Chapter 16A

Sensory, Motor & Integrative Systems

Is Sensation Different from Perception?

- **Sensation** is a conscious or unconscious awareness of external or internal stimuli
- **Perception** is the conscious awareness & interpretation of a sensation
  - Blood pressure is unconsciously sensed but not perceived

Sensory, Motor & Integrative Systems

- The components of the brain interact to receive sensory input, integrate and store the information, and transmit motor responses.

  - Levels and components of sensation
  - Pathways for sensations from body to brain
  - Pathways for motor signals from brain to body
  - Integration Process
    - wakefulness and sleep
    - learning and memory

What is this?
Sensory Modalities

- Different types of sensations
  - touch, pain, temperature, vibration, hearing, vision
  - Generally, each type of sensory neuron can respond to only one type of stimulus
- Two classes of sensory modalities
  - general senses
    - somatic (tactile, thermal, pain, proprioceptive)
    - visceral (organs)
  - special senses

Structural Classification of Receptors

- Free nerve endings
  - bare dendrites
  - pain, temperature, tickle, itch & light touch
- Encapsulated nerve endings
  - dendrites enclosed in connective tissue capsule
  - pressure, vibration & deep touch
- Separate sensory cells
  - specialized cells that respond to stimuli
  - vision, taste, hearing, balance

Process of Sensation

- Events occurring within a sensation
  - stimulation of the receptor
  - conversion of stimulus into a graded potential
  - generation of impulses when graded potential reaches threshold
  - integration of sensory input by the CNS
Classification by Stimuli Detected

- **Mechanoreceptors**
  - detect pressure or stretch
  - touch, pressure, vibration, hearing, proprioception, equilibrium & blood pressure
- **Thermoreceptors** detect temperature
- **Photoreceptors** detect light
- **Chemoreceptors** detect molecules
  - taste, smell & changes in body fluid chemistry
- **Nociceptors** detect damage to tissues

Classification by Response to Stimuli

- **Generator potential**
  - free nerve endings, encapsulated nerve endings & olfactory receptors produce generator potentials
  - when large enough, it generates a nerve impulse in a first-order neuron
- **Receptor potential**
  - vision, hearing, equilibrium and taste receptors produce receptor potentials
  - receptor cells release neurotransmitter molecules on first-order neurons, which may trigger a nerve impulse
  - Amplitude of potentials vary with stimulus intensity

Classification by Location

- **Exteroceptors**
  - near surface of body
  - receive external stimuli
  - hearing, vision, smell, taste, touch, pressure, pain, vibration & temperature
- **Interoceptors**
  - monitors internal environment (blood vessels or viscera)
  - not conscious except for pain or pressure
- **Proprioceptors**
  - muscle, tendon, joint & internal ear
  - senses body position & movement

Adaptation of Sensory Receptors

- **Change in sensitivity to long-lasting stimuli**
  - decrease in responsiveness of a receptor
    - bad smells disappear
    - very hot water starts to feel only warm
- **Variability in tendency to adapt:**
  - Rapidly adapting receptors (smell, pressure, touch)
    - specialized for detecting changes
  - Slowly adapting receptors (pain, body position)
    - nerve impulses continue as long as the stimulus persists – Pain is not easily ignored.
SOMATIC SENSATIONS

- Tactile sensations
  - touch, pressure, vibration, itch and tickle
- Thermal sensations
  - warm and cold
- Pain sensations (nociception)
- Proprioceptive sensations
  - sense of head and limb position and movement

Tactile Sensations

- **Crude touch** - something has simply touched the skin
- **Discriminative touch (fine touch)** - specific information about shape, size, and texture
- **Pressure** - sustained sensation over a larger area
  - result from stimulation of Pacinian corpuscles in deeper tissues
- **Vibration** - rapid, repetitive sensory signals from tactile receptors
- **Itch and tickle**
  - Tickle is the only sensation that you may not elicit on yourself
- **Tactile receptors include**
  - Merkel disc
  - Meissner corpuscle
  - Ruffini corpuscle
  - Hair root plexus

Thermal Sensations

- Free nerve endings near the skin surface
  - Cold receptors respond to temperatures between 50-105°F
  - Warm receptors respond to temperatures between 90-118°F
- Both adapt rapidly at first, but continue to generate impulses at a low frequency
- Pain is produced below 50°F and over 118°F
Pain Sensations

- *Pain receptors (nociceptors)* are located in nearly every body tissue except the brain
- Stimulated by excessive distension, muscle spasm & inadequate blood flow
- Tissue injury releases chemicals such as $K^+$, kinins & prostaglandins that stimulate nociceptors

Types of Pain

- **Fast pain (acute)**
  - occurs rapidly after stimuli (.1 second)
  - sharp pain like needle puncture or cut
  - not felt in deeper tissues
  - larger A nerve fibers
- **Slow pain (chronic)**
  - begins more slowly & increases in intensity
  - aching or throbbing pain of toothache
  - in both superficial and deeper tissues
  - smaller C nerve fibers

Types of Pain

- **Somatic pain**
  - *superficial* - in the skin
  - *deep* - from skeletal muscles, joints, and tendons
- **Visceral pain** is usually felt in or just under the skin that overlies the stimulated organ (referred pain)
  - localized damage (cutting) intestines may cause no pain, but diffuse visceral stimulation can be severe
  - distension of a bile duct from a gallstone
  - distension of the ureter from a kidney stone

Referred Pain

- Skin area & organ are served by the same segment of the spinal cord
  - Heart attack is felt in skin along left arm since both are supplied by spinal cord segment T1-T5
Phantom pain

- Phantom pain is the sensation of pain in a limb that has been amputated.
- The brain interprets nerve impulses arising in the remaining proximal portions of the sensory nerves as coming from the nonexistent (phantom) limb.

Pain Relief

- Aspirin and ibuprofen block formation of prostaglandins that stimulate nociceptors.
- Novocaine blocks conduction of nerve impulses along pain fibers.
- Morphine lessens the perception of pain in the brain.

Proprioceptive Sensations

- Receptors located in skeletal muscles, in tendons, in and around joints, and in the internal ear convey nerve impulses related to muscle tone, movement of body parts, and body position.
- Awareness of body position, movement, balance & equilibrium is the proprioceptive or kinesthetic sense.
  - Walk or type without looking
  - Estimate weight of objects

Muscle Spindles

- Specialized muscle fibers enclosed in a capsule.
- Stretching of the muscle stretches the muscle spindles sending sensory information back to the CNS.
- Monitors changes in muscle length.
- Similar receptors in tendons.
- Joint receptors respond to pressure in joints and acceleration/deceleration of joints.
SOMATIC SENSORY PATHWAYS

- **Somatic sensory pathways** relay information from somatic receptors to the primary somatosensory area in the cerebral cortex.
- The pathways consist of three neurons:
  - first-order
  - second-order
  - third-order
- Axon collaterals of somatic sensory neurons simultaneously carry signals into the cerebellum and the reticular formation of the brain stem.

Somatic Sensory Pathways

- First-order neuron conduct impulses to the CNS (brainstem or spinal cord):
  - either spinal or cranial nerves
- Second-order neurons conducts impulses from brain stem or spinal cord to thalamus:
  - cross over to opposite side of body
- Third-order neuron conducts impulses from thalamus to primary somatosensory cortex (postcentral gyrus of parietal lobe).

Somatosensory Map of Postcentral Gyrus

- Homunculus
- Relative sizes of cortical areas:
  - proportional to number of sensory receptors
  - proportional to the sensitivity of each part of the body
- Can be modified with learning:
  - learn to read Braille & will have larger area representing fingertips

Somatic Motor Pathways - Overview

- Control of body movement:
  - motor portions of cerebral cortex
    - initiate & control precise movements
    - basal ganglia help establish muscle tone & integrate semivoluntary automatic movements
    - cerebellum helps make movements smooth & helps maintain posture & balance
Primary Motor Cortex

- The primary motor area is located in the precentral gyrus of the frontal lobe.
  - Upper motor neurons initiate voluntary movement.
- The cortical area devoted to a muscle is proportional to the number of motor units.
  - More cortical area is needed if the number of motor units in a muscle is high.
    - Vocal cords, tongue, lips & fingers.

INTEGRATIVE FUNCTIONS OF THE CEREBRUM

- The integrative functions include sleep and wakefulness, memory, and emotional responses.

Reticular Activating System (RAS)

- Many types of inputs can activate the RAS -- pain, light, noise, muscle activity, touch.
- When the RAS is activated, the cerebral cortex is also activated and arousal occurs.
- The result is a state of wakefulness called consciousness.

Sleep

- Circadian rhythm
  - 24 hour cycle of sleep and awakening
  - Established by hypothalamus and pineal gland.
- During sleep, a state of altered consciousness or partial unconsciousness.
- During sleep, activity in the RAS is very low.
- Normal sleep consists of two types:
  - Non-rapid eye movement sleep (NREM)
  - Rapid eye movement sleep (REM) - most dreaming.
Learning and Memory

• *Learning* is the ability to acquire new knowledge or skills through instruction or experience
• *Memory* is the process by which that knowledge is retained over time
• For an experience to become part of memory, it must produce persistent structural and functional changes in the brain
• The capability for change with learning is called *plasticity*

Learning and Memory

• Memory occurs in stages over a period and is described as immediate memory, short term memory, or long term memory
  – *Immediate memory* is the ability to recall for a few seconds
  – *Short-term memory* lasts only seconds or hours and is the ability to recall bits of information; it is related to electrical and chemical events
  – *Long-term memory* lasts from days to years and is related to anatomical and biochemical changes at synapses