Classification of Sensory Receptors

Classes of mechanoreceptors (**Figure 13.12**):

- **Merkel cell fibers** consist of a nerve ending surrounded by a capsule of **Merkel cells**
  - Found in floors of *epidermal ridges*, primarily in skin of *hands* (especially *fingertips*)
  - Action potentials appear to stem from **mechanically gated ion channels** in the nerve ending
  - Slowly adapting receptors, have the finest special resolution of any of the skin mechanoreceptors, primarily detect *discriminative touch stimuli* such as form and texture.

Classification of Sensory Receptors

Classes of mechanoreceptors (continued):

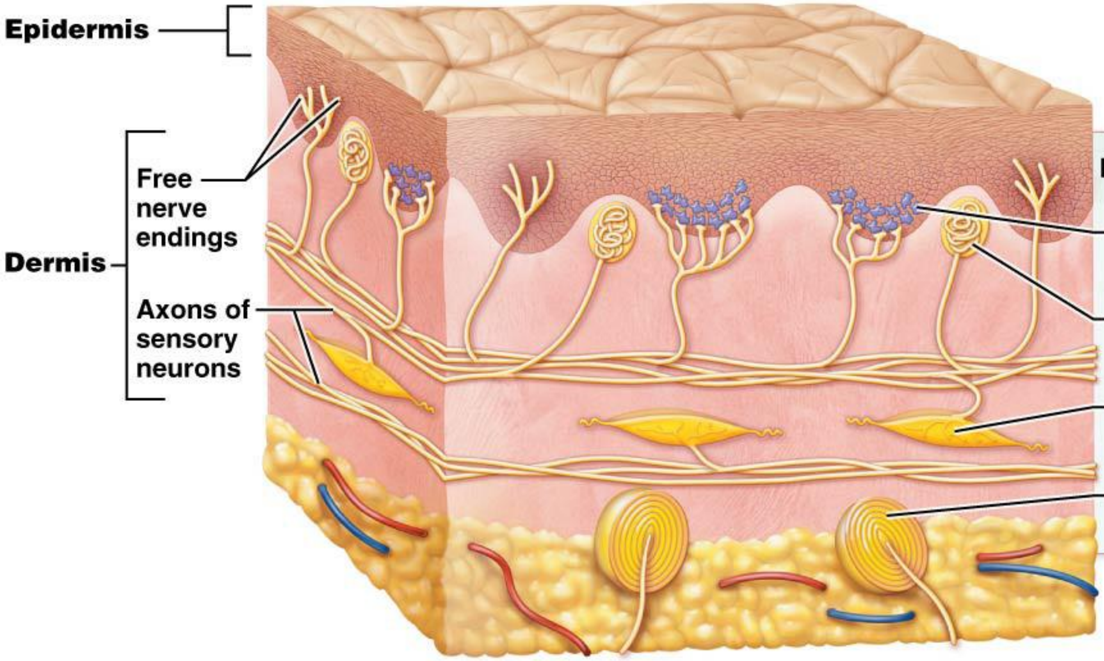
- **Tactile corpuscles** (**Meissner corpuscles**) – in *dermal papillae*; rapidly adapting receptors; more numerous than Merkel cell fibers, transmit *discriminative touch stimuli, although resolution is not as fine.*
- **Ruffini endings** (**bulbous corpuscles**) – receptors found in *dermis*, *hypodermis*, and *ligaments*; slowly adapting receptors respond to *stretch* and *movement*

Classification of Sensory Receptors

Classes of mechanoreceptors (continued):

- **Lamellated corpuscles** (**Pacinian corpuscles**) – layered onion-like appearance; rapidly adapting receptors found deep within *dermis*; detect *high-frequency vibratory* and *deep pressure stimuli*; example of **Structure-Function Core Principle**
- **Hair follicle receptors** – free nerve endings surrounding base of *hair follicles* found only in thin skin; respond to stimuli that cause hair to *bend*
- **Proprioceptors** – in musculoskeletal system; detect *movement* and *position* of a joint or body part

Classification of Sensory Receptors



MECHANORECEPTOR	FUNCTION
Merkel cell fiber	Discriminative touch with fine spatial resolution
Tactile corpuscle	Discriminative touch with less spatial resolution
Ruffini ending (bulbous corpuscle)	Stretch and movement
Lamellated corpuscle	Vibration and deep pressure

Figure 13.12 Mechanoreceptors in the skin.

Classification of Sensory Receptors

- **Types of thermoreceptors** – usually small knobs on end of free nerve endings in *skin, 2 types of thermoreceptors:*
  - "**Cold**" **receptors** – respond to temperatures between 10 °C and 40 °C (50–104 °F); in *superficial dermis*
  - "**Hot**" **receptors** – respond to temperatures between 32 °C and 48 °C (90–118 °F); *deep in dermis*
  - Temperatures <u>outside</u> these ranges are detected by *nociceptors*; reason extremes of temperature are interpreted as pain

Sensory Neurons

- Somatic sensory neurons are *pseudounipolar neurons* with three main components (**Figure 13.13**):
  - **Cell body** – cell bodies located in *posterior* (*dorsal*) *root ganglion*, lateral to spinal cord; cell bodies of cranial nerves are in *cranial nerve ganglia* in head and neck
  - **Peripheral process** – long axon that transmits action potential from *sensory receptor* to neuron's *central process*
  - **Central process** – exits *cell body* and travels through posterior root; enters posterior horn (or brainstem for cranial nerves), transmits an action potential from the peripheral process to the posterior horn, eventually synapsing on a neuron in the spinal cord or brainstem.

Sensory Neurons

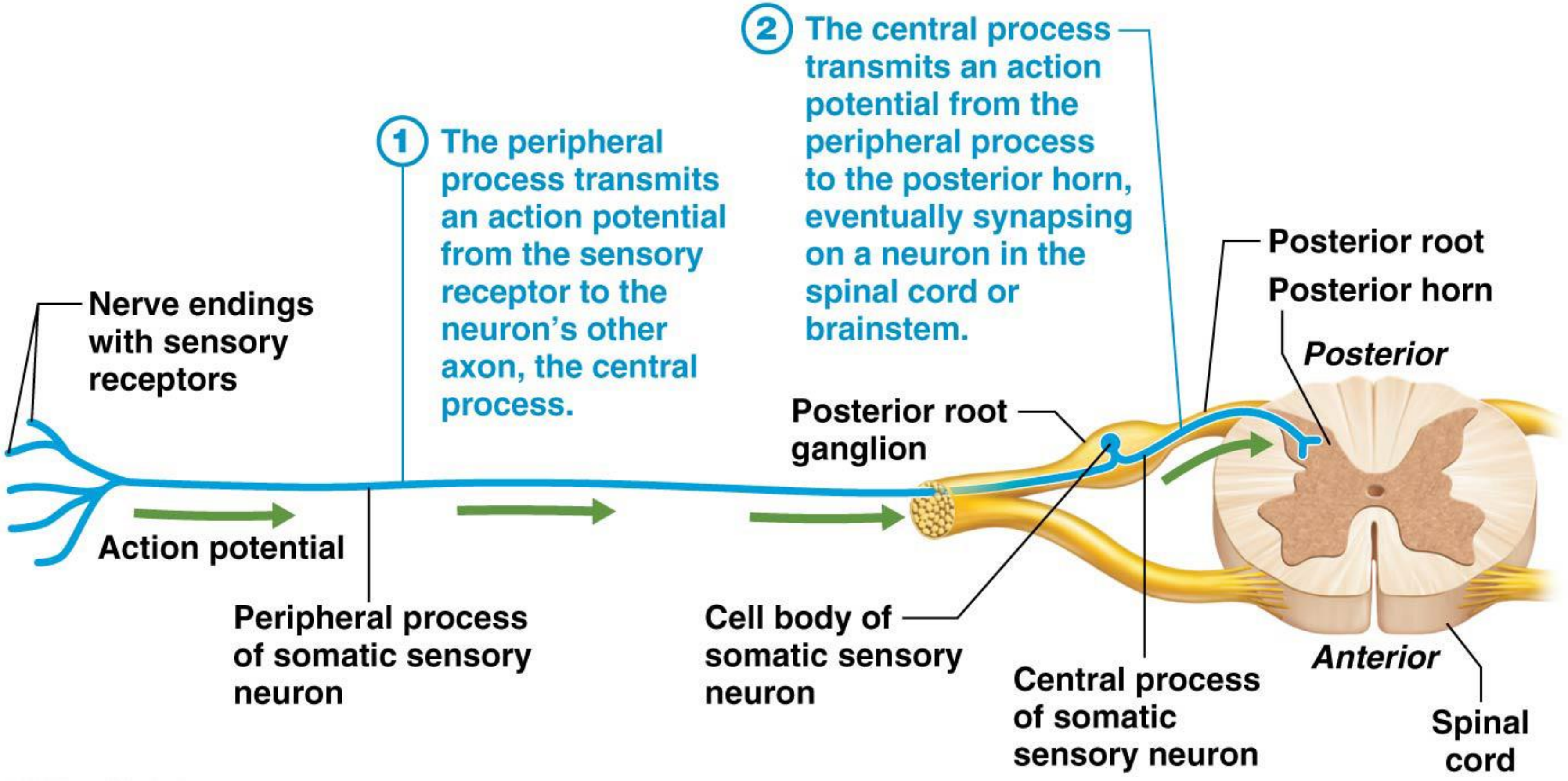


Figure 13.13 Somatic sensory neuron structure and function.

Sensory Neurons

- Sensory neurons are generally classified according to the speed with which their peripheral axons conduct action potentials, 2 factors determine speed: diameter of *axon* and thickness of its *myelin sheath*
  - Large-diameter axons with thick myelin sheaths conduct *fastest* impulses; include axons that:
    - Convey *proprioceptive* information to CNS
    - Convey discriminative and nondiscriminative *touch* information
  - Small-diameter axons with least myelin transmit action potentials *slowest*; include axons that carry *pain* and *temperature* stimuli to CNS

Sensory Neurons

- **Receptive fields** – areas served by a particular neuron; each somatic sensory neuron has an extensive network of branches in the skin, the more branching that exists, the larger the neurons receptive field (**Figure 13.14**)
  - The skin of the fingertips is richly innervated with sensory neurons, and each of these neurons has a relatively small receptive field.
  - Skin of forearm is innervated by much smaller number of neurons, so each neuron has a somewhat larger receptive field.
  - **Body regions that have a primary function of sensing the environment (like fingertips) contain MORE neurons and smaller receptive fields**

- Different regions of the body contain neurons with receptive fields of varying size.
- These differences account for the fact that you can accurately determine an object’s size and texture with your fingertips, but not with your forearm or back.
- The relative sizes of receptor fields can be measured by **two-point discrimination threshold** – in this test two stimuli are placed closely together on the skin, stimuli are then moved apart until the subject can feel two distinct points (**Figure 13.14b**).

Sensory Neurons

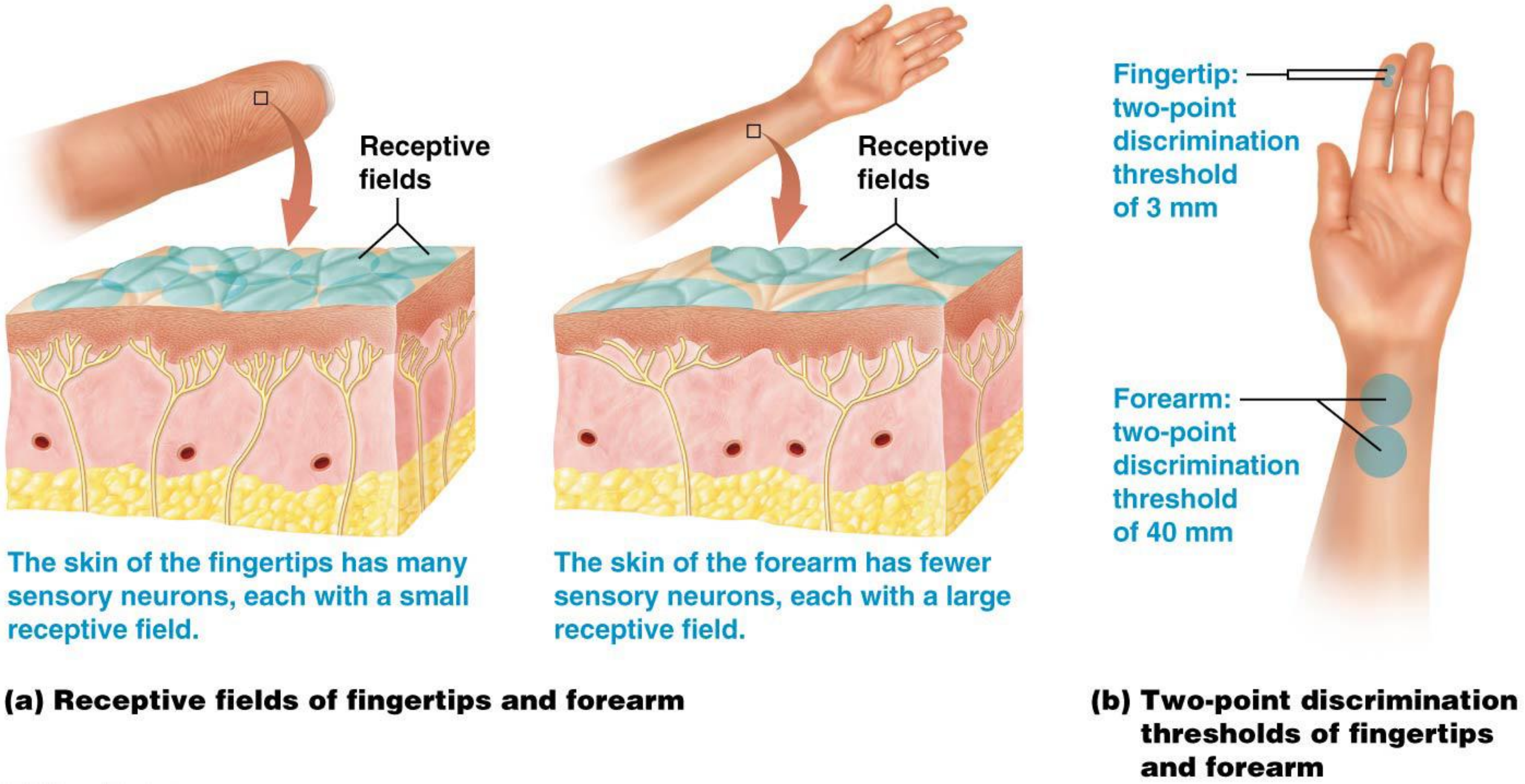
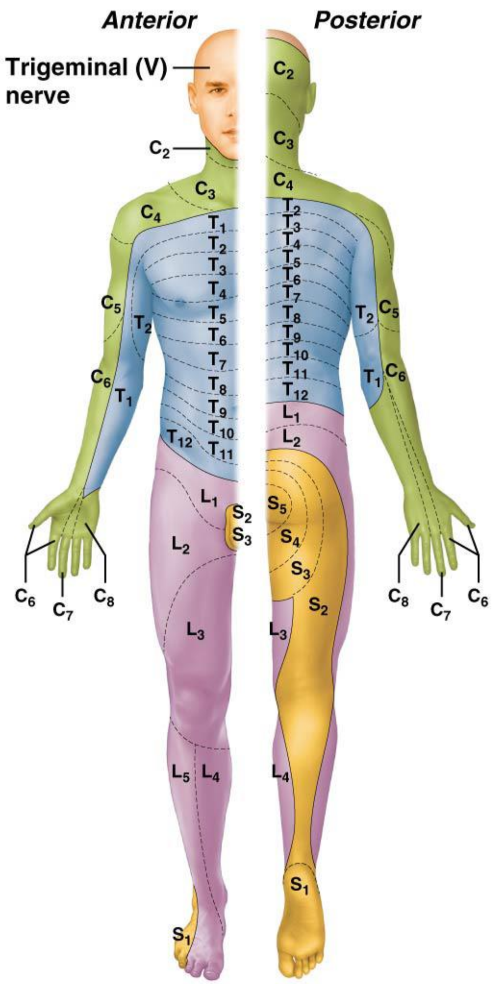


Figure 13.14 Receptive fields and two-point discrimination.

Dermatomes and Referred Pain

- Skin can be divided into different segments called **dermatomes** based on spinal nerve that supplies region with *somatic sensation*
  - Dermatomes can be combined to assemble a **dermatome map**; represents all (except first cervical spinal nerve) of the spinal nerves. (**Figure 13.15a**)
  - Dermatome maps can be used clinically to test *integrity of sensory pathways* to different parts of body
  - For example, a patient with a cervical spinal cord injury may be able to feel his lateral hand, thumb, 2nd and 3rd digits, but unable to feel his medial hand or 4th or 5th digits. This would tell you the location of the spinal cord injury-about level of C8.

Dermatomes and Referred Pain



(a) Dermatome map

Figure 13.15a The dermatome map and referred pain.

Dermatomes and Referred Pain

- Many spinal nerves carry both somatic and visceral neurons, so visceral sensations travel along the same pathways as do somatic sensations. This anatomical arrangement has a consequence known as **referred pain.**
- **Referred pain-** pain that originates in an organ is perceived as cutaneous pain
  - Referred pain is generally located along *dermatome* for that *nerve. Ex, pain caused by a heart attack is often perceived as pain in anterior chest wall, left arm, neck and lower jaw. This is because nerves that carry pain signals from the heart serve these particular dermatomes.*

Dermatomes and Referred Pain

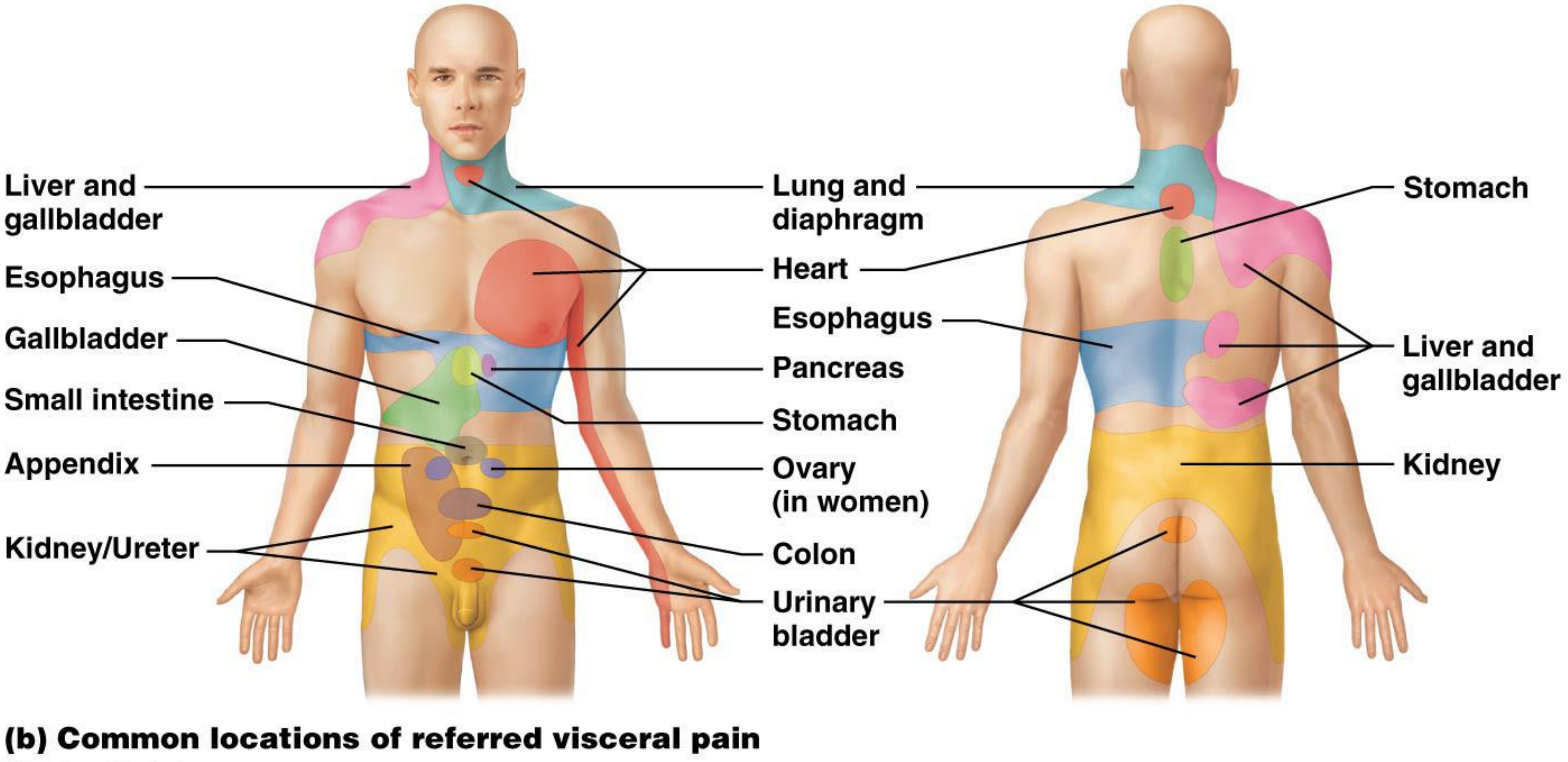


Figure 13.15b The dermatome map and referred pain.

The Big Picture of Detection and Interpretation of Somatic Sensation by the Nervous System

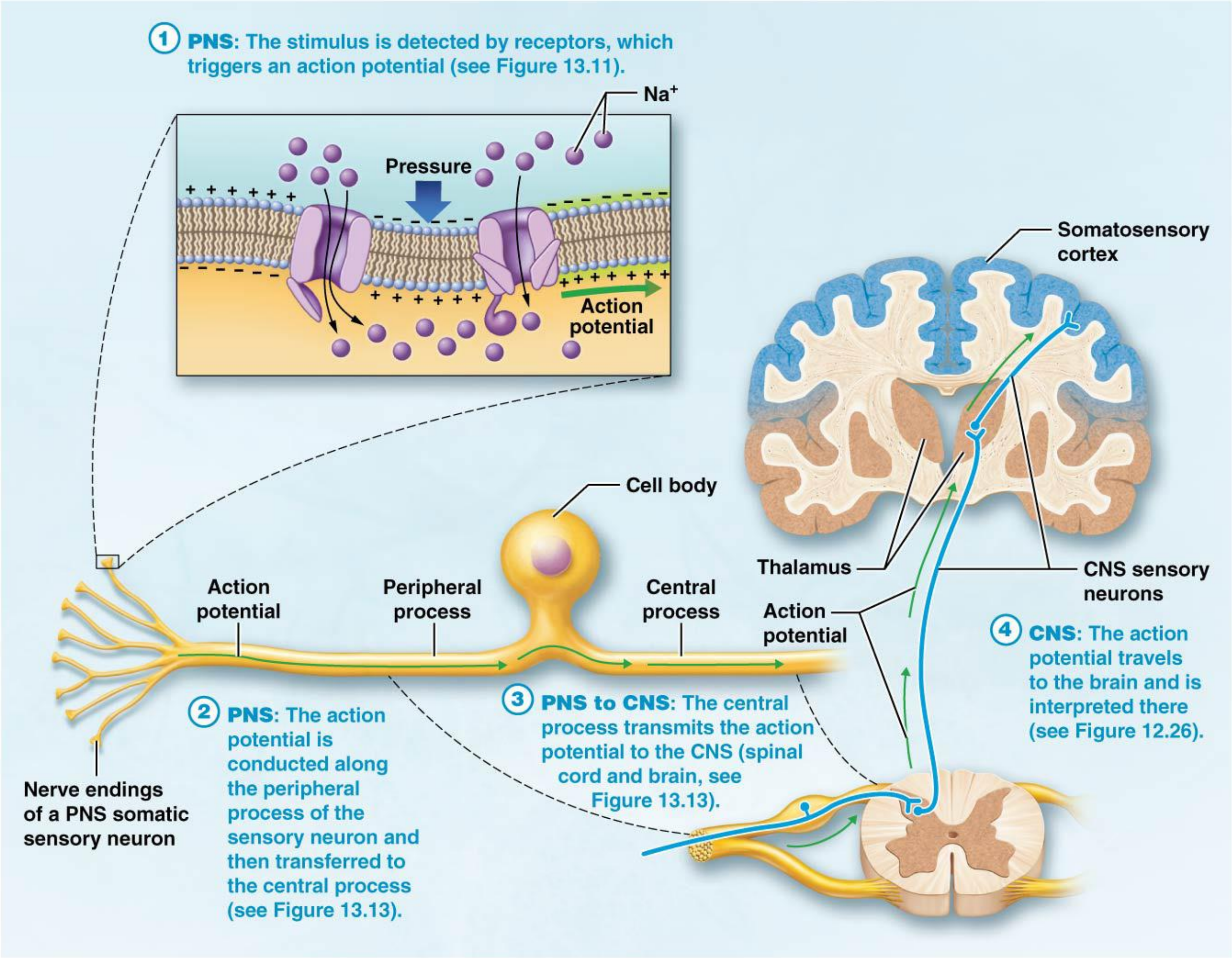


Figure 13.16 The Big Picture of Detection and Interpretation of Somatic Sensation by the Nervous System.

Module 13.5 Movement Part II: Role of the PNS in Movement

From CNS to PNS: Motor Output

- There is a close relationship between muscular and nervous systems, skeletal muscle fibers are **voluntary**; contract only when stimulated to do so by a *somatic motor neuron*
- *CNS initiates movement:*
  - **Upper motor neurons** – in primary motor cortex make *decision* to move and *initiate* that movement; but not in contact with muscle fiber itself
  - **Lower motor neurons** – receive messages from upper motor neurons; in contact with skeletal muscle fibers; release acetylcholine onto muscle fibers to *initiate contraction*

The Role of Lower Motor Neurons

- **Lower motor neurons** – *multipolar neurons* whose cell bodies are in either anterior horn of spinal cord or brainstem; axons are in PNS
- **Motor neuron pools** – *groups* of lower motor neurons that innervate same muscle; found together in *anterior horn* of spinal cord

The Big Picture of Control of Movement by the Nervous System

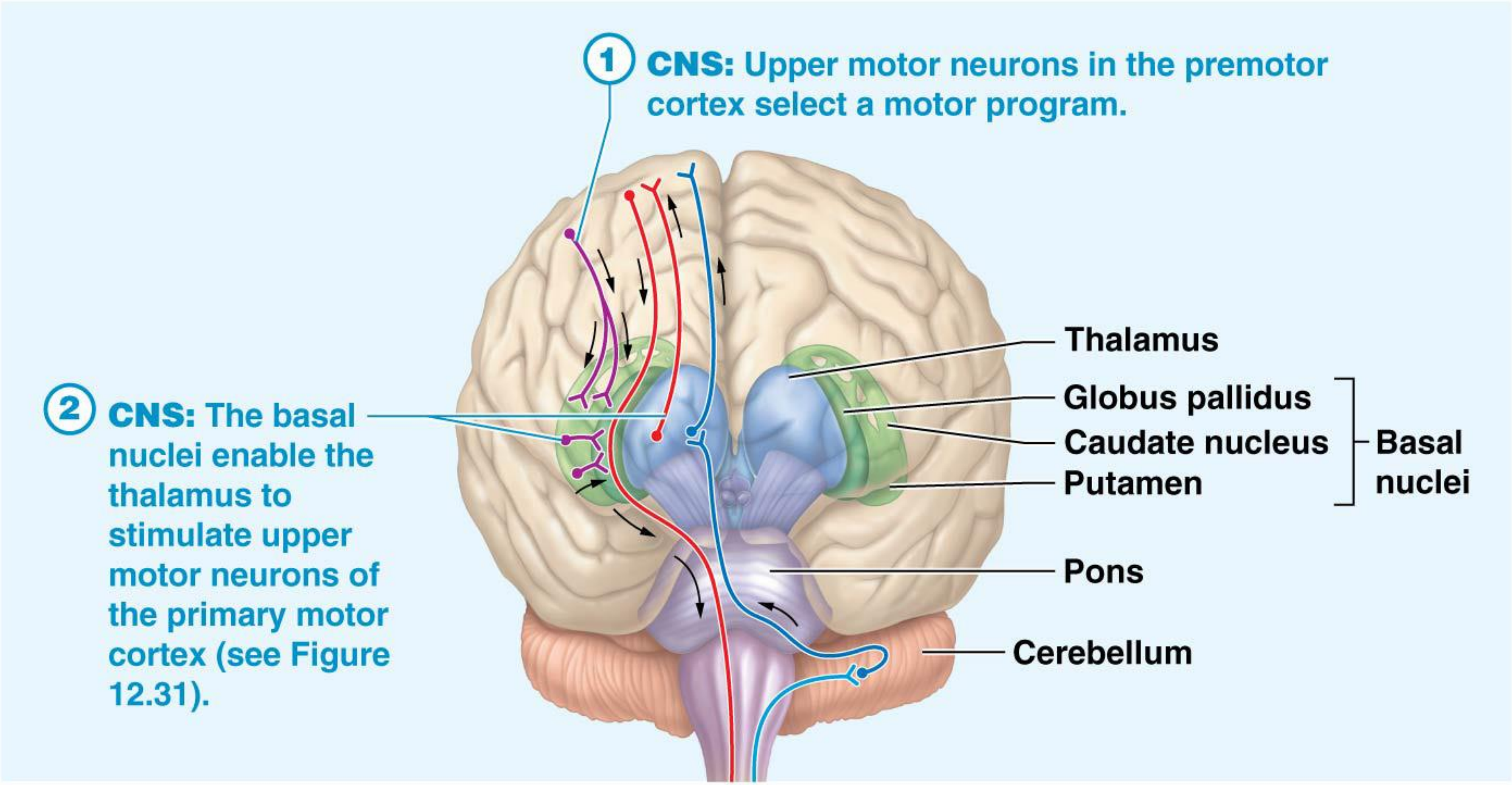


Figure 13.17 The Big Picture of Control of Movement by the Nervous System.

The Big Picture of Control of Movement by the Nervous System

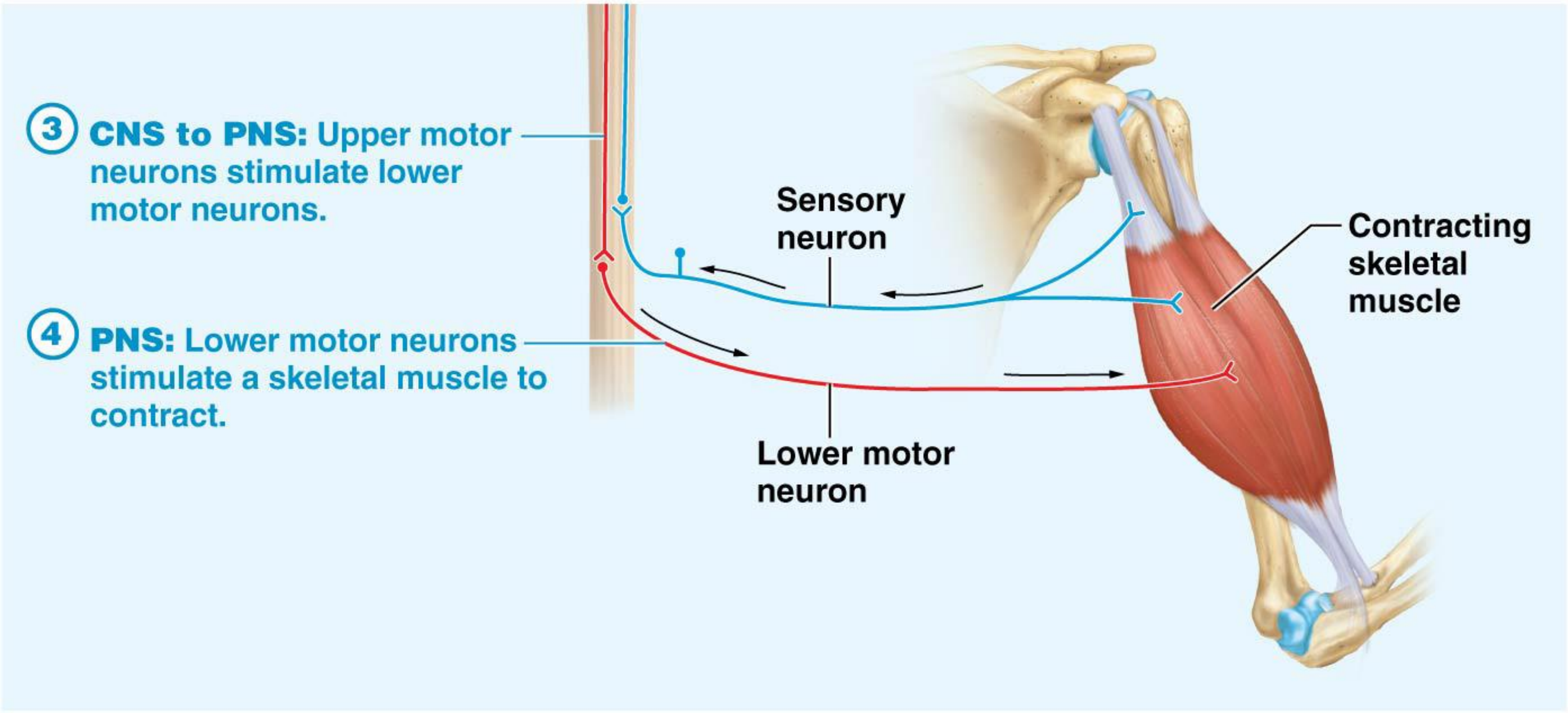


Figure 13.17 The Big Picture of Control of Movement by the Nervous System.

The Big Picture of Control of Movement by the Nervous System

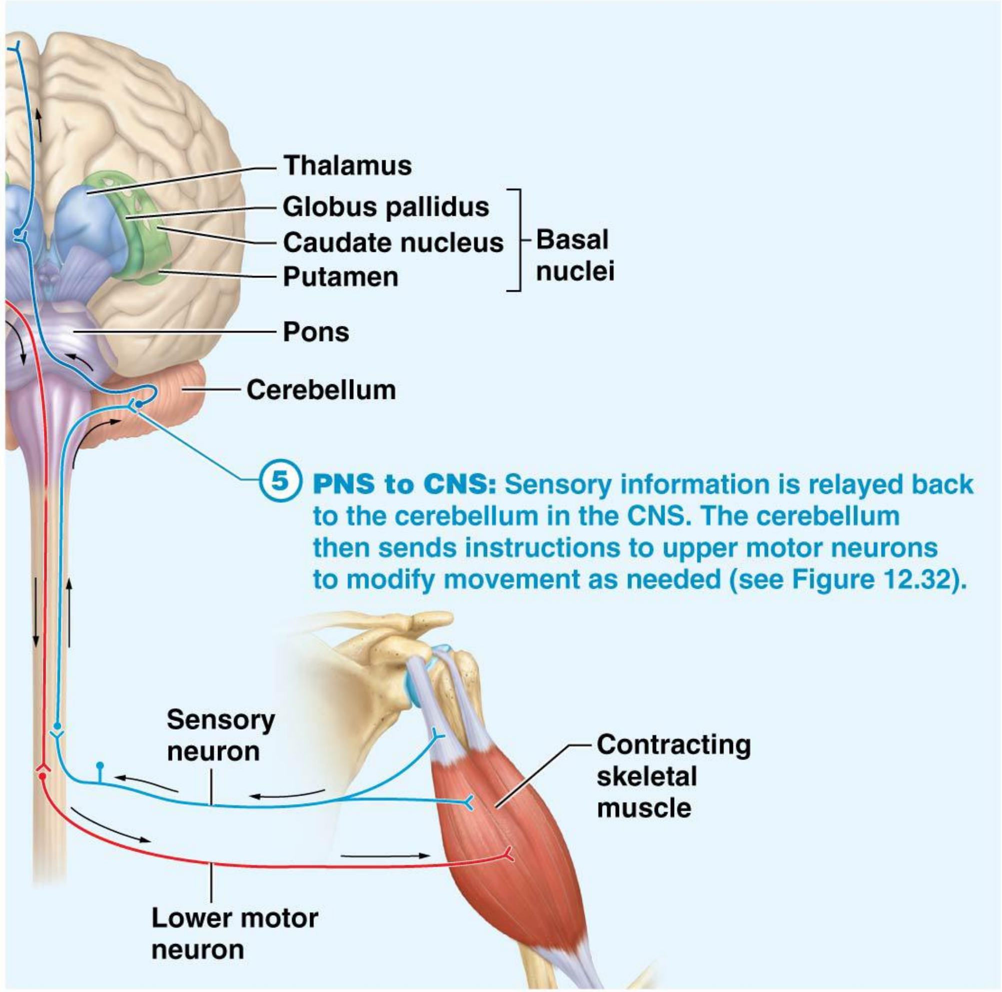


Figure 13.17 The Big Picture of Control of Movement by the Nervous System.

The Big Picture of Control of Movement by the Nervous System

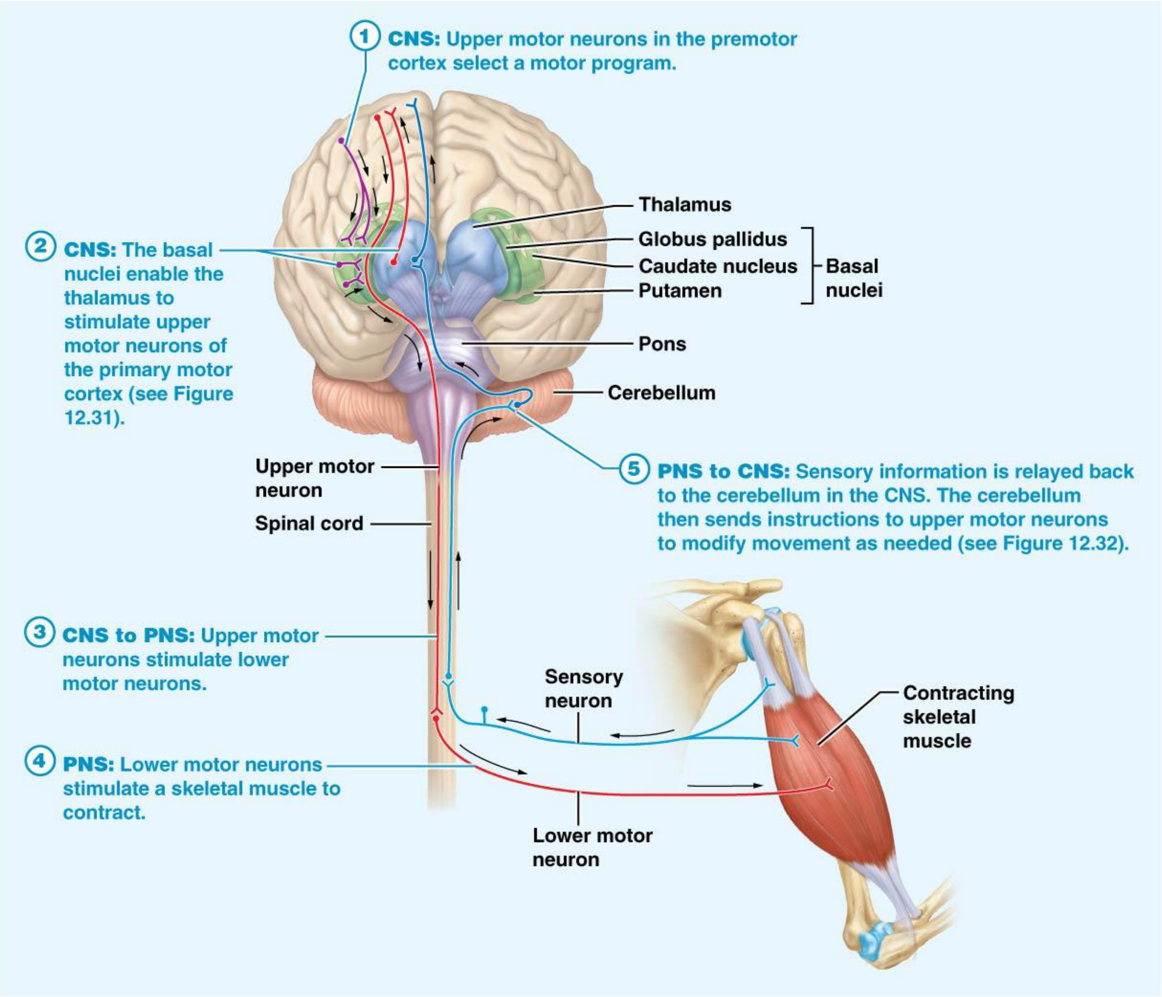


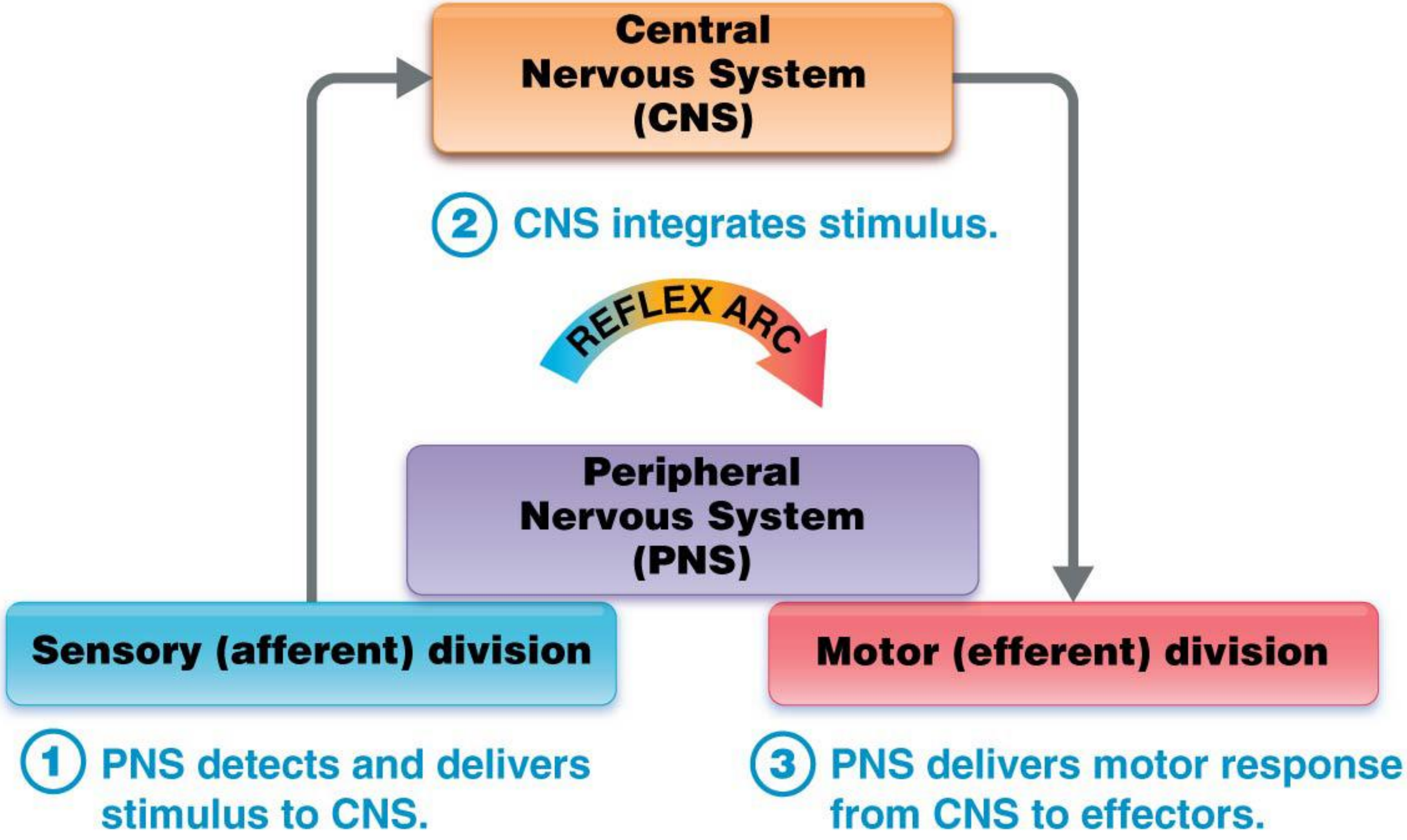
Figure 13.17 The Big Picture of Control of Movement by the Nervous System.

Module 13.6 Reflex Arcs: Integration of Sensory and Motor Functions

Reflex Arcs

- **Reflexes** – *programmed*, *automatic responses* to stimuli; usually *protective* preventing tissue damage in someway, occur in a three-step sequence of events called a **reflex arc**
  - Reflexes begin with a *sensory stimulus* and finish with a rapid *motor response*
  - *Neural integration* between sensory stimulus and motor response occurs in CNS, typically within *brainstem or spinal cord*

Reflex Arcs


Central Nervous System (CNS)
2 CNS integrates stimulus.
REFLEX ARC
Peripheral Nervous System (PNS)
Sensory (afferent) division
Motor (efferent) division
1 PNS detects and delivers stimulus to CNS.
3 PNS delivers motor response from CNS to effectors.

The Role of Stretch Receptors in Skeletal Muscles

Some of the most common reflexes occur without our realizing it. These reflexes are part of normal movement and allow the CNS to correct motor error and prevent muscle damage.

Sensory component of these reflexes is detected by mechanoreceptors within muscles and tendons called **muscle spindles and Golgi tendon organs**, monitor muscle *length* and *force of contraction*; communicate this information to spinal cord, cerebellum, and cerebral cortex (**Figure 13.18**)

The Role of Stretch Receptors in Skeletal Muscles

- **Muscle spindles** – tapered structures found embedded among regular contractile muscle fibers (**extrafusal muscle fibers**) (**Figure 13.18a**) (continued):
  - Within each spindle are 2-12 specialized muscle fibers, **intrafusal muscle fibers,** have contractile filaments composed of actin and myosin at their *poles*; innervated by motor neurons
  - Contractile filaments are absent in the *central area* of intrafusal fibers

The Role of Stretch Receptors in Skeletal Muscles

- Two structural and functional classes of *sensory neurons* innervate intrafusal fibers:
  - **Primary afferent** responds to *stretch* when it is first initiated
  - **Secondary afferent** responds to both *static length* of a muscle and *position* of a limb

The Role of Stretch Receptors in Skeletal Muscles

- **Golgi tendon organs** – *mechanoreceptors* located within tendons near *muscle-tendon junction*; have following features (**Figure 13.18b**):
  - Monitor *tension* generated by a muscle contraction
  - Consist of an *encapsulated bundle of collagen fibers* attached to about 20 *extrafusal muscle fibers*
  - Contain a single somatic sensory axon whose endings are wrapped around its enclosed collagen fibers. The rate at which these neurons fire depends on the amount of muscle tension generated with each contraction-the greater the tension, the more rapidly they fire.

The Role of Stretch Receptors in Skeletal Muscles

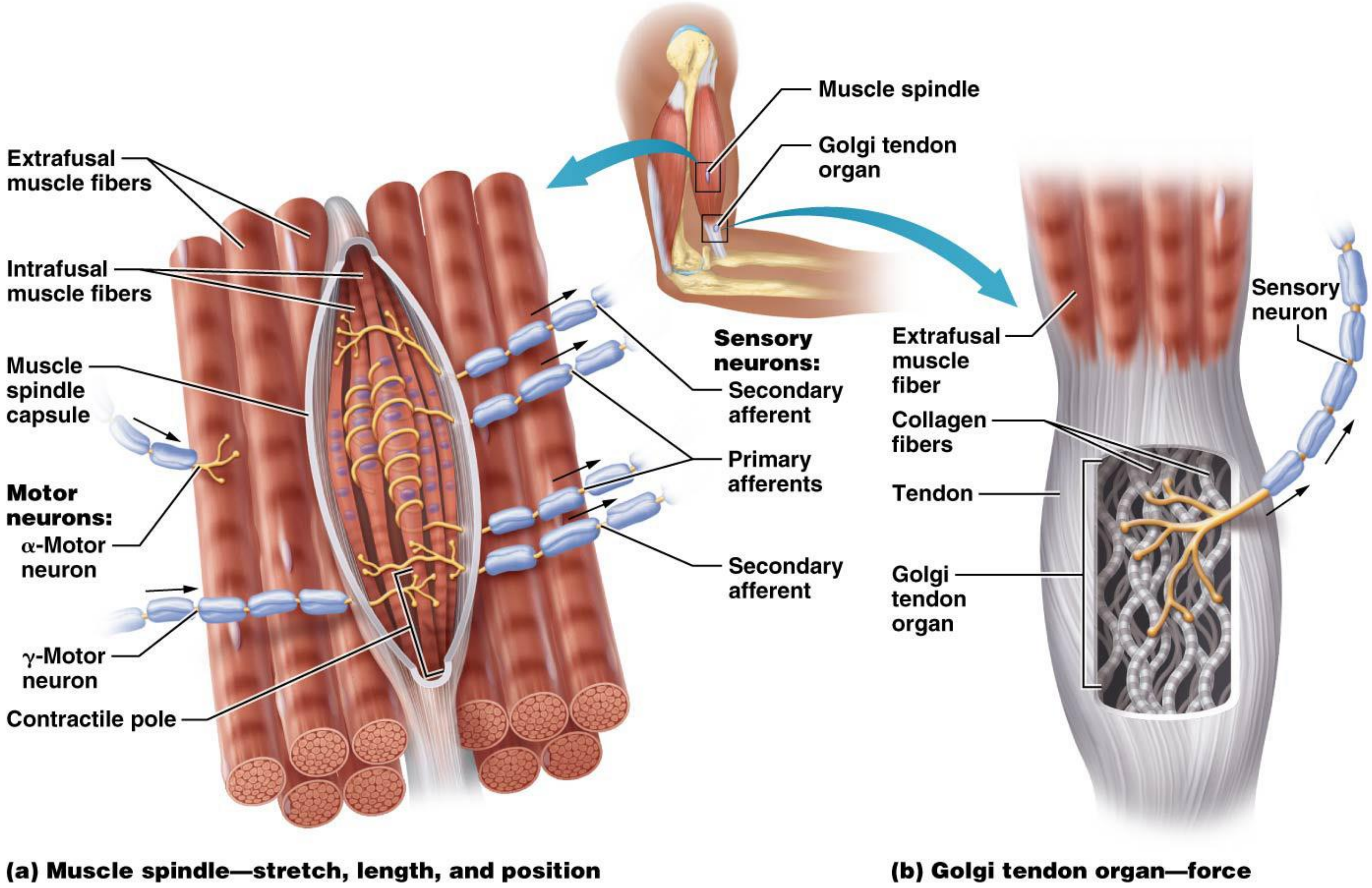


Figure 13.18 Muscle spindles and Golgi tendon organs.

Types of Reflexes

- Reflexes can be classified by at least two criteria (**Figures 13.19**, **13.20**):
  - *Number of synapses* that occur between neurons involved in arc
  - *Type of organ* in which reflex takes place, either visceral or somatic
- Simplest reflex arcs (**monosynaptic reflexes**) involve only a single synapse within spinal cord between a sensory and motor neuron; more complicated types of reflex arcs (**polysynaptic reflexes**) involve multiple synapses

Types of Reflexes

- When a muscle is stretched it deviates from its optimal length, the body's reflexive response is to shorten the muscle so that it returns to its optimal length via a monosynaptic reflex known as **simple stretch reflex.**
- **Patellar** (**knee-jerk**) **reflex** is example of simple stretch reflexes

Types of Reflexes

- **Simple stretch reflex** (continued):
  - Steps in a simple stretch reflex in a spinal nerve (**Figure 13.19**):
    - External force *stretches* muscle
    - Muscle spindles *detect* stretch; primary and secondary afferents *transmit* an action potential to spinal cord
    - In spinal cord, sensory afferents *synapse* on motor neurons and *trigger* an action potential
    - Motor neurons *stimulate* muscle to contract and it returns to its *optimal length*

Types of Reflexes

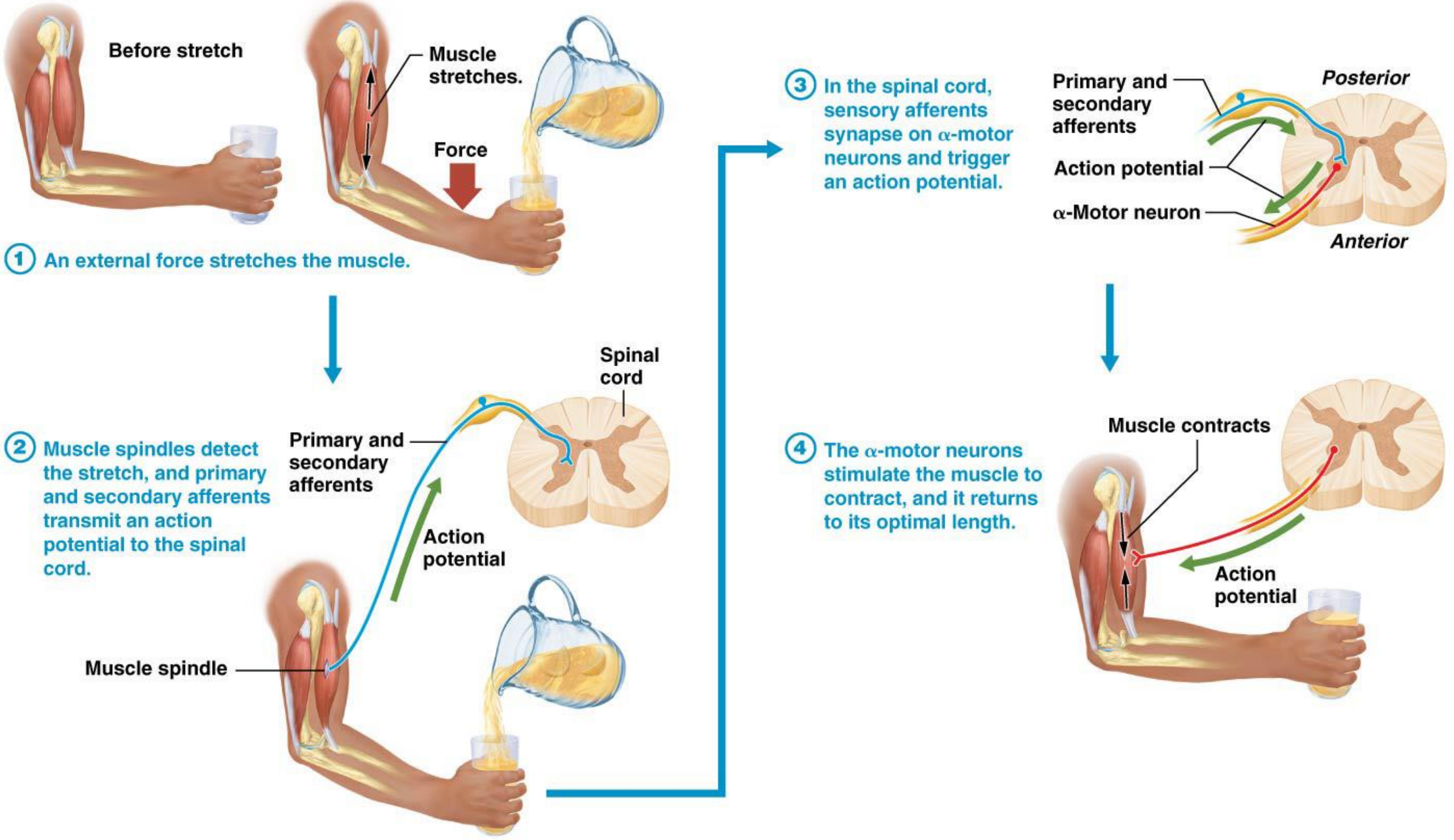


Figure 13.19 A simple stretch reflex.

Types of Reflexes

- **Golgi tendon reflex** – *polysynaptic* reflex; also protects muscles and tendons from damage
  - Causes muscle *relaxation*; <u>opposite</u> of simple stretch reflex action
  - When tension in muscle and tendon *increases dramatically*, Golgi tendon organs signal spinal cord and cerebellum
  - Motor neurons innervating muscle are *inhibited* while antagonist muscles are simultaneously *activated*
  - *The Golgi tendon reflex is part of the reason why you should perform certain weight-lifting exercises with a spotter, if the weight is too heavy, the Golgi tendon reflex might cause you to drop the weight. Although this would prevent muscle/tendon damage, you could be seriously injured by dropping the weight on yourself.*

Types of Reflexes

- **Flexion (withdrawal) and crossed-extension spinal reflexes (Figure 13.20):**
  - When you touch a very hot object or step on a tack you almost immediately pull your hand or foot away from the source of pain, these are examples of the **flexion or withdrawal reflex-** involves rapidly conducting nociceptive afferents and multiple synapses in spinal cord (**Figure 13.20a**)
  - **Crossed-extension reflex** occurs simultaneously with flexion reflex, when flexion reflex is stimulated, the hip extensors of <u>opposite</u> limb are triggered to contract, in the given example
  - Allows for withdrawal from painful stimulus (**Figure 13.20b**)

Types of Reflexes

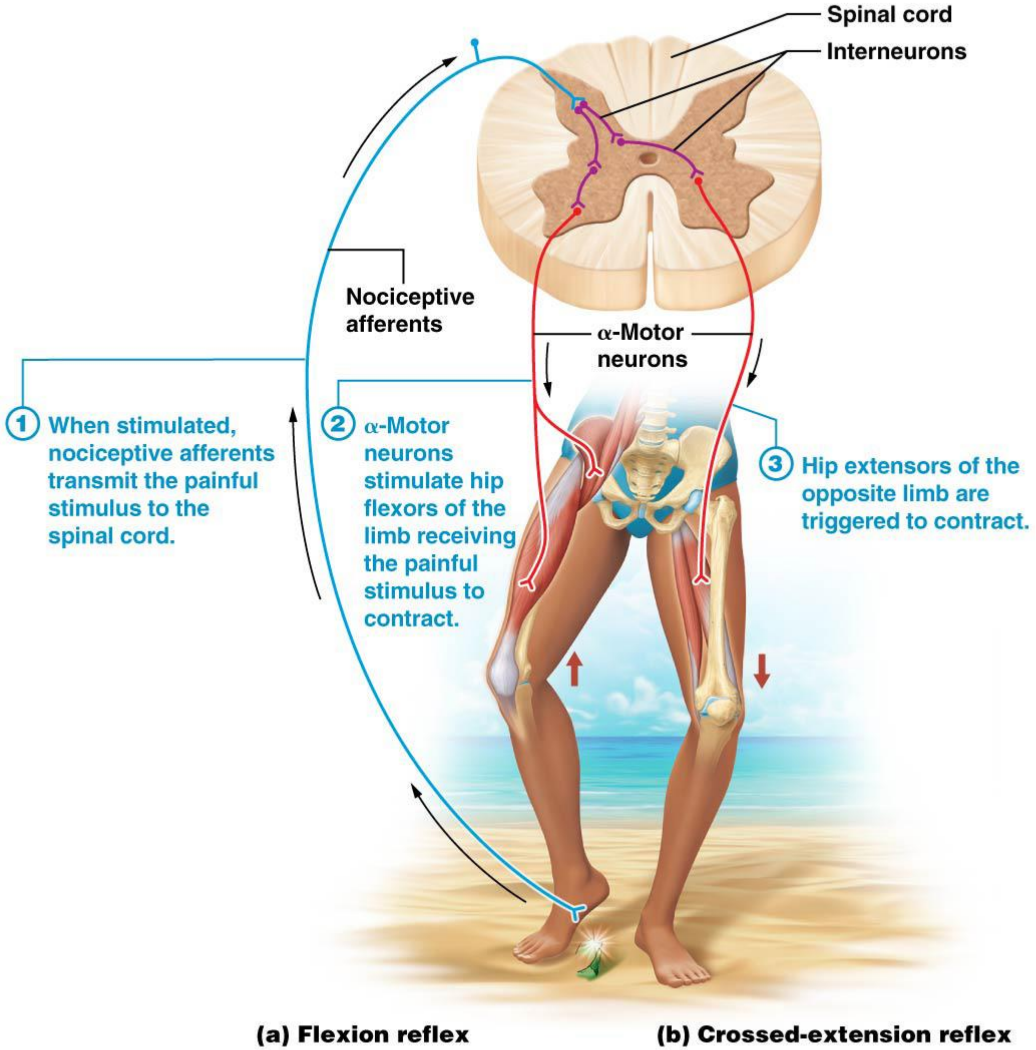


Figure 13.20 The flexion and crossed-extension reflexes.

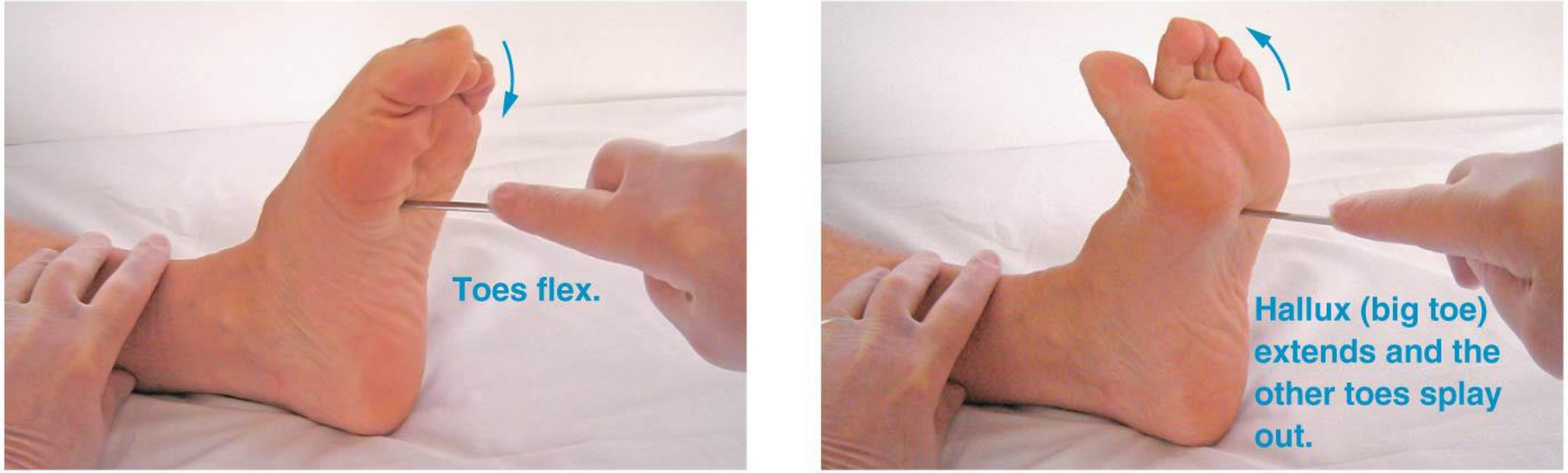
Types of Reflexes

- **Cranial nerve reflexes** – several *polysynaptic* reflex arcs involve *cranial nerves*
  - **Gag reflex** – triggered when visceral sensory nerve endings of glossopharyngeal nerve in *posterior throat* are stimulated unilaterally
  - **Corneal blink reflex** – triggered when a stimulus reaches somatic sensory receptors of trigeminal nerve in thin *outer covering of eye* (**cornea**); something contacts eye leading to a blink response

Sensory and Motor Neuron Disorders

- Disorders that impact sensory and motor neurons of PNS are collectively called **peripheral neuropathies** (**Figure 13.21**)
  - **Sensory neuron disorders** – symptoms and severity depends on which spinal or cranial nerve is involved
  - **Lower motor neuron disorders** – most often result from injury to a spinal or cranial nerve or injury of lower motor neuron cell body; prevent motor nerve from *stimulating* skeletal muscle contraction

Sensory and Motor Neuron Disorders



(a) Plantar reflex—normal response

(b) Positive Babinski sign—present in adults with upper motor neuron disorders

Figure 13.21 The Babinski sign.

Sensory and Motor Neuron Disorders

- **Upper motor neuron disorders** – impact neurons of CNS, so not considered *peripheral* neuropathies (**Figure 13.21**)
  - Can result from damage or disease anywhere along pathways from motor cortices to spinal cord
  - Body's initial response to upper motor neuron damage is **spinal shock**, characterized by paralysis; believed to result from "shock" experienced by spinal cord circuits when input from upper motor neurons is *removed*

Sensory and Motor Neuron Disorders

- **Upper motor neuron disorders** (continued):
  - After a few days shock wears off and **spasticity** often develops; characterized by an increase in *stretch reflexes*, an increase in *muscle tone*, and a phenomenon called **clonus** (alternating contraction/relaxation of stretched muscle)
  - Spasticity is likely due to a *loss of normal inhibition* mediated by upper motor neurons

Sensory and Motor Neuron Disorders

- **Upper motor neuron disorders** (continued):
  - **Babinski sign** also develops; elicited by stroking bottom of foot:
    - Healthy adult will *flex toes*, a response known as **plantar reflex** (**Figure 13.21a**)
    - Patient with an upper motor neuron disorder will *extend hallux* (*big toe*) *and splay out other toes* (**Figure 13.21b**)
  - A positive Babinski sign is often present in *infants up to 18 months old* and does not signify pathology; same response in an adult is always considered *abnormal*

Amyotrophic Lateral Sclerosis

- **Amyotrophic lateral sclerosis** (**ALS**), also known as **Lou Gehrig's disease**, involves *degeneration* of cell bodies of *motor neurons* in anterior horn of spinal cord as well as upper motor neurons in cerebral cortex; cause of degeneration is *unknown* at present; many factors likely play a role
- Most common early feature of disease is *muscle weakness*, particularly in distal muscles of limbs and hands; over time weakness spreads to other muscle groups; upper motor neuron symptoms also develop

Amyotrophic Lateral Sclerosis

- Death typically results within 5 years of disease's onset; in most forms of ALS, cognitive functions are spared; patient is *fully aware* of effects and complications of disease
- Although intensive research efforts are ongoing, at this time there is *no cure or treatment* that prevents disease progression