SENSORY, MOTOR, AND INTEGRATIVE SYSTEMS
• The components of the brain interact
  – to receive sensory input,
  – integrate and store the information,
  – transmit motor responses.
To accomplish the primary functions of the nervous system there are neural pathways to transmit impulses from receptors to the circuitry of the brain, which manipulates the circuitry to form directives that are transmitted via neural pathways to effectors as a response.
SENSATION

- **Sensation** is a conscious or unconscious awareness of external or internal stimuli.

- **Perception** is the conscious awareness and interpretation of sensations.
Components of Sensation

• For a sensation to arise, four events must occur.
• These are
  – *stimulation*,
  – *transduction*,
  – *conduction*,
  – *translation*. 
A stimulus, or change in the environment, capable of initiating a nerve impulse by the nervous system must be present.

A sensory receptor or sense organ must pick up the stimulus and transduce (convert) it to a nerve impulse by way of a generator potential.

The impulse(s) must be conducted along a neural pathway from the receptor or sense organ to the brain.

A region of the brain or spinal cord must translate the impulse into a sensation.
Sensory Receptors

• According to location, receptors are classified as
  – *exteroceptors*,
  – *interoceptors* (visceroceptors),
  – *proprioceptors*.
On the basis of type of stimulus detected, receptors are classified as
- mechanoreceptors,
- thermoreceptors,
- nociceptors,
- photoreceptors,
- chemoreceptors.
Mechanoreceptors of Hairy Skin

- Hair Follicle Receptor
- Pacinian corpuscle
- Ruffini organ
- Merkel disks
- Free nerve endings

Epidermis

Dermis

Sweat gland
1. In this simple hand-withdrawal reflex, information is carried from skin receptors along a sensory neuron to the spinal cord (shown by the red arrows). From here it is passed via interneurons to motor neurons that lead to muscles in the hand and arm (blue arrows).

2. Because this reflex involves only the spinal cord, the hand jerks away from the candle flame even before information about the event has reached the brain, causing the experience of pain.
• The impulse(s) must be conducted along a neural pathway from the receptor or sense organ to the brain.
• A region of the brain or spinal cord must translate the impulse into a sensation.
SOMATIC SENSORY PATHWAYS

- Somatic sensory pathways relay information from somatic receptors to the primary somatosensory area in the cerebral cortex.
SOMATIC SENSORY PATHWAYS

- The peripheral axons arise from dorsal root ganglia and enter spinal cord through the dorsal roots.

**Diagram:**
- Sensory receptor
- Periphery
- Dorsal root ganglion
- CNS
- Supraspinal sites
- Nociceptors
  - A-mechanical
  - C-polymodal silent
- Sensory axon
- Spinal cord
Posterior Column-Medial Lemniscus Pathway

• Impulses conducted along this pathway are concerned with
  – *discriminative touch,*
  – *stereognosis,*
  – *proprioception,*
  – *weight discrimination,*
  – *vibratory sensations.*
The primary, or first-order, neuron has its perikaryon in dorsal root ganglion.
The primary, or first-order, neuron has its perikaryon in dorsal root ganglion

- The *ascending axonal branch* runs up the *ipsilateral* dorsal column
- The sacral fibers, the medial-most wedge, the lumbar fibers, and the thoracic fibers 6-12 form the *fasciculus gracilis (Goll’s column)*
- The arm fibers, the lateral-most wedge, and the thoracic fibers 1-6 form the *fasciculus cuneatus (Burdach’s column)*
- The ascending spinal axons terminate in the dorsal column nuclei.
The secondary, or second-order neuron is in the dorsal column nuclei, **the nucleus gracilis** and **nucleus cuneatus**

- From the dorsal column nuclei the axons decussate, form the origin of the **medial lemniscus**, and ascend to the thalamus.
The tertiary, or third-order, neuron runs from the thalamus to the somatosensory area of the cerebral cortex, the postcentral gyrus.
Anterolateral Pathways to the Cortex

- The anterolateral or spinothalamic pathways carry mainly
  - pain and
  - temperature impulses.
The primary, or first-order, neuron has its perikaryon in dorsal root ganglion.
The secondary, or second-order neuron is in the spinal cord.

The axons decussate at the ventral white commissure and then turn rostrally in the ventrolateral quadrant as the lateral spinothalamic tract.
The tertiary, or third-order, neuron runs from the thalamus to the somatosensory area of the cerebral cortex, the postcentral gyrus.
Dorsal column–medial lemniscal pathway

Cerebral cortex

Thalamus

Medial lemniscus

Dorsal column nuclei

Dorsal column

Dorsal root axon (Aα, Aβ, Aδ)

Midline

Spinothalamic pathway

Cerebral cortex

Thalamus

Medulla

Spinal cord

Lateral spinothalamic tract

Dorsal root axon (Aδ, C)

Midline

Touch, vibration, two-point discrimination, proprioception

Pain, temperature, some touch
Somatic Sensory Pathways to the Cerebellum

• The posterior spinocerebellar and the anterior spinocerebellar tracts are the major routes whereby *proprioceptive impulses reach the cerebellum*.

• The receptors are the Golgi tendon organs and muscle spindles.
The primary, or first-order, neuron has its perikaryon in dorsal root ganglion.
Dorsal spinocerebellar tract (green)

- The secondary, or second-order neuron is the neurons of the nucleus dorsalis of Clarke
Dorsal spinocerebellar tract (green)

- The neurons of the nucleus dorsalis send their axons laterally to the periphery of the **ipsilateral** column, where they ascend as the **dorsal spinocerebellar tract**
Gracile fasciculus
Cuneate fasciculus
Ipsilateral loss of tactile discrimination and position and vibration sensation from leg
ipsilateral loss of position & motion sense
ipsilateral spastic paresis
contralateral loss of pain and temperature sensation one segment below lesion
ipsilateral flaccid paralysis in affected myotomes
Bilateral loss of pain and temperature sensation within dermatomes of involved segments
ventral white commissure
corticospinal tract
spinocerebellar tract
spinothalamic tract
Dorsal horn
Ventral horn
Dorsal spinocerebellar tract (green)

- the dorsal tract enters the cerebellum through the inferior cerebellar peduncle
Ventral spinocerebellar tract (blue)

- The secondary, or second-order neuron is the neurons of the spinal cord
Ventral spinocerebellar tract (blue)

- **The nucleus** in the spinal gray matter is not clearly identified for the ventral tract, as is the nucleus dorsalis for the dorsal tract.
- The axons of the ventral spinocerebellar tract decussate in the white commissure of the spinal cord before ascending in the periphery of the **contralateral** lateral column.
Ventral spinocerebellar tract (blue)

- the ventral tract enters the cerebellum through the superior cerebellar peduncle
SOMATIC MOTOR PATHWAYS

- Upper Motor Neurons
  - Precentral gyrus
- Lower Motor Neurons
  - Spinal cord
- Brainstem
  - Cerebral peduncle
  - Internal capsule
- Neural connections to voluntary muscles

Anatomical regions:
- Head
- Hand
- Shoulder
- Butt
- Leg
- Spinal cord
- Brainstem

Motor regions:
- Elbow
- Wrist
- Shoulder Trunk
- Hip
- Ankle
- Toes
- Thumb
- Middle
- Ring
- Little
- Index
- Face
- Jaw
- Tongue
- Swallowing

Orientation:
- Lateral
- Midline
• The brain influences somatic motor activity through groups of descending pathways designated in the early clinical literature as the **pyramidal** and **extrapyramidal** systems.

• The pyramidal system constitutes a **direct link** and the extrapyramidal system an **indirect link** from the motor cortical areas to the lower motoneurons of the cranial and spinal nerves.
The direct (pyramidal) pathways

- The motor cortex (primary motor area or precentral gyrus) is the major control region for initiation of voluntary movements.
The direct (pyramidal) pathways

- Voluntary motor impulses are propagated from the motor cortex to somatic efferent neurons (voluntary motor neurons) that innervate skeletal muscles via the direct or pyramidal pathways.
- The simplest pathways consist of upper and lower motor neurons.
The direct (pyramidal) pathways include:

- lateral corticospinal tracts
- anterior corticospinal tracts
- corticobulbar tracts.
The lateral corticospinal, anterior corticospinal, and corticobulbar tracts contain axons of upper motor neurons (precentral gyrus).
Corticobulbar fibers depart ipsilaterally and contralaterally to end at various brainstem levels – motoneurons of cranial nerves (lower motor neurons)
– Corticospinal fibers descend ipsilaterally through the brainstem, passing through the basis pontis and the medullary pyramids to the cervicomedullary junction.

– Corticospinal axons terminate at motoneurons of the ventral horn (lower motor neurons)
Lateral corticospinal tract

- The majority of the corticospinal fibers decussate at the cervicomedullary junction to descend in the contralateral lateral column as the lateral corticospinal tract
Anterior corticospinal tract

- A minority of fibers continue **ipsilaterally** into the ventral column as the anterior (ventral) corticospinal tract
- The anterior (ventral) corticospinal tract crosses in the ventral white commissure
• Damage or disease of lower motor neurons produces flaccid paralysis of muscles on the same side of the body.

• Injury or disease of upper motor neurons results in spastic paralysis of muscles on the opposite side of the body.
Indirect Pathways

- **Indirect or extrapyramidal pathways** include all somatic motor tracts other than the corticospinal and corticobulbar tracts.
- Indirect pathways involve the motor cortex, basal ganglia, thalamus, cerebellum, reticular formation, and nuclei in the brain stem.
- Major indirect tracts are the rubriospinal, tectospinal, vestibulospinal, and reticulospinal tracts.
RUBROSPINAL TRACT

• The corticorubral tract originates in the premotor cortex and terminates in the nucleus ruber.

• The rubrospinal tract originates in the red nucleus, crosses over in the ventral tegmentum of the midbrain, descends in the lateral funiculus of spinal cord.

• Because these tracts decussate, they exert their influences on the opposite side from their sites of origin.

• Functionally, these pathways have a critical role in the fine manipulative and independent movements of the extremities.
TECTOSPINAL TRACT

• The corticotectal tract originates in visual association cortical areas 18 & 19 and terminates in the superior colliculus of the tectum.

• The tectospinal tract from the superior colliculus decussates in the midbrain tegmentum (dorsal tegmental decussation) and joins the medial longitudinal fasciculus.

• This tract is presumed to be involved with coordinating head and neck movements with eye movements.
VESTIBULOSPINAL TRACT

• The lateral vestibular nucleus gives rise to the lateral vestibulospinal tract, which descends as an uncrossed somatotopically organized tract throughout the entire length of the spinal cord in the anterior region of the lateral funiculus.

• The descending tracts of the vestibular system are primarily involved in maintaining muscle tone and antigravity postural poses (e.g. standing erect).
Rubrospinal and Vestibulospinal Tracts

Position of RuSp and VesSp

ML

SC
OctNu
RNu
DTegDec (TecSp)
SN
VTegDec (RuSp)

LVNu
MVNu
LVSp
MVSp

LTeg

LCSp
RuSp
to Laminae
V-VIII

MVSp
LVSp
LCSp
RuSp

ML

Py

MVNu
SpVNu
MLF
RuSp
IO

LVSp

MVSp
in MLF
The sequence of corticoreticular and reticulospinal tracts comprises the corticoreticulospinal pathways. From their origin in the premotor cortex corticoreticular fibers descend and terminate in the pontine and medullary reticular nuclei of the brainstem reticular formation on both sides. The latter also receives input from the cerebellum. The reticulospinal tracts include the lateral (medullary) reticulospinal tract and medial (pontine) reticulospinal tract. These tracts are primarily uncrossed and are not somatotopically organized. The medial (pontine) reticulospinal tract originates from the nuclei reticularis pontis and descends as uncrossed fibers in the anterior funiculus. The lateral (medullary) reticulospinal tract originates from the nucleus reticularis gigantocellularis and descends as uncrossed fibers in the anterior region of the lateral funiculus. The reticulospinal tracts are thought to be involved in the more automatic, involuntary movements of the axial and limb musculature involved with posture and locomotion.
DISORDERS:

- **Spinal cord injury** can be due to damage in a number of ways, such as compression or transection, and the location and extent of damage determines the type and degree of loss in neural abilities.
- 1. Cord damage caused by anything from tumors to trauma can compress neurons and either permanently or temporarily diminish capacity, depending on the type of nerves compromised.
  - a. Sensory nerve damage leads to the loss of the particular sensation that normally travels along the injured route, below the level of incident.
  - b. Motor pathway injury leads to paralysis that is described by the extent of motor loss, below the level of incident.
- 2. Damage to the cord, particularly transection, results in spinal cord shock, described as the loss of spinal reflexes, such as with incontinence.
Gracile fasciculus
Cuneate fasciculus
Ipsilateral loss of tactile discrimination and position and vibration sensation from leg
Ipsilateral loss of tactile discrimination and position and vibration sensation from arm
Corticospinal tract
Dorsal horn
Ipsilateral spastic paresis
Ipsilateral loss of position & motion sense
Spinocerebellar tract
Spinthalamic tract
Ventral horn
Ventral white commissure
Contralateral loss of pain and temperature sensation one segment below lesion
Ipsilateral flaccid paralysis in affected myotomes
Bilateral loss of pain and temperature sensation within dermatomes of involved segments
Cerebral Palsy

• This condition entails loss of muscle control due to problems during development that impact the motor control areas of the brain.

• The conditions are non-progressive, but permanent.
• Parkinson’s disease is a progressive degeneration of CNS neurons of the basal nuclei region due to unknown causes that decreases dopamine neurotransmitter production.
• 1. This condition produces motor coordination problems of involuntary tremor and/or rigidity.
• 2. Motor performance can be described as bradykinesia (slow) and hypokinesia (limited).
• 3. Limited treatment is provided with L-dopa, a precursor to dopamine, or through acetylcholine inhibitors.