz. They are classified as *rapidly adapting receptors*, meaning they respond mainly to dynamic changes in the *stimulus* rather than to *sustained pressure*.

When vibration passes through tissue, deformation of the lamellae alters the ionic permeability of the nerve terminal, generating a receptor potential is transmitted along myelinated A β fibers. The signal reaches the spinal cord and then the cortical somatosensory areas, where it is processed and integrated with other sensory inputs.

At a finer level of detail, the interaction between mechanical vibration, also described as a multi-stage functional process that converts an elastic wave into a coded neural signal. This is not instantaneous; it occurs through an ordered sequence of filtering, transduction, and integration of information.

PHASE 1: MEDICAL FILTERING AND SELECTIVE TRANSMISSION

The lamellar capsule of the Pacinian corpuscle performs a highly specialized mechanical function. Its concentric architecture—together with the presence of a viscous fluid between lamellae—acts as a mechanical high-pass filter and an impedance transformer (impedance-matching structure).

Static or slowly varying stimuli—typically low frequency inputs below approximately 30-50 Hz—are progressively dissipated and distributed across the capsule. Under these conditions, deformation does not concentrate on the central nerve ending, and the stimulus is not efficiently transduced. This mechanism helps explain why a constant pressures, such as the prolonged contact of clothing on the skin, tend to disappear rapidly from conscious perception.

By contrast, rapid and transient vibrations—typically in the 50-500 Hz range—overcome the mechanical inertia of the lamellar system. In this case, the capsule transmits deformation efficiently, almost instantaneously, to the central nerve ending, effectively amplifying it and making the corpuscle particularly sensitive to the dynamic components of the stimulus. The net effect is selective transmission of rapid changes, with a marked emphasis on higher frequency components.

PHASE 2: MECHANOELECTRICAL TRANSDUCTION

When mechanical deformation reaches the central nerve ending, it is converted into an electrical signal through mechanoelectrical transduction.

Deformation of the neuronal membrane leads to the opening of mechanosensitive ion channels, primarily from the Piezo family, which are permeable to sodium ions (Na^+). The influx of positive charge generates a local depolarization known as the receptor potential or generator potential.

If the amplitude of this depolarization exceeds a critical threshold, voltage-gated sodium channels are activated, producing action potentials that propagate along the myelinated nerve fiber for the central nervous system. In this way, a physical deformation of tissue is translated into a discrete, transmissible neural signal.

PHASE 3: ENCODING OF SENSORY INFORMATION

Vibrational information is not encoded by a single action potential, but by the overall activation pattern of the receptor system. In particular, encoding occurs through multiple parameters:

DISCHARGE FREQUENCY: vibrations of greater amplitude increase the firing rate of generated action potentials.

RECEPTOR RECRUITMENT: an elastic wave that extends spatially can activate many Pacinian corpuscles simultaneously, increasing the perception salience of the stimulus.

RAPID ADAPTATION: Pacinian corpuscles are rapidly adapting receptors on off response. They respond mainly at stimulus onset and offset or to cyclic changes in vibration, making them well suited for detecting dynamic changes rather than static stimuli.

Signals generated by Pacinian corpuscles travel along myelinated **A β** fibers, (large-diameter, heavily myelinated sensory neurons primarily responsible for transmitting non-painful sensations such as touch, vibration, and pressure) characterized by high conduction velocity. The sensory pathway includes:

- * entry into the spinal cord,
- * projection to the ventral posterolateral (VPL) nucleus of the thalamus,
- * arrival at the primary somatosensory cortex (S1)—particularly areas 3b and 1—where vibrational information is processed and made available to conscious perception.

Through this complex interaction and transduction mechanism, Pacinian corpuscles contribute essentially to several sensory functions:

- * perception of high frequency vibrations,
- * detection of deep pressure and rapid impacts,
- * support for dynamic proprioception, through sensitivity to fast mechanical changes during movement,
- * tool-mediated perception, enabling an individual to quote the vibrations of handheld objects and to finally modulate interaction with them.

Pacinian corpuscles therefore play a central role in perceiving deep vibration and detecting rhythmic variations in tissue pressure. These receptors also participate in encoding cutaneous vibrations generated during tactile exploration of surfaces.

MEISSNER'S CORPUSCLES: perception of superficial vibration and skin motion

Meissner corpuscles are located in the superficial dermis, especially in areas of glabrous skin, such as the palms of the hands, the soles of the feet, and the hips.

They're composed of modified Schwann cells and intertwined nerve fibers forming an ovoid structure. These receptors are also rapidly adapting, but they are specialized for detecting low dash frequency vibration, generally between 5 - 150 Hz, with peak sensitivity between approximately 10 - 65 Hz.

Their primary function is to detect light, rapid changes in tactile contact, such as an object sliding across the skin or superficial tissue motion. This sensitivity makes them fundamental to fine motor coordination and the regulation of grip. In vibroacoustics, Meissner corpuscles contribute to the perception of superficial vibration and to the modulation of early sensory responses.

MERKEL CELL-NEURITE COMPLEXES (Merkel Discs): perception of static pressure and tactile discrimination

Merkel discs are located in the basal layer of the epidermis and consist of specialized epithelial cells associated with afferent nerve endings.

These receptors are classified as slowly adapting, because they maintain activity during sustained mechanical stimulation. They are particularly sensitive to static pressure and prolonged skin deformation.

Merkel cells have functional features similar to neuroendocrine cells and can release neurotransmitters in response to mechanical deformation. This enables the nervous system to acquire detailed information about object shape and the distribution of pressure on the skin surface. These receptors contribute to the perception of slower components of vibration and to the stabilization of tactile information.

RUFFINI ENDINGS: perception of stretch and tissue tension

Ruffini endings are receptors located in deeper layers of the dermis and in connective tissues. They are sensitive to skin stretch and prolonged tissue deformation.

They are slowly adapting receptors and play an important role in perceiving joint position and movement, contributing to proprioception. Their activation provides information about mechanical tension and tissues and about body orientation in space.

Ruffini endings may be involved in the perception of low frequency vibration and in the modulation of muscle tone and posture.

HAIR FOLLICLE RECEPTORS: detection of hair movement in micro-vibrations

Hair follicle receptors are nerve endings associated with hair follicles. They respond to hair movement and are particularly sensitive to light rapid mechanical stimulation.

These receptors contribute to the perception of superficial micro vibrations and represent an important component of tactile sensitivity in hair-bearing skin.

INTEGRATION WITH THE NERVOUS SYSTEM

Information from cutaneous mechanoreceptors is transmitted via afferent fibers of the somatosensory system, particularly through the dorsal column-medial lemniscus system. Signals reached the thalamus and then the somatosensory cortex, where they are interpreted and integrated with other sensory inputs.

Beyond conscious perception, mechanoreceptor stimulation can activate spinal reflex circuits and modulate autonomic nervous system activity, influencing physiological parameters such as muscle tone, microcirculation, and autonomic regulation.

IMPLICATIONS FOR VIBROACOUSTICS

Different classes of mechanoreceptors respond selectively to different frequency ranges and modes of stimulation. Lower-frequency vibrations tend to involve more superficial and proprioceptive pathways, whereas faster vibrations predominantly engaged deeper receptors.

Understanding the functional characteristics of McKenna receptors makes it possible to interpret the physiological effects of fiber acoustic stimulation more precisely and provides a scientific basis for developing applied protocols and research models.