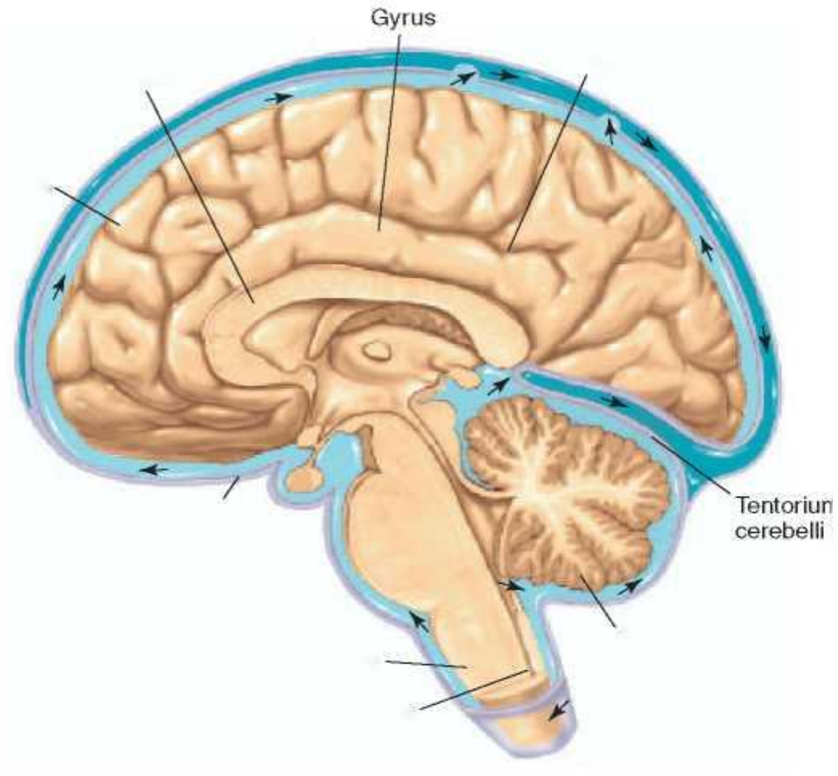
STRUCTURAL ORGANIZATION OF THE NERVOUS SYSTEM

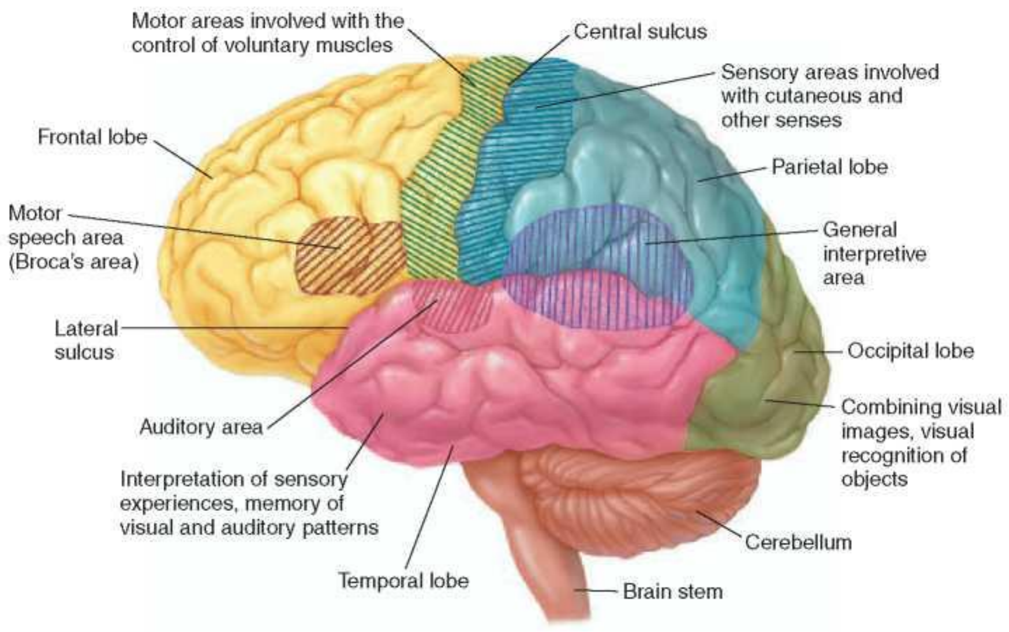
STRUCTURAL ORGANIZATION OF THE BRAIN



- The **central nervous system (CNS),** consisting of the brain and spinal cord, receives input from *sensory neurons* and directs the activity of *motor neurons* that innervate muscles and glands.
- The *association neurons* within the brain and spinal cord are in a position, as their name implies, to associate appropriate motor responses with sensory stimuli, and thus to maintain homeostasis in the internal environment and the continued existence of the organism in a changing external environment.
- CNS of all vertebrates (and most invertebrates) are capable of at least rudimentary forms of learning and memory. This capability—most highly developed in the human brain—permits behavior to be modified by experience and is thus of obvious benefit to survival. Perceptions, learning, memory, emotions, and perhaps even the self-awareness that forms the basis of consciousness, are creations of the brain.

The CNS consists of the brain and the spinal cord. Both of these structures are covered with meninges and bathed in cerebrospinal fluid.

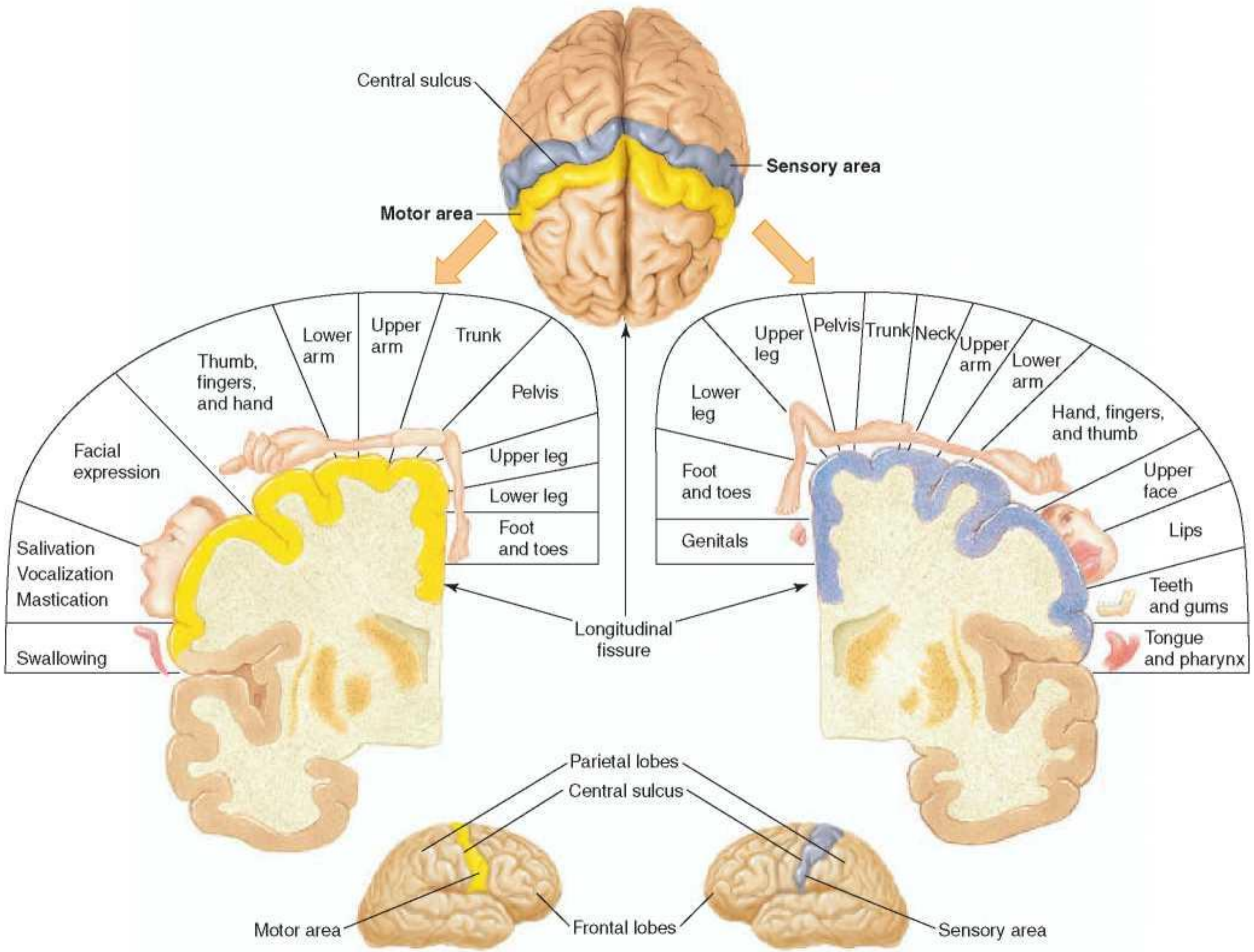
Cerebral Cortex



The cerebrum. A lateral view

The **frontal lobe** is the anterior portion of each cerebral hemisphere. A deep fissure, called the *central sulcus,* separates the frontal lobe from the **parietal lobe.** The *precentral gyrus*, involved in motor control, is located in the frontal lobe, just in front of the central sulcus. The neuron cell bodies located here are called *upper motor neurons,* because of their role in muscle regulation. The *postcentral gyrus,* which is located just behind the central sulcus in the parietal lobe, is the primary area of the cortex responsible for the perception of *somatesthetic sensation*—sensation arising from cutaneous, muscle, tendon, and joint receptors. The **temporal lobe** contains auditory centers that receive sensory fibers from the cochlea of each ear. This lobe is also involved in the interpretation and association of auditory and visual information. The **occipital lobe** is the primary area responsible for vision and for the coordination of eye movements. The functions of the temporal and occipital lobes will be considered in more detail in chapter 10, in conjunction with the physiology of hearing and vision. The **insula** is implicated in memory encoding and in the integration of sensory information (principally pain) with visceral responses. In particular, the insula seems to be involved in coordinating the cardiovascular responses to stress.

MOTOR AND SENSORY AREAS OF THE CORTEX



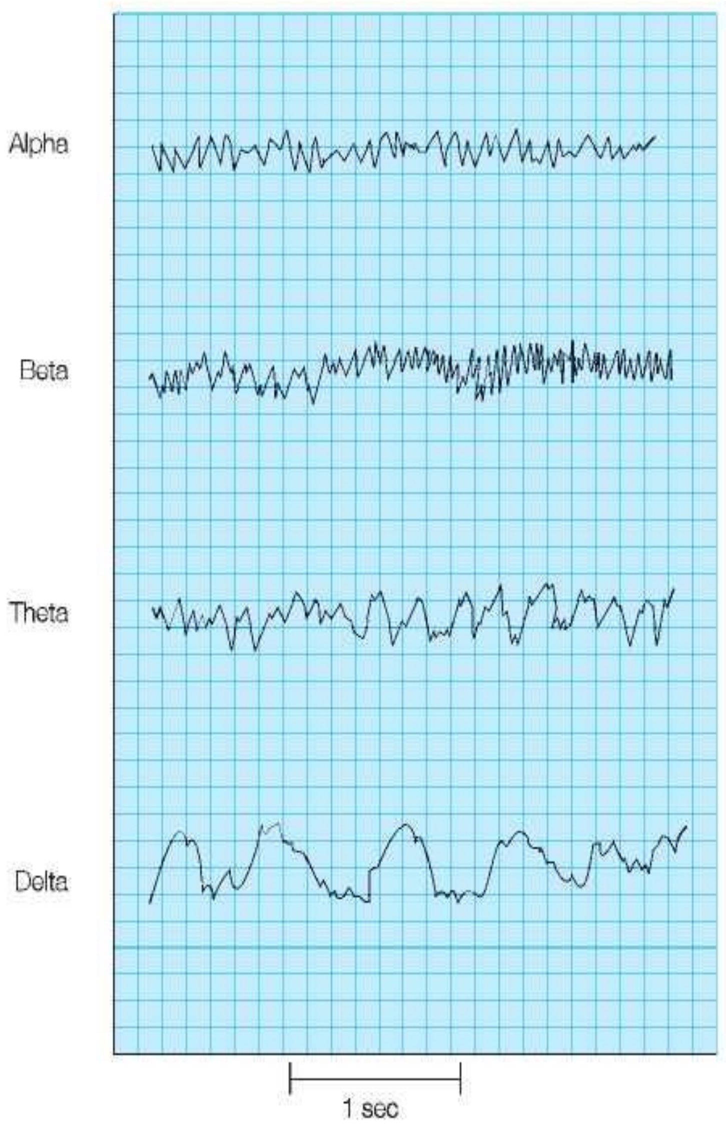
Visualizing the Brain

- **X-ray computed tomography (CT).** CT involves complex computer manipulation of data obtained from x-ray absorption by tissues of different densities. Using this technique, soft tissues such as the brain can be observed at different depths.
- **Positron-emission tomography (PET).** In this technique, radioisotopes that emit positrons are injected into the bloodstream. Positrons are like electrons but carry a positive charge. The collision of a positron and an electron results in their mutual annihilation and the emission of gamma rays, which can be detected and used to pinpoint brain cells that are most active. Scientists have used PET to study brain metabolism, drug distribution in the brain, and changes in blood flow as a result of brain activity.
- **Magnetic resonance imaging (MRI).** This technique is based on the concept that protons (H+) respond to a magnetic field. The magnetic field is used to align the protons, which emit a detectable radio-wave signal when appropriately stimulated. Scientists are now using MRI together with other techniques to study the function of the brain in a technique called ***functional magnetic resonance imaging (fMRI).***
- **Electroencephalogram.** The synaptic potentials produced at the cell bodies and dendrites of the cerebral cortex create electrical currents that can be measured by electrodes placed on the scalp. A record of these electrical currents is called an **electroencephalogram,** or **EEG.** Deviations from normal EEG patterns can be used clinically to diagnose epilepsy and other abnormal states, and the absence of an EEG can be used to signify brain death.

METHODS OF THE BRAIN STUDYING

EEG	**Electroencephalogram**	**Neuronal activity is measured as maps with scalp electrodes.**
fMRI	Functional magnetic resonance imaging	Increased neuronal activity increases cerebral blood flow and oxygen consumption in local areas. This is detected by effects of changes in blood oxyhemoglobin/deoxyhemoglobin ratios.
MEG	Magnetoencephalogram	Neuronal magnetic activity is measured using magnetic coils and mathematical plots.
PET	Positron emission tomography	Increased neuronal activity increases cerebral blood flow and metabolite consumption in local areas. This is measured using radioactively labeled deoxyglucose.
SPECT	Single photon emission computed tomography	Increased neuronal activity increases cerebral blood flow. This is measured using emitters of single photons, such as technetium.

TYPES OF WAVES IN EEG



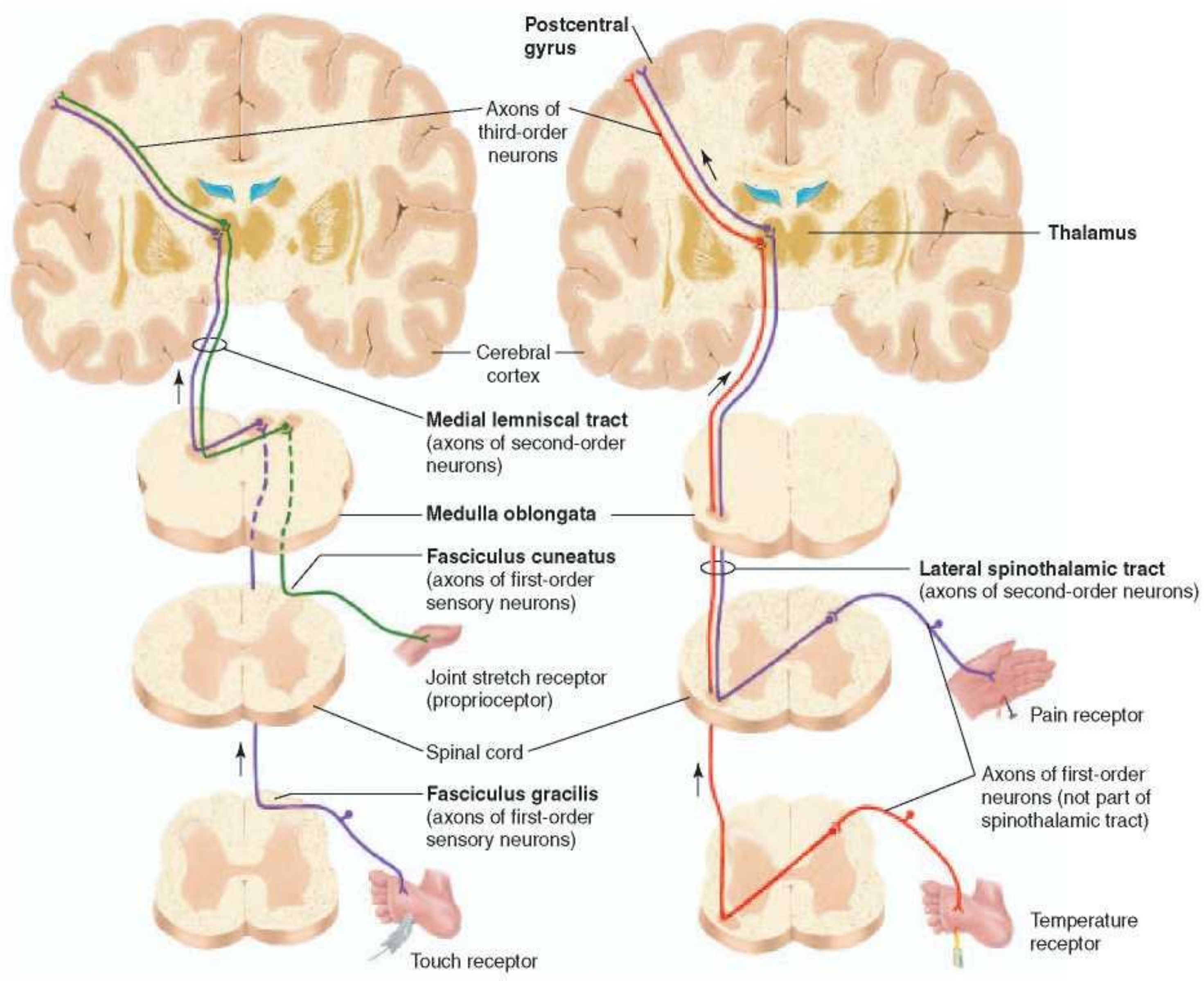
Alpha waves are best recorded from the parietal and occipital regions while a person is awake and relaxed but with the eyes closed. These waves are rhythmic oscillations of 10 to 12 cycles/second. The alpha rhythm of a child under the age of 8 occurs at a slightly lower frequency of 4 to 7 cycles/second.

Beta waves are strongest from the frontal lobes, especially the area near the precentral gyrus. These waves are produced by visual stimuli and mental activity. Because they respond to stimuli from receptors and are superimposed on the continuous activity patterns, they constitute *evoked activity.* Beta waves occur at a frequency of 13 to 25 cycles per second.

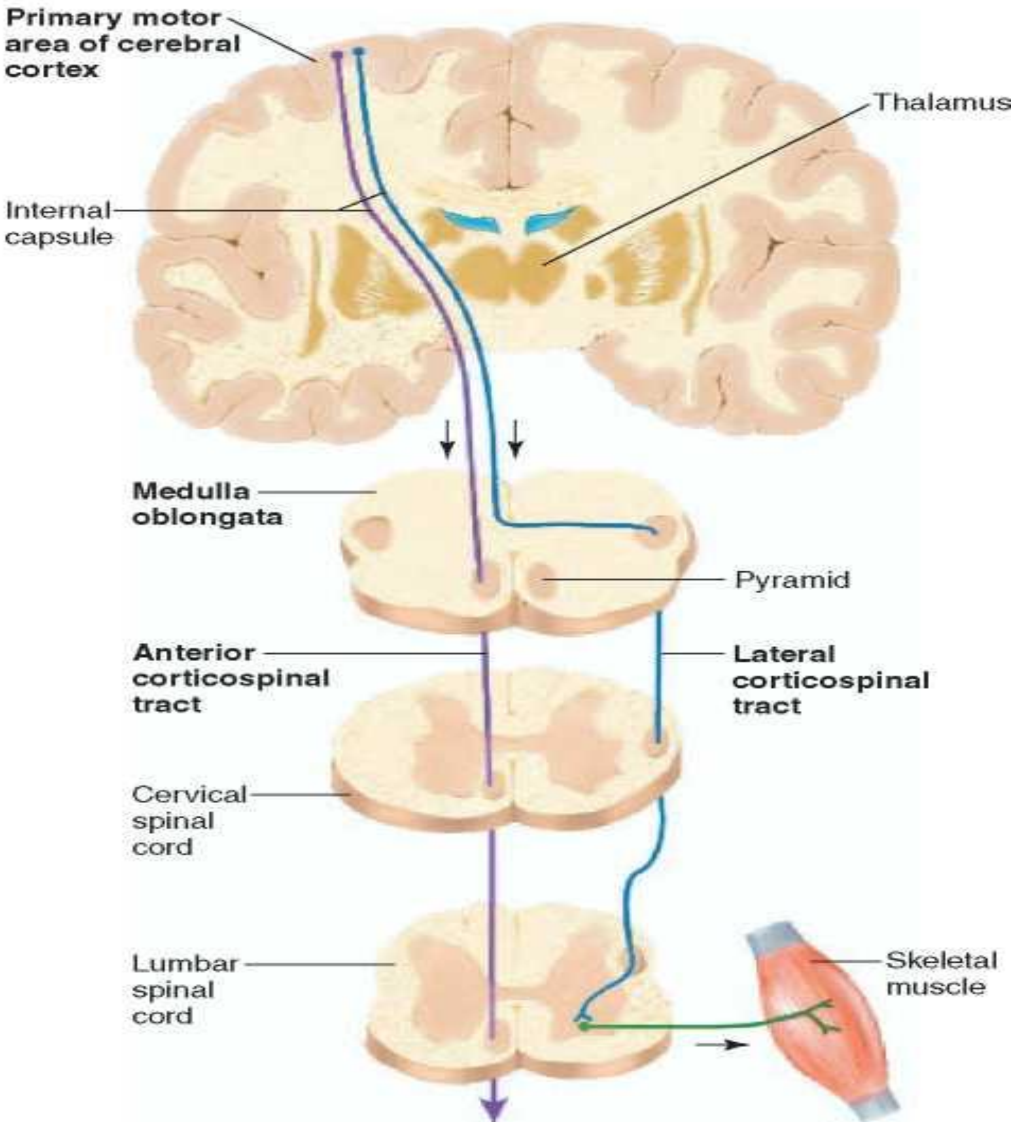
Theta waves are emitted from the temporal and occipital lobes. They have a frequency of 5 to 8 cycles/second and are common in newborn infants. The recording of theta waves in adults generally indicates severe emotional stress and can be a forewarning of a nervous breakdown.

Delta waves are seemingly emitted in a general pattern from the cerebral cortex. These waves have a frequency of 1 to 5 cycles/second and are common during sleep and in an awake infant. The presence of delta waves in an awake adult indicates brain damage. Two different types of EEG patterns are seen during sleep, corresponding to the two phases of sleep: **rapid eye movement (REM)** sleep, when dreams occur, and **non-REM,** or **resting,** sleep. During non-REM sleep the EEG displays large, slow delta waves (high amplitude, low-frequency waves). Superimposed on these are *sleep spindles,* which are waxing and waning bursts of 7 to 14 cycles per second that last for 1 to 3-second periods. During REM sleep, when the eyes move about rapidly, the EEG waves are similar to that of wakefulness. That is, they are lower in amplitude and display high-frequency oscillations.

ASCENDING TRACTS OF SPINAL CORD

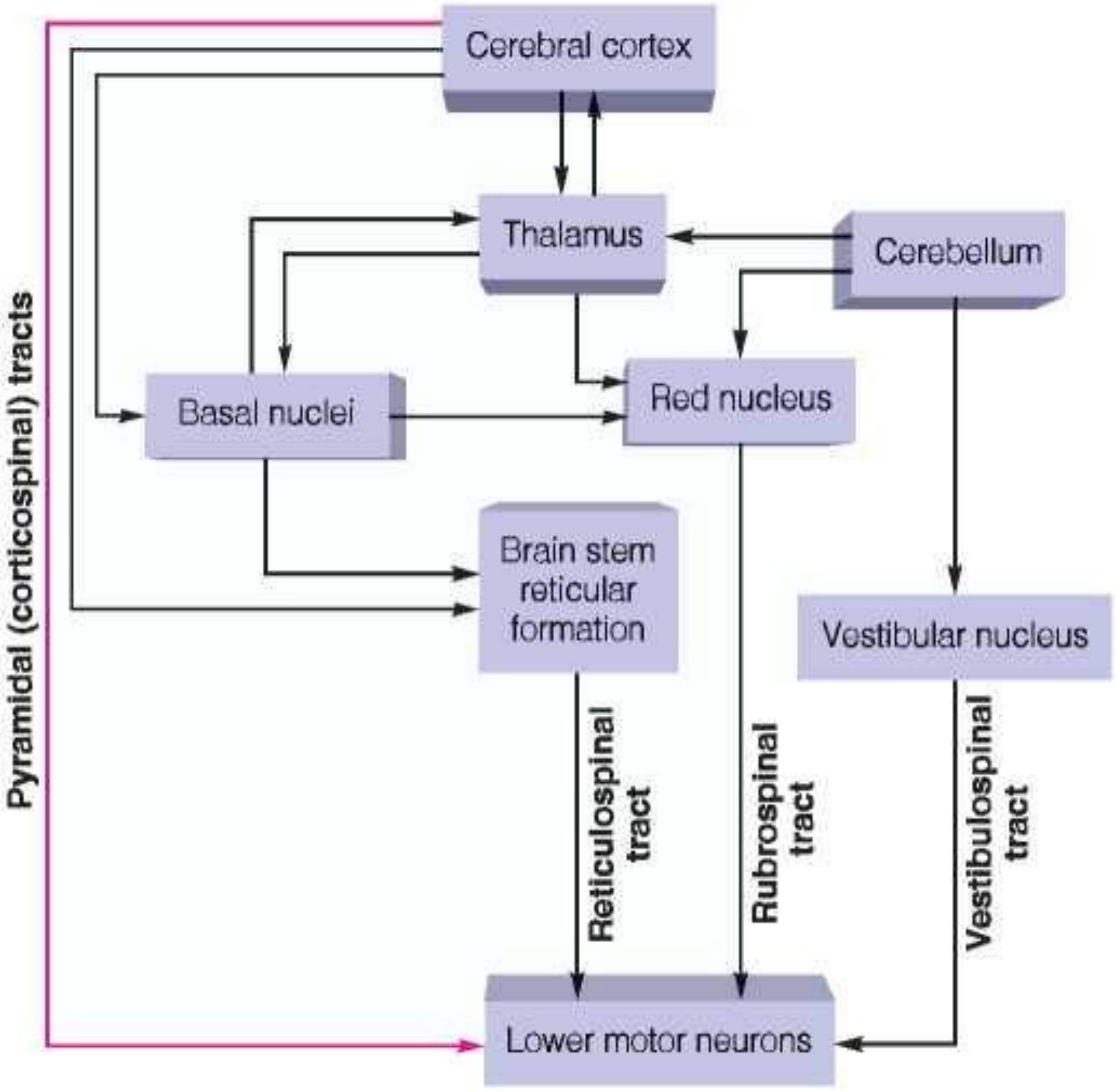


DESCENDING CORTICOSPINAL (PYRAMIDAL) MOTOR TRACTS.

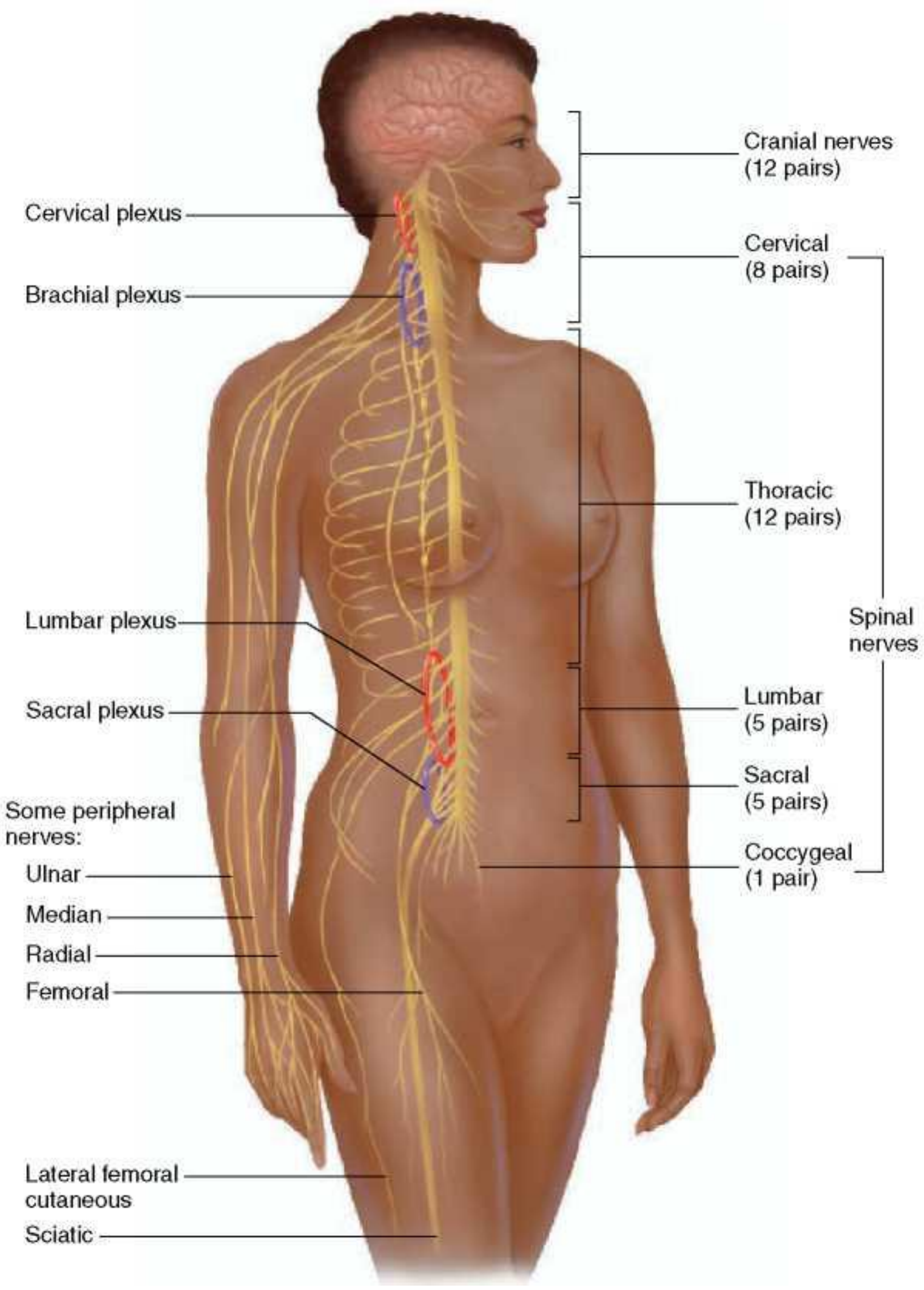


These tracts contain axons that pass from the precentral gyrus of the cerebral cortex down the spinal cord to make synapses with spinal intemeurons and lower motor neurons. The descending fiber tracts that originate in the brain consist of two major groups: the **corticospinal,** or **pyramidal tracts,** and the **extrapyramidal tracts**). The pyramidal tracts descend directly, without synaptic interruption, from the cerebral cortex to the spinal cord. The cell bodies that contribute fibers to these pyramidal tracts are located primarily in the *precentral gyrus* (also called the *motor cortex).* Other areas of the cerebral cortex, however, also contribute to these tracts.

THE HIGHER LEVELS OF MOTOR CONTROL



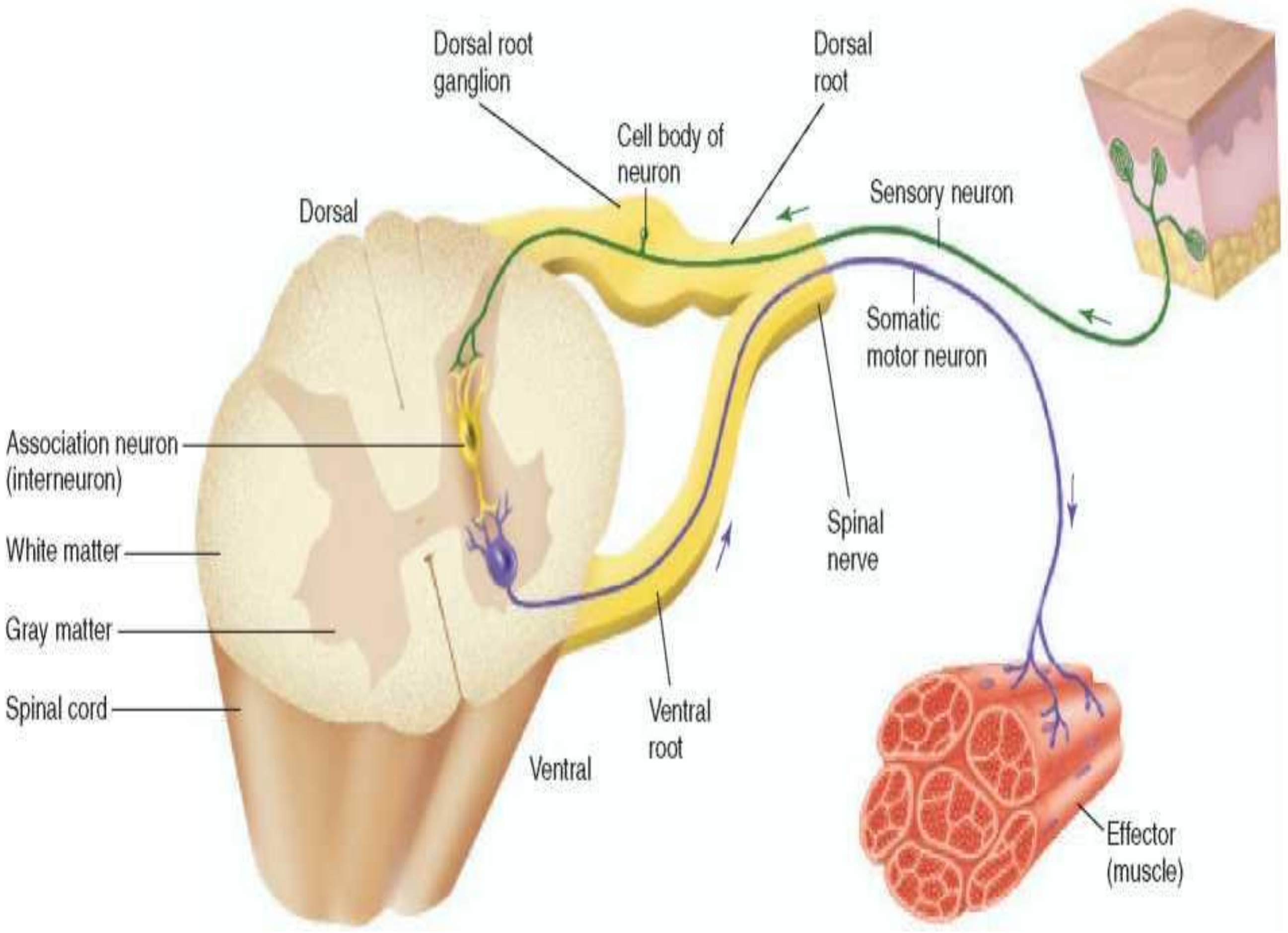
The *reticulospinal tracts* are the major descending pathways of the extrapyramidal system. These tracts originate in the reticular formation of the brain stem, which receives either stimulatory or inhibitory input from the cerebrum and the cerebellum. There are no descending tracts from the cerebellum; the cerebellum can influence motor activity only indirectly by its effect on the vestibular nuclei, red nucleus, and basal nuclei (which send axons to the reticular formation). These nuclei, in turn, send axons down the spinal cord via the *vestibulospinal tracts*, *rubrospinal tracts*, and *reticulospinal* tracts, respectively.



SPINAL NERVES

There are thirty-one pairs of spinal nerves. These nerves are grouped into eight cervical, twelve thoracic, five lumbar, five sacral, and one coccygeal according to the region of the vertebral column from which they arise. Each spinal nerve is a mixed nerve composed of sensory and motor fibers. These fibers are packaged together in the nerve, but they separate near the attachment of the nerve to the spinal cord. This produces two “roots” to each nerve. The **dorsal root** is composed of sensory fibers, and the **ventral root** is composed of motor fibers. An enlargement of the dorsal root, the **dorsal root ganglion,** contains the cell bodies of the sensory neurons.

A SPINAL REFLEX CIRCUIT



The functions of the sensory and motor components of a spinal nerve can be understood most easily by examining a simple reflex; that is, an unconscious motor response to a sensory stimulus. Figure demonstrates the neural pathway involved in a **reflex arc.** A sensory neuron synapses with an association neuron (or interneuron), which in turn synapses with a somatic motor neuron. The somatic motor neuron then conducts impulses out of the spinal cord to the muscle and stimulates a reflex contraction. Notice that the brain is not directly involved in this reflex response to sensory stimulation. Some reflex arcs are even simpler than this; in a muscle stretch reflex (the knee-jerk reflex, for example) the sensory neuron synapses directly with a motor neuron. Other reflexes are more complex, involving a number of association neurons and resulting in motor responses on both sides of the spinal cord at different levels.

REVIEW QUESTIONS

- Can we be aware of a reflex action involving our skeletal muscles? Is this awareness necessary for the response?
- Explain, identifying the neural pathways involved in the reflex response and the conscious awareness of a stimulus.
- Describe the locations of the sensory and motor areas of the cerebral cortex and explain how these areas are organized.
- Explain why each cerebral hemisphere receives sensory input from and directs motor output to the contralateral side of the body.
- List the tracts of the pyramidal motor system and describe the function of the pyramidal system.
- List the tracts of the extrapyramidal system and explain how this system differs from the pyramidal motor system.