1. Somatosensory Pathways

Objectives
1. Describe the general characteristics of sensory pathways
2. Understand the general organization and numbered areas of spinal cord gray matter
3. Understand dermatomes and be able to name them on the body surface.
4. Understand the general characteristics of tactile sensory receptors.
5. Understand how axon diameter relates to transmission of tactile information.
6. Describe the names and locations of the cell bodies and axons in the pathway that transmits tactile information. Describe the cortical area involved.
7. Understand the concept of somatotopic orientation and describe it for tactile information at the level of the spinal cord, brainstem, and cortex.
8. Understand the term lesion and describe how lesions in the spinal cord, brainstem and cortex affect tactile sensibility.
9. Understand the terms: Lesion, Tabes Dorsalis, and Romberg test

Case Description:
A 24-year-old man was brought to the emergency room after he was shot during an argument outside a bar. On exam, he had the following symptoms: there was loss of touch and vibration sense in his left lower limb beginning at L2 (top of thigh). He could not tell the position of his left leg when it was passively moved by his physician. Tactile, vibration and position sense were normal in his right lower limb. Pinprick sensation was absent in his right lower limb starting at L4 (below the knee), but normal in his left lower limb and elsewhere.

Questions:
• Which sensory systems were affected; where on body?
• Why did he lose some sensation on his right side but other sensation on left.
• Is there a single location where damage (Lesion) causes these symptoms.

1. General Features of Sensory Pathways
• relevant stimuli
  • somatosensory information includes: light touch (tactile sensation tested by lightly touching skin with cotton), vibration, proprioception (sense of body position), pain (tested by pin prick), temperature.
  • sensory stimuli from the body enter the spinal cord
  • sensory stimuli from the head enter the brainstem via cranial nerves
• sensory receptors:
  modified nerve endings and bare nerve endings

![Sensory Neuron Diagram](image_url)
• **Common Aspects of Pathways:**
  - Pathways carry info for perception and reflexes
  - 3-neuron pathways for perception – begin in periphery, end in cortex
  - Locations of axons (tracts) and cell bodies (nuclei)

<table>
<thead>
<tr>
<th>Cell Body</th>
<th>Axon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1º Dorsal Root Gang</td>
<td>Dorsal Root</td>
</tr>
<tr>
<td>2º Spinal cord or brainstem</td>
<td>CROSSES CNS</td>
</tr>
<tr>
<td>3º Thalamus</td>
<td>Internal capsule</td>
</tr>
</tbody>
</table>

• Perception (conscious appreciation) of sensory stimuli occurs in cortex.

• Spinal Cord Laminae – Precise “geographic” regions of the gray matter were defined by Rexed and numbered from I to X; these correspond to named regions such as Nucleus Proprius, but numbers are more precise.

*modified from Neuroanatomy, J.D. Fix, Williams & Wilkins, 1992*
THE DERMATOME RAP
By Susan Naselli, M.D. (class of 1995)
University at Buffalo School of Medicine

IF YOU’RE LOOKING FOR C1, YOU WON’T FIND NONE
BUT IF YOU WANT C2, THE BACK OF THE HEAD WILL DO

C3 IS WHERE YOU PLACE THE NOOSE FROM THE TREE
C4 IS WHERE SOMEBODY’S HEAD MAY BE

THE LATERAL UPPER LIMB IS AWFULLY BUSY
THAT’S WHERE C5, 6 & 7 SHOULD BE

NOW DON’T GIVE UP, YOU’RE DOING GREAT,
JUST FLEX YOUR PINKY AND SAY C8

THE BRACHIAL PLEXUS HAS TOO MUCH TO DO
WHICH IS WHY IT SHOULD INCLUDE BOTH T1 AND T2

T2 BEGINS THE SEGMENTATION OF THE CHEST
SO LEARN TWO LANDMARKS, YOU CAN FIGURE OUT THE REST

MALE NIPPLE IS FOUND AT LEVEL OF T4
FEMALE NIPPLE, WELL, NEED I SAY MORE?

ONE MORE LANDMARK, NOW DON’T GET BORED,
YOU CAN FIND T10 AT THE UMBILICAL CORD

THE LUMBAR REGION IS SUCH A NICE PLACE
STIMULATION OF L1 MAY PUT A SMILE ON YOUR FACE

L2 AND L3 EXTEND DOWN TO THE KNEE
THIS IS HOW TO LEARN NEUROANATOMY

BEING KICKED IN THE SHIN MAY MAKE YOU CRY
BECAUSE YOU’RE FEELING IT AT L4 & L5

LIKE DANCING, IT’S LOTS OF FUN,
BUT I’M ALWAYS STEPPING ON MY PARTNERS L5 & S1

THE BACK OF THE LEG, THERE’S AN INTERESTING PLACE,
S2 FILLS UP MOST OF THE SPACE

WELL YOUR’RE NEAR THE END, YOU HAVE A BULLSEYE VIEW,
AND THIS DERMATOME RAP IS ALMOST THROUGH

YOU’VE HAD A LOT OF FUN BUT THIS ISN’T JUST JIVE
IF YOU DON’T LEARN YOUR DERMATOMES YOU’LL BE AN S4,5.
2. Tactile Sensation and Proprioception

A. Sensory stimuli – light touch, vibration, and proprioception

• Discriminative or two-point touch is an important collective property of this pathway

B. Sensory Receptors:

• Types of receptors include:
  1. Cutaneous mechanoreceptors: Meissner’s, Pacinian, Ruffini Corpuscles, Merkel receptors, hair receptors
  2. Muscle and skeletal mechanoreceptors: muscle spindles, joint capsule receptors, Golgi Tendon Organ

• The cutaneous mechanoreceptors differ in:
  1. their location in the skin (hairy vs non-hairy regions, superficial vs deep skin)
  2. the size of the skin area over which each receptor can respond to skin deformation (receptive field)
  3. the duration of action potential activity in their axons – slowly vs rapidly adapting

• These different properties of mechanoreceptors produce the basic, component sensations of touch – flutter sensation, vibration, skin indentation – and determine whether the receptor can resolve fine or coarse spatial differences

• In real life, several different types of receptors are activated simultaneously to allow us to discriminate the tactile qualities of an object. Collectively, this information is processed by synaptic interactions in the cortex to enable us to identify objects based on tactile sensation, a property known as Stereognosis.

• Diameter of primary axons

<table>
<thead>
<tr>
<th>Nerve Fiber Group</th>
<th>Axon Diameter</th>
<th>Conduction Velocity</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A (myelinated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α</td>
<td>10 – 20 µm</td>
<td>60 - 120 m/sec</td>
<td>mechanoreceptors</td>
</tr>
<tr>
<td>β</td>
<td>5 – 15 µm</td>
<td>30 – 90 m/sec</td>
<td>mechanoreceptors</td>
</tr>
<tr>
<td>γ</td>
<td>3 – 10 µm</td>
<td>10 - 50 m/sec</td>
<td>mechanoreceptors</td>
</tr>
<tr>
<td>δ</td>
<td>1 – 5 µm</td>
<td>6 - 30 m/sec</td>
<td>nociceptors, thermal r.</td>
</tr>
<tr>
<td>Group C (unmyelinated)</td>
<td></td>
<td>0.5 – 2 µm</td>
<td>0.5 – 2 m/sec</td>
</tr>
</tbody>
</table>
C. Pathway:

<table>
<thead>
<tr>
<th>First-Order Neuron</th>
<th>Cell Body/Nucleus</th>
<th>Axon/Tract</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRG</td>
<td>Spinal Nerve/ F. Gracilis &amp; Cuneatus</td>
</tr>
<tr>
<td>Second-Order Neuron</td>
<td>Nuclei Gracilis &amp; Cuneatus</td>
<td>Medial Lemniscus</td>
</tr>
<tr>
<td>Third-Order Neuron</td>
<td>Ventral Posterior Lateral</td>
<td>Post. Limb Internal Capsule</td>
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</table>

• 1° axons branch as they enter the spinal cord → pathway to cortex for sensory **perception**
local connections in spinal cord for **reflexes**
D. Cortical Localization – Postcentral gyrus is Somatosensory Cortex

Paracentral lobule

E. Somatotopic Orientation – the relationship between where on the body a stimulus occurred and the anatomical position in tracts or nuclei of the consequent activity.

spinal cord:

brainstem:

medulla
Caudal pons
Rostral pons
Perception is the process by which we recognize, organize, and make sense of sensations we receive from stimuli. It occurs at the level of the cortex as activity generated by a stimulus is analyzed at specific cortical locations. A common principle is that activity is analyzed first where a sensory pathway “terminates” (in this case the postcentral gyrus), providing recognition of simple stimulus features. Then analysis continues at neighboring cortical regions or the information is transferred to more distant cortical areas by axonal highways. This allows integration of the sensory information from a particular system with information residing at other cortical locations so that aspects of memory, language and other capabilities can be used to understand the stimulus. For example, tactile information that arrives at the postcentral gyrus first provides awareness of the type of stimulus we have touched and then this is integrated with information about language and vision nearby in the cortex so that we can relate a tactile stimulus to letters, numbers, or objects we have seen. This is the basis for complex functions like graphesthesia and stereognosis.

As frequently happens in the cortical processing of information, analysis and integration of stimulus features occur at multiple cortical locations. This makes it possible for damage at a particular cortical location to impair some functions without affecting other functions. Lesions (dysfunction) localized to specific areas will impact some, but not all of these functions. Thus, a patient might lose the capacity for more complex tactile function while retaining the simple ability to feel. Loss of any of the complex tactile functions while simple, peripheral tactile awareness is intact (a condition known as agnosia), indicates a parietal cortex lesion. This concept extends to other sensory systems/modalities as well.
COMPLEX FUNCTIONS

• 2-point discrimination - perception of closely spaced stim
• stereognosis - identify objects based on tactile quality
• graphesthesia - identify numbers drawn on palm
• double simultaneous stimulation - bilateral sensory stimulation

DEFICITS (tactile agnosia)

loss of 2-point discrimination
astereognosis
agraphesthesia
extinction on DSS*

*Damage to the parietal lobe can cause misperception of or inattention to tactile stimuli.

These properties can be tested clinically. If they are intact, it indicates that sensory signals have reached the cortex AND that the cortex has analyzed them properly.

G. Other Clinical Considerations:

• a lesion is an area of localized dysfunction in the nervous system. It may be caused by a variety of factors including trauma, loss of blood supply, tumors, congenital malformations, genetic disorders, viral and bacterial infection, disease, etc. The symptoms caused by a lesion provide clues to its location in the nervous system. Lesions typically block conduction/function, but in some situations they can irritate adjacent tissue and induce activity (e.g. seizures).

• Romberg test: assesses the tactile sensory system by testing proprioceptive awareness. Patient tries to assume a steady stance with feet together, arms outstretched, and eyes closed.

• Tabes Dorsalis (advanced syphilis) and Vitamin B12 deficiency: cause damage to dorsal column pathway. What symptoms are associated with these disorders?
• **Deficits Associated with Lesions at Different Levels**
  • Where in the CNS could this pathway be damaged; what deficits would this cause:
    • Spinal cord
    • Brainstem
    • Thalamus
    • Internal Capsule
    • Postcentral gyrus

  • loss of tactile sensibility

  • More widespread damage to the parietal lobe, which is more common than localized damage to the postcentral gyrus, may lead to any of following:
    • loss of 2-point discrimination
    • astereognosis
    • agraphesthesia
    • extinction on double simultaneous stimulation (inattention to bilateral tactile stimuli)

These deficits are key symptoms that imply damage to the cortex

• The transmission of *tactile* information depends on specific sensory receptors and a unique pathway to cortex, which allow us to appreciate the stimulus as tactile. Other sensory modalities such as pain, vision, hearing likewise require specific receptors and distinct pathways. This organization underlies the physiological concept of stimulus encoding by *labeled lines*, ie sensory information is encoded (labeled) by specific receptors and their pathways (lines) capable of transmitting only specific modalities of sensory information. Within a particular modality, however, information often is encoded by a population of axons (*population encoding*) transmitting slightly different stimulus qualities whose collective activity determine our sensory experience.

• CASE: On returning home from shopping, a wife finds her 59 year-old husband unconscious on the floor. He has no pulse. After calling 911, she begins CPR. When Mr. T arrives in the ED, he is in ventricular fibrillation. Spontaneous circulation is eventually restored, but Mr. T remains comatose. After 3 days in coma, his wife asks about her husband’s condition and the probability of a good outcome.
  • No clinical methods exist to assess cerebral cortex damage/function in unconscious patients
  • How can a physician assess the extent of CNS damage and chances for recovery?

  1. Somatosensory Evoked Potential

• Reminder: **Check out the tutorials available from the OMC link on the module web site.**