Organization of the CNS

- Spinal cord -

1. Organization of the CNS
2. Spinal cord
3. Pathways of the spinal cord
   1. Long ascending tracts
   2. Long descending tracts
4. Spinal cord in cross sections
Grey Matter = Cell Body

White Matter = Myelinated axon
Grey Matter

- Cortex
- Nucleus (CNS)
- Ganglion (PNS); exception: Basal Ganglia
White Matter

- Nerve (PNS)
- Tract (CNS)
- Fasciculus/Funiculus = group of fibers with common origin and destination
- Lemniscus = ribbon-like fiber tract
- Peduncle = massive group of fibers (usually several tracts)
Tracts are named with origin first, then destination

- Corticobulbar tract
- Corticospinal tract
- Spinocerebellar tract
- Mammilothalamic tract
Spinal cord

- Spinal cord is SMALL!
- 40-45 cm long
- 1 cm wide at widest point
- Does not extend all the way to the bottom of the spinal column
- From foramen magnum to intervertebral disc (L1-L2); continues as filum terminale (to sacral canal)

- Upper 2/3 of the vertebral column
Pattern of grey/white matter is reversed in the cord
- White matter tracts on outside
- Grey matter on the inside
- Staining reverses this!!!
Internal structure of spinal cord

*White matter - funiculi:*
- Dorsal (posterior)
- Lateral
- Ventral (anterior)

*Gray matter – butterfly shaped – horns:*
- Anterior
- Posterior
- Intermediolateral cell column (IML)
Posterior (dorsal) horn
Intermediate grey
Anterior (ventral) horn
Laminar organisation
Rexed laminae
Spinal cord - general organization

- Spinal cord is segmented anatomically
- Input and output occurs in groups of rootlets arranged in a series longitudinally along the cord
  - Dorsal rootlets = Input (carry sensory information)
  - Ventral rootlets = Output (motor neurons)
Dorsal and ventral roots

Common spinal nerve trunk (1-2 mm)

Dorsal and ventral ramus
Spinal cord

- 31 pair of spinal nerves
  - 8 cervical (C1 - C8)
  - 12 Thoracic (T1 - T12)
  - 5 Lumbar (L1 - L5)
  - 5 Sacral (S1 - S5)
  - 1 Coccygeal
Spinal cord

- The spinal cord is housed within the vertebral column
- Each cord segment has a corresponding vertebra of the same name (e.g., C3)
- Spinal nerves enter/exit underneath their corresponding vertebral segment
But wait! Something doesn’t add up!

- How can spinal nerves exit below their corresponding vertebral segment if the cord is only 40cm-45cm long?

- Answer: Spinal nerves extend down to the appropriate vertebral segment forming the cauda equina

- This means cord segments and vertebral segments don’t line up
Each set of rootlets forms a spinal nerve that innervates a corresponding segment of the body.

Area of the skin supplied by the right and left dorsal roots of a single spinal segment.

Overlapping areas!
Cord is not of uniform thickness throughout its length. Why not?

Answer:
- Segments of the cord innervate parts of the body that differ in complexity.
- There are fewer white matter tracts lower in the cord.
2 enlargements:
- Cervical (C5-T1)
- Lumbar (L1-S2)
  - C1-C4 = plexus cervicalis
  - C5-T1 = plexus brachialis
  - L1-L4 = plexus lumbalis
  - L4-S2 = plexus sacralis
Pathways of the spinal cord:

- Association
- Projection
- Commissural
General senses:

- **Exteroceptive (from surface):** touch, vibration, pain, temperature, localization

- **Proprioceptive (deep, protopathic):** locomotor system (periost, tendon and muscle spindles, joints); mostly nonconscious!

- **Interoceptive:** from visceral system; mostly nonconscious! Base for proper function of the autonomic reflexes, homeostasis, neuroendocrine system
Long ascending tracts (projections):

- Tractus spinothalamicus
- Tractus spinocerebelaris
- Fasciculus gracilis and cuneatus
Tractus spinothalamicus

1. **Direct pathway** (pain, temperature, simple tactile sensations)
   - Neospinothalamic tract

2. **Indirect pathways** (affective, autonomic, endocrine, motor, and arousal components of pain, and simple tactile sensations)
   - Paleospinothalamic
   - Spinoreticular
   - Spinomesencephalic tracts
Neospinothalamic tract

**Neuron I**
- Receptors in skin
- Dorsal root ganglion

**Neuron II**
- Dorsal root
- Dorsal horn (nucleus proprius)
- Anterior white commissure
- Lateral white column

**Neuron III**
- Ventral posterolateral nucleus of thalamus
- Capsula interna
- Postcentral gyrus (area 3, 1, 2)
- Tractus neospinothalamicus
Neurons located in the dorsal horn and intermediate gray matter

Ascend contralaterally and ipsilaterally

Synapses in *reticular formation*

Project in *midline* and *intralaminar thalamic nuclei* – diffuse projections to the cortex and *limbic regions* (cingulate gyrus)
Spinoreticular tract

- Neurons located in the dorsal horn and intermediate gray matter
- Ascend contralaterally and ipsilaterally
- Synapses in medullary and pontine reticular formation
- Project in midline and intralaminar thalamic nuclei – diffuse projections to the cerebral cortex
Spinomesencephalic tract

- Neurons located in the dorsal horn and intermediate gray matter
- Ascend to the *midbrain (PAG)*
  - Descending projections to the spinal cord to *inhibit pain sensations*
- Transmission to the amygdala via parabrachial nuclei?
Neospinothalamic tract

- **RIGHT SIDE OF BODY**
  - Thalamus

- **LEFT SIDE OF BODY**
  - Primary somatosensory area of cerebral cortex
  - THIRD NEURON

- **SECOND NEURON**
  - Midbrain

- **FIRST NEURON**
  - Medulla oblongata
  - Posterior gray horn
  - LATERAL SPINOThALAMIC TRACT
  - Spinal nerve
  - ANTERIOR SPINOThALAMIC TRACT

- **Receptors for pain, cold, warmth, tickle, and itch**
  - Spinal cord
Clinical importance...

- **Neospinothalamic tract** – anesthesia, thermoanesthesia, loss of simple tactile sensations

- **Sacral sparing** – damage to the neospinothalamic tract leaves intact the pain, temperature, and simple tactile sensations in sacral dermatomes (lesion in the gray matter first affects thoracic and cervical fibers due to somatotopic organization of the tract)
Tactile and kinesthetic sense – fasciculus gracilis et cuneatus

- Tactile sense: vibration, deep touch, two-point discrimination
- Kinesthetic sense: position and movement

- Sacral and lumbar part = medial
  - fasciculus gracilis (Goll’s fascicle)

- Toracal and cervical part = lateral
  - fasciculus cuneatus (Burdach’s fascicle)
Discriminative touch and kinesthesia – fasciculus gracilis and cuneatus

- Neuron I
  - Dorsal root ganglion
  - Receptors in dermis; proprioceptors

- Neuron II
  - Dorsal root
  - Dorsal horn

- Neuron III
  - Medial lemniscus
  - Ventral posterolateral nucleus of thalamus
  - Capsula interna
  - Postcentral gyrus (area 3,1,2)

- Nucl. gracilis and cuneatus
  - Ipsilateral dorsal columns

- Fasciculus gracilis and cuneatus
Dorsal (posterior) columns

- Primary somatosensory area of cerebral cortex
- Thalamus
- Medial lemniscus
- Midbrain
- Nuclei of medulla
- Medulla oblongata
- Posterior column
- Spinal cord
- Receptors for fine touch, proprioception, and vibration

(A) Thalamus
(B) Primary somatosensory cortex

- Primary sensory neuron
- Sensory decussation
- Dorsal root ganglion
- Posterior (dorsal) columns
- Vibration, proprioception, light touch
- Primary somatosensory neuron
- Posterior (dorsal) column nuclei
- Gracile nucleus
- Cuneate nucleus
- Thalamus: Ventral posterior lateral nucleus
- Secondary sensory neuron
- Medulla
- Spinal cord
Tractus spinocerebellaris

- *Tractus spinocerebellaris anterior* – information about whole limb movement and postural adjustments (lower limb)
- *Tractus spinocerebellaris rostralis* – upper limb
- *Tractus spinocerebellaris posterior* – status of individual muscles and groups of muscles + *tractus cuneocerebellaris*

- *All enter cerebellum ipsilaterally!!!*
Nonconscious proprioception – tractus spinocerebellaris anterior: lower limb

Receptors in tendons → Dorsal root ganglion → Dorsal root → Dorsal horn → Superior cerebellar peduncle → Lateral funiculus → Tractus spinocerebellaris anterior → Cerebellum (anterior lobe) → Neuron I → Neuron II
Nonconscious proprioception – tractus spinocerebellaris rostralis: upper limb

1. **Receptors in tendons** → **Dorsal root ganglion** → **Dorsal root** → **Dorsal horn**
2. **Neuron I**
3. **Neuron II**
4. **Cerebellum (anterior lobe)** → **Inferior cerebellar peduncle** → **Lateral funiculus** → **Tractus spinocerebellaris rostralis**
Nonconscious proprioception – tractus spinocerebellaris posterior: lower limb

- **Neuron I**
  - Receptors in joints, tendons and muscles
  - Dorsal root ganglion
  - Dorsal root
  - Inferior cerebellar peduncle (restiform body)
  - Cerebellum (anterior lobe)

- **Neuron II**
  - Dorsal horn (nucl. dorsalis of Clarke)
  - Lateral funiculus
  - Tractus spinocerebellaris posterior

- **Tractus spinocerebellaris posterior**

Additional terms:
- Dorsal root
- Dorsal horn
- Nucl. dorsalis of Clarke
- Inferior cerebellar peduncle (restiform body)
- Cerebellum (anterior lobe)
- Tractus spinocerebellaris posterior
Tractus cuneocerebellaris

- Nonconscious proprioception of upper limb
- Rostral to C8 (no nucl. dors. of Clarke)
- Ipsilaterally in the fasciculus cuneatus
- Neuron II = accessory cuneate nucleus
## Long ascending tracts

<table>
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<tr>
<th>Neuron</th>
<th>Tractus neospinothalamicus</th>
<th>Tractus spinocerebelaris</th>
<th>Fasciculus gracilis et cuneatus</th>
</tr>
</thead>
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</tr>
<tr>
<td>Neuron III</td>
<td>thalamus</td>
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<tr>
<th>Function</th>
<th>Pain and temperature</th>
<th>Nonconscious proprioception</th>
<th>Discriminative touch and kinesthesia</th>
</tr>
</thead>
</table>
Long descending tracts:

- Corticospinal tract
- Rubrospinal tract
  - Flexor motor system, fine movements of the limbs

- Tectospinal tract
- Vestibulospinal tract
- Reticulospinal tract
  - Antigravity muscles, posture, and balance
Tractus corticospinalis

- Homunculus – precentral gyrus
- Primary motor cortex
Tractus corticospinalis

- Precentral gyrus (area 4) → Corona radiata → Capsula interna → Crus cerebri
- Neuron I (upper motoneuron)
  - Tractus corticospinalis lateralis (90%)
- Neuron II (lower motoneuron)
  - Anterior horn*
  - Ventral root
  - Spinal nerve
- Pyramids
  - Tractus corticospinalis anterior (10%)
Corticospinal tract

- 90% fibers cross at pyramidal decussation → lateral funicle (tractus corticospinalis lateralis): limb muscles

- 10% fibers descend ipsilaterally (tractus corticospinalis anterior) and cross at the level of lower motoneuron: axial muscles
Lower motor neuron paralysis:
- loss of voluntary movement,
- flaccid paralysis,
- loss of muscle tone,
- atrophy of muscles,
- loss of all reflexes

Upper motor neuron paralysis:
- loss of voluntary movement,
- spasticity,
- increased deep tendon reflexes,
- loss of superficial reflexes,
- Babinski sign
Damage to corticospinal tract

- monoplegia
- hemiplegia
- diplegia
- paraplegia
- quadriplegia (tetraplegia)
<table>
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<td>Neuron II (lower motoneuron)</td>
<td>Spinal cord: anterior horn</td>
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</table>

*Plexus brachialis: C5-Th1
Plexus lumbosacralis: L1-S5
Spinal reflexes

- Motor responses to afferent stimulation
- **Automatic reactions** – fast response to pain and noxious stimuli

- **Reflex arc – spinal segment:**
  - Aferent neuron
  - Interneuron = *Renshaw’s cell*
  - Eferent neuron
  - Efector (muscle)
Triceps muscle stretch elicited by tapping the tendon causes agonists (triceps) to contract and antagonists (biceps) to relax.
Extrapyramidal motor pathways

- Tractus rubrospinalis
- Tractus tectospinalis
- Tractus vestibulospinalis (medialis and lateralis)
- Tractus reticulospinalis
- Fasciculus longitudinalis medialis

- Fasciculi proprii – intrinsic reflex mechanisms of the spinal cord
Tractus rubrospinalis

- Facilitation of flexor motor neurons
- Inhibition of extensor motor neurons
Tractus tectospinalis

- Aid in directing head movements in response to auditory and visual stimuli
Tractus vestibulospinalis lateralis

- Facilitation of ipsilateral extensor muscles
- Maintaining upright posture and balance
Tractus vestibulospinalis medialis

- Adjustment of head position in response to changes in posture (i.e. while walking)
Tractus reticulospinalis

- **Motor functions**
  - Medullary (lateral) reticulospinal tract – supresses extensor spinal reflexes
  - Pontine (medial) reticulospinal tract – facilitates extensor spinal reflexes

- **Autonomic functions** (ventrolateral medulla – IML of thoracolumbar cord)

- **Modulation of pain** (enkephalinergic)
  - Midbrain PAG → nucl. raphe magnus → dorsal horn interneurons → spinothalamic system
Mainly ascending fibers!!!
Head position control in response to excitation by the labyrinth
The Spinal Cord in Cross Section
Cross Sectional Organization

- Posterior intermediate sulcus
- Tract of Lissauer
- Posterior median sulcus
- Anterior white commissure
- Anterior median fissure
Cord Sections

- Segments of the spinal cord have a similar organization, but vary in appearance.

- Always know where you are in the cord (i.e., cervical, thoracic, lumbar, sacral)
Cervical cord is wide, flat, almost oval in appearance.
Cord Sections -- Cervical Enlargement

What’s different about the cervical enlargement?

Cervical

Cervical Enlargement
Cord Section -- Thoracic

- Less white matter than cervical
- Rounder appearance
- Less prominent ventral horns than cervical enlargement
Cord Section -- Lumbar

- Less white matter than thoracic
- Rounder appearance
- Larger ventral horns, especially in lumbar enlargement
Cord Section -- Sacral

- Not much white matter
- Mostly grey, although not much of that either
Cross sections:

- IML = T1-L2
- Clarke’s nucleus = C8-L3
- Fasciculus cuneatus = above T6
The Big Four

- Corticospinal tract
  - Voluntary movement

- Dorsal columns
  - Discriminative touch
  - Conscious proprioception

- Spinocerebellar tract (dorsal and ventral)
  - Unconscious proprioception

- Spinothalamic tract
  - Pain/temperature

- Corticospinal tracts
- Dorsal Columns
- Spinothalamic tracts
- Spinocerebellar tracts
Questions?