The Adult Spinal Cord

- About 18 inches (45 cm) long
- 1/2 inch (14 mm) wide
- Ends between vertebrae L₁ and L₂
  - At birth, cord and vertebrae are about the same size but cord stops elongating at around age 4
- 31 segments (31 pairs of spinal nerves)
- Each pair of nerves exits the vertebral column at the level it initially lined up with at birth

The Distal End

- **Conus medullaris:**
  - thin, conical end of the spinal cord
- **Cauda equina:**
  - nerve roots extending below conus medullaris
- **Filum terminale:**
  - thin thread of fibrous tissue at end of conus medullaris
  - attaches to coccygeal ligament
Size of cord segments

- The more superior, the more white matter. Why do you think this is?
- Grey matter larger in cervical and lumbar regions. Why is this?

31 Spinal Cord Segments

- C8, T12, L5, S5, Co1
- Based on vertebrae where spinal nerves originate
- Positions of spinal segment and vertebrae change with age

Roots

- 2 branches of spinal nerves:
  - ventral root:
    - contains axons of motor neurons
  - dorsal root:
    - contains axons of sensory neurons
- Dorsal root ganglia:
  - contain cell bodies of sensory neurons
  - Pseudounipolar neurons - weird

Dorsal Root Ganglia

Spinal Nerves

- 31 pairs
- one per segment on each side of the spine:
  - dorsal and ventral roots join to form a spinal nerve
- Carry both afferent (sensory) and efferent (motor) fibers = mixed nerves

Spinal Meninges

- Specialized membranes isolate spinal cord from surroundings
- Spinal meninges:
  - protect spinal cord
  - carry blood supply
  - continuous with cranial meninges
The Spinal Dura Mater

- Are tough and fibrous
- Cranially:
  - fuses with periosteum of occipital bone
  - is continuous with cranial dura mater
- Caudally:
  - tapers to dense cord of collagen fibers
  - joins filum terminale in coccygeal ligament (for longitudinal stability)

The Epidural Space

- Between spinal dura mater and walls of vertebral canal (above the dura)
- No such space in the brain
- Contains loose connective and adipose tissue
- Anesthetic injection site

Inter-Layer Spaces – just like in the brain

- Subdural space:
  - between arachnoid mater and dura mater
- Subarachnoid space:
  - between arachnoid mater and pia mater
  - filled with cerebrospinal fluid (CSF)
- Spinal Tap withdraws CSF from inferior lumbar region (below conus medularis) for diagnostic purposes.
- Where do they get the CSF?

Sectional Anatomy of Spinal Cord

- Sensory roots and sensory nuclei are dorsal
- Motor roots and motor nuclei are ventral
In general

• Spinal cord has a narrow central canal
• Central canal is surrounded by gray matter containing sensory and motor nuclei
• White matter is on the outside of the gray matter (opposite of the brain)

What’s the Matter?

• Gray Matter
  – Surrounds central canal of spinal cord
  – Contains neuron cell bodies, neuroglia
  – Forms a butterfly or H-shape
• White Matter
  – Is superficial
  – Contains myelinated and unmyelinated axons (tracts to and from the brain)

Gray Matter Organization

• Dorsal (Posterior) horns:
  – contain somatic and visceral sensory nuclei
• Ventral (Anterior) horns:
  – contain somatic motor nuclei
• Lateral horns:
  – are in thoracic and lumbar segments only
  – contain visceral motor nuclei

Control and Location

• Location of cells (nuclei) within the gray matter determines which body part it controls. For example:
  – Neurons in the ventral horn of the lumbar cord control the legs and other inferior body structures
  – Neurons in the dorsal horn of the cervical cord are sensory for the neck and arms
**Dermatomes**
- Bilateral region of skin
- Each is monitored by specific pair of spinal nerves

**Organization of White Matter**
- 3 columns on each side of spinal cord:
  - posterior white columns
  - anterior white columns
  - lateral white columns

**Tracts**
- Tracts (or fasciculi):
  - bundles of axons in the white columns
  - relay certain type of information in same direction
- Ascending tracts:
  - carry information to brain
- Descending tracts:
  - carry motor commands to spinal cord

**Summary**
- Gray matter is central
- Thick layer of white matter covers it:
  - consists of ascending and descending axons
  - organized in columns
  - containing axon bundles with specific functions
- Spinal cord is so highly organized, it is possible to predict results of injuries to specific areas

**Spinal Nerves**
- Every spinal nerve is surrounded by 3 connective tissue layers that support structures and contain blood vessels (just like muscles)
3 Connective Tissue Layers

- **Epineurium:**
  - outer layer
  - dense network of collagen fibers
- **Perineurium:**
  - middle layer
  - divides nerve into fascicles (axon bundles)
- **Endoneurium:**
  - inner layer
  - surrounds individual axons

Peripheral Distribution of Spinal Nerves

- **Spinal nerves:**
  - start where dorsal and ventral roots unite (just lateral to the vertebral column), then branch and form pathways to destination

Peripheral Distribution of Spinal Nerves

**Motor fibers: First Branch**

- From the spinal nerve, the first branch (blue):
  - carries *visceral* motor fibers to sympathetic ganglion of autonomic nervous system (More about this later)

Communicating Rami

- Also called *Rami Communicantes*, means "communicating branches"
- made up of gray ramus and white ramus together

Communicating Rami

- **White Ramus**:
  - Preganglionic branch
  - Myelinated axons (hence: white)
  - Going "to" the sympathetic ganglion
- **Gray Ramus**
  - Unmyelinated nerves (so: gray)
  - Return "from" sympathetic ganglion
  - Rejoin spinal nerve, go to target organ
Dorsal and Ventral Rami

Both are somatic and visceral outflow to the body
• Dorsal ramus:
  – contains somatic and visceral motor fibers that innervate the back
• Ventral ramus:
  – larger branch that innervates ventrolateral structures and limbs

Sensory Nerves

• Dorsal, ventral, and white rami (but not gray) also carry sensory information in addition to motor efferent outflow.

Peripheral Distribution of Spinal Nerves

Dermatomes

• Bilateral region of skin
• Each is monitored by specific pair of spinal nerves

Peripheral Neuropathy

• Regional loss of sensory or motor function
• Due to trauma, compression, or disease

Reflexes
**Reflexes**

- Rapid, automatic responses to specific stimuli coordinated within the spinal cord
- Occurs via interconnected sensory, motor, and interneurons
- Can be a movement, like a knee jerk, or visceral, like pupil dilation or swallowing

**Functional Organization of Neurons in the NS**

- **Sensory neurons:**
  - about 10 million that deliver information to CNS
- **Motor neurons:**
  - about 1/2 million that deliver commands to peripheral effectors
- **Interneurons:**
  - about 20 billion that interpret, plan, and coordinate signals in and out = information processors

**The Reflex Arc**

- The wiring of a single reflex
  - Begins at sensory receptor
  - Ends at peripheral effector (muscle, gland, etc)
  - Generally opposes original stimulus (negative feedback)

**5 Steps in a Neural Reflex**

- **Step 1:** Arrival of stimulus, activation of receptor
  - physical or chemical changes
- **Step 2:** Activation of sensory neuron
  - graded depolarization
- **Step 3:** Information processing by postsyn. cell
  - triggered by neurotransmitters
- **Step 4:** Activation of motor neuron
  - action potential
- **Step 5:** Response of peripheral effector
  - triggered by neurotransmitters

**Classification of Reflexes**

There are several ways to classify reflexes but most common is by **complexity** of the neural circuit: monosynaptic vs polysynaptic
Monosynaptic Reflexes

- Have the least delay between sensory input and motor output:
  - *e.g.*, stretch reflex (such as patellar reflex)
- Completed in 20–40 msec
- No interneurons involved

Muscle Spindles

- The receptors in stretch reflexes
- Bundles of small, specialized *intrafusal* muscle fibers
- Innervated by sensory and motor neurons

Polysynaptic Reflexes

- More complicated than monosynaptic reflexes
- Interneurons involved that control more than 1 muscle group
- Produce either EPSPs or IPSPs
- Examples: the withdrawal reflexes

5 General Characteristics of Polysynaptic Reflexes

1. Involve pools of neurons
2. Are intersegmental in distribution
3. Involve *reciprocal inhibition*
4. Have reverberating circuits:
   - which prolong reflexive motor response
5. Several reflexes cooperate:
   - to produce coordinated, controlled response
Withdrawal Reflexes

- Move body part away from stimulus (pain or pressure):
  - flexor reflex:
    - pulls hand away from hot stove
  - crossed extensor reflex
- Strength and extent of response depends on intensity and location of stimulus

Key = Reciprocal Inhibition

- For flexor reflex to work:
  - the stretch reflex of the antagonistic (extensor) muscles must be inhibited
  - reciprocal inhibition by interneurons in spinal cord causes antagonistic extensors to be inhibited

Crossed Extensor Reflexes

- Occur simultaneously and coordinated with flexor reflex
- Example: flexor reflex causes leg to pull up:
  - crossed extensor reflex straightens other leg to receive body weight

Reflex Arcs

- Crossed extensor reflexes:
  - involves a contralateral reflex arc
  - occurs on side of body opposite from the stimulus

Integration and Control of Spinal Reflexes

• Though reflex behaviors are automatic, processing centers in brain can facilitate or inhibit reflex motor patterns based in spinal cord

Reinforcement of Spinal Reflexes

• Higher centers can reinforce spinal reflexes:
  – by stimulating excitatory neurons in brain stem or spinal cord
  – creating EPSPs at reflex motor neurons
  – facilitating postsynaptic neurons

Inhibition of Spinal Reflexes

• Higher centers can inhibit spinal reflexes:
  – by stimulating inhibitory neurons
  – creating IPSPs at reflex motor neurons
  – suppressing postsynaptic neurons

Voluntary Movements and Reflex Motor Patterns

• Higher centers of brain incorporate lower, reflexive motor patterns
• Automatic reflexes:
  – can be activated by brain as needed
  – use few nerve impulses to control complex motor functions
  – e.g. walking, running, jumping