SPINAL CORD

Kenneth Alonso, MD, FACP

Spinal cord

- Segmentally organized.
- Cervical and lumbar enlargements. These receive sensory (afferent) information from the limbs and send motor (efferent) axons to the limb muscles.
- In adults, the spinal cord ends at L1-L2.
- The dural (thecal) sac ends at S2. This level is at the level of the posterior superior iliac spines.
- The spinal cord is attached distally to the coccyx by the filum terminale (pia covered by dura).

Spinal cord

- The anterior root is ventral (motor, efferent).
- The posterior root is dorsal (sensory, afferent).
- Somatotropic organization.
- A dermatome is an area of skin innervated by a specific segment of spinal cord.
- A myotome is a muscle mass innervated by a specific segment of spinal cord.
- Myotomes contain portions of several muscles.
- Many muscles contain portions of more than one myotome.

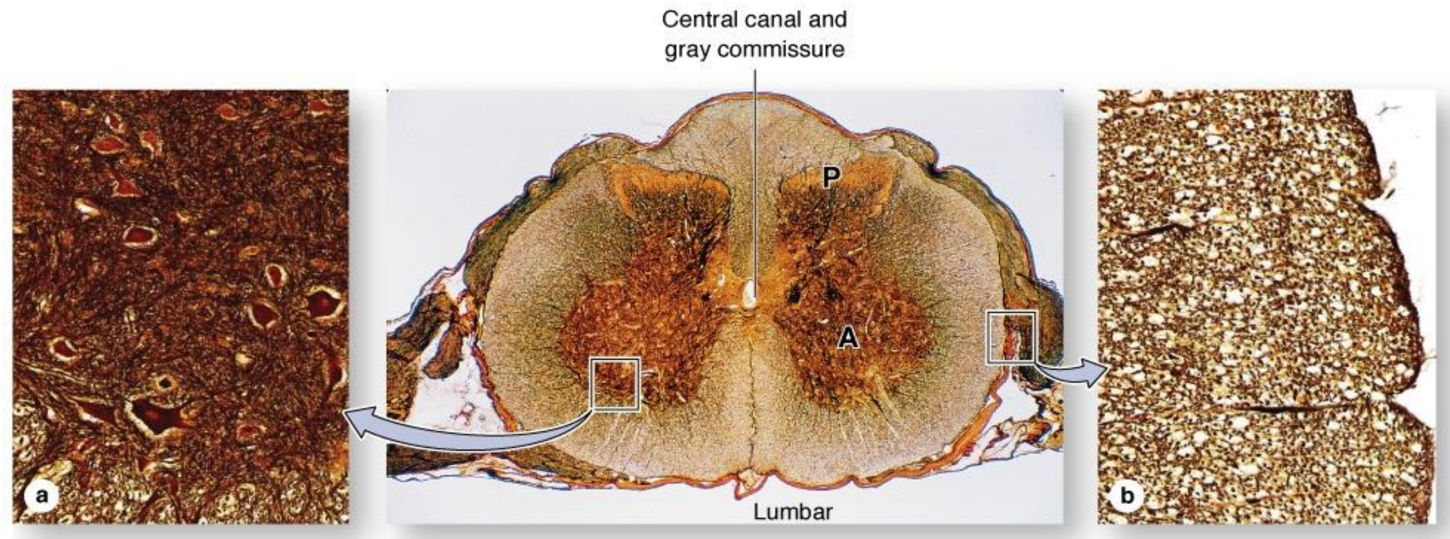
Spinal cord

- When cut in transverse section, white matter is on the outside. It contains tracts (bundles of myelinated axons). It is organized somatotropically.
- The gray matter contains neuronal cell bodies and dendrites. It forms an H-shape. It has its own cytoarchitecture.
- The dorsal or posterior horn contains the sensory portion of the cord, laminae I-VI.
- The ventral or anterior horn contains the motor portion of the cord, laminae VIII-IX.
- Lamina VII is the intermediazte zone. Lamina X is around the central canal.

Spinal cord

- The lower motor neurons that innervate axial muscles are medial.
- Those innervating the proximal limbs are lateral to axial muscles.
- Those innervating the distal limb muscles are lateral to the proximal muscles.
- Flexors are more dorsal (posterior) while extensors are more ventral (anterior) and lie above the girdle muscles.

Spinal cord



Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition*: http://www.accessmedicine.com

The spinal cord always shows bilateral symmetry around the small, CSF-filled central canal. In the spinal cord the gray matter is internal, forming a roughly H-shaped structure that consists of two posterior (P) horns (sensory) and two anterior (A) (motor) horns all joined by the gray commissure around the central canal. (a): The gray matter contains abundant astrocytes and large neuronal cell bodies.(b): The white matter surrounds the gray matter and contains primarily oligodendrocytes and tracts of myelinated axons. Fig. 9-17 Accessed 07/01/2010

Spinal cord

- The **ventral** (or **anterior**) gray column (also called the **ventral**, or **anterior**, **horn**) is in front of the central canal. It contains the cells of origin of the fibers of the ventral roots, including alpha and gamma motor neurons ("lower" motor neurons).
- The **intermediolateral gray column** (or **horn**) is the portion of gray matter between the dorsal and ventral gray columns; it is a prominent lateral triangular projection in the thoracic and upper lumbar regions but not in the midsacral region. It contains preganglionic cells for the autonomic nervous system column.

Spinal cord

- Within spinal segments **T1 to L2**, **preganglionic sympathetic neurons** within the intermediolateral gray column give rise to sympathetic axons that leave the spinal cord within the ventral roots and then travel to the sympathetic ganglia via the white rami communicantes.

Spinal cord

- Within spinal segments **S2**, **S3**, and **S4**, there are **sacral parasympathetic neurons** within the intermediolateral gray column. These neurons give rise to preganglionic parasympathetic axons that leave the spinal cord within the sacral ventral roots. After projecting to the pelvic viscera within the pelvic nerves, these parasympathetic axons synapse on postganglionic parasympathetic neurons that project to the pelvic viscera.

Spinal cord

- The **dorsal gray column** (also called the **posterior**, or **dorsal, horn**) reaches almost to the posterolateral (dorsolateral) sulcus. A compact bundle of small fibers, the **dorsolateral fasciculus (Lissauer's tract)**, part of the pain pathway, lies on the periphery of the spinal cord.

Spinal cord

- Lamina I – IV are receiving centers for cutaneo-mucous afferents.
- Lamina V and VI comprise a proprioceptive area.
- Type I, II mechano-receptors target laminae II-VI and proceed to anterior horn.
- Nociceptors, visceral afferents, thermo-receptors, mechano-receptors to levels I-V.
- Lamina II and III comprise substantia gelatinosa. Lamina III connects to posterior column nuclei. It consists of interneurons.

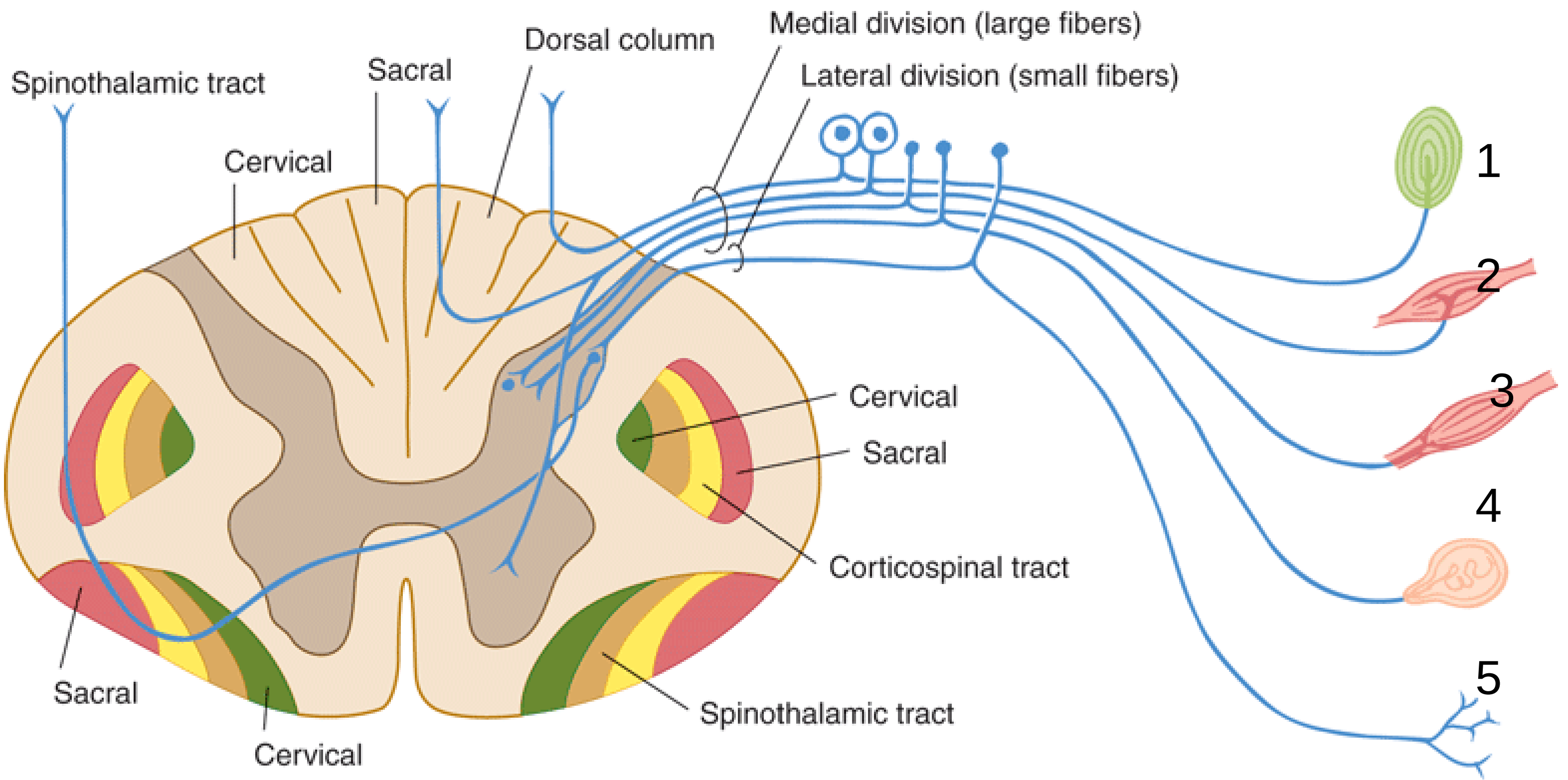
Spinal cord

- Lamina VII contains the IML and nucleus dorsalis of Clarke; sacral parasympathetic nucleus inhibitory interneuron.
- Lamina VIII contains propriospinal interneurons.
- Lamina IX contains α, β and γ motor neurons.
- Lamina X about central canal.
- Lower motor neurons reside in the anterior horn. Their axons innervate skeletal muscle (motor portion of the peripheral nerve). They are the final common pathway because they receive input from higher brain areas. The axons from the higher centers (upper motor neurons) excite or inhibit lower motor neurons.

Somatic reflexes

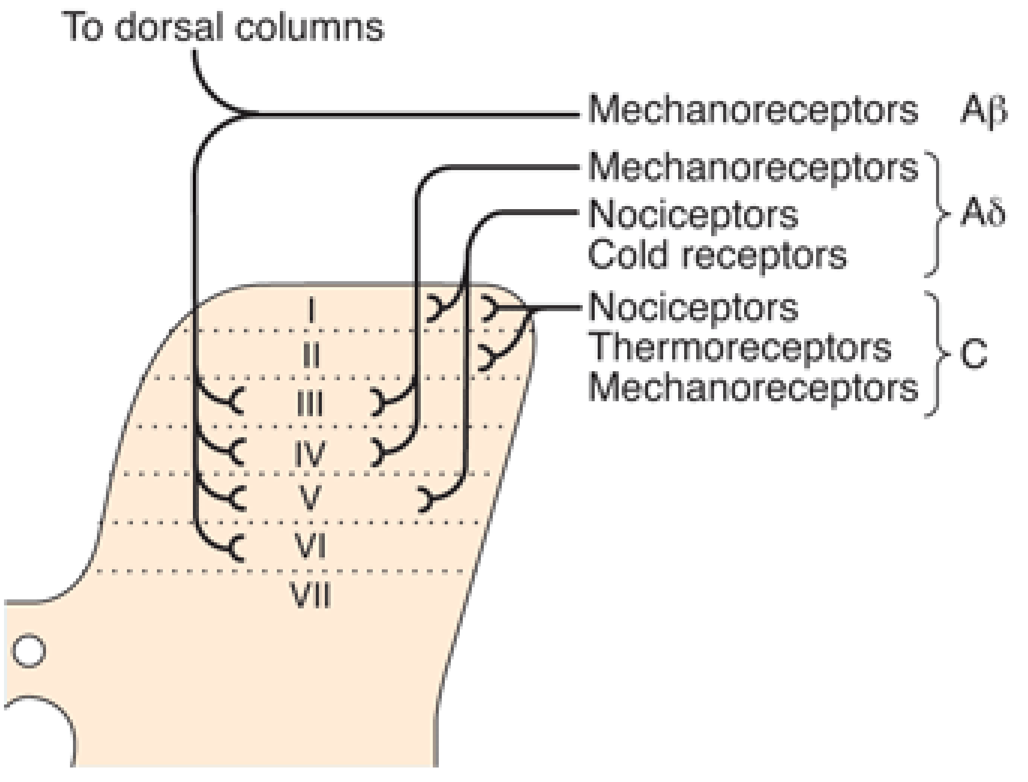
- Primary afferent (sensory) neurons reside in dorsal root ganglia.
- Peripheral axon carries information from receptors.
- Central axons within the dorsal roots carry afferent information.
- α-motor neurons form neuromuscular junctions on extra-fusal muscle fibers.
- A single motor neuron and the muscle fibers innervated are a motor unit.
- γ-motor neurons from junctions on intra-fusal muscle fibers. These regulate tension on muscle spindles.
- Acetylcholine is the neurotransmitter.

Sensory afferents



1: Pacinian corpuscle; 2: muscle spindle; 3: Golgi tendon organ; 4: encapsulated ending; 5: free nerve endings. Fig. 5-7 Modified Accessed 07/01/2010

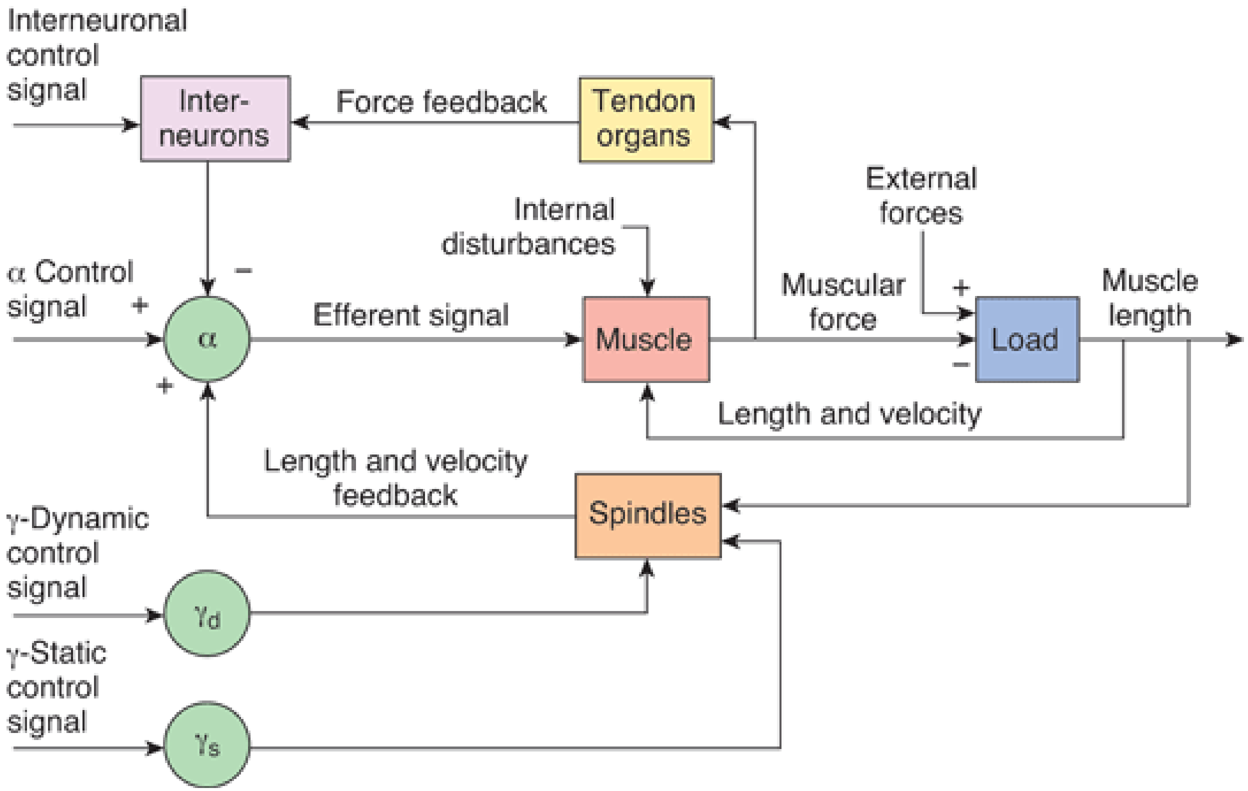
Sensory afferents



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

Fig. 11-1
Accessed 07/01/2010

Peripheral motor control system

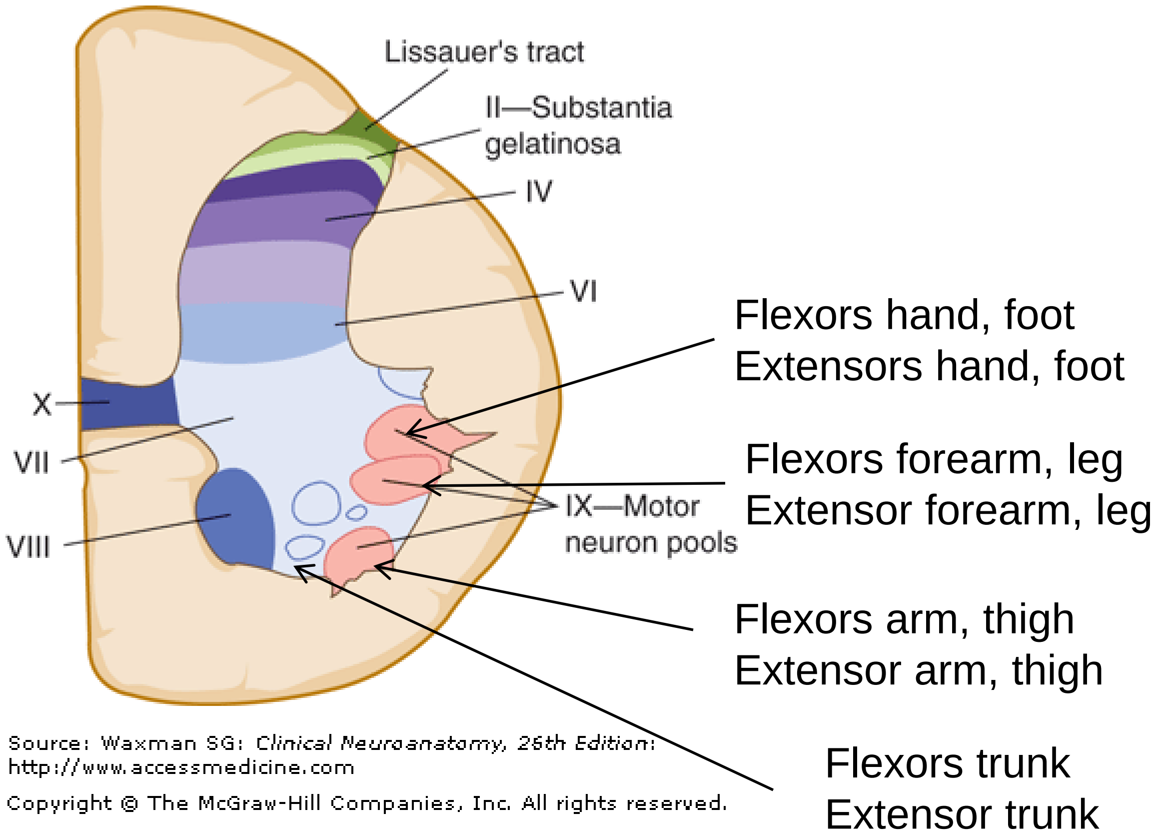


(Reproduced, with permission, from Houk J in: *Medical Physiology,* 13th ed. Mount-Castle VB (editor). Mosby, 1974.)

Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

Fig. 9-6
Accessed 07/01/2010

Motor system



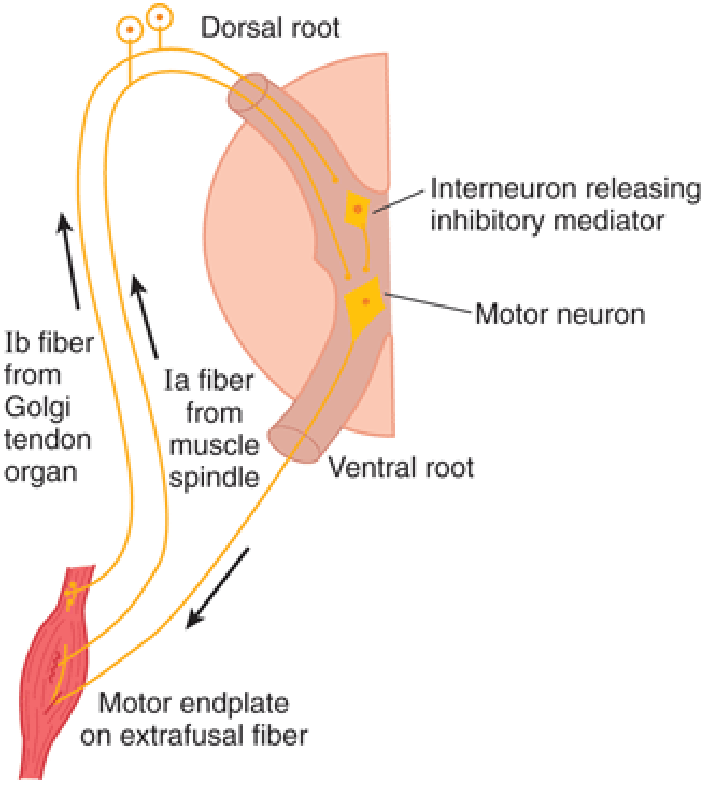
Source: Waxman SG: *Clinical Neuroanatomy, 26th Edition*: http://www.accessmedicine.com

Fig. 5-11 Modified
Accessed 07/01/2010

Reflex arc

- Stretch stimulates the muscle spindle, and impulses pass up the Ia fiber to excite the lower (α) motor neuron. (The γ- neuron innervates intrafusal fibers.) Monosynaptic.
- Stretch also stimulates the Golgi tendon organ, which is arranged in series with the muscle, and impulses passing up the Ib fiber activate the inhibitory neuron.
- Muscle contracts when α-motor neuron fires.
- With strong stretch, the resulting hyperpolarization of the motor neuron is so great that it stops discharging.

Reflex arc



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

Fig. 9-3
Accessed 07/01/2010

Flexor withdrawal crossed extensor reflex

- Polysynaptic.
- A painful or noxious stimulus to the foot leads to the flexor withdrawal reflex.
- To maintain balance and posture, contra-lateral extensor motor neurons are activated.

Withdrawal reflex

- Nociceptors send impulse trains along afferent fibers having parent posterior root ganglion somas. The impulses ascend and descend via Lissauer's tract to activate adjacent segments. Lateral spinothalamic tract neurons relay inputs from Lissauer's tract to cortex.
- Flexor relfex internuncials in the base of the posterior horn are activated by primary nociceptive afferents. Axons of medially placed internuncials cross the midline in the gray commisure to activate contralateral internuncials.

Withdrawal reflex

- α and γ motor neurons contract flexors. (In the lower limb, ipsilateral inhibitory internuncials silence antigravity motor neurons.
- In the lower limb, as posture must be maintained though withdrawal is activated, α and γ neurons on contralateral side contract gluteus maximus and quadriceps femoris.)

Motor function

Muscle	Main Root	Peripheral Nerve	Main Action
Diaphragm	C3, C4	Phrenic	Respiration
Supraspinatus	C5	Suprascapular	Abduction of arm
Infraspinatus	C5	Suprascapular	External rotation of arm at shoulder
Deltoid	C5	Axillary	Abduction of arm
Biceps	C5, C6	Musculocutaneous	Flexion of forearm
Brachioradialis	C5, C6	Radial	Flexion of forearm
Extensor carpi radialis longus	C6, C7	Radial	Wrist extension
Flexor carpi radialis	C6, C7	Median	Wrist flexion
Extensor carpi ulnaris	C7	Radial	Wrist extension
Extensor digitorum	C7	Radial	Finger extension
Triceps	C8	Radial	Extension of forearm

Motor function

Muscle	Main Root	Peripheral Nerve	Main Action
Flexor carpi ulnaris	C8	Ulnar	Wrist extension
Abductor pollicis brevis	T1	Median	Abduction of thumb
Opponens pollicis	T1	Median	Opposition of thumb
First dorsal interosseous	T1	Ulnar	Abduction of index finger
Abductor digiti minimi	T1	Ulnar	Abduction of little finger
Iliopsoas	L2, L3	Femoral	Hip flexion
Quadriceps femoris	L3, L4	Femoral	Knee extension
Adductors	L2, L3, L4	Obturator	Adduction of thigh
Gluteus maximus	L5, S1, S2	Inferior gluteal	Hip extension
Gluteus medius and minimus, tensor fasciae latae	L4, L5, S1	Superior gluteal	Hip abduction

Motor function

Muscle	**Main Root**	**Peripheral Nerve**	**Main Action**
Hamstrings	L5, S1	Sciatic	Knee flexion
Tibialis anterior	L4, L5	Peroneal	Dorsiflexion of ankle
Extensor hallucis longus	L5	Peroneal	Dorsiflexion of great toe
Extensor digitorum longus	L5, S1	Peroneal	Dorsiflexion of toes
Extensor digitorum brevis	S1	Peroneal	Dorsiflexion of toes
Peronei	L5, S1	Peroneal	Eversion of foot
Tibialis posterior	L4	Tibial	Inversion of foot
Gastrocnemius	S1, S2	Tibial	Plantar flexion of ankle
Soleus	S1, S2	Tibial	Plantar flexion of ankle

Superficial reflexes

- Upper abdomen: T_7-T_9
- Lower abdomen: T_{10}-T_{11}
- Cremasteric: T_{12}-L_2
- Plantar: L_4-S_2
- Anal wink: S_2-S_4

Proprioception

- Input from muscle spindle, Golgi tendon organ, and joint receptors are perceived in Brodmann areas 3a and 2. Those from cutaneous receptors are perceived in areas 3b and 1.
- Loss of texture discrimination is associated with a lesion of Brodmann area 1; stereognosis, 2. Both are lost if a lesion of 3b.
- The secondary somatosensory cortex (Brodmann area 7) receives input from the ipsilateral primary sensory cortex and the ventral postero-inferior thalamic nucleus. Supplied by the middle cerebral artery.

Proprioception

- Input from muscle spindle, Golgi tendon organ, and joint receptors are perceived in cerebral areas 3a and 2. Those from cutaneous receptors are perceived in areas 3b and 1.
- Loss of texture discrimination is associated with a lesion of Brodmann area 1; stereognosis, 2. Both are lost if a lesion of 3b.
- The secondary somatosensory cortex (area 7) receives input from the ipsilateral primary sensory cortex and the ventral postero-inferior thalamic nucleus. Supplied by the middle cerebral artery.

Proprioception

- Area 5 and the lateral portion of area 7 (7b) receives input from the ipsilateral primary sensory cortex and the pulvinar thalami. Lesions include agnosia (contralateral part is lost from the personal body map).
- Nociceptors respond to intense stimuli that have the potential to damage the tissue. Non-discriminative. Lesions may be noted as paresthesia.
- Free nerve endings of Aδ or C fibers are located in the heart, respiratory system, gastrointestinal and genitourinary systems.

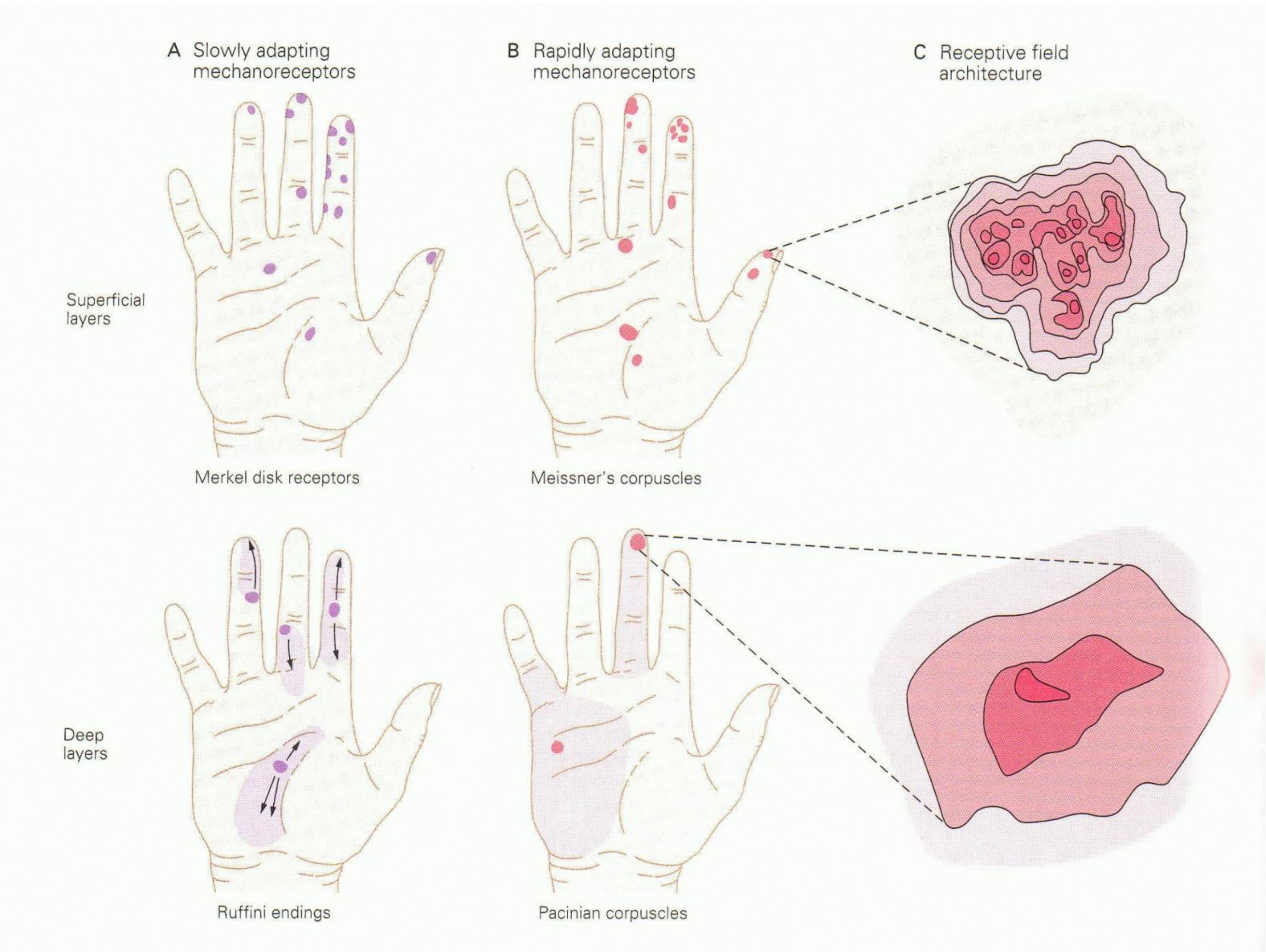
Proprioception

- Physiologic receptors respond to innocuous stimuli as well as mediate normal reflexes.
- **Rapidly adapting mechanoreceptors s**ignal dynamic events like the sudden changes of pressure or movement. Aβ fibers.
- Found in the organs of thoracic, abdominal and pelvic cavities.
- In the skin, Meissner's corpuscles and hair follicle receptors are tactile receptors. In the airways the cough receptors are tactile as well, sensitive for inhaled particles. Non-encapsulated. Superficial location.
- Largest receptor is the Paccinian corpuscle (vibration).

Proprioception

- **Slowly adapting mechanoreceptors**
- Signal stretch and tension in the organs. Typically encapsulated. Aβ fibers.
- Located in the superficial skin and subuctaneous tissues, the muscle layer of the airways, and the hollow abdominal and pelvic viscera. Essential for the perception of fullness.
- Internal thermo-receptors
- Merkel's disks and Paccini endings respond to pressure. Maximal sensitivity over the site of the receptor.
- **Specialized receptors** include baroreceptors, chemoreceptors, and osmoreceptors.

Proprioception



Source: Kandel ER, Schwartz JH, Jessell TM, *Principles of Neural Science 4th edition*
Fig. 22-3. Accessed 04/04/2011

Muscle spindles

- Two types of fibers are present in the spindle. One is a nuclear bag and the other is a nuclear chain.
- Each spindle has two bag fibers (one static and one dynamic) and five chain fibers.
- The central portion is non-contractile and is the receptor portion.
- The distal portion of each spindle has striated fibers and is contractile.

Muscle spindles

- Spindles are aligned in parallel to the extrafusal fibers of the muscle; the receptors are in series.
- Tension in the receptor portion can be increased by contraction of the extrafusal fibers.
- Tension can be applied to the sensory portion by contraction of the contractile portion of the spindle (intrafusal fiber).
- Dynamic, kinesthetic as are Golgi tendon organs.

Muscle spindles

- One-third of motor fibers are γ-fibers.
- With isotonic contraction the spindles are unresponsive; this interferes with commands to change muscle length.
- With activation of γ-fibers, the spindle contracts, leading to an increase in Ia and II firing with increased activity in alpha fibers and resulting muscle contraction.
- Activation of gamma motor neurons can be used to define a new baseline for the muscle (alter muscle tone).

Golgi tendon organs

- Golgi tendon organs are not entirely restricted to tendons.They are composed of a network of collagen fibers intertwined with naked sensory endings (Ib axons). Receptors are arranged in series.
- Contraction of the spindles makes them more sensitive . Stimulation of dynamic gamma neurons makes the Ia more sensitive to rate; stimulation of static gamma neurons makes the Ia mores sensitive to absolute length.

Golgi tendon organs

- When the spindle shortens, the activity of Ia fibers decreases until it reaches a new steady state (with loss of this afferent information, movements become jerky).
- Stretching results in a depolarization of nuclear bag and chain fibers; increased activity along Ia and II axons
- In the spinal cord, some the these primary sensory axons influence α-motor neurons. Some circuits are intrinsic to the spinal cord (muscle stretch reflex, walking patterns).

Golgi tendon organs

- Activation of α-motor neurons and subsequent contraction of involved muscle is a monosynaptic pathway (Ia to the α-motor neuron). The resulting contraction is of the same muscle at the same time. Antagonistic muscles are inhibited.
- The stretch causes a contraction to oppose the stretch. Group II axons are minimally stimulated. The group Ib axons from the Golgi tendon organs innervate inhibitory interneurons in the spinal cord.

Golgi tendon organs

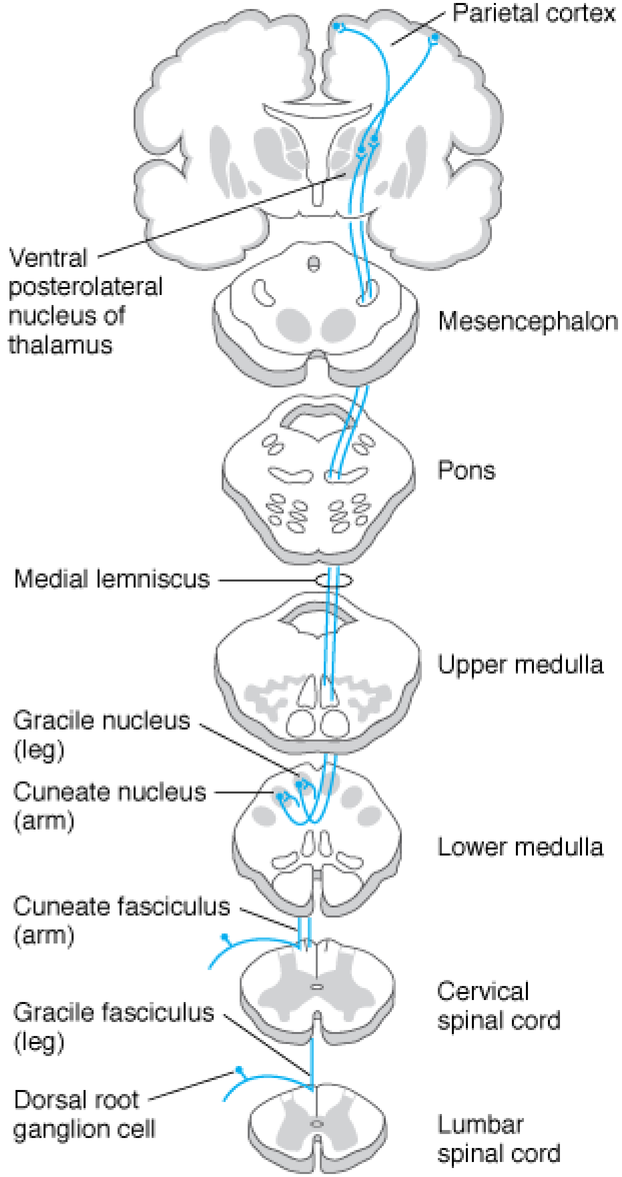
- Applying (excess) tension to the muscle activates the organ and produces an increase in the activity of Ib axons.
- A stretch during muscle contraction indicates excessive load. This activates the Golgi tendon organ. The result is inhibition of synergistic muscles and facilitation of antagonistic muscles. This functions to distribute load evenly over several motor units.
- Kinesthetic, dynamic, as are muscle spindles.

Touch, temperature, pain

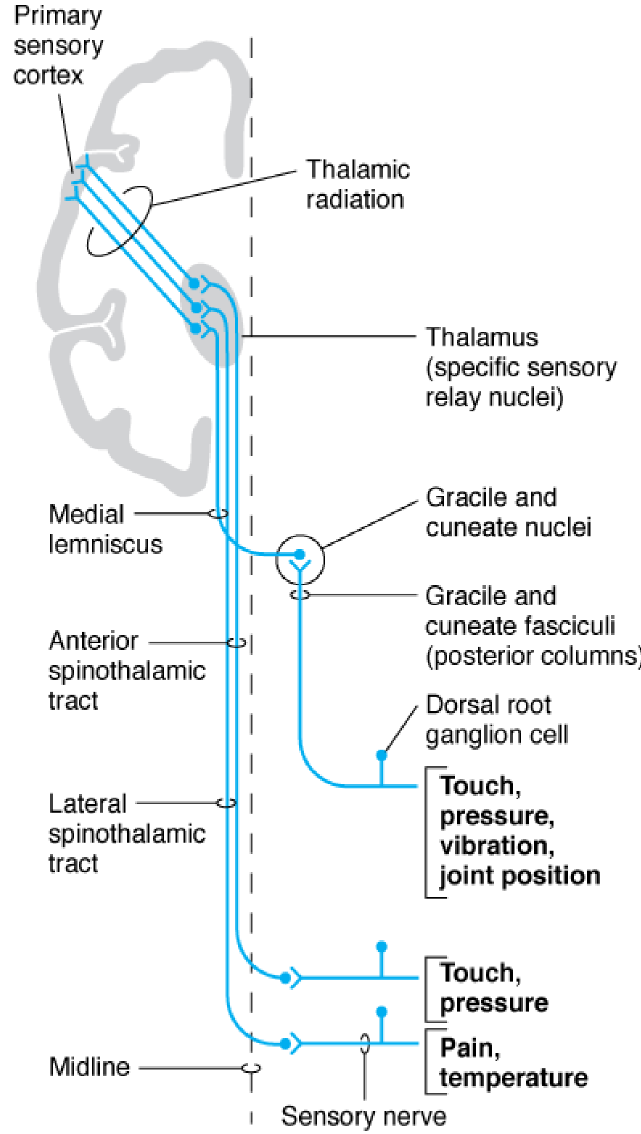
- Discriminative touch involves reception of sensation from the limb via the nucleus gracilis (leg) or cuneatus (arm) crossing at the medullo-cervical junction and ascending via the medial lemniscus to the thalamus and parietal sensory cortex and post-central gyrus.
- Non-discriminative touch as well as temperature and pain involve reception of sensation from the limb and ascending (uncrossed) via the lateral funiculus to the thalamus and parietal sensory cortex and post-central gyrus.

Pain

- The anterior insula is the cortical center for pain. The central region is continuous with the frontoparietal and temporal opercular cortex. It appears to have a language function (silent in those with congenital dyslexia).
- The posterior insula is interconnected with the entorhinal cortex and the amygdala and is thought to function in the evaluation of the pain stimulus and intensity.
- Acupuncture diminishes activity in the anterior insula bilaterally as well as in contralateral primary somatosensory cortex, ipsilateral sensorimotor cortex, and contralateral supplementary motor cortex, relieving pain.

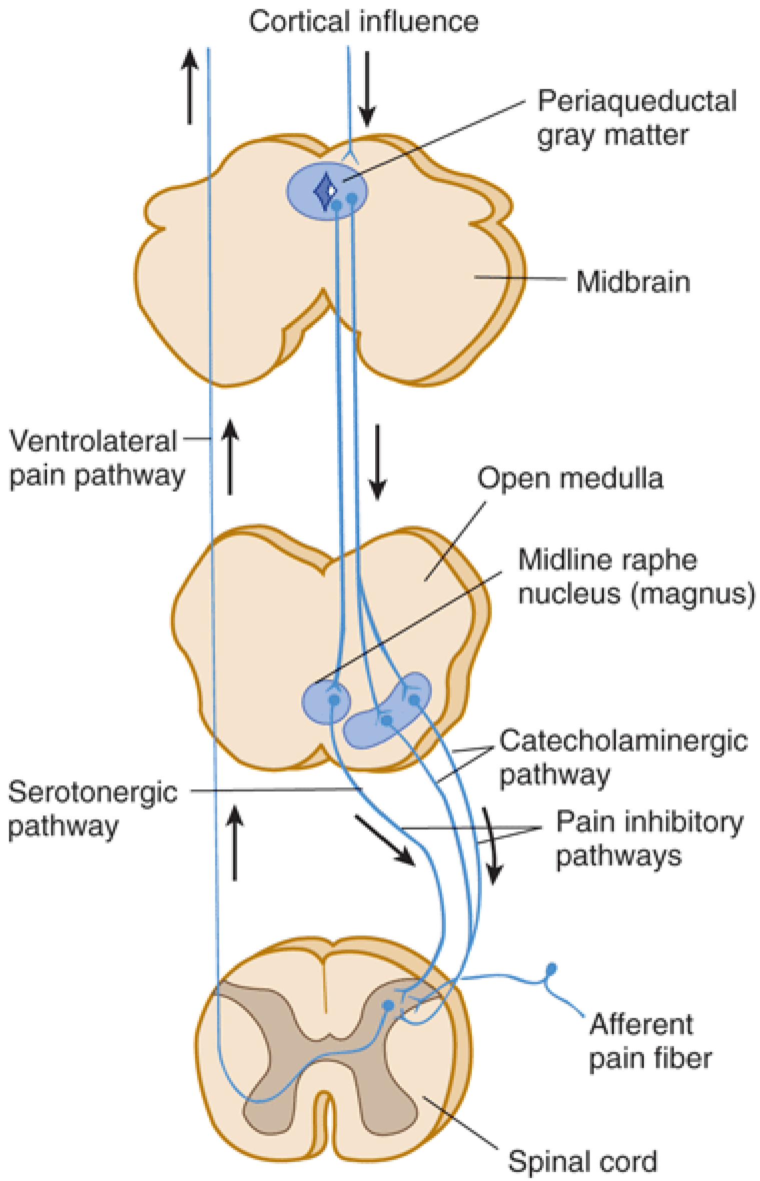


Source: Simon RP, Greenberg DA, Aminoff MJ: *Clinical Neurology, 7th Edition*: http://www.accessmedicine.com



Source: Simon RP, Greenberg DA, Aminoff MJ: *Clinical Neurology, 7th Edition*: http://www.accessmedicine.com

Figs. 3-5 and 6-1
Accessed 07/01/2010



Source: Waxman SG: *Clinical Neuroanatomy, 26th Edition*: http://www.accessmedicine.com

Pathways involved in pain control.

(Courtesy of Al Basbaum.)

Fig. 14-6 Accessed 07/01/2010

Opioid receptor subtypes

Receptor subtype	**Functions**	**Endogenous opioid peptide affininity**
μ (mu)	1. Supraspinal and spinal analgesia 2. Sedation and inhibition of respiration 3. Slow GI transit 4. Modulation of hormones and neurotransmitter release	Endorphins > enkaphalins > dynorpnins
δ (delta)	1. Supraspinal and spinal analgesia 2. Modulation of hormones and neurotransmitter release	Enkaphalins > endorphins and dynorphins
κ (kappa)	1. Supraspinal and spinal analgesia 2. Slow GI transit 3. Psychomimetic effects	Dynorphins >> endorphins and enkaphalins

Mechanism of analgesia

- Opiod receptors are found in peripheral tissues, dorsal horn cells, peribrachial nuclei (afferent to amygdala), ventral thalamus, peri-acqueductal gray, and rostral ventral medulla.
- Inhibition of pre-synaptic voltage-gated Ca^{2+} channels with activation of post synaptic voltage-gated K^{+} channels.

Pain

- Visceral pain is poorly localized, lacks detailed point to point representation, because receptor density is low (receptor fields are large) and the input converges.
- Fibers from laminae I and V travel in the Antero-lateral system and end up in the Ventral posterolateral nucleus. Fibers from laminae VII and VIII travel in the spinoreticular tract and end up in the reticular formation.

Pain

- Reticuloreticular fibers form connections between the different parts of the reticular formation (interneurons).
- Reticulohypothalamic fibers travel through dorsal longitudinal fasciculus, mamillary peduncle and medial forebrain bundle (autonomic-endocrine connection).
- Reticulothalamic fibers project to the intralaminar nuclei of the thalamus to diverse areas of the cerebral cortex.

Referred pain

- Within the spinal gray matter the visceral afferent fibers and the somatic afferent fibers may synapse with the same interneuron. Follows embryologic distribution.
- This interneuron can fire and transmit pain sensation to the brain from both sources. Thus, unable to discriminate origin.

Nociception

- Nociceptive fibers from the abdominal and thoracic viscera travel via cardiac nerves and splanchnic nerves through the paravertebral ganglia and the white communicating branch.
- Nociceptive information from the pelvic viscera (e.g., prostate, sigmoid colon) runs through the hypogastric plexus and lumbar splanchnic nerves.
- Fibers enter the spinal cord at the level where the organ is located. Cell bodies are located in dorsal root ganglia of T1-L1. Central fibers terminate on the intermediolateral column T1-L2 (reflexes), and in the laminae.

Autonomic afferents

- 90% of the viscero-sensory fibers are unmyelinated or thinly myelinated (slow conduction).
- Splanchnic nerves course to white communicating branch T1-L2 to thoracic and upper lumbar spinal nerves. Run with sympathetic fibers.
- Cranial nerves IX and X and lower sacral spinal nerves run with parasympathetic fibers.
- Fibers associated with physiologic receptors (reflex control of the viscera, intestinal movements) travel primarily in parasympathetic nerves.

Autonomic afferents

- Fibers associated with nociceptors (visceral sensations such as abdominal pain) almost exclusively accompany sympathetic nerves.
- Visceral afferent fibers from peripheral blood vessels travel centrally in all spinal nerves.
- The phrenic nerve also contains visceral afferent fibers from pericardium, diaphragm, hepatic ligaments and capsule, pancreas, and suprarenal glands.
- All viscero-sensory neurons are pseudo-unipolar with cell bodies in the sensory ganglia (dorsal root ganglia or sensory cranial nerve ganglia).

Parasympathetic innervation

- The anterior and posterior vagal nerves enter the abdomen at the esophageal hiatus and distribute to the pulmonary and cardiac plexi along the aorta.
- The vagus nerve is preganglionic and synapses with postganlionic cell bodies in the walls of the organs. The vagus nerve supplies the gastrointestinal tract to the splenic flexure. Activation increases peristalsis, increases secretion.
- Activation of stretch receptors in the wall of the gut (afferent information) return to the brain via the vagus nerve.

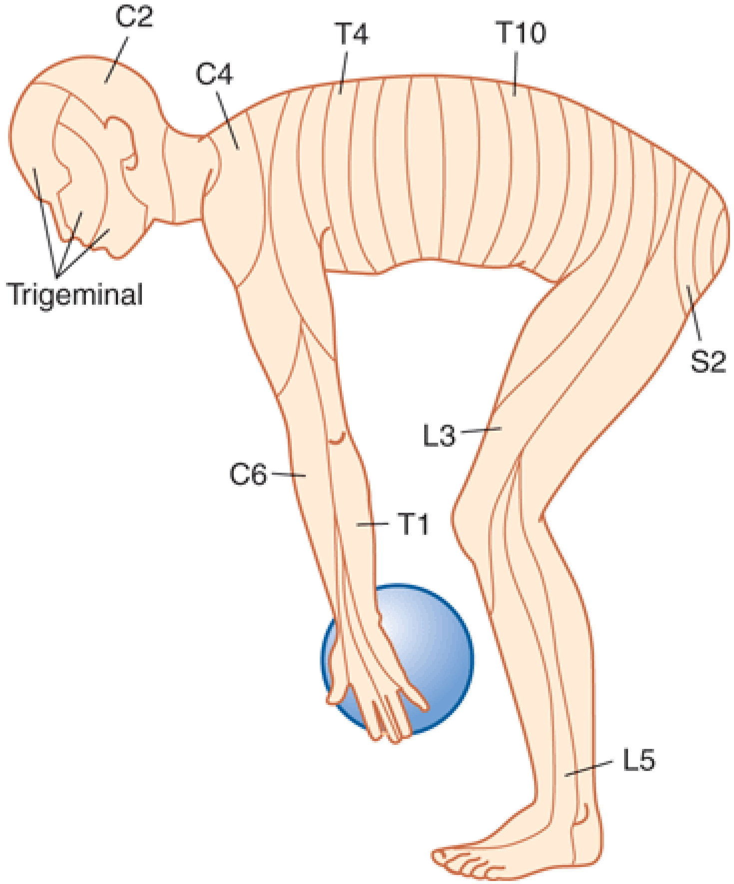
Parasympathetic innervation

- The descending colon, sigmoid, and rectum are innervated by pelvic sphanchnics (S2-S4) which enter the abdomen by ascending behind the rectum through the sigmoid mesocolon to reach the splenic flexure.

Mechanism of analgesia

- Opiod receptors are found in peripheral tissues, dorsal horn cells, peribrachial nuclei (afferent to amygdala), ventral thalamus, peri-acqueductal gray, and rostral ventral medulla.
- Inhibition of pre-synaptic voltage-gated Ca^{2+} channels with activation of post synaptic voltage-gated K^{+} channels.

Dermatomes



Source: Waxman SG: *Clinical Neuroanatomy, 26th Edition*: http://www.accessmedicine.com

Fig. 5-8 Accessed 07/01/2010

Because in many patients there is no C1 dorsal root, there is no C1 dermatome (when a C1 dermatome does exist as an anatomic variant, it covers a small area in the central part of the neck, close to the occiput).

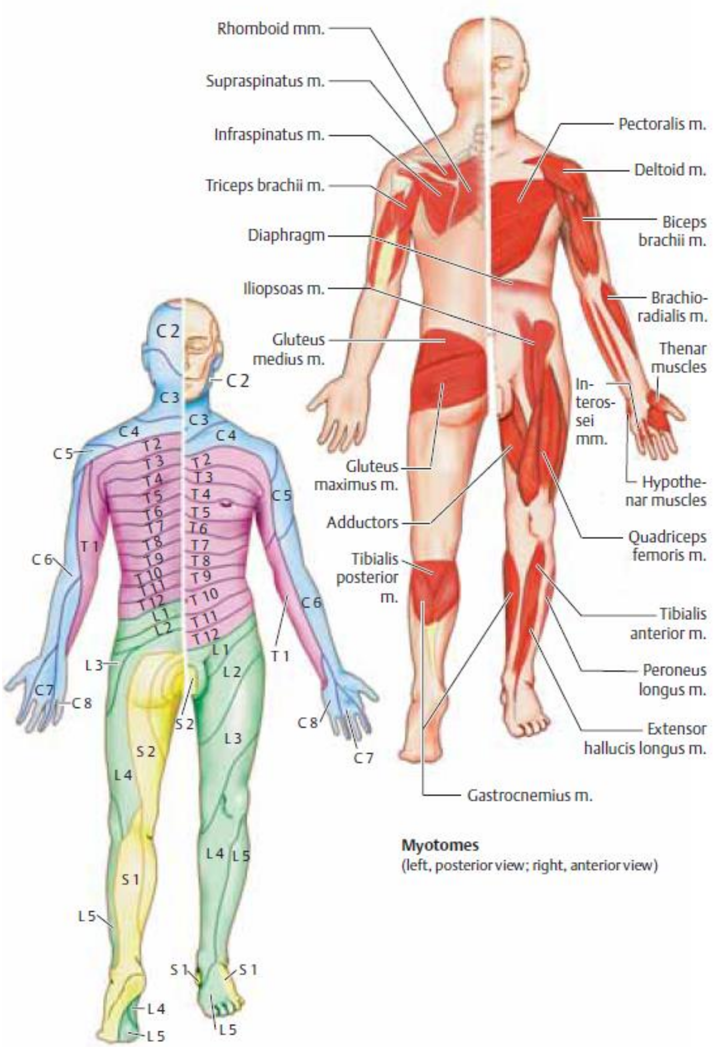
The dermatomes for C5, C6, C7, C8, and T1 are confined to the arm, and the C4 and T2 dermatomes are contiguous over the anterior trunk.

The thumb, middle finger, and fifth digit are within the C6, C7, and C8 dermatomes, respectively.

The nipple is at the level of T4.

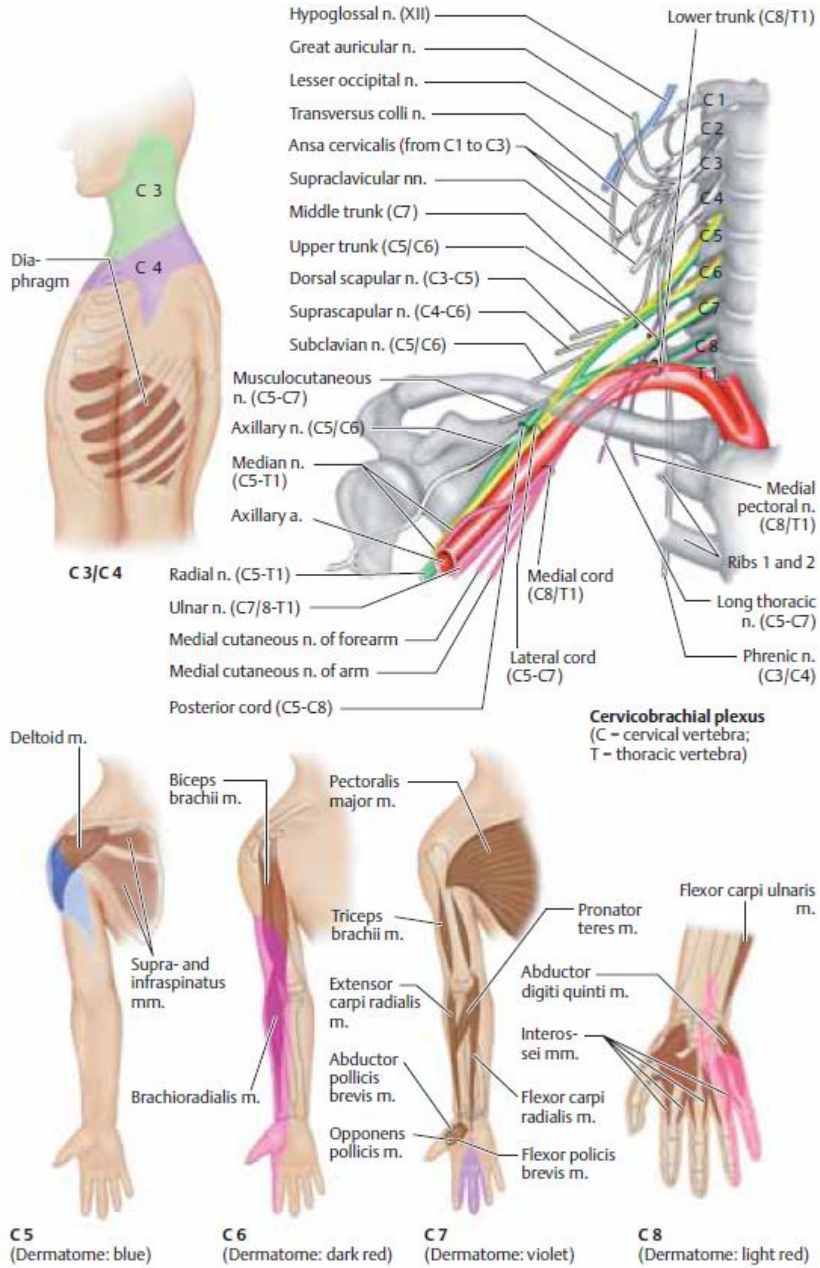
The umbilicus is at the level of T10.

Dermatomes and myotomes

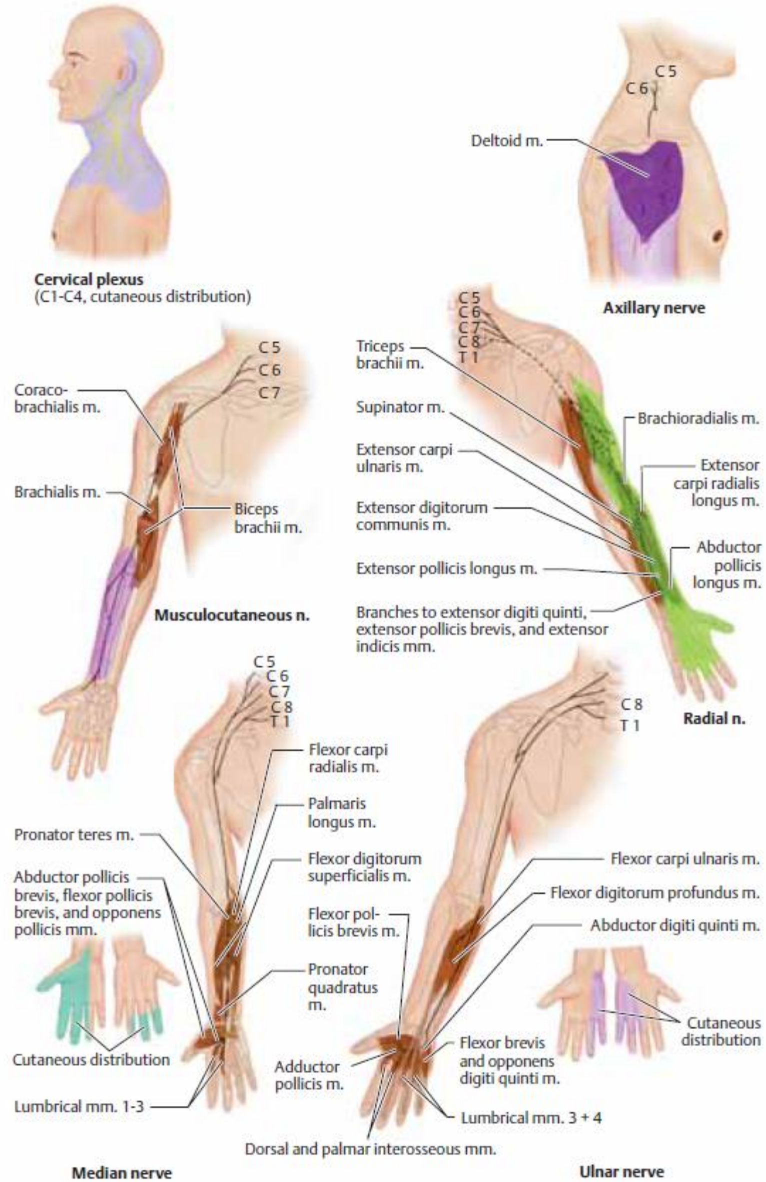


Myotomes
(left, posterior view; right, anterior view)

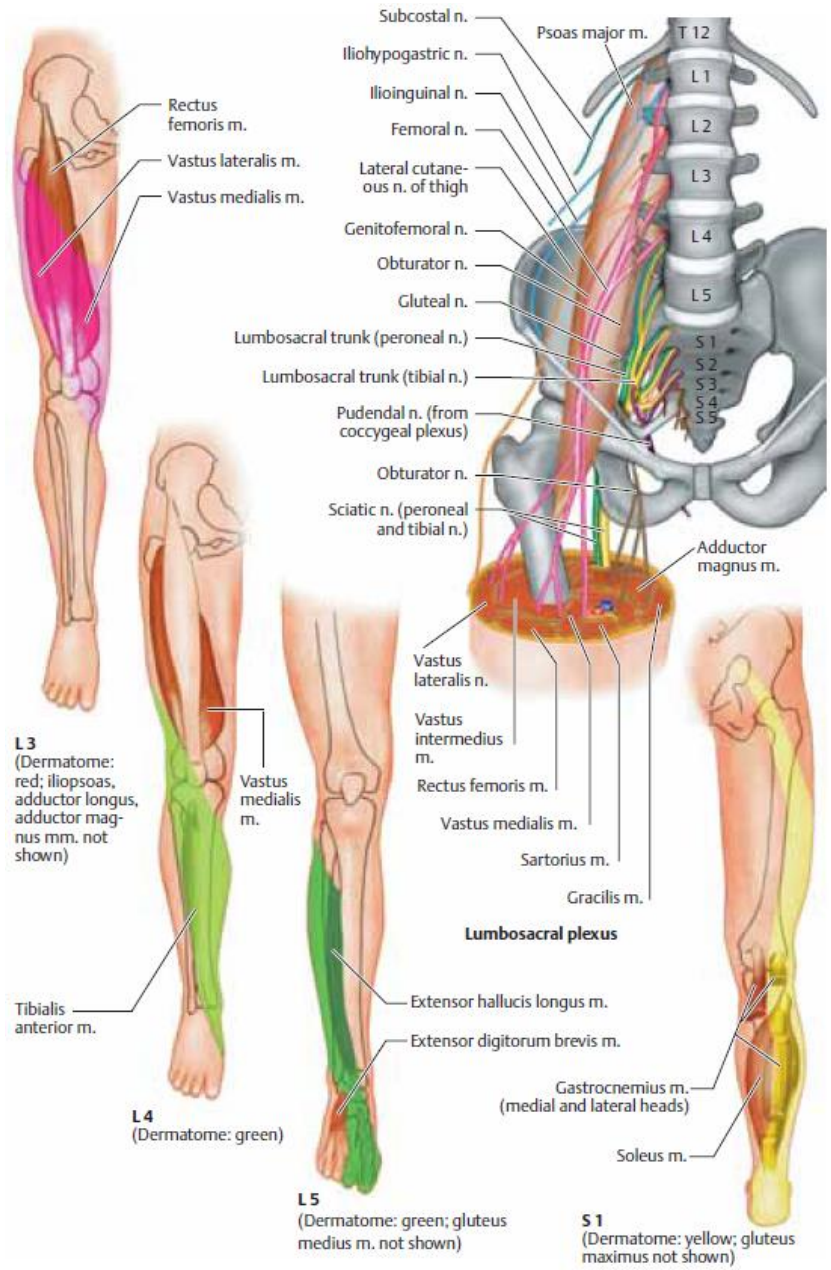
Dermatomes (left, posterior view; right, anterior view)



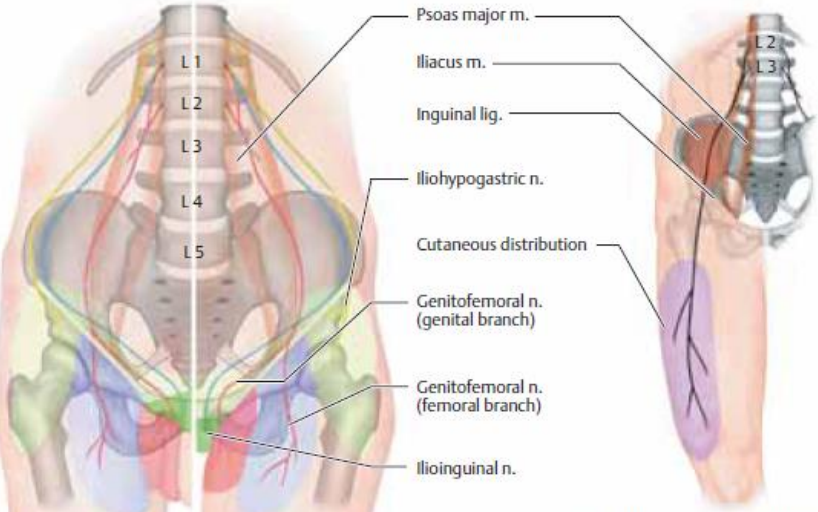
Cervicobrachial plexus
(C = cervical vertebra;
T = thoracic vertebra)



Cervical plexus
(C1-C4, cutaneous distribution)
C 5
C 6
Deltoid m.
Axillary nerve
C 5
C 6
C 7
Coraco-brachialis m.
Brachialis m.
Biceps brachii m.
Musculocutaneous n.
C 5
C 6
C 7
C 8
T 1
Triceps brachii m.
Supinator m.
Extensor carpi ulnaris m.
Extensor digitorum communis m.
Extensor pollicis longus m.
Branches to extensor digiti quinti, extensor pollicis brevis, and extensor indicis mm.
Brachioradialis m.
Extensor carpi radialis longus m.
Abductor pollicis longus m.
Radial n.
C 5
C 6
C 7
C 8
T 1
Flexor carpi radialis m.
Palmaris longus m.
Pronator teres m.
Flexor digitorum superficialis m.
Abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis mm.
Flexor pol-licis brevis m.
Pronator quadratus m.
Cutaneous distribution
Adductor pollicis m.
Lumbrical mm. 1-3
Median nerve
C 8
T 1
Flexor carpi ulnaris m.
Flexor digitorum profundus m.
Abductor digiti quinti m.
Flexor brevis and opponens digiti quinti m.
Cutaneous distribution
Lumbrical mm. 3 + 4
Dorsal and palmar interosseous mm.
Ulnar nerve

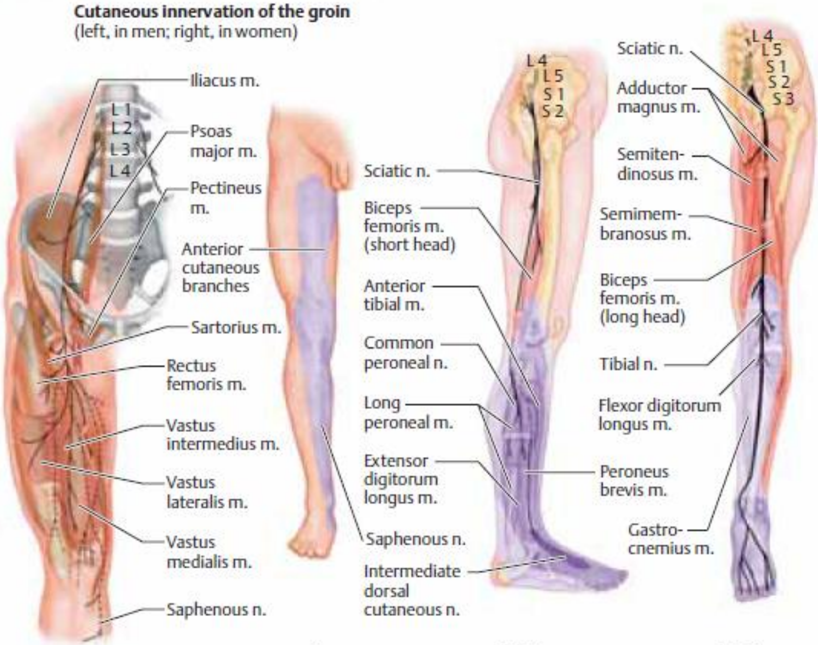


Subcostal n.
Iliohypogastric n.
Ilioinguinal n.
Femoral n.
Lateral cutaneous n. of thigh
Genitofemoral n.
Obturator n.
Gluteal n.
Lumbosacral trunk (peroneal n.)
Lumbosacral trunk (tibial n.)
Pudendal n. (from coccygeal plexus)
Obturator n.
Sciatic n. (peroneal and tibial n.)
Psoas major m.
T 12
L 1
L 2
L 3
L 4
L 5
S 1
S 2
S 3
S 4
S 5
Adductor magnus m.
Vastus lateralis n.
Vastus intermedius m.
Rectus femoris m.
Vastus medialis m.
Sartorius m.
Gracilis m.
Lumbosacral plexus
Rectus femoris m.
Vastus lateralis m.
Vastus medialis m.
L 3
(Dermatome: red; iliopsoas, adductor longus, adductor magnus mm. not shown)
Vastus medialis m.
Tibialis anterior m.
L 4
(Dermatome: green)
Extensor hallucis longus m.
Extensor digitorum brevis m.
L 5
(Dermatome: green; gluteus medius m. not shown)
Gastrocnemius m. (medial and lateral heads)
Soleus m.
S 1
(Dermatome: yellow; gluteus maximus not shown)



Lateral cutaneous n. of thigh

Cutaneous innervation of the groin
(left, in men; right, in women)



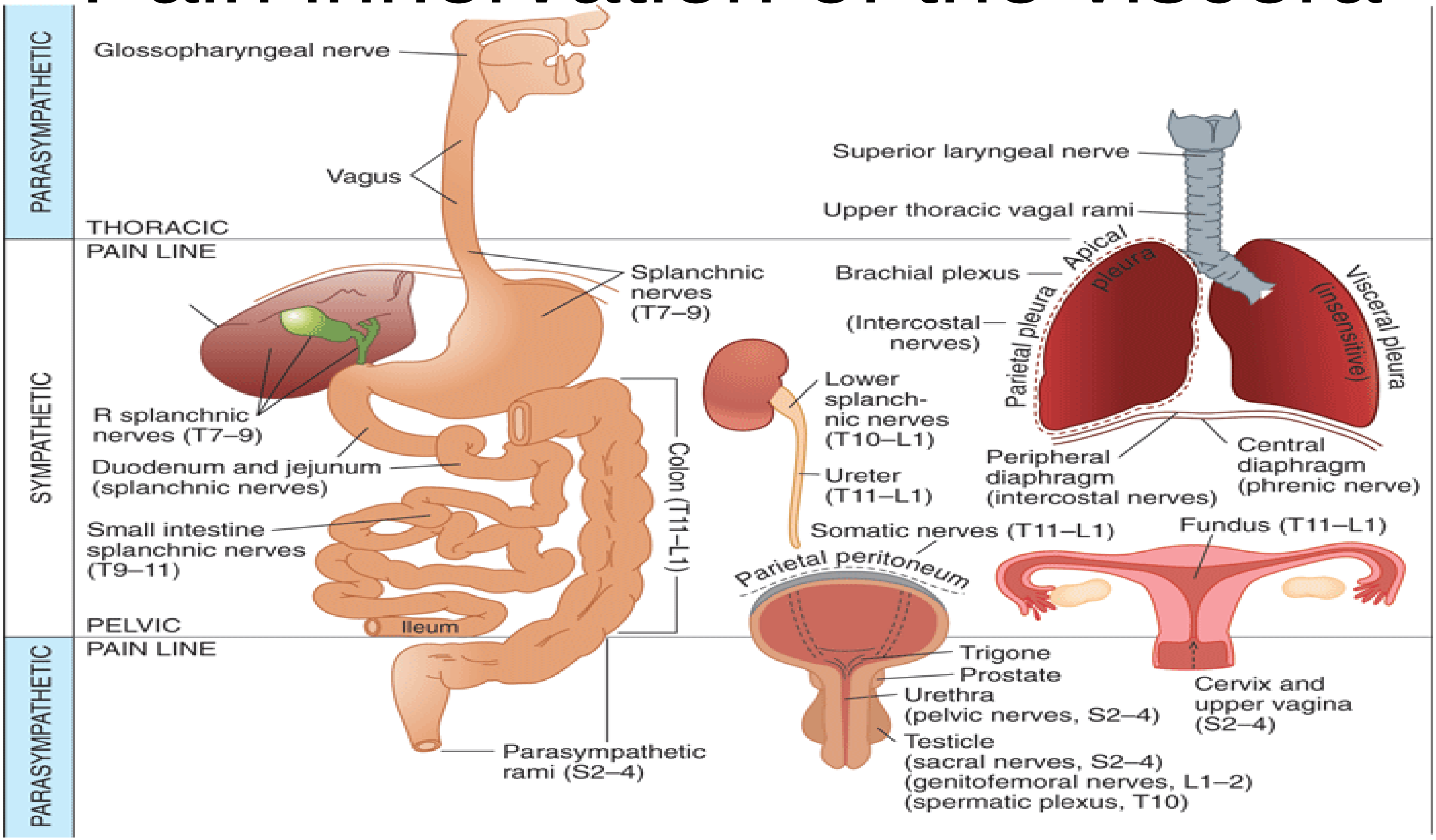
Femoral nerve

Femoral nerve
(cutaneous distribution)

Sciatic nerve, peroneal nerve
(purple: cutaneous distribution)

Sciatic nerve, tibial nerve
(purple: cutaneous distribution)

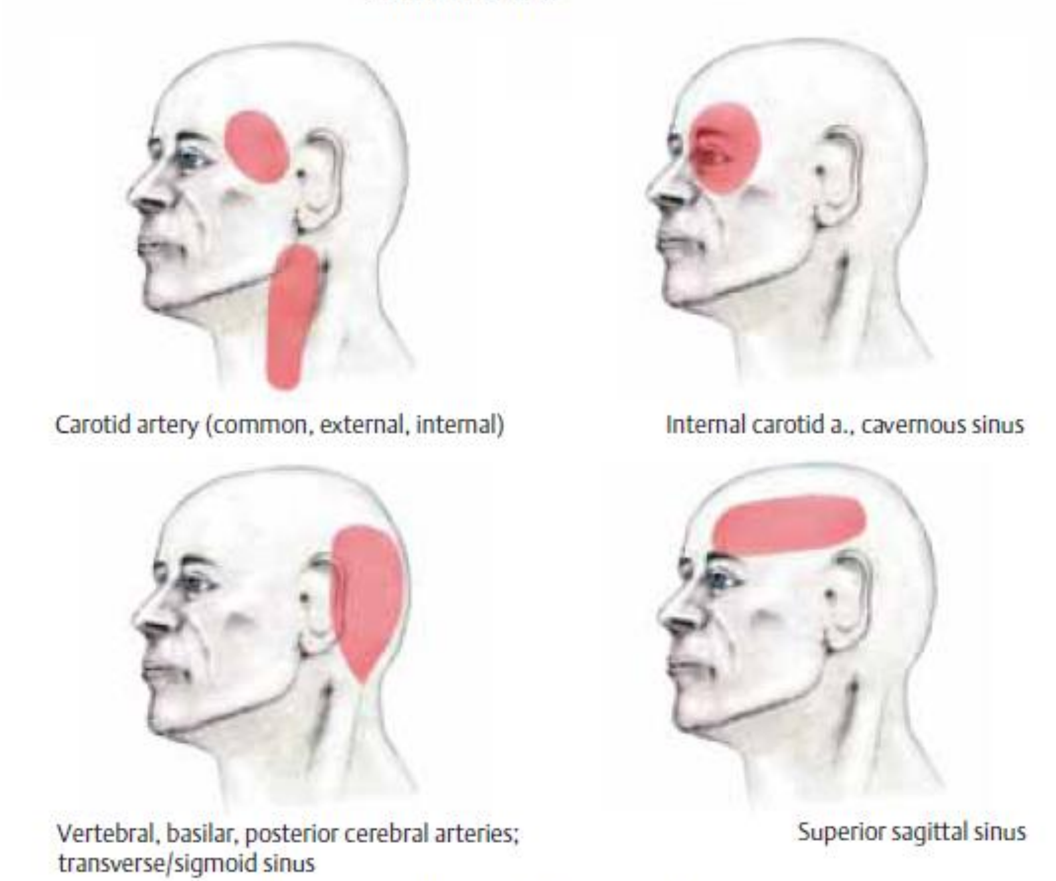
Pain innervation of the viscera



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

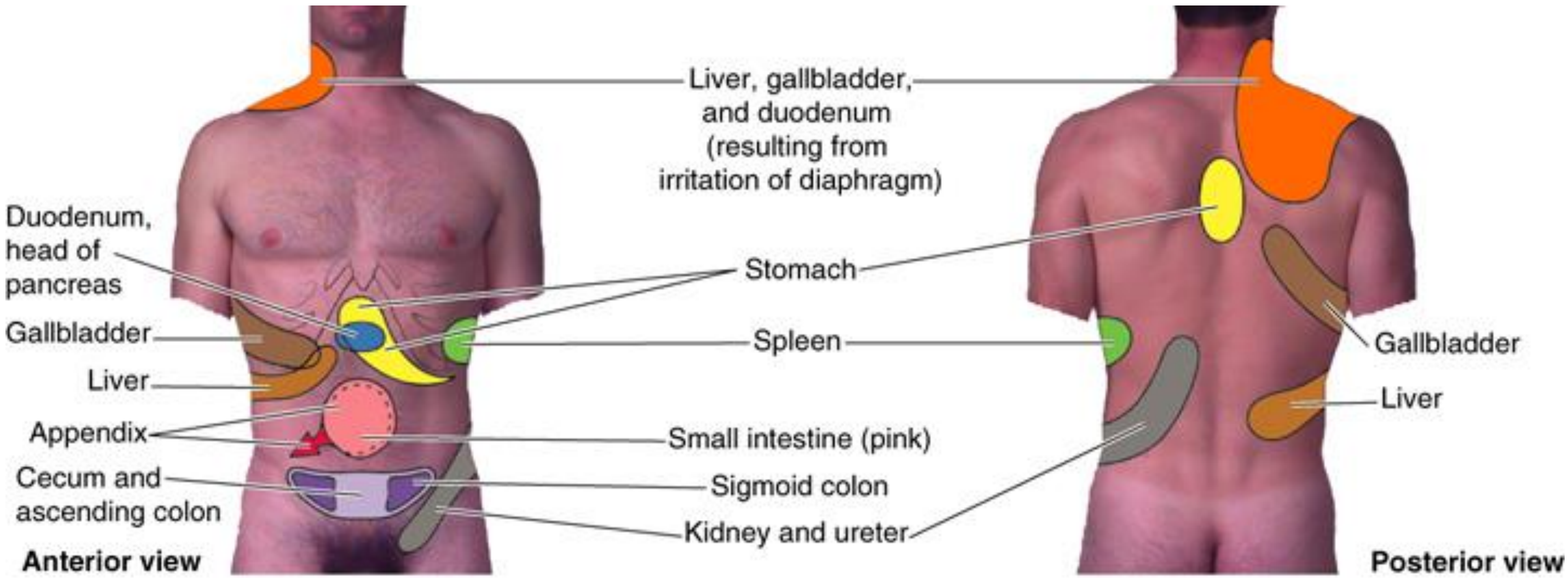
(After White JC. Reproduced with permission from Ruch TC: In *Physiology and Biophysics,* 19th ed. Ruch TC, Patton HD (editors). Saunders, 1965.) Fig. 10-2 Accessed 07/01/2010

Referred pain

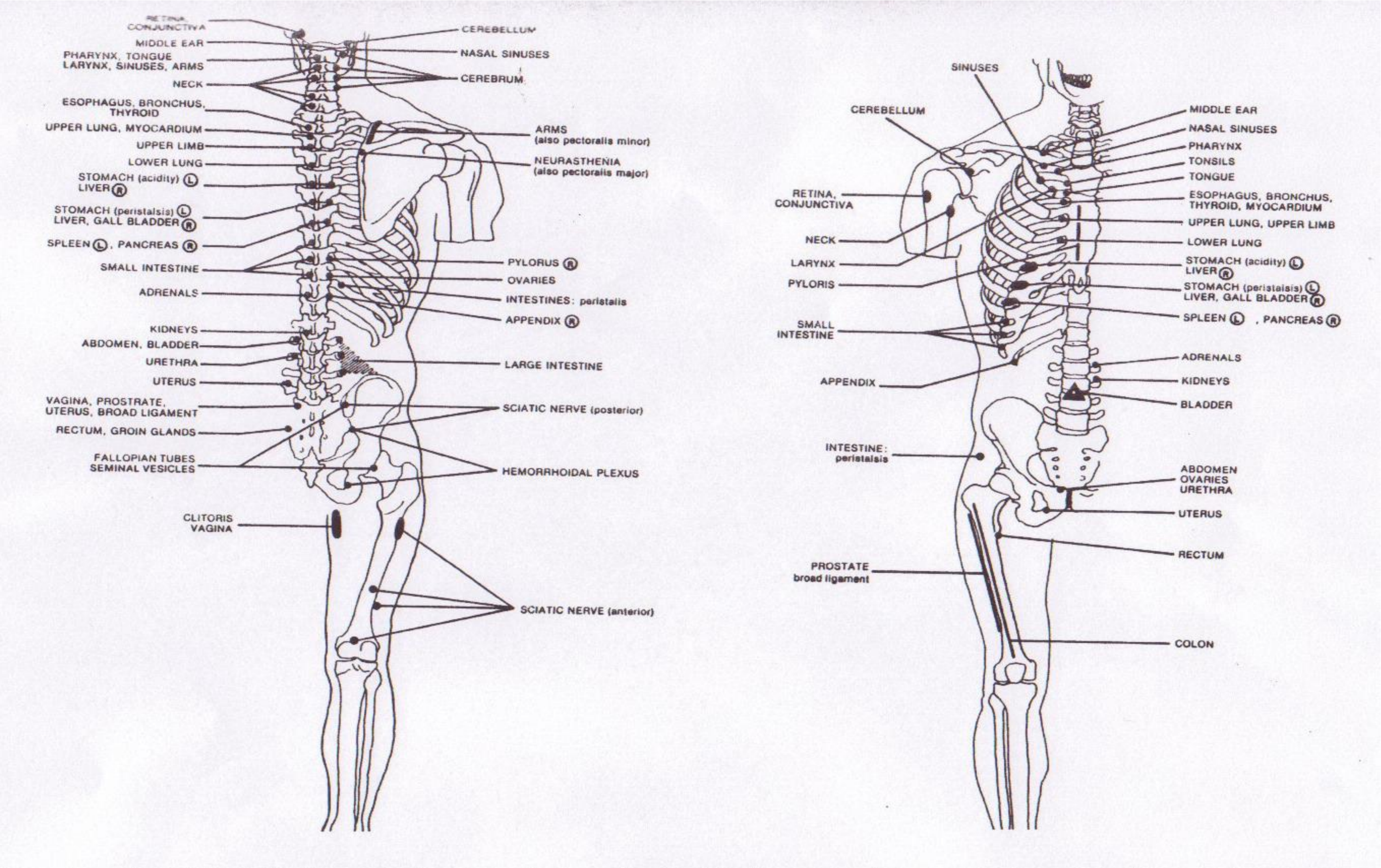


Referred pain due to cerebrovascular lesions

Referred abdominal pain



Chapman reflex points



Chapman's reflex points

- Smooth, firm, discretely palpable nodules 2-3mm in diameter located within deep fascia or on the periosteum of a bone.
- May represent viscerosomatic reflexes (empirical evidence only)

Reflex Point	Location
Appendix	At tip of the right 12^{th} rib
Adrenals	2 inches superior and 1 inch lateral to the umbilicus and/or the spinous process of T11
Kidneys	1 inch superior and 1 inch lateral to the umbilicus and/or the spinous process of L1
Bladder	At the umbilicus
Colon	Along the femur

Chapman's reflex points

Posterior	**Reflex point**
OA laterally	Cerebellum
OA mid-lateral	Middle ear
C2 adjacent to spinous process	Pharynx, tongue, larynx, sinuses
C3-5 adjacent to spinous process	Cerebrum
C3-4 and C6-7 adjacent to spinous process	Neck

Chapman's reflex points

Posterior	Reflex point
T1 adjacent to transverse process	Esophagous, bronchus, thyroid
T2 adjacent to transverse process (apex)	Upper lung
T3 adjacent to transverse process (base)	Lower lung
T4 adjacent to spinous process (base, left)	Stomach (acidity)
T4 adjacent to transverse process (base, right)	Liver
T5 adjacent to spinous process (base, left)	Stomach (peristalsis
T5 adjacent to transverse process (base, right)	Liver, gallbladder
T6 adjacent to spinous process (base, left)	Spleen
T6 adjacent to transverse process (base, right)	Pancreas
T7-9 adjacent to spinous process (base, left)	Small intestine
T8 adjacent to transverse process (base, right)	Pylorus
T9 adjacent to transverse process (base, right)	Ovaries
T11 adjacent to spinous process	Adrenals

Chapman’s reflex points

Posterior	**Reflex point**
L1 adjacent to spinous process	Kidneys
L2 adjacent to transverse process	Bladder
L3 adjacent to transverse process	Urethra
L4 adjacent to transverse process	Uterus
L2-4 adjacent to transverse process and extending to iliac crest	Colon
L5 at junction with sacrum	Prostate
Posterior superior iliosacral joint	Fallopian tubes (women) or seminal vesicles (men)
Posterior inferior iliosacral joint	Rectum

Chapman’s reflex points

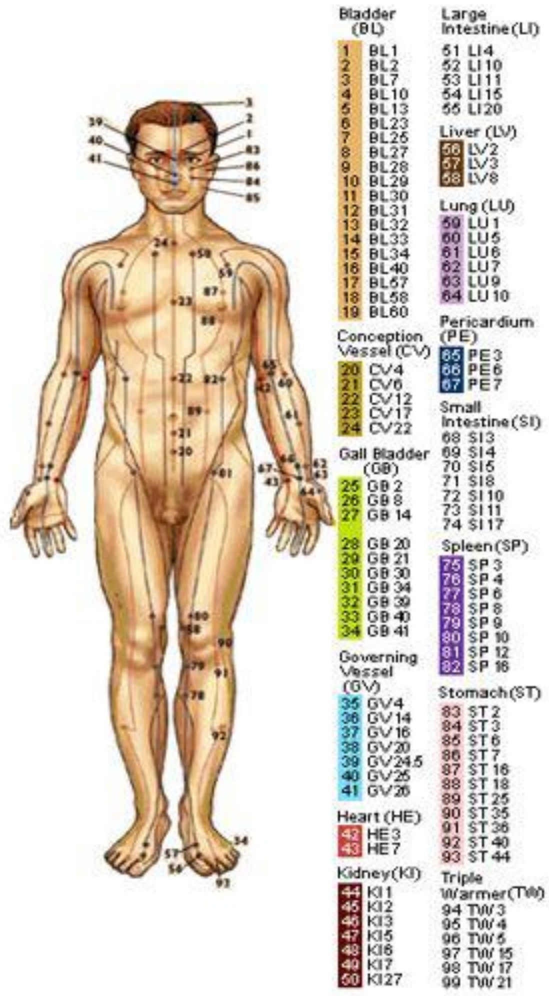
Anterior	Reflex point
Clavicle lateral to claviculosternal junction (superior)	Middle ear
Clavicle lateral to claviculosternal junction (inferior)	Nasal sinuses
At the the claviculosternal junction	Tonsils
At the junction of the sternum and second rib (superior)	Tongue
At the junction of the sternum and second rib (inferior)	Esophagous, bronchus, thyroid
At the junction of the sternum and third rib (inferior)	Upper lung
At the junction of the sternum and fourth rib (inferior)	Lower lung
At the fifth costochondral junction (left)	Stomach (acidity)

Chapman's reflex points

Anterior	**Reflex point**
At the fifth costochondral junction (right)	Liver
At the sixth costochondral junction (left)	Stomach (peristalsis)
At the sixth costochondral junction (right)	Liver, gallbladder
At the seventh costochondral junction (left)	Spleen
At the seventh costochondral junction (right)	Pancreas
At the costochondral junction of 8-11	Small intestine
At the tip of rib 11 (right)	Appendix
Tenderness at the lateral aspect of the humeral head as well as the occiput behind and blow the ear	Retina, conjunctiva
Tenderness along the lateral aspect of the femur	Prostate (men) or broad ligament (women)
Upper inner aspect of thigh	Clitoris, vagina

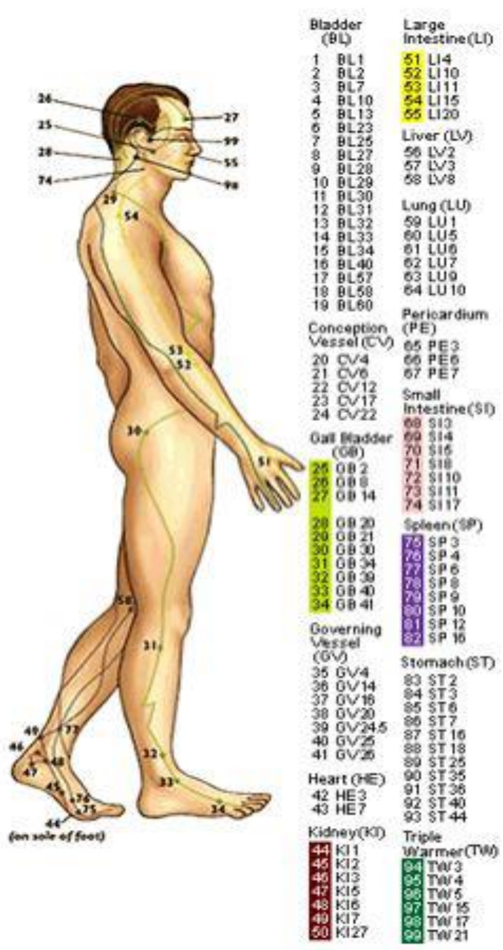
Acupuncture points and meridians

Figure 1a



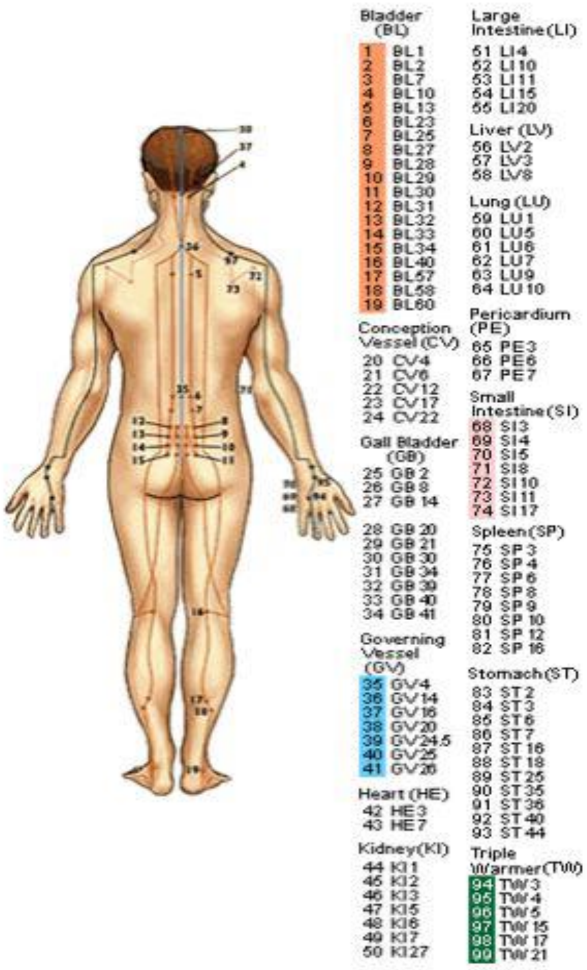
Acupuncture points and meridians

Figure 1b



Acupuncture points and meridians

Figure 1c



Solar reflex points