NERVOUS SYSTEM BLOCK

15th Lecture

Pathways of Proprioception

PHYSIOLOGY TEAM – 430

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Whatever is written in gray font is an additional detail.

- **PROPRIOCEPTION** :

Derives from the Latin for "one's own" → arise within the body.

(Extroceptive sensations are those from the surface of the body)

Proprioceptive sensations are those having to do with the physical state of the body, including position sensations, tendon and muscle sensations and pressure sensations from the bottom of the feet.

- **TYPES OF PROPRIOCEPTION :**

1. ***CONSCIOUS proprioception***:

Communicated by the dorsal column-medial lemniscus pathway to the cerebral cortex, conscious proprioception it is the ability to sense stimuli from within the body.
For example, if the eyes are closed a person will still know if the arm is raised above the head or hanging by the side. The person is consciously aware of the limb despite not being able to see it.

2. ***UNCONSCIOUS proprioception:***

Communicated by the spinocerebellar tract to the cerebellum, unconscious proprioception can be noted in the body's reaction once a skill has been acquired.
For example, once a child has mastered movements required for walking, the unconscious proprioception can take over to provide a feedback system to produce the skill as required without thinking about it

- **SENSORY RECEPTORS:**

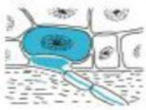
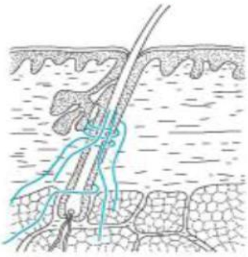
Peripheral sensory receptors are classified according to:

1. ***Location***
2. ***Type of stimulus*** →
Mechanoceptors (touch & proprioception), nociceptors (pain), and thermoceptors (detect skin temperature).
3. ***Structure*** → Unencapsulated and encapsulated nerve endings.

a. ***Unencapsulated nerve endings:***

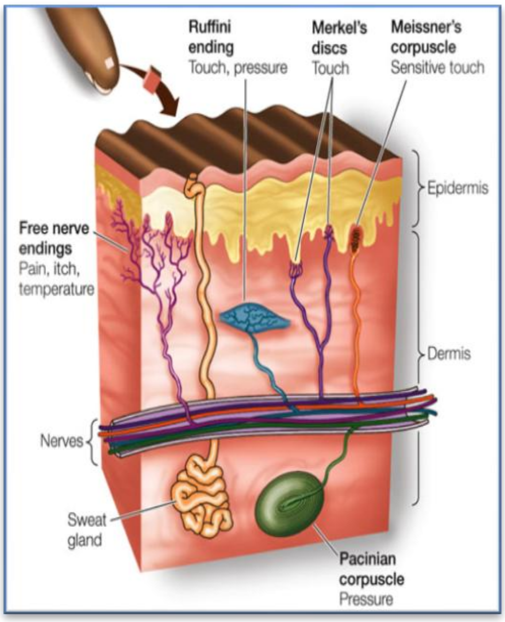
1. Free nerve endings of sensory neurons
(Found everywhere in the skin and many other tissues, can detect touch and pressure)
2. Modified free nerve endings: Merkel discs
(they respond to sustained pressure and touch signals which allow one to determine continuous touch of objects against skin.)
3. Hair follicle receptors
(Slight movement of any hair on the body stimulates a nerve fiber entwining its base)

Table 14.1 General Sensory Receptors Classified by Structure and Function (1 of 3)

Anatomical Class (structure)	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
UNENCAPSULATED			
Free nerve endings of sensory neurons		L: Exteroceptors, interoceptors, and proprioceptors S: Nociceptors (pain), thermoreceptors (heat and cold), possibly mechanoreceptors (pressure)	Most body tissues; densest in connective tissues (ligaments, tendons, dermis, joint capsules, periostea) and epithelia (epidermis, cornea, mucosae, and glands)
Modified free nerve endings: Merkel discs		L: Exteroceptors S: Mechanoreceptors (light pressure)	Basal layer of epidermis
Hair follicle receptors		L: Exteroceptors S: Mechanoreceptors (hair deflection)	In and surrounding hair follicles

b. ***Encapsulated nerve endings:***

- Consist of one or more end fibers of sensory neurons
- Enclosed in connective tissue
- Include four main types

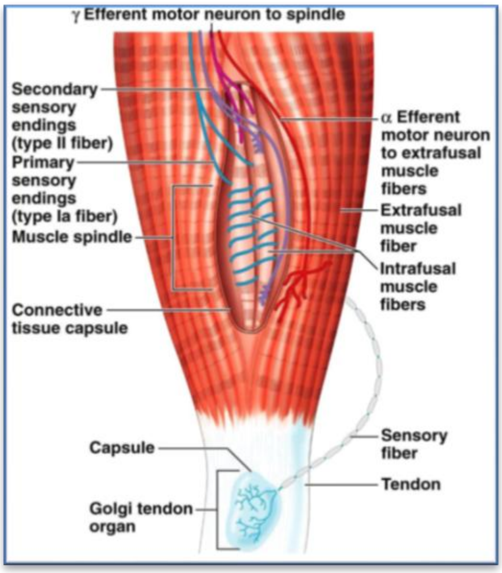


1. Meissner's corpuscles
(Touch receptors with great sensitivity. They are abundant in finger-tips, lips, and other areas of the skin where one's tactile discrimination is highly developed. Therefore, they contribute in detecting two-point discrimination.)
2. Pacinian corpuscles
(They're the most rapidly adapting mechanoreceptors. They mainly encode the sensation of vibration.)

3. Ruffini's corpuscles

(They are important for signaling continuous states of pressure and heavy prolonged touch. They also help to signal degree of joint rotation)

4. Proprioceptors



Provide information about position of the body in space in any given moment

- Encapsulated Nerve Endings
- Monitor stretch in locomotory organs
- **Three types of proprioceptors:**

a. *Muscle spindles (stretch receptors)*

- measure the changing length of a muscle
- Imbedded in the perimysium between muscle fascicles within extrafusal muscles.

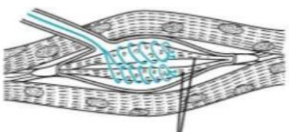
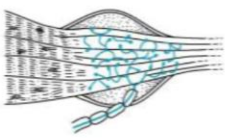
b. *Golgi tendon organs*

- located near the muscle-tendon junction.
- Monitor tension within tendons

c. *Joint kinesthetic receptors*

- Sensory nerve endings within the joint capsules
- ***Pacinian corpuscles***

TABLE 14.1 General Sensory Receptors Classified by Structure and Function *(continued)*

Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
PROPRIOCEPTORS			
Muscle spindles		L: Proprioceptors S: Mechanoreceptors (muscle stretch)	Skeletal muscles, particularly those of the extremities
Golgi tendon organs	Intrafusal fibers	L: Proprioceptors S: Mechanoreceptors (tendon stretch)	Tendons
Joint kinesthetic receptors (Pacinian and Ruffini endings, free nerve endings, and receptors resembling Golgi tendon organs)		L: Proprioceptors S: Mechanoreceptors and nociceptors	Joint capsules of synovial joints

- **AN OVERVIEW OF SENSORY PATHWAYS:**

- Afferent pathways
  Sensory information coming from the sensory receptors through peripheral nerves to the spinal cord and to the brain.
- Efferent pathways
  Motor commands coming from the brain and spinal cord, through peripheral nerves to effecter organs.

- **ASCENDING SENSORY PATHWAYS:**

- Sensory systems allow us to detect, analyze and respond to our environment
- "ascending pathways"
- Carry information from sensory receptors to the brain
- Conscious → reach cerebral cortex
- Unconscious → do not reach cerebral cortex
- Sensations from body reach the opposite side of the brain
- Thalamus is the relay station for all sensory modalities except olfaction.

- **MAJOR SENSORY PATHWAYS:**

1. Dorsal column pathway : -

Carries signal of fine touch, pressure, vibration , stereognosis and **concious proprioception**, ascends up dorsal white column in fasciculus gracilis or cutaneatus to medulla oblongata to the thalamus to primary somatosensory cortex (post central gyrus).

2. Spintothalamic tracts: –

Carry signals of pain, temperature and course touch. From posterior gray horn decussate into lateral and anterior funiculi up to the thalamus to primary somatosensory cortex (postcentral gyrus).

3. Spinocerebellar tracts :–

Carry **subsconcious proprioception**. Dorsal gray horn- to lateral column- to medulla oblongata- to pons – to cerebellum.

2 major sensory pathways are concerned with PROPRIOCEPTION:
Dorsal column pathway (conscious) + Spinocerebellar tracts (subconscious)

Dorsal Column—Medial Lemniscal System

1. Touch sensations requiring a high degree of localization of the stimulus
2. Touch sensations requiring transmission of fine gradations of intensity
3. Phasic sensations, such as vibratory sensations
4. Sensations that signal movement against the skin
5. Position sensations from the joints
6. Pressure sensations related to fine degrees of judgment of pressure intensity

Anterolateral System

1. Pain
2. Thermal sensations, including both warmth and cold sensations
3. Crude touch and pressure sensations capable only of crude localizing ability on the surface of the body
4. Tickle and itch sensations
5. Sexual sensations

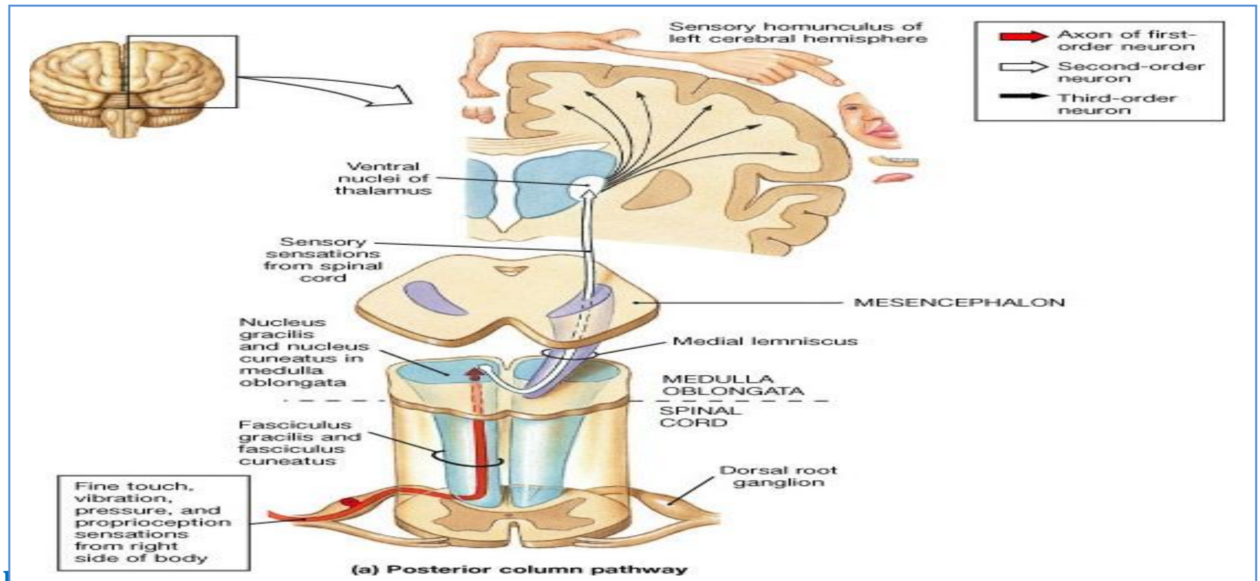
DORSAL COLUMN PATHWAY: CONSICOUS PROPRIOCEPTON

***Sensations carried by this pathway**:*

1. ***Fine discriminative touch**:*
   High degree of localization of stimulus e.g. two point discrimination, demographic sensation, Tactile localization.
2. ***Vibration***
3. ***Stereognosis***
4. *Conscious proprioception* joint position sense
   (Thus, it provides the parietal lobe an instantaneous body image so that we are constantly aware of the position of body parts both at rest and during movement.)

*** PATHWAY:**

The sensory information is transmitted from the peripheral receptor to the CNS along a series of 3 neurons:



(a) Posterior column pathway

1. **Fi**

Enter the spinal cord through the dorsal root and have their cell bodies in the dorsal root ganglion cells. Then, they enter the dorsal column to *ascend ipsilaterally* uninterrupted to the nucleus gracilis and nucleus cunateus in the medulla.

2. Second order neurons:

In the medulla the first order neurons synapse on second order neurons, they *cross* the midline immediately to opposite side (*sensory decussation*). The second order neurons *ascend* as the <u>medial lemnisicus</u> to terminate in the ventral posterior nucleus of the *contralateral thalamus*.
**(Therefore, the somatosensory information from one side of the body is received in the contralateral thalamus)*
**While passing through the brain stem it is joined by fibers from sensory nucleus of trigeminal nerve carrying sensations from face.*

3. Third order neurons:

In the thalamus the 2nd order neurons synapse on 3rd order neurons, which ascend to the somatosensory area 1 in post central gyrus and also in sensory area 2 situated in the margin of lateral sulcus.

SUMMARY of dorsal column pathway:
Discriminative touch, vibratory sense, conscious muscle joint sense (PROPRIOCEPTION) →
Meissner's corpuscles, pacinian corpuscles, muscle spindles, tendon organs→
Posterior root ganglion→
Nuclei gracilis and cunateous in medulla →
Ascend as Medial lemniscus→
Ventral posterolateral nucleus of thalamus→
Posterior central gyrus (somatosensory cortex)

** DORSAL COLUMN DAMAGE:*

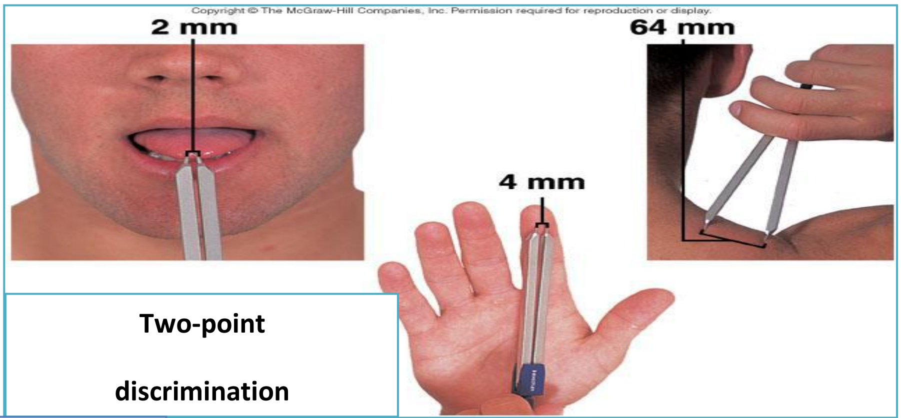
- ***SENSORY ATAXIA***: is the classic symptom. This term signifies a *movement disorder resulting from sensory impairment*, in contrast to cerebellar ataxia, in which a movement disorder results from a lesion within the motor system.

- The *patient staggers (cannot perceive position or movement of legs*) and the gait has a *stamping* action "stamp and stick gait" to enhance any remaining proprioceptive facility.

- *Visual clues help movement*. The unsteadiness in gate is compensated to some extent by vision; however, in the dark or if the eyes are closed, the ataxia becomes worse and the person falls.

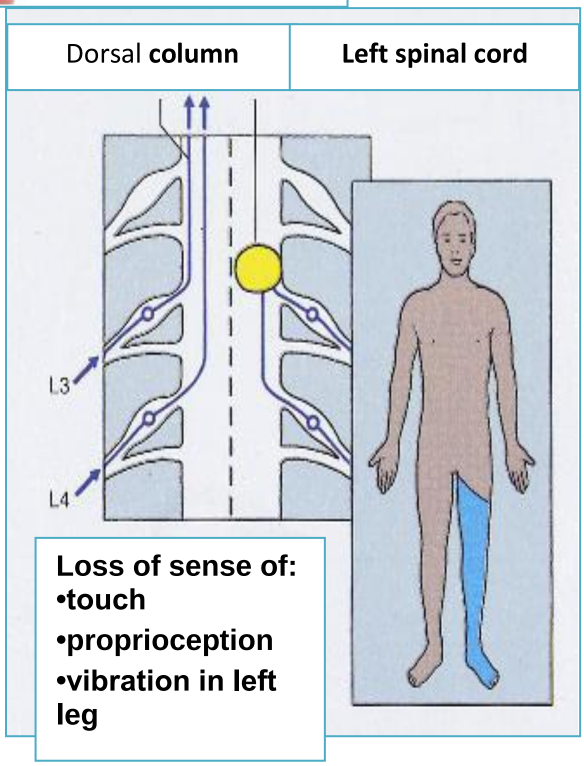
(Romberg's sign/ Rombergism-trouble standing with their eyes closed. If the patient falls down upon closing the eyes, he is considered to have a positive Romberg's test, which indicates sensory ataxia)

- *Impairment of tactile discrimination*. The patient has difficulty discriminating between single and paired stimuli applied to the skin (two-point discrimination)



Two-point discrimination

The 'stamp and stick'



2. SPINOCEREBELLAR TRACT: UNCONSCIOUS PROPRIOCEPTIO

Sensatios carried by this tract:

- Unconscious proprioception (muscle joint sense)

Receptors:

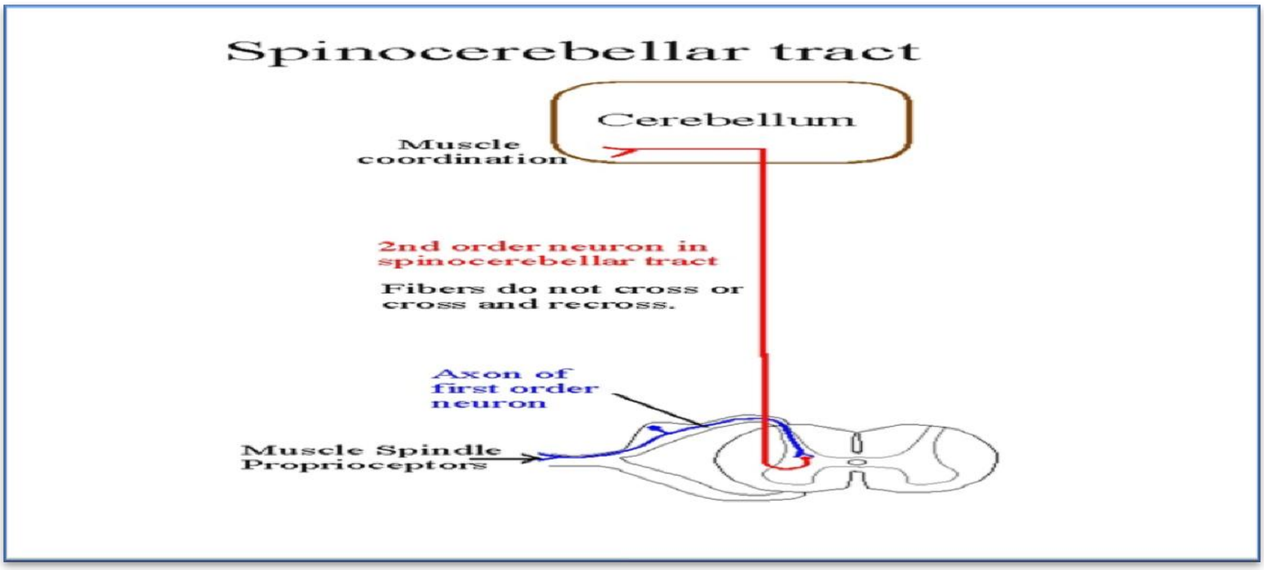
-Muscle spindle, Golgi tendons organs, joint receptors

**Divisions*:*

1. The posterior spinocerebellar tract *2 . The anterior spinocerebellar tract*

Receive muscle joint information from the muscle spindles, tendon organs, and joint receptors of the trunk and lower limbs and upper limbs, concerning tension of muscle tendons and the movements of muscles and joints. This information is used by the cerebellum in the coordination of limb movements and maintenance of posture.

*** Pathway: .***



1. **First order neurons:** enters spinal cord through dorsal root ganglia.
2. **Second order neurons:** ascends to cerebellum and terminate directly there.

- Posterior spinocerebellar tract→ 2nd order neuron axons ascend ipsilaterally to the medulla oblongata. Here, the tract joins the inferior cerebellar peduncle and terminates in cerebellar cortex.- Anterior spinocerebellar tract →2nd order neuron axons cross to the opposite side, then they enter the cerebellum through the superior cerebellar peduncle and they cross back within cerebellum.

3. **NO 3rd neuron to cortex, hence unconscious**

SUMMARY:

Unconscious muscle joint sense (PROPRIOCEPTION) →
Muscle spindles, tendon organs, joint receptors→
Posterior root ganglion→
Nucleus dorsalis→
Anterior and posterior spinocerebellar→
Cerebellar cortex

Spinocerebellar tract damage:

- Cerebellar ataxia
- Clumsy and jerky movements
- Incoordination of the limbs (intention tremor)
  **Intention tremor is a tremor that occurs during a voluntary movement (such as pressing a button) or aims for a target (as when reaching for an object with the hand). The person may miss the targeted object because of the tremor. This tremor is absent when muscles are resting.*
- Wide-based, reeling gait (ataxia)
- Alcoholic intoxication produces similar effects (therefore it is also referred to as drunken gait).

MOTOR AND SENSORY ATAXIA

*Pathophysiology:

–Result from any condition that affects the central and peripheral nervous systems.

MOTOR ATAXIA	***SENSORY ATAXIA***
–Caused by *cerebellar* disorders - Inability to control the coordinate movements of the muscles. 1. *Intact* sensory receptors and afferent pathways 2. Integration of proprioception is faulty 3. Midline cerebellar lesions cause *truncal ataxia* (imbalance of the trunk) 4. Lateral cerebellar lesions cause *limb ataxia* 5. Thalamic infarcts may cause contralateral ataxia with sensory loss N.B cerebellar ataxia will be discussed in details later with cerebellum lecture.	**–Failure of proprioceptive information to the CNS** **- movement disorder resulting from sensory impairment** **–May be due to disorders of spinal cord or peripheral nerves** **–Can be compensated for by *visual inputs*** ***Romberg's test/Rombergism: A test used to investigate the cause of ataxia. This test is performed by asking the patient to stand, feet together with eyes open, then with eyes closed. The patient with sensory ataxia will be able to stand still with eyes open because vision will compensate for the loss of position sense but will sway or fall with their eyes closed because they are unable to keep their balance. Hence, they have a positive Romberg's sign. However, patients with cerebellar ataxia will have trouble standing whether their eyes were open or closed.***

- **SOMATOSENSORY CORTEX:**

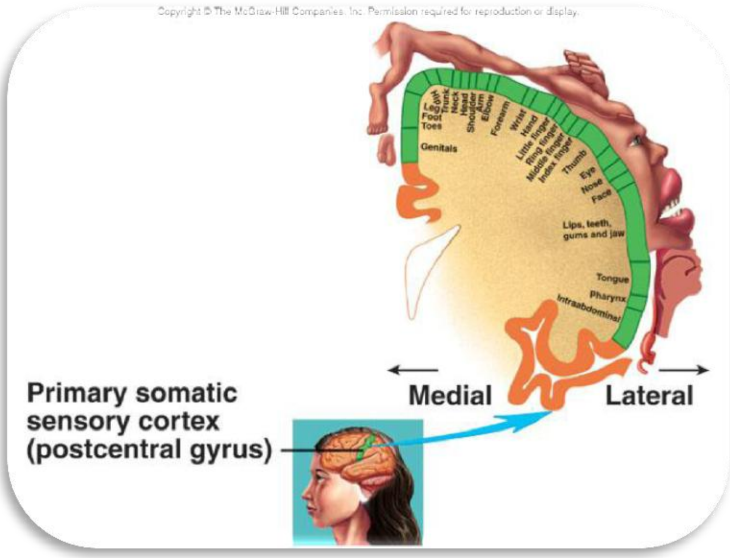
- Located in the post central gyrus of the human cerebral cortex.

-Spatial orientation of signals:

1) Each side of the cortex receives sensory information exclusively from the opposite side of the body (exception: sensations from the face are received from the same side).

2) The lips, face and thumb are represented by large areas in the somatic cortex, whereas the trunk and lower part of the body, relatively small area. *The sizes of these areas are directly proportional to the number of specialized sensory receptors in each respective peripheral area of the body.*

3) The head in the most lateral portion and the lower body is presented medially



- SEGMENTAL FIELDS OF SENSATION: DERMATOMES

Each spinal nerve innervates a segmental field of the skin called a dermatome. One can use a dermatomal map to determine the level in the spinal cord at which a cord injury has occurred when the peripheral sensations are disturbed by the injury.

The recommended reference for this lecture is chapter 47 Guyton and Hall Textbook of Medical Physiology.