Peripheral Nervous System

*Learn and Understand:*
- Peripheral nerves connect the edges of the body and outside world to the CNS.
- Most nerves carry specific types of information to/from specific locations.
- PNS includes nervous-like tissue: sensitive and excitable.
- Humans possess both instinctual and learned reflexes. Many subconscious and involuntary, many protective, many postural/positional, most homeostatic.

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**Figure 13.1** Place of the PNS in the structural organization of the nervous system.

Provides neuronal link to and from body and outside world

Includes all neural structures outside brain
- Sensory receptors
- Peripheral nerves and associated ganglia, plexuses
- Efferent motor endings

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**Figure 13.4b** Structure of a nerve.

- Axon
- Myelin sheath
- Endoneurium
- Perineurium
- Epineurium
- Fascicle
- Blood vessels
Peripheral Nervous Tissue: Classification of Nerves

- Most nerves are mixtures of afferent and efferent fibers and somatic and autonomic fibers
- Classified according to direction of impulses
  - Mixed nerves – both sensory and motor fibers; impulses both to and from CNS
  - Sensory (afferent) nerves – impulses only toward CNS
  - Motor (efferent) nerves – impulses only away from CNS
- Peripheral nerves classified as cranial or spinal nerves

Spinal Nerves

- 31 pairs of mixed nerves named for point of issue from spinal cord
  - Supply all body parts but head and part of neck
  - 8 cervical (C₁–C₈)
  - 12 thoracic (T₁–T₁₂)
  - 5 Lumbar (L₁–L₅)
  - 5 Sacral (S₁–S₅)
  - 1 Coccygeal (C₀)

Figure 13.8a Formation of spinal nerves and rami distribution.

(a) Anterior view showing spinal cord, associated nerves, and vertebrae. The dorsal and ventral roots arise medially as rootlets and join laterally to form the spinal nerve.
Cranial Nerves

- Twelve pairs of nerves associated with brain
  - Ten attach to brain stem
- Most are mixed nerves; two pairs purely sensory
- Each numbered (I through XII) and named from rostral to caudal
  
  "On occasion, our trusty truck acts funny—very good vehicle anyhow"
  
  "Oh once one takes the anatomy final, very good vacations are heavenly"
Filaments of olfactory nerve (I)
Olfactory bulb
Olfactory nerve (II)
Optic chiasma
Optic tract
Oculomotor nerve (III)
Trochlear nerve (IV)
Trigeminal nerve (V)
Abducens nerve (VI)
Cerebellum
Medulla oblongata

Frontal lobe
Temporal lobe
Infundibulum
Facial nerve (VII)
Vestibulocochlear nerve (VIII)
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Accessory nerve (XI)
Hypoglossal nerve (XII)

Figure 13.6a Location and function of cranial nerves.

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Sensory Function</th>
<th>Somatic Motor Function</th>
<th>Parasympathetic Motor Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – olfactory</td>
<td>Smell</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>II – optic</td>
<td>Vision</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>III – oculomotor</td>
<td>None</td>
<td>Extrinsic eye muscles (rectus and inf. oblique); innervates pupil</td>
<td>Intrinsics eye muscles – control pupil and lens</td>
</tr>
<tr>
<td>IV – trochlear</td>
<td>None</td>
<td>Superior oblique</td>
<td>None</td>
</tr>
<tr>
<td>V – trigeminal</td>
<td>General Sensory: anterior scalp, nasal cavity, esophagus; Taste: anterior tongue; parotid salivary glands</td>
<td>Muscles of mastication</td>
<td>None</td>
</tr>
<tr>
<td>VI – abducens</td>
<td>None</td>
<td>Lateral rectus</td>
<td>None</td>
</tr>
<tr>
<td>VII – facial</td>
<td>Taste: anterior tongue</td>
<td>Muscles of facial expression</td>
<td>Secretion of tears, saliva</td>
</tr>
<tr>
<td>VIII – vestibulocochlear</td>
<td>Hearing, equilibrium</td>
<td>None</td>
<td>Secretion of parotid salivary glands</td>
</tr>
<tr>
<td>IX – glossopharyngeal</td>
<td>General Sensory and taste posterior tongue; General Sensory: parotid salivary glands; Visceral Sensory: carotid bodies</td>
<td>One pharyngeal muscle</td>
<td>None</td>
</tr>
<tr>
<td>X – vagus</td>
<td>Visceral Sensory: heart, lungs, abdominal organs; General Sensory: posterior tongue, pharynx, larynx; Visceral Sensory: larynx</td>
<td>Most pharyngeal muscles; pharyngeal muscles</td>
<td>Smooth muscle and glands: heart, lungs, larynx, trachea, submandibular glands</td>
</tr>
<tr>
<td>XI – accessory</td>
<td>None</td>
<td>Trapezius, sternocleidomastoid</td>
<td>None</td>
</tr>
<tr>
<td>XII - hypoglossal</td>
<td>none</td>
<td>Innervates intrinsic and extrinsic tongue muscles</td>
<td>None</td>
</tr>
</tbody>
</table>

Primary Functions of Cranial Nerves

Peripheral Nervous Tissue:
Sensory Receptors

- Specialized to respond to changes in environment (stimuli)
- Activation results in graded potentials that trigger nerve impulses
- Sensation (awareness of stimulus) and perception (interpretation of meaning of stimulus) occur in brain
Classification by Stimulus Type

- **Mechanoreceptors**—respond to touch, pressure, vibration, and stretch
- **Thermoreceptors**—sensitive to changes in temperature
- **Photoreceptors**—respond to light energy (e.g., retina)
- **Chemoreceptors**—respond to chemicals (e.g., smell, taste, changes in blood chemistry)
- **Nociceptors**—sensitive to pain-causing stimuli (e.g., extreme heat or cold, excessive pressure, inflammatory chemicals)

Classification by Location

- **Exteroceptors** respond to
  - stimuli arising outside body
  - Receptors in skin for touch, pressure, pain, and temperature and most special sense organs
- **Interoceptors** (visceroceptors) respond to
  - stimuli arising in internal viscera and blood vessels
  - Sensitive to chemical changes, tissue stretch, and temperature changes
  - May cause discomfort but usually unaware of their workings
- **Proprioceptors** respond to
  - stretch in skeletal muscles, tendons, joints, ligaments, and connective tissue coverings of bones and muscles
  - Inform brain of movements, body part position/location

Table 13.1  General Sensory Receptors Classified by Structure and Function
Table 13.1 General Sensory Receptors Classified by Structure and Function (2 of 3)

<table>
<thead>
<tr>
<th>STRUCTURAL CLASS</th>
<th>ILLUSTRATION</th>
<th>FUNCTIONAL CLASS: ACCORDING TO LOCATOR (AJ) AND STIMULUS TYPE (GJ)</th>
<th>BODY LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tactile (mechanosensitive) capsules</td>
<td><img src="image1.png" alt="Illustration" /></td>
<td>1. Mechanoreceptor; 2. Mechanosensitive; 3. Movement, vibration of low frequency; 4. Vibration of high frequency; 5. Slowly adapting</td>
<td>Sensory in touch, proprioception, and vestibular receptors</td>
</tr>
<tr>
<td>Limbal (hair) cones</td>
<td><img src="image2.png" alt="Illustration" /></td>
<td>1. Mechanoreceptor, interoceptors; 2. Mechanosensitive; 3. Movement, vibration; 4. Slowly adapting</td>
<td>Sensory in touch, proprioception, and vestibular receptors</td>
</tr>
<tr>
<td>Retinal (dorsal) receptors</td>
<td><img src="image3.png" alt="Illustration" /></td>
<td>1. Mechanoreceptor, interoceptors; 2. Mechanosensitive; 3. Movement, vibration; 4. Slowly adapting</td>
<td>Sensory in touch, proprioception, and vestibular receptors</td>
</tr>
</tbody>
</table>

### Processing at the Receptor Level

- **In general sense receptors**, graded potential called **generator potential**
  
  **Stimulus**
  
  ✅
  
  **Generator potential in afferent neuron**
  
  ✅
  
  **Action potential**
  
  ✅

- **In special sense receptors**:
  
  **Stimulus**
  
  ✅
  
  **Graded potential in receptor cell called receptor potential**
  
  ✅
  
  **Affects amount of neurotransmitter released**
  
  ✅
  
  **Neurotransmitters generate graded potentials in sensory neuron**
  
  ✅
Peripheral Nervous Function: Basic Reflexes

- Basic functional unit of nervous system and simplest portion capable of receiving a stimulus and producing a response
- Automatic response to a stimulus that occurs without conscious thought.
- Quick, protective, homeostatic.

Variety of Reflexes

- Some integrated within spinal cord; some within brain (those related to head) using cranial nerves
- Some involve excitatory neurons yielding a response; some involve inhibitory neurons that prevent an action
- Higher brain centers can influence, suppress, or exaggerate reflex responses

Functional classification

- **Somatic reflexes**
  - Activate skeletal muscle

- **Autonomic (visceral) reflexes**
  - Activate visceral effectors (smooth or cardiac muscle or glands)
Figure 13.15 The five basic components of all reflex arcs.

1. Receptor
2. Sensory neuron
3. Integration center
4. Motor neuron
5. Effector

- **Stimulus**: Skin
- **Receptor**: Site of stimulus action
- **Sensory neuron**: Transmits afferent impulses to CNS
- **Integration center**: Either monosynaptic or polysynaptic region within CNS
- **Motor neuron**: Conducts efferent impulses from integration center to effector organ
- **Effector**: Muscle fiber or gland cell that responds to efferent impulses by contracting or secreting

---

**Stretch and Tendon Reflexes**

- To smoothly coordinate skeletal muscle nervous system must receive proprioceptor input regarding
  - **Length of muscle**
    - From muscle spindles
  - **Amount of tension in muscle**
    - From tendon organs

---

Figure 13.16 Anatomy of the muscle spindle and tendon organ.

- **Flower spray endings**: Secondary sensory endings
- **Anulo-spiral endings**: Primary sensory endings
- **Muscle spindle**
- **Capsule**: Connective tissue
- **Tendon organ**
- **Tendon**
• Excited in two ways
  1. External stretch of muscle and muscle spindle
  2. Internal stretch of muscle spindle
• Stretch causes increased rate of impulses to spinal cord
• Adjustment for moving/contracting muscles:
  – Contracting muscle reduces tension on muscle spindle
  – Sensitivity lost unless muscle spindle shortened by impulses in \( \gamma \) motor neurons
  – \( \alpha-\gamma \) coactivation maintains tension and sensitivity of spindle during muscle contraction

Figure 13.17a Operation of the muscle spindle.

Stretch Reflexes

• How stretch reflex works
  – Stretch activates muscle spindle
  – Sensory neurons synapse directly with \( \alpha \) motor neurons in spinal cord
  – \( \alpha \) motor neurons cause stretched muscle to contract
• All stretch reflexes are monosynaptic and ipsilateral
Stretch Reflexes

• Reciprocal inhibition also occurs—IIa fibers synapse with interneurons that inhibit α motor neurons of antagonistic muscles
  – Example: In patellar reflex, stretched muscle (quadriceps) contracts and antagonists (hamstrings) relax

The patellar (knee-jerk) reflex—an example of a stretch reflex

The Tendon Reflex

• Polysynaptic reflexes
• Helps prevent damage due to excessive stretch
• Important for smooth onset and termination of muscle contraction
• Produces muscle relaxation (lengthening) in response to tension
The Tendon Reflex

- Quadriceps strongly contracts.
- Tendon organs are activated.
- Afferent fibers synapse with interneurons in the spinal cord.
- Interneurons

- Efferent impulses from muscle with stretched tendon are damped.
- Muscle relaxes, reducing tension.
- Efferent impulses to antagonist muscle cause it to contract.

The Flexor and Crossed-Extensor Reflexes

- **Flexor (withdrawal) reflex**
  - Initiated by painful stimulus
  - Causes automatic withdrawal of threatened body part
  - Ipsilateral and polysynaptic
  - Protective; important
  - Brain can override
    - E.g., finger stick for blood test

Flexor and Crossed-Extensor Reflexes

- **Crossed extensor reflex**
  - Occurs with flexor reflexes in weight-bearing limbs to maintain balance
  - Consists of ipsilateral withdrawal reflex and contralateral extensor reflex
    - Stimulated side withdrawn (flexed)
    - Contralateral side extended
    - E.g., step barefoot on broken glass
Figure 13.20: The crossed-extensor reflex.

+ Excitatory synapse
− Inhibitory synapse

Afferent fiber

Efferent fibers

Extensor fibers

Flexor fibers

Arm movements

Flexor inhibited Extensor stimulated

Site of stimulus: A noxious stimulus causes a flexor reflex on the same side, withdrawing that limb.

Site of reciprocal activation: At the same time, the extensor muscles on the opposite side are activated.

Excitatory synapse
Inhibitory synapse

Arm movements

Flexor inhibited Extensor stimulated