Peripheral Nervous System (PNS)

- PNS – all neural structures outside the brain and spinal cord
- Includes sensory receptors, peripheral nerves, associated ganglia, and motor endings
- Provides links to and from the external environment
Sensory Receptors

- Structures specialized to respond to stimuli
- Activation of sensory receptors results in graded potentials that trigger nerve impulses along the afferent PNS fibers to the CNS
- The realization of these stimuli, sensation and perception, occur in the brain
Receptor Classification by Stimulus Type

- **Mechanoreceptors** – respond to touch, pressure, vibration, stretch, and itch
- **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
Receptor Class by Location: Exteroceptors

- Respond to stimuli arising outside the body
- Found near the body surface
- Sensitive to touch, pressure, pain, and temperature
- Include the special sense organs
Receptor Class by Location: Interoceptors (Visceroreceptors)

- Respond to stimuli arising within the body
- Found in internal viscera and blood vessels
- Sensitive to chemical changes, stretch, and temperature changes
Receptor Class by Location: Proprioceptors

- Respond to degree of stretch of the organs they occupy
- Found in skeletal muscles, tendons, joints, ligaments, and connective tissue coverings of bones and muscles
- Constantly “advise” the brain of one’s movements
Receptor Classification by Structural Complexity

- Receptors are structurally classified as either simple or complex

- Most receptors are simple:
  - Are modified dendritic endings of sensory neurons
  - Encapsulated and unencapsulated varieties

- Complex receptors are special sense organs associated with special senses (vision, hearing, equilibrium, smell, taste)
Simple Receptors: Unencapsulated

- Free dendritic nerve endings
  - Respond chiefly to temperature and pain
    - Cold receptors found superficially (10-40°C)
    - Heat receptors found deeper (32-48°C)
  - Outside of these ranges, nociceptors are activated and pain is perceived
  - Nociceptors also respond to pinch and chemicals released from damaged tissue
  - Itch receptor activated by histamine and other chemicals
Simple Receptors: Unencapsulated

- Abundant in epithelia and connective tissues
- Unmyelinated
- Distal ends have knob-like swellings
- Merkel Cells (tactile; form Merkel discs) lying in the deeper dermal layers. Function as light touch receptors
- Hair follicle receptors (free nerve endings wrapped around hair follicles) are light touch receptors that detect bending hair (e.g. detection of a landing mosquito)
Simple Receptors: Encapsulated Dendritic Endings

- Enclosed in a connective tissue capsule
- All are mechanoreceptors
- Meissner’s corpuscles (tactile corpuscles): found beneath the epidermis and are numerous in sensitive, hairless skin, e.g. fingers & soles of feet
- Pacinian corpuscles (lamellated corpuscles): found deep in the dermis and subcutaneous tissue underlying the skin
  - Mechanoreceptors stimulated by deep pressure
  - Stimulated only when pressure is first applied, e.g. sense vibrations (on/off)
  - Huge receptor!! Up to 3 mm long and 1.5 mm wide!
- Muscle spindles, Golgi tendon organs, and Ruffini’s corpuscles
- Joint kinesthetic receptors
Simple Receptors: Encapsulated Dendritic Endings

- Ruffin endings: found in the dermis, subcutaneous tissue, and joint capsules. Respond to deep, continuous pressure.

- Muscle spindles:
  - Proprioceptors found throughout the perimysium of skeletal muscle.
  - They detect muscle stretch and initiate a reflex that resists the stretch.

- Joint kinesthetic receptors:
  - Proprioceptors that monitor stretch in the anterior capsules that enclose the synovial joints.
  - Provide info. on joint position and motion.

- Golgi tendon organs:
  - Proprioceptors located in tendon close to the skeletal muscle insertion.
  - Activated by compression when tendon fibers are stretched with muscle contraction.
  - When golgi tendon organs are activated, the contracting muscle is inhibited causing it to relax.
From Sensation to Perception…and Beyond!!

- Survival depends upon sensation and perception

- Sensation is the awareness of changes in the internal and external environment

- Perception is the conscious interpretation of those stimuli
Organization of the Somatosensory System

- Input comes from exteroceptors, proprioceptors, and interoceptors

- The three main levels of neural integration in the somatosensory system are:
  - Receptor level – the sensor receptors
  - Circuit level – ascending pathways
  - Perceptual level – neuronal circuits in the cerebral cortex
Processing at the Receptor Lever

In order for a stimulus to excite a receptor:

- The receptor must have specificity for the stimulus energy (e.g. light, chemicals, touch, etc.)
- The receptor’s receptive field must be stimulated. The smaller the field, the better the brain can localize it
- Stimulus energy must be converted into a graded potential (transduction)
- A generator potential in the associated sensory neuron must reach threshold
  - Voltage gated Na+ channels on the axon are opened and nerve impulse propagates toward CNS
Adaptation of Sensory Receptors

- Adaptation occurs when sensory receptors are subjected to an unchanging stimulus

- Phasic receptors:
  - Fast adapting burst of impulses at onset and offset
  - Report changes in environment

- Tonic receptors
  - Provide sustained response with no adaptation
Processing at the Circuit Level

- The task here is to deliver impulses to the appropriate region of the cerebral cortex for stimulus localization and perception.

- Ascending Sensory Pathways: Chains of three neurons conduct sensory impulses upward to the brain:
  - First-order neurons – soma reside in dorsal root or cranial ganglia, and conduct impulses from the skin to the spinal cord or brain stem.
  - Second-order neurons – soma reside in the dorsal horn of the spinal cord or medullary nuclei and transmit impulses to the thalamus or cerebellum.
  - Third-order neurons – located in the thalamus and conduct impulses to the somatosensory cortex of the cerebrum.
Processing at the Perceptual Level

- Interpretation of sensory input occurs at the cerebral cortex
- The ability to identify a sensation depends on the location of the target neurons in the cortex regardless of what stimulated the neurons
Main Aspects of Sensory Perception

- Perceptual detection – detecting that a stimulus has occurred
- Magnitude estimation – how much of a stimulus is acting
- Spatial discrimination – identifying the site or pattern of the stimulus (e.g., the 2-point discrimination test)
- Feature abstraction – used to identify a substance that has specific texture or shape
- Quality discrimination – the ability to identify submodalities of a sensation (e.g., sweet or sour tastes)
- Pattern recognition – ability to recognize patterns in stimuli (e.g. familiar face)
Structure of a Nerve

- Nerve – cordlike organ of the PNS consisting of peripheral axons enclosed by connective tissue
- Connective tissue coverings include:
  - Endoneurium – loose connective tissue that surrounds axons
  - Perineurium – coarse connective tissue that bundles fibers into fascicles
  - Epineurium – tough fibrous sheath around a nerve
Classification of Nerves

- Sensory and motor divisions
  - Sensory (afferent) – carry impulse to the CNS
  - Motor (efferent) – carry impulses from CNS
- Mixed – sensory and motor fibers carry impulses to and from CNS; most common type of nerve
- Ganglia: a collection of neuron cell bodies associated with nerves in the PNS
Regeneration of Nerve Fibers

- Rengeneration is most effective, in general, only over short distances
- Damage to nerve tissue is serious because mature neurons are amitotic
- If the soma of a damaged nerve remains intact, damage can be repaired
- Regeneration involves coordinated activity among:
  - Macrophages – remove debris
  - Schwann cells – form regeneration tube and secrete growth factors
  - Axons – regenerate damaged part
Regeneration of Nerve Fibers

- Axon and myelin sheath distal to injury disintegrate due to lack of nutrients from the cell body (Wallerian degeneration)
- Neurilemma remains intact
- Schwann cells proliferate and migrate to injury site and form a regeneration tube that guide axon sprouts
- Cell body changes; chromatophilic substance breaks up and massive protein synthesis begins (cell body swells)
Cranial Nerves

- Twelve pairs of cranial nerves arise from the brain
- I & II attach to the forebrain
- III-XII originate from the brain stem
- They serve the head and neck (except for X, the vagus nerve, serving the abdomen)
Cranial Nerves

Frontal lobe

Temporal lobe

Infundibulum

Facial nerve (VII)

Vestibulocochlear nerve (VIII)

Glossopharyngeal nerve (IX)

Vagus nerve (X)

Accessory nerve (XI)

Hypoglossal nerve (XII)

Filaments of olfactory nerve (I)

Olfactory bulb

Olfactory tract

Optic nerve (II)

Optic chiasma

Optic tract

Oculomotor nerve (III)

Trochlear nerve (IV)

Trigeminal nerve (V)

Abducens nerve (VI)

Cerebellum

Medulla

(a)

Figure 13.5a
Cranial Nerve I: Olfactory

- Arises from the olfactory epithelium
- Fibers run through the olfactory bulb and terminate in the primary olfactory cortex
- Functions solely by carrying afferent impulses for the sense of smell
Cranial Nerve II: Optic

- Arises from the retina of the eye
- Really a brain tract (outgrowth of brain) and NOT a nerve
Cranial Nerve III: Oculomotor

- Supplies 4 of the 6 extrinsic muscles that move the eyeball in the orbit
- Functions in raising the eyelid, directing the eyeball, constricting the iris, and controlling lens shape
Cranial Nerve IV: Trochlear

- Innervate the superior oblique muscle
- Primarily a motor nerve that directs the eyeball
Cranial Nerve V: Trigeminal

- Three divisions: ophthalmic (V₁), maxillary (V₂), and mandibular (V₃)
- Largest cranial nerve
- Conveys sensory impulses from various areas of the face (V₁) and (V₂), and supplies motor fibers (V₃) for mastication
Cranial Nerve VI: Abduces

- Primarily a motor nerve innervating the lateral rectus muscle (abducts the eyeball)
Cranial Nerve VII: Facial

- Fibers leave the pons, travel through the internal acoustic meatus, and emerge through the stylomastoid foramen to the lateral aspect of the face
- Mixed nerve with five major branches
- Motor functions include facial expression, and the transmittal of autonomic impulses to lacrimal and salivary glands
- Sensory function is taste from the anterior two-thirds of the tongue
Cranial Nerve VIII: Vestibulocochlear

- Fibers arise from the hearing and equilibrium apparatus of the inner ear, pass through the internal acoustic meatus, and enter the brainstem at the pons-medulla border
- Two divisions – cochlear (hearing) and vestibular (balance)
- Functions are solely sensory – equilibrium and hearing
Cranial Nerve IX: Glossopharyngeal

- Fibers emerge from the medulla, leave the skull via the jugular foramen, and run to the throat
- Nerve IX is a mixed nerve with motor and sensory functions
- Motor – innervates part of the tongue and pharynx, and provides motor fibers to the parotid salivary gland
- Sensory – fibers conduct taste and general sensory impulses from the tongue and pharynx
Cranial Nerve X: Vagus

- The only cranial nerve that extends beyond the head and neck
- Fibers emerge from the medulla via the jugular foramen
- The vagus is a mixed nerve
- Most motor fibers are parasympathetic fibers to the heart, lungs, and visceral organs
- Its sensory function is in taste
Cranial Nerve XI: Accessory

- Formed from a cranial root emerging from the medulla and a spinal root arising from the superior region of the spinal cord
- The spinal root passes upward into the cranium via the foramen magnum
- The accessory nerve leaves the cranium via the jugular foramen
Cranial Nerve XI: Accessory

- Primarily a motor nerve
  - Supplies fibers to the larynx, pharynx, and soft palate
  - Innervates the trapezius and sternocleidomastoid, which move the head and neck
Cranial Nerve XII: Hypoglossal

- Fibers arise from the medulla and exit the skull via the hypoglossal canal

- Innervates both extrinsic and intrinsic muscles of the tongue, which contribute to swallowing and speech
Help with memorizing cranial nerves and functions

- Nerve Function: Sensory, Motor, Both
  - “Some Say Marry Money, But My Brother Believes (its) Bad Business (to) Marry Money.”

- Nerve Names: