The Somatosensory System
Divisions of the Somatosensory System

- **Exteroceptive**: External stimuli
  - Touch
  - Pain
  - Temperature

- **Proprioceptive**: Body position
  - Muscles
  - Joints
  - Balance

- **Interoceptive**: Body conditions
  - Internal organs

- Somatosensory System
Skin can be vibrated, pressed, pricked and stroked, and its hairs can be bent or pulled.

Accordingly, there are many kinds of cutaneous receptors (with specialized endings) including:
- Meissner’s corpuscles
- Merkel’s disks
- Ruffini endings
- Pacinian corpuscles
Mechanoreceptors vary in receptive fields sizes, preferred stimulus frequencies, and pressures. The identification of objects by touch is called stereognosis.

<table>
<thead>
<tr>
<th></th>
<th>Field Diameter</th>
<th>Frequency Range</th>
<th>Adaptation (pressure)</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meissner</td>
<td>3-4 mm</td>
<td>10-60 Hz</td>
<td>Rapid</td>
<td>Light touch, stroke</td>
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<tr>
<td>Merkel</td>
<td>3-4 mm</td>
<td>DC-30 Hz</td>
<td>Slow</td>
<td>Touch, fine spatial details</td>
</tr>
<tr>
<td>Ruffini</td>
<td>&gt; 10 mm</td>
<td>DC-15 Hz</td>
<td>Slow</td>
<td>Stretch, finger position</td>
</tr>
<tr>
<td>Pacinian</td>
<td>&gt; 20 mm</td>
<td>50-1000 Hz</td>
<td>Rapid</td>
<td>Vibration, strong pressure</td>
</tr>
</tbody>
</table>
Transduction in Touch Receptors

Stimuli applied to the skin deform, bend or stretch the membrane of the receptor, and this in turn changes its permeability to ions.
Pain and Temperature Receptors

The transduction of painful and thermal stimuli occurs at free nerve endings.

Pain receptors (nociceptors) may respond selectively to strong mechanical, thermal or chemical stimuli, or respond to all three kinds (polymodal).

Thermoreceptors are highly sensitive to temperature in the innocuous range. There are distinct warm and cold types.

Transmission is via myelinated $A\delta$ fibers (rapid adapting) or unmyelinated $C$ fibers (slow).
Exteroceptors are not uniformly distributed across the body.

Finger tips are enriched in mechanoreceptors with small receptive fields.

There is a high density of nociceptors in palms and soles.

There are more cold than warm thermoreceptors in the body, with the highest density of receptors on the face and ears.
Dermatomes

Fibers from cutaneous receptors gather together in nerves and enter the spinal cord via the dorsal roots.

Dermatome: area of the body that is innervated by the left and right dorsal roots of a given segment of the spinal cord.
Two Major Exteroceptor Pathways

**Dorsal-Column Medial Lemniscus**

- Mainly touch and muscles/joints
- First synapse in the dorsal column nuclei of the medulla

**Anterolateral System**

- Mainly pain and temperature
- First synapse in the spinal cord

- Three tracts

- Interneurons endorphins (endogeneous opioids)

- Periaqueductal gray (PAG)
Proprioception from Muscles

Muscle have two types of proprioceptors.

Muscle spindles are in parallel with muscle fibers; they signal muscle length.

Golgi tendon organs are in series with muscle fibers; they signal muscle tension.
There are four types of mechano-sensitive proprioceptors in joints.

They respond to changes in angle, direction and velocity of the joint.
Balance: The Vestibular System

The vestibular system monitors the movement and position of the head, giving us our sense of balance or equilibrium. The system includes two structures: the semicircular canals and the otolith organs.
The Semicircular Canals

The semicircular canals detect turning movements of the head, in particular angular accelerations.

Semicircular canals are paired with another on the opposite side of the head. Rotation in one axis excites the hair cells of one canal, and inhibits the other canal: push-pull.
The Otolith Organs

The otolith organs sense changes of head angle (position of head), and linear accelerations.
Central Proprioceptive Pathways

Dorsal-Column Medial Lemniscus

Mainly touch and muscles/joints
First synapse in the dorsal column nuclei of the medulla

Central connections of the vestibular system

SI (face area)

Limb motor neurons

Neck motor neurons

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Primary somatosensory cortex (SI) is located in the postcentral gyrus.

Input is largely contralateral.

It is organized according to a map of the body (i.e., it is somatotopic).

The somatosensory homunculus is distorted; more sensitive tactile/position discrimination, more cortex.
Columnar Organization of SI

Primary somatosensory is composed of four strips.

Each strip is most sensitive to a different kind of somatosensory input.
Two Streams from SI

Dorsal stream from SI to posterior parietal cortex: direct attention
Ventral stream through SII (bilateral) to prefrontal: perception of object shape