Lecture 17: Somatosensory System

Today: Basics of the somatosensory system
Next time: Stages of decision-making in the somatosensory system during frequency discrimination tasks.

The somatosensory system is perhaps the most diverse sensory system

3 major components:
- Tactile perception system (touch, vibration, pressure, etc)
- Proprioceptive system (muscle lengths, tensions, joint angles)
- Pain system

We will focus mainly on tactile perception, with a bit about proprioception

The receptive field of each afferent fiber is defined as the region of skin surface over which cell responds

RF size is determined by the branching of dendritic endings.

RF sizes vary dramatically across different parts of the body, being smallest on the fingers, lips, and face

RF size and overlap determines thresholds for two-point discrimination: how far apart do two tactile probes need to be for you to feel two points instead of one.

Note that the idea of two-point discrimination and RF size is conceptually similar to whether population activity shows bimodal response (visual system)

Two basic classes of temporal response properties of somatosensory afferents:

- Slowly adapting (SA)
- Rapidly adapting (RA)

Both types of neurons adapt to a sustained stimulus, but SA neurons have a sustained response whereas RA responses are transient
An experiment that examined the response dynamics of somatosensory neurons. Tactile patterns such as random dots or letters were embossed onto a drum and the drum was rotated to move the tactile stimuli across the receptive field of the neuron in a controlled fashion.

Data below show spike patterns produced in response to a sequence of letters. Note the difference in response pattern between the SA and RA neurons.

**Slowly Adapting**

**Rapidly Adapting**

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**Specialized Mechanoreceptors**

Each type of mechanoreceptor has a specialized ending that makes it sensitive to a different range of frequencies and amplitudes of skin indentation.

**Proprioceptors**

Are important for sensing the length and tension of muscles.

Two major types: muscle spindles and Golgi tendon organs.

Muscle spindle fibers are intermingled with contractile (extrafusal) fibers and act as strain gauges to sense the length of the muscle. These sensors can be tuned by descending input via the gamma motor neurons. Spindles mediate the stretch reflex, whereby a muscle automatically contracts when it gets stretched. Why?

Golgi tendon organs sense the tension applied by a muscle. Found at the interface between muscle and tendon. Why is this useful?

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**TABLE 13**

<table>
<thead>
<tr>
<th>Afferent Systems and Their Properties</th>
<th>Small motor field</th>
<th>Large motor field</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Tip of epidermis</td>
<td>Dorsal papillary (v--v inner surface)</td>
</tr>
<tr>
<td><strong>Axis diameter</strong></td>
<td>1-3 μm</td>
<td>6-12 μm</td>
</tr>
<tr>
<td><strong>Conduction velocity</strong></td>
<td>10-25 m/s</td>
<td>20-35 m/s</td>
</tr>
<tr>
<td><strong>Sensory function</strong></td>
<td>Dermal receptors</td>
<td>Dermal receptors</td>
</tr>
<tr>
<td><strong>Effective stimulus</strong></td>
<td>Edges, points,</td>
<td>Skin cutaneous</td>
</tr>
<tr>
<td><strong>Receptive field area</strong></td>
<td>0.5 mm</td>
<td>20 mm</td>
</tr>
<tr>
<td><strong>Frequency range</strong></td>
<td>0.1-100 kHz</td>
<td>1-100 kHz</td>
</tr>
</tbody>
</table>

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**Somatosensory inputs** from the dorsal column-medial lemniscal and trigeminal pathways pass through the ventral posterior nuclei of the thalamus, and then project to primary somatosensory cortex (SI).

SI is composed of 4 distinct sub-fields, known as areas 1, 2, 3a, and 3b.
Each area within SI contains a complete **somatotopic map** of the body surface.

Areas 3b and 1 process mainly cutaneous stimuli, whereas 3a processes mainly proprioceptive signals, and area 2 is a mixture of tactile and proprioceptive.

The representation of the body surface (magnification factor) is not uniform: homunculus.

On a finer scale, there is even more detailed organization. There are columns of neurons representing each digit of the hand.

Within a digit representation, there is an orderly mapping of receptive fields onto the proximal, middle, and distal segments of the finger. There is also a segregation of slowly and rapidly adapting neurons.

Somatosensory signals are found in many other parts of cortex, often in combination with other sensory signals. For example, neurons in the ventral intraparietal area (VIP), next to LIP, have visual receptive fields and respond to moving objects approaching the head. They often also have somatosensory receptive fields on a corresponding part of the face, torso, or arm, such that they might signal objects approaching the body.

Electrical microstimulation of VIP can elicit defensive movements of the face and body, similar to those that occur when air is puffed onto the face.

Somatosensory cortex has been a valuable model for studying plasticity. Map of digits reorganizes substantially after a digit is amputated, even in adults.

Much more plasticity in primary somatosensory and auditory cortices than in V1 – reasons are unclear.
Microstimulation of VIP and a pre-central sulcus zone (PZ) can also elicit defensive movements of the limbs, as shown above.

These visual/somatosensory neurons may be specialized to respond to objects that are on a collision course with the head or body. Thus, electrical stimulation of those neurons elicits defensive movements that would be used to protect against such a collision.