Lab Activity 13

Spinal Cord

Portland Community College
BI 232
Definitions

- **Tracts**: collections of axons in CNS
- **Nerves**: collections of axons in PNS
- **Ganglia**: collections of neuron cell bodies in PNS
- **Nucleus (nuclei)**: collections of neuron cell bodies in CNS
Meninges

Subarachnoid Space: contains the spinal fluid

Subdural Space

Epidural Space: out here between the dura mater and the bone
Spinal Cord: Conus Medullaris

Conus Medullaris

Ends at the level of L1 or L2
Spinal Cord: Cauda Equina

These are spinal nerves that extend down the vertebral canal past the level of the spinal cord.
Spinal Cord: Gray Matter

The central “butterfly” is gray matter: it contains cell bodies, dendrites and unmyelinated axons.
Gray Matter Horns

- **Posterior gray horns** contain somatic and visceral sensory nuclei
- **Anterior gray horns** contain somatic motor nuclei
- **Lateral gray horns** (only located in the thoracic and lumbar segments) contain visceral motor nuclei
Spinal Cord: White Matter

The frame around the “butterfly” is white matter: it contains myelinated axons.
White Matter Columns

- Each column contains tracts (axons)
- *Ascending tracts* carry sensory information from the body toward the brain
- *Descending tracts* carry motor commands to the spinal cord
Spinal Cord Structures

- Posterior white column
- Posterior median sulcus
- Posterior gray commissure
- Lateral gray horn
- Anterior gray horn
- Anterior white commissure
- Anterior gray commissure
- Anterior white column
- Anterior median fissure
- Dorsal root ganglion
- Somatic sensory
- Visceral sensory
- Visceral motor
- Somatic motor
- Ventral root
Dorsal Root (Afferent=Sensory)

Dorsal Root Ganglion (Cell bodies of sensory neurons)

Posterior (Dorsal)

Anterior (Ventral)

Ventral Root (Efferent=Motor)

Spinal Nerve Mixed motor and sensory.
Poliomyelitis

- Polio means gray matter
- The polio virus causes inflammation of the gray matter in the anterior horn motor neurons.
  - These neurons innervate muscles
- **Symptoms**: causes muscle paralysis
Lou Gehrig’s Disease
Amyotrophic Lateral Sclerosis

- ALS is a genetic disease that causes progressive destruction of anterior horn motor neurons.

- Leads to paralysis and death
Spinal Nerves: 31 Pair

8 + 12 + 5 + 5 + 1 = 31

C1-C7 Emerge above the vertebra for which they are named

C8 Emerges between C7 and T1

Thoracic, Lumbar, Sacral and Coccygeal spinal nerves emerge below the vertebra for which they are named
Spinal Nerves
Spinal Nerves → Nerve Plexus

- Dorsal and Ventral roots exit the spinal cord and join together to make a spinal nerve
- The spinal nerve then splits into dorsal and ventral rami (ramus)
  - Some ventral rami give off branches to the sympathetic ganglion
  - The other ventral rami mix and match to make up nerve plexuses
Ventral Rami

• The Dorsal Root only contains sensory neurons going toward the spinal cord
• The Ventral Root only contains motor neurons going out of the spinal cord
• Ventral Rami contain BOTH sensory and motor neurons
• As the spinal nerves, rami and plexus are crisscrossing, everything gets mixed around.
Spinal Cord

Ventral Roots (Motor)

Dorsal Roots (Sensory)

Spinal Nerve
(this is where sensory and motor mix)

Dorsal Ramus (mixed)

Ventral Ramus (mixed)

Rami Communicantes (White ramus + Gray Ramus)

Nerve Plexuses

Sympathetic ganglia
Phrenic Nerve

The cervical plexus is from C1 to C5

Phrenic Nerve: C3, C4 C5
Supplies the diaphragm
The brachial plexus is from C5 to T1
Brachial Plexus

- Brachial plexus
- 5 ventral rami
- 3 anterior divisions
- 3 posterior divisions
- 3 trunks
- 3 cords
- 5 peripheral nerves
- Musculocutaneous n.
- Axillary n.
- Radial n.
- Median n.
- Ulnar n.
- C5, C6, C7, C8, T1
Brachial Plexus Nerves

- **Axillary nerve (C5-C6):**
  - Motor to the deltoid and teres minor muscles
  - Sensory to the skin of the shoulder

- **Musculocutaneous nerve (C5-T1):**
  - Motor to the flexor muscles of the arm
  - Sensory to the lateral surface of the forearm
Brachial Plexus Nerves

- **Radial nerve** (C5-T1)
  - Motor to muscles of the posterior arm and forearm
  - Sensory to the posterior-lateral side of the hand, but not the fingers (purple in picture)
Brachial Plexus Nerves

- **Median nerve (C6-T1):** Travels through the carpal tunnel of the wrist
  - Motor to the flexor muscles on the radial side of the forearm
  - Sensory to the anterolateral surface (thenar side) of the hand, posterior fingers 1 & 2, lateral-posterior finger 3
Brachial Plexus Nerves

- **Ulnar nerve (C8-T1)**
  - Motor to many flexor muscles of forearm and hand on ulnar side
  - Sensory to the medial surface of the hand.
Lumbar Plexus

The Lumbar plexus is from T12 to L4

Femoral nerve
Obturator nerve

(a) The lumbar plexus, anterior view
Lumbar Plexus

- The major nerves:
  - **Femoral nerve** L₂-L₄
    - Motor to Quadriceps group, Pectineus and Iliopsoas muscles, sensory anterior-medial thigh and medial surface of leg and foot.
    - Injury to femoral nerve causes inability to extend leg & loss of sensation in thigh
  - **Obturator nerve** L₂-L₄
    - Motor to adductors of hip. Sensory to medial surface of thigh.
    - Injury to obturator nerve causes paralysis of thigh adductors
Sacral Plexus

The sacral plexus is from L4 to S4
Sacral Plexus

- Arises from L₄-S₄ and serves the buttock, lower limb, pelvic structures, and the perineum
- The major nerves:
  - Sciatic nerve L₄–S₃ Branches behind the knee:
    - Common Fibular nerve: Lateral and anterior muscles of the leg
    - Tibial nerve: Posterior muscles of the leg
  - Pudendal nerve S₂-S₄ Muscles of the perineum
Sciatic Nerve Branches

- **Common fibular nerve** injury produces foot drop (inability to dorsiflex foot) or numbness on dorsum of foot
- **Tibial nerve** injury produces dorsiflexion and eversion with loss of sensation on plantar surface of foot
Sympathetic Chain Ganglia

- Next to the thoracic and lumbar regions
- The ventral root gives rise to a myelinated preganglionic fiber (white rami) to the sympathetic chain ganglia
  - These fibers may synapse here or in collateral ganglia or in the adrenal medulla.
Lab Activity 14

Reflexes
Reflexes

- A reflex is a rapid, predictable motor response to a stimulus

- Reflexes may:
  - Be inborn (intrinsic) or learned (acquired)
  - Involve only peripheral nerves and the spinal cord (aka: spinal reflexes)
  - Involve higher brain centers as well
Reflex Arc

There are five components of a reflex arc:

1. **Receptor** – site of stimulus
2. **Sensory neuron** – transmits the afferent impulse to the CNS
3. **Integration center** – either monosynaptic or polysynaptic region within the CNS
4. **Motor neuron** – conducts efferent impulses from the integration center to an effector
5. **Effector** – muscle fiber or gland that responds to the efferent impulse
Reflex Arc

**STEP 1:**
Arrival of stimulus and activation of receptor

**STEP 2:**
Activation of a sensory neuron

**STEP 3:**
Information processing in CNS

**STEP 4:**
Activation of a motor neuron

**STEP 5:**
Response by effector

**KEY**
- **Red**
  - Sensory neuron (stimulated)
- **Dotted Line**
  - Excitatory interneuron
- **Black**
  - Motor neuron (stimulated)

Dorsal root

Sensation relayed to the brain by collateral

Ventral root

REFLEX ARC

Stimulus

Receptor

Effector
Innate Reflexes

• **Innate reflexes:** Reflexes you are born with.
• The are genetically or developmentally programmed
• **Examples:**
  • Withdrawing from pain
  • Suckling
  • Chewing
  • Tracking objects with the eyes
Acquired Reflexes

• Acquired reflexes are learned motor patterns
• Generally more complex than innate reflexes
• Examples:
  • Slamming on the break when driving
  • Professional skier making quick adjustments in body position
Reflexes

- **Visceral (Autonomic) reflexes** regulate body functions
  - Digestion, blood pressure, sweating etc...

- **Somatic reflexes** involve skeletal muscles
  - Function to maintain posture, balance and locomotion
Reflexes

- **Spinal reflexes:** The important interconnections and processing events occur in the spinal cord.

- **Cranial reflexes:** The integration center is in the brain
Types of Reflexes

- **Monosynaptic reflexes:** The sensory neuron synapse directly on a motor neuron.
  - The delay between stimulus and the response is minimized.
  - The synapse is considered the integration center.

- **Polysynaptic reflexes:** There is at least one interneuron between the sensory and motor neuron.
  - More complex responses
Upper Motor Neurons

• Upper motor neurons: Starts in the motor cortex of the brain and terminates within the medulla (another part of the brain) or within the spinal cord.

• Damage to upper motor neurons can result in spasticity and exaggerated reflexes (because of the loss of inhibition) “Spastic Paralysis”
Lower Motor Neurons

- Lower motor neurons go from the spinal cord to a muscle.
- The cell body of a lower motor neuron is in the spinal cord and its termination is in a skeletal muscle.
- The loss of lower motor neurons leads to weakness, twitching of muscle (fasciculation), and loss of muscle mass (muscle atrophy). “Flaccid Paralysis”
Reflexes

- Intact reflexes require
  - Intact sensory afferent nerves (coming to the spinal cord)
  - Intact synapse within the spinal cord
  - Intact efferent motor nerves coming from the spinal column
  - Adequately functioning muscle.
Testing Reflexes

- Reflexes can also be modified by conditions higher in the cord than the relevant synapse including the brain itself.
- The purpose of testing reflexes is to check the integrity of the system as a whole.
- An absent reflex indicates a problem somewhere in the reflex arc but it does not tell you where.
Stretch Reflexes

1. Stretching of the muscle activates a muscle spindle
   - A muscle spindle is a bundle of specialized skeletal muscle fibers that act as sensory receptors
2. An impulse is transmitted by afferent fibers to the spinal cord
3. Motor neurons in the spinal cord cause the stretched muscle to contract
4. The integration area in the spinal cord causes the antagonist muscle to relax (reciprocal inhibition)
Stretch Reflex Example
Patellar Reflex (L2, L3, L4)

- Tap the patellar tendon
  - muscle spindle signals stretch of muscle
  - motor neuron activated & muscle contracts
- Quadriceps muscle contracts
- Hamstring muscle is inhibited (relaxes)
  - Reciprocal innervation (polysynaptic- interneuron)
  - antagonistic muscles relax as part of reflex
- Lower leg kicks forward
- Demonstrates sensory and motor connections between muscle and spinal cord are intact.
1. Stretching stimulates SENSORY RECEPTOR (muscle spindle)
2. SENSORY NEURON excited
3. Motor neuron to antagonistic muscles is inhibited
4. MOTOR NEURON excited
5. EFFECTOR (same muscle) contracts and relieves the stretching

To brain

Within INTEGRATING CENTER (spinal cord), sensory neuron activates motor neuron

Antagonistic muscles relax

Spinal Nerve

Inhibitory interneuron

Stretch Reflex
Stretch Reflex Example
Ankle Jerk (S1, S2)

- Stretch the Achilles tendon by pushing up with your left hand on the ball of the foot (extend the ankle)
- Swing the patellar hammer onto the tendon striking it sharply.
- Measure the response by feeling the push against your left hand and observing the contraction of the calf muscles
Stretch Reflex Example
Biceps jerk (C5, C6)

- Bend the patient’s arm at the elbow, lying relaxed across the lower part of the chest.
- Find the long head of biceps tendon in the antecubital fossa and stretch it by pushing down on it with your thumb.
- Swing the patellar hammer down sharply.
Grading Reflexes

Grading of reflexes:
- 0+ = absent
- 1+ = hyporeflexic (reduced reflex)
- 2+ = normal
- 3+ = hyperreflexia (exaggerated reflex)
- 4+= clonus
- Say “one plus”

Conditions such as hypothyroidism and spinal shock diminish reflexes.
Stimulant drugs, anxiety, and hyperthyroidism increase reflexes.
Tendon Reflexes

• Controls muscle tension by causing muscle relaxation that prevents tendon damage
• Golgi tendon organs in tendon
  • Activated by stretching of tendon
  • Inhibitory neuron is stimulated (polysynaptic)
  • Motor neuron is hyperpolarized and muscle relaxes
• Both tendon & muscle are protected
Tendon Reflex

1. Increased tension stimulates SENSORY RECEPTOR (tendon organ)

2. SENSORY NEURON excited

3. Within INTEGRATING CENTER (spinal cord), sensory neuron activates inhibitory interneuron

4. MOTOR NEURON inhibited

5. EFFECTOR (muscle attached to same tendon) relaxes and relieves excess tension

Motor neuron to antagonistic muscles is excited

Antagonistic muscles contract

Spinal nerve

Inhibitory interneuron

To brain

Excitatory interneuron
Flexor Reflex

• Withdrawal reflex

• When pain receptors are activated it causes automatic withdrawal of the threatened body part.

• Reciprocal inhibition: Interneurons in the spinal cord prevent a stretch reflex in the antagonistic muscles
Flexor (Withdrawal) Reflex

1. Stepping on a tack stimulates sensory receptor (dendrites of pain-sensitive neuron).
2. Sensory neuron activated.
3. Within integrating center (spinal cord), sensory neuron activates interneurons in several spinal cord segments.
5. Effectors (flexor muscles) contract and withdraw leg.
Crossed Extensor Reflex

• Complex reflex that consists of an ipsilateral withdrawal reflex and a contralateral extensor reflex

• This keeps you from falling over, for example if you step on something painful. When you pull your foot back, the other leg responds to hold you up.
Crossed Extensor Reflex

1. Stepping on a tack stimulates SENSORY RECEPTOR (dendrites of pain-sensitive neuron) in right foot.
2. SENSORY NEURON excited.
3. Within INTEGRATING CENTER (spinal cord), sensory neuron activates several interneurons.
4. MOTOR NEURONS excited.
5. EFFECTORS (extensor muscles) contract, and extend left leg.

Withdrawal of right leg (flexor reflex)
Cutaneous Reflexes

• Elicited by gentle cutaneous stimulation

• Important because they depend on upper motor pathways (Brain) and spinal cord reflex arcs
Cutaneous Reflexes
Plantar Reflex

- Tests spinal cord from L4 to S2
- Indirectly determines if the corticospinal tracts of the brain are working
- Draw a blunt object downward along the lateral aspect of the plantar surface (sole of foot)
- Normal: Downward flexion (curling) of toes
Abnormal Plantar Reflex
Babinski’s Sign

• Great toe dorsiflexes (points up) and the smaller toes fan laterally

• Happens if the primary motor cortex or corticospinal tract is damaged

• Normal in infants up to one year old because their nervous system is not completely myelinated.
Plantar Reflex

Normal

Abnormal (Babinski’s)
The End