Chapter 16

Introduction to Sensory, Motor, and Integrative Systems
General Properties of Receptors

• **transduction** – the conversion of one form of energy to another

  – fundamental purpose of any sensory receptor
  – conversion of stimulus energy (light, heat, touch, sound, etc.) into nerve signals
  – sense organ, gasoline engine, light bulb are all transducers

• **sensation** // a subjective awareness of the stimulus

  – some do not require conscious awareness like pH and body temperature

  – most sensory signals delivered to the CNS produce no conscious sensation // filtered out in the brainstem
Definitions

• **sensory input**  // a stimulus - vital to the integrity of personality and intellectual function

• **sensory receptor**  // a structure of a neuron that is specialized to detect a stimulus  // commonly a “dendrite”

• **sense organs** – tissues that surround dendrites and enhance the response of dendrites to certain type of stimulus
  
  – tissue added can be epithelium, muscle or connective tissue
Type of Receptors & Stimuli

- Mechanoreceptors
- Thermoreceptors
- Nociceptors (pain)
- Photoreceptors
- Chemoreceptors
- Osmoreceptors
General Senses vs Special Senses

- GS = structurally simple receptors  //  one or a few sensory fibers  //  no or little additional tissue surrounding the dendrite

- SS = complex structures / localized in head / sight, hearing, vision, taste, smell  //  additional tissue surrounding the dendrites
General Senses

• GS - structurally simple receptors

  • **unencapsulated nerve endings**
    – free nerve endings
    – E.g. tactile (Merkel) discs & hair receptors (peritrichial endings)

  • **encapsulated nerve endings**
    – Krause end bulbs
    – bulbous (Ruffini) corpuscles
    – lamellar (pacinian) corpuscles
    – muscle spindles
Unencapsulated Nerve Endings

- dendrites not wrapped in connective tissue

- **free nerve endings** // for pain and temperature
  - skin and mucous membrane

- **tactile discs** // for light touch and texture
  - associated with Merkel cells at base of epidermis

- **hair receptors** // wrap around base hair follicle
  - monitor movement of hair
Encapsulated Nerve Endings

- **Corpuscle of Touch**
  Or Meissner Corpuscles

- **End bulb**

- **Bulbous corpuscle**

- **Lamellar corpuscle** (pressure)

- **Muscle spindle**

- Dendrites wrapped by glial cells or connective tissue

- Connective tissue enhances sensitivity or selectivity of response
Encapsulated Nerve Endings

- **Krause end bulb** // tactile; in mucous membranes

- **Lamellated (Pacinian) corpuscles** – phasic
  - deep pressure, stretch, tickle and vibration
  - periosteum of bone, and deep dermis of skin

- **Bulbous (Ruffini) corpuscles** – tonic
  - heavy touch, pressure, joint movements and skin stretching
Positioning of Different Types of Sensory Receptors

- **Epidermis**
  - **FREE NERVE ENDING** senses pain, itch, tickle, cold, and warmth.

- **Dermis**
  - **TYPE I CUTANEOUS MECHANOSENSOR (TACTILE DISC)** senses fine touch and pressure.
  - **CORPUSCLE OF TOUCH (MEISSNER CORPUSCLE)** senses fine touch, pressure, and slow vibration.
  - **TYPE II CUTANEOUS MECHANOSENSOR (RUFFINI CORPUSCLE)** senses crude touch and stretching of skin.
  - **HAIR ROOT PLEXUS** senses crude touch.
  - **LAMELLATED (Pacinian) CORPUSCLE** senses pressure and fast vibration.

- **Subcutaneous layer**
Generator VS Receptor Potentials

Two Kinds of Graded Potentials // These Determine “IF” Action Potential Occur

- **Generator Potentials**
  - Receptors are *dendrites* of free nerve endings, encapsulated nerve endings, receptive part of olfactory receptors
  - Stimulus open ion channels // graded potential
  - Stimulus great enough triggers action potential in sensory first order neuron
  - GP generate action potentials

- **Receptor Potentials**
  - Receptors are *separate cells*
  - Receptor potentials trigger release of neurotransmitter into synaptic cleft // receptor on post synaptic membrane of dendrite
  - If stimulus great enough then EPSP generate AP in first order neuron
(a) First-order sensory neuron with free nerve endings

Cold stimulus → FREE NERVE ENDINGS (DENDRITES) → Axon

Generator potential → Triggers → Nerve impulses → Propagate into CNS
(b) First-order sensory neuron with encapsulated nerve endings

Pressure stimulus → Generator potential → Triggers → Nerve impulses → Propagate into CNS

Dendrite

ENCAPSULATED NERVE ENDING

Axon
(c) Sensory receptor synapses with first-order sensory neuron

Sugar molecule → GUSTATORY (TASTE) RECEPTOR

Synaptic vesicle
Neurotransmitter
Dendrite
Axon
Propagate into CNS

Receptor potential → Triggers
Release of neurotransmitter from sensory receptor
Triggers
Nerve impulses
Types of Somatic Sensations // Tactile Sensations

Free nerve endings or encapsulated receptors

Include touch, pressure, vibration, itch, tickle

Tickle is an intriguing sensation
  * only occurs when someone else touches you
  * you can not tickle yourself
    • tickle cancelled by signal sent to cerebellum by your finger
Types of Somatic Sensations // Thermal Sensations

Free nerve endings

Cold receptors // located in basal stratum // stimulated between 10 and 40 degree C (50 – 105 F)

Warm receptors // located in dermis // not as abundant as cold receptors // stimulated between 30 and 48 degree C (90 – 118 F)

Temperature below 30 and above 118 primarily stimulate pain receptors
Types of Somatic Sensations // Pain Sensations

Indispensable for survival // protect by signaling noxious, tissue-damaging conditions

Nociceptors = pain receptors // free nerve endings // Located in all tissue except brain // little adaptation / pain persist

Activated by prostaglandins, kinins (e.g. bradykinin), potassium ions, ATP // also stretch, prolonged muscle contractions & ischemia

Superficial somatic pain = skeletal muscles, joints, tendons
Deep somatic pain = fascia
Visceral pain = visceral organs
Types of Somatic Sensations // Proprioceptive

Proprioceptive

Project information about position of body and tension/length of muscle // also within inner ear to provide sensory pathway for equilibrium

Located in muscles, tendons, joints, and inner ear

Proprioceptors do not adapt (they are tonic)

Proprioceptors also provide pathway for weight discrimination // how we tell how much something weighs

Three types of proprioceptors: muscle spindles / Golgi tendon organs / synovial joint kinesthetic receptors
Three General Pathways of Somatic Sensory

**Posterior column pathway** // medial lemmiscus pathway // cuneate (upper limbs) and gracilus (lower limbs) fasciculus tracts // sensation of touch, pressure, vibration, visceral pain, and conscious proprioception

**Anterolateral pathway** // spinothalamic tract // sensations of pain, temperature, itch and tickle // limbs, truck, neck, posterior head

**Trigemiothalamic pathway** // first order neuron from face, nasal cavity, oral cavity and teeth enter cranium via CN-5 (thrgeminal) // sensations - tactile, thermal and pain
Somesthetic (Somatic Sensory) Projection Pathways

• Pathway from receptor to final destination in the brain // post central gyrus // most somesthetic signals travel by way of **three neurons**

• **1st order neuron** (afferent neuron)
  – from body, enter the dorsal horn of spinal cord via spinal nerves
  – from head, enter pons and medulla via cranial nerve
  – touch, pressure and proprioception on large, fast, myelinated axons
  – heat and cold on small, unmyelinated, slow fibers

• **2nd order neuron**
  – decussation to opposite side in spinal cord, medulla, or pons
  – **end in thalamus**
  – except for **proprioception, which ends in cerebellum**

• **3rd order neuron**
  – thalamus to primary somesthetic cortex of cerebrum
Posterior Column Pathway

- **Right Side of Body**
  - Thalamus (ventral posterior nucleus)

- **Left Side of Body**
  - Primary somatosensory area of cerebral cortex

- **Second-Order Neurons**
  - Medial lemniscus
  - Midbrain

- **First-Order Neurons**
  - Gracile nucleus
  - Cuneate nucleus

- **Posterior Column**
  - Posterior root ganglion
  - Cervical spinal cord
  - Lumbar spinal cord

Receptors for touch, pressure, vibration, and proprioception in the upper limbs, upper trunk, neck, and posterior head.

Receptors for touch, pressure, vibration, and proprioception in the lower limbs and lower trunk.

Posterior column–medial lemniscus pathway.
Spinothalamic Pathway

- RIGHT SIDE OF BODY
- LEFT SIDE OF BODY
- Primary somatosensory area of cerebral cortex
- THIRD-ORDER NEURON
- Thalamus (ventral posterior nucleus)
- SECOND-ORDER NEURON
- Midbrain
- Medulla
- Posterior gray horn
- LATERAL SPINOthalamic TRACT
- Spinal nerve
- ANTERIOR SPINOthalamic TRACT
- Receptors for pain, cold, warmth, tickle, and itch
- Spinal cord
- Anterolateral (spinothalamic) pathways
Trigeminothalamic Pathway

- **RIGHT SIDE OF BODY**
- **LEFT SIDE OF BODY**
- Primary somatosensory area of cerebral cortex
- Thalamus (ventral posterior nucleus)
- Third-order neuron
- Second-order neuron
- First-order neuron
- Midbrain
- Trigeminothalamic tract
- Pons
- Trigeminal ganglion
- Trigeminal (V) nerve
- Second-order neuron
- Medulla

Receptors for touch, pressure, vibration, pain, cold, warmth, itch, and tickle in the face, nasal cavity, oral cavity, and teeth
Postcentral Gyrus = Somatic Sensory Gyrus

Illustrates Somatotopy
Motor Control
(How we regulate our skeletal muscles)

Feedback loop

Indirect Pathway

Note: motor programs are stored in motor association area, basal nuclei, cerebellum

Direct Pathway

Compared Intent to performance
Precentral Gyrus = Motor Sensory Gyrus

Illustrates Somatotopy
Muscle Spindle Structure & Function

Sensor which sends signal to spinal cord which results in a spinal cord reflex

Adjust tension within groups of muscles as muscles are stretched // requires feedback integration within the brain

Muscle spindles are proprioceptors
Illustrates how cerebellum’s integrates information from different parts of the CNS to regulate Motor Control.

Not shown is basal nuclei which also plays role in feedback mechanism which helps to regulate Motor Control.
Lateral Corticospinal Pathway

(a) The lateral corticospinal pathway
Anterior Corticospinal Pathway

(b) The anterior corticospinal pathway
Corticobulbar Tract
Stop
Cerebral peduncle

Corticobulbar tract

Midbrain of brain stem